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

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ABSTRACT: *Developing countries face issues in adopting technologies for facilitating various tasks. It is happening mostly in sectors with low levels of innovation such as the construction industry. The adoption of technologies in developing countries is a challenge that affects health, economy, and consciousness advancement. The scepticism in what, how, and why certain technologies influence the cost-benefit of tasks has impeded the decision-making process of adopting them. Nevertheless, the cost-benefit decisions related to Unmanned Aerial Systems (UAS) applications, cover the regulatory and practical implications. These are barriers in developed countries, but developing ones, seem to have another set of configurations that should be investigated 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 of the implementation of UAS for the Construction Industry in the Dominican Republic. This study was part of a longitudinal study by conducting 4 interviews and 30 surveys as a first study and a second study undertaking an iterative strategy of interviewing 24 participants in a semi-structured format to address an in-depth investigation of the topic. Then, the Nvivo 2020 software was used to identify cases utilising ground theory coding, thematic and content analysis to elaborate them. Later, a model and a framework were developed to map the process of adoption utilising the social technical theory and refining the factors of policy embedded in the problem. The model presents the theoretical composition of the adoption process and the framework reflects on the key ideas discussed. The outcomes contribute to understand, how the adoption process of UAS should be developed at a national level considering the stakeholders involved in construction. Further works are recommended in merging various emerging technologies with UAS.*

KEYWORDS: *POLICY, UAS, FRAMEWORK, ADOPTION, TECHNOLOGY, MODEL, CONSTRUCTION, DOMINICAN REPUBLIC.*

1. INTRODUCTION

Developing countries face challenges when the discussion of adopting technologies is considered. Some of the reasons are related to the agenda in force, requirements in enhancing IT infrastructures and issues in culture adaptation towards the integration of novel technologies. Based on these challenges, the concept of smart cities has appeared to be a solution for the gap. The concept of designing or enhancing cities with technologies has been observed as a panacea for tackling poverty, social deprivation (Portugal, Moreira, Póvoas, Silva, & Guedes, 2021), improve local economic in terms of agriculture, construction, public safety, traffic, logistics (Maghazei, Lewis, & Netland, 2022) and others. However, despite the stage of the country, in terms of digital development, there are social and technical challenges to overcome in order to proliferate the adoption of technologies, especially, in sectors with low level of innovation as the construction industry.

In some countries, the construction industry significantly dwells in local and/or foreign workers. However, the common educational profile of these workers is based on non-formal qualifications (Kikwasi, 2011). The knowledge and skills gained, most of the time, are obtained through practice rather than a theoretical process. In contrast to digital skills that dwells in the limitations accordingly to the IT infrastructure held by the country or worker. In some countries, phones are more utilized than tables, or more utilized than any sophisticated software of CAD or digital design. Therefore, the access and use of smartphones could be considered as the first point of contact with the cyberspace for low skilled workers implying a baseline standard on digital skills. Furthermore, the baseline enables to these workers their inclusion within the data capture, flow and management of Building Information Modelling (BIM). For example, the tasks of communicating progress or making requests of materials, allow to this segment of the workers to be part of the BIM value stream data by providing evidence of agreements or modifications (Dominicis, Depari, Flammini, Rinaldi, & Sisinni, 2013). Furthermore, with the simplification of BIM tools with smartphones and tables for 3D reconstruction and BIM 360° (Díaz-Vilariño, Tran, Frías, Balado, & Khoshelham, 2022), there is a possibility to provide polished, refined, accurate, and detailed digital geometry of the assets during the construction process (Tavani, et al., 2022; Díaz-Vilariño, Tran, Frías, Balado, & Khoshelham, 2022). Nevertheless, the distrust on digital platforms, the limited access to sophisticated technological tools, the fails in previews attempts with technology and the costs involved in developing the IT infrastructure, within the organization, provoke uncertainty during the decision-making process in updating or incorporating low level workers within the information workflow. The scepticism emerges from the questions of what information should be relevant to pursuit? how the processes of data gathering should be established? and why specific piece of information should be captured for future liabilities from contractors' perspective? These questions have been the principles of the risk assessment at the instant of initiating the full digital process inside the organizations. Furthermore, these queries persist until a reasonable degree of reliability is measured in the organization with technology. The implementation of them may not be a causation of digital workflows or BIM but it supports the digitalization of the construction process as Unmanned Aerial System (UAS) does (Irizarry & Costa, 2016; Ham & Kamari, 2019).

UAS, Unmanned Aerial Vehicles (UAV), Remotely Piloted Aircraft System (RPAS) or drones have been an aerial instrument of data collection to elevate digitalization process within the construction (Zhou & Gheisari, 2018). Additionally, to digitalization, it has promoted health and safety as well as understanding on what tasks are likely to be performed by humans instead of machines. The application of UAS have encountered many layers of challenges according to the land in which are deployed (Vanderhorst, Heesom, Suresh, Renukappa, & Burnham, 2022). From political adversity to design specification has been the range on the challenges faced. In some developed countries (USA, UK, Spain), the application of UAS is limited to qualified workers by the civil aviation of the country and in others, as in the developing country of the Dominican Republic, it is restricted by the model used. Furthermore, after the layer of qualification, the application on construction is delimitated based on the legal requirements of the project in which is applied. For example, on infrastructure projects, the UAS applications are attached to the standards on inspections; on urban planning are linked to the congested airspace regulation in force as well as radio frequency length, and, on construction, is related to the standards embedded towards digitalization. For those reasons, each country takes into consideration aspects of business, technology, tasks and humans' resources. However, there are some ontologies in innovation and business for construction that could provide an answer or insight into the query of how the complex epistemological implications of the UAS could consolidate and forecast the digitalization of construction?

2. THEORETICAL BACKGROUND

The adoption process of UAS incorporates different approaches according to its usage and 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 evolution of the technology 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.

Past studies have established theoretical lens to produce understanding of UAS applications in different sectors (Sepasgozar & Davis, 2019; Hamed Golizadeh, 2019). Furthermore, some studies propose ontologies based on task-technology fit theory for barriers, technology-organization-environment to explain the adoption, diffusion of innovation theory to understand the proliferation and social-technical theory to describe the drivers benefits and regulation involved. The outcomes produced based on these theories had contributed to assess the adoption process in construction industry, health industry and in policy development in general. However, for developing countries, social-technical theory has been prominent based on its merit explaining the technical process in which stakeholder can relies on (Haula & Agbozo, 2020).

Table 1: Theory lens found in the application of UAS. In the table is defined the theories found to describe the application of UAS for different aspects.

No.	Theories	Description	Literature
1	Task-Technology fit theory (TTF)	UAS are implemented according to the task to be solved	(Hamed Golizadeh, 2019)
2	Technology-Organization-Environment (TOE)	Organizations adopt the UAS by internal demands governed, until certain degree, by the regulations in forced.	(Vanderhorst, Suresh, Renukappa, & Heesom, 2021) (Comtet & Johannessen, 2022)
3	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	(Ali, Kaur, Gupta, Ahmad, & Elnaggar, 2021)

	(DOI)	channels, 4) time and 5) social system.	
4	Social-Technical Theory (ST)	The theory consists in two sub-systems: the social and technical sub-system. Social sub-system compromise people and organizational structures, and the technical sub-system encompass technologies, processes, procedures, and the physical environment relationships.	(Haula & Agbozo, 2020)
5	Unified Theory of Acceptance and Use of Technology (UTAUT)	Presents the consumer's perspective in adopting UAS.	(Tom, 2020)

Other theories such as DOI, TOE and UTAUT are based on technologies targeted with many Information System studies explaining end-user adoption at the organizational 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 behavior adoption process of technology. It is focused on the social aspect and behavior of adoption of technologies rather than the technical one covered by the task-technology fit theory (TTF). Furthermore, the holistic perspective of social-technical theory (ST) allows to unify, consolidate, and relate the aspects of people/business and technology/tasks in one ontology.

Additionally, there are other theories that explain other behaviors of the UAS adoption such as the learning organization theory and community structure theory, which are subcategories of the social aspects of the framework within the field of business management. The theory of learning organization describes the process of knowledge generation and management within the organization to produce quality results approaching continuous learning. In addition, the community structure theory defines the boundaries of how communities are interconnected between them and how they interact with their environment supplying the needs of a niches (Tran, Shin, & Spitz, 2022). Furthermore, the concern of viability in the UAS application is addressed on the social systems merging with learning organization theory. On the opposite side, the UAS industry, from a technical perspective, is influenced by the DOI for the case of this research.

Nevertheless, no preview studies had intertwined the governances, airspace management and business influence in people within organizations as well as with the theories underlined in this type of studies. Do the approach in combining or assembling theories would explain these complex scenarios?

3. METHODOLOGY

As the data regarding UAS is addressing the issue of scepticism for generating insight into the change accomplished in organizations, 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 conducting academic investigations: pure qualitative, pure quantitative and mixed-method research (Harrison, Reilly, & Creswell, 2020) (Creswell, 2014) (Saunders, lewis, & Thronhill, 2016) (Mingers, 2003). However, as the claim of scepticism corresponds to a philosophical perspective of epistemology or implies that the research should provide an understanding of what could be an actual truth or fact rather than a conjecture, and as truth or fact can be adapted to an audience, the ontology was intended to be built (Burg, Cornelissen, Stam, & Jack, 2020).

Then, the nature of the research, the integration, and the application of UAS in different fields by civilians determined that it was a novel topic for policymakers, academics, and the industry, as identified by the following examples. In the last seven years, various funding opportunities for research (Horizon 2020) entrepreneurial activities have been raised to try the feasibility of UAS and explore the potential solutions embedded in the life of humans. The majority of the investments towards UAS projects were in manufacturing UAS solutions for transport, 3D reconstruction, agriculture, and probably UAS on Mars. However, there was not specific ontologies that guide the criterial of why, what, how, which, when, and where should be favorable to invest or proceed to carry on for developing countries.

Therefore, observations during a period of 4 years were considered. On the first study, purposed sample of 4 interviews reported cases, issues with personnel and technology availability in general. Then, 30 surveys inside the UAS community on social media, with open-ended and close-ended questions regarding number of UAS (link: https://forms.gle/vj43PnK7tJ4pgL1T7), certification and other topics were assessed to provide a snapchat of how the sample behave with UAS. For example, Pilots had 1 to 2 UAS for operations, certification or any commercial permission were not required until significant national projects were involved (highways, hotels, etc).

Fig. 1. (a) UAS knowledge transfer, (b) Discussion of UAS applications, (c) Availability of specialised systems for surveys, (d) Sponsored projects for construction. On this figure is presented samples of the research process on the second study.

However, with the years other communities and sectors were growing and offering open access to knowledge of UAS. However, the gap prevailed until the organizations in whether or not adopt it. Moreover, a second study was developed. The numbers and types of organizations were explored in-depth to understand the niche and provide recommendations that can be suitable for the community. Unfortunately, a few organizations and key knowledgeable stakeholders were opened to provide their ideas as a consequence of the lack of knowledge and intellectual property issues. So, further research with records from the Civil Aviation Authority combined with other sources (Whatsapp groups with OpenBIM RD and Drone Association) were explored. They showed that the proliferation of UAS obtained a peak in 2016 and 2018. 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 only provided an idea of business-to-business relationships instead to business to customer. In addition, the wisdom of the UAS application seemed to be significantly easily to replicate or transfer. For example: the due diligence of UAS selection, credential of the pilot, personnel profile and tasks to address were key knowledge in providing services with UAS. However, in practical sense, the skills gained piloting the UAS and data translation to the specific field were extremely valuable, time-consuming, and contributed to the initial path of being involved in the industry. Nevertheless, apps and software have supported some of the initiations paths for UAS in construction such as Pix4D, Revit, BIM 360 and Procore. But, specialization by field have been the next step for avoiding unfair competition, maintaining standards, and understanding the market.

Table 2. Demographic Information of the participants and knowledge quantification. On this table is presented the demographic information of the participants and their knowledge in one of the 7 areas identified related to the construction industry.

							Cases						
No	Type	Person	Age Group	Sex	Years of Experience	Occupation	Infrastructure	Building	Urban Planning	Real Estate	Traffic	Disaster Management	Mining
1	Public	P10-FA1	50-60	Male	5-10 years	Chief of the General Aviation and air Works Division	1					1	
2	Public	P11-LN1	20-30	Male	0-5 years	Architect Drone Pilot		1					
3	Public	P12-GNS1	30-40	Male	5-10 years	Head of the Information, Communication and Technology Department			1			1	1
4	Private	P13-PUC1	50-60	Male	15-20 years	Coordinator of School Civil and Environmental Engineering		1				1	
5	Public	P14-SIN1	50-60	Male	0-5 years	Director of Operations						1	
6	Public	P15-COO1	30-40	Male	5-10 years	Technical Director		1					
7	Ong	P16-ORL1	50-60	Male	10-15 years	Executive Director	1	1					
8	Private	P17-EM1	60-70	Male	20+ years	Chairman of the Board	1	1	1				
9	Public	P18-SSI1	20-30	Female	0-5 years	Assistant Technical Director		1					

10	Private	P19-ANE1	30-40	Male	5-10 years	Technician	1	1					
11	Public	P1-WQ1	50-60	Male	5-10 years	Quality Water Management	1					1	
12	Private	P20-PRE1	40-50	Male	20+ years	Aeronautic Assessor	1						
13	Public	P21-INT1	30-40	Male	5-10 years	Project Analyst			1		1		
14	Public	P23-IDC11	40-50	Male	0-5 years	Coordinator of Flight drone operations	1				1		
15	Public	P24-INA1	40-50	Male	15-20 years	Topography Technician	1						
16	Public	P2-MP1	60-70	Male	15-20 years	Director of Government Monitoring and Coordination							
17	Public	P3-ZO1	30-40	Female	5-10 years	Technical Support		1				1	
18	Public	P4-EC1	30-40	Male	5-10 years	Vice Minister of Operations and Road Maintenance	1	1			1		
19	Private	P5-WN1	30-40	Male	5-10 years	General Manager				1			
20	Private	P6-SD1	30-40	Male	5-10 years	CEO							
21	Private	P7-EPLA1	50-60	Male	15-20 years	General Manager	1	1		1	1		
22	Private	P8-KL1	30-40	Female	10-15 years	BIM Manager	1	1					
23	Ong	P9-PB1	20-30	Male	5-10 years	Director of the organization		1					
24	Public	P22-IDC21	30-40	Male	15-20 years	Technical in-Flight Drone regulations	1			1			
						Total	12	12	3	3	4	6	1

The WhatsApp groups found, clearly, identified the key knowledge holders for construction. These groups contribute to the digitalization process of the industry in the country. Based on the technical frameworks required for UAS adoption, construction bodies have updated their current standards and operations with UAS as well as with BIM 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 were implemented in the country that the awareness and tools for BIM, technically, were spread at an accelerated rate. Then, the cases of real estate, buildings, disaster management, urban planning and infrastructure preparations with land surveying were assessed. Many projects founded by international organization were running to intend to understand the application of UAS for different productive sectors in order to rise the technological capabilities of the country.

Therefore, a ground theory approach was utilized to gather empirical data from 24 semi-structured interviews of the Dominican Republic. The findings were used to reflect in theory built for the discernment of the topic (Torraco, 2005). Furthermore, during the data analysis other analyses were made such as content analysis and thematic analysis in order to satisfy aspects of the ontology in creation. Nvivo software were used to make an in-depth analysis and contrast the industry insights and theoretical view to pursuit an ontology that reflects the actual process of adoption. Further validations were made utilizing 3 professionals in the field that discuss their perspective of the model.

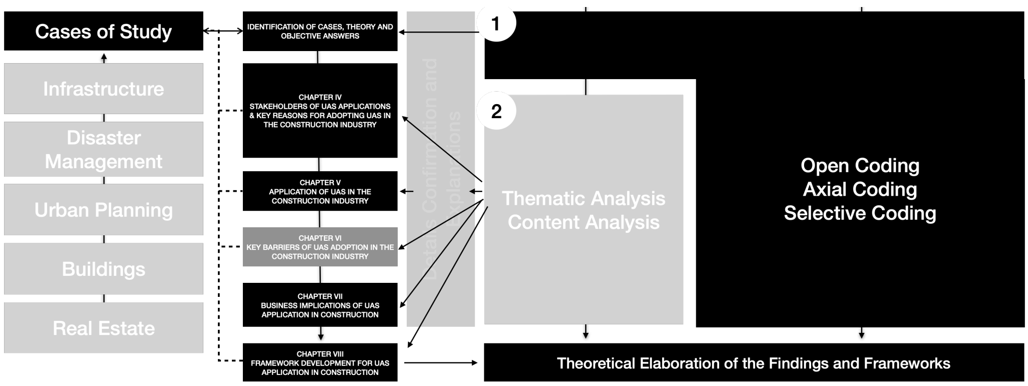

Fig. 2. Research methodology map. On this figure is presented the objectives, cases and analysis took in order to produce the model.

4. DATA ANALYSIS AND DISCUSSION

The above methodology propitiated the narrative of the participants' transcripts. Then, the ground coding strategy identified the concepts of parental and child nodes segmenting, the iterative process, in 3 phases from different angles to produce the following ideas:

The first perspective was related to the tasks and ideas needed to enhance the proliferation of digital practices in construction. However, despite the need in resources, incentive and technical knowledge, the culture of cost involved in the industry made difficult the adoption process of many technologies. Furthermore, a second iteration, considering the cases in which the UAS were adopted and how the organization were interacting between them, permitted to clarify the 4 major stakeholders within this sector: Drone manufacturer, implementors, construction organization and public entities. These stakeholders were evaluating their process in terms of speed, risk reduction, digitalization and digital skills. Furthermore, the sustainability of the UAS application was dwelling in the recurrency of the tasks of the department as well as the policies related to 2D and 3D outcomes referring to the legal system in place. Some observations regarding the UAS were made as the photogrammetry outcomes and UAS models, in those times, did not satisfied completely the requirements of accuracy for sustainability of these digital workflows.

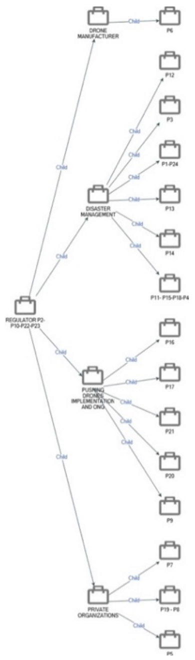

Fig. 3. Second iteration allocating cases. In this figure is presented the four-mayor categories of organisations involved in the UAS adoption in the country. The regulatory body govern them and provide recommendations for safe operations.

Finally, from the perspective of adoption, it was examined the intentions, maturity of the digital infrastructure, competitiveness, applications of UAS and frameworks for its adoption as presented in Fig. 4. In this attempt, all the key information concerning the stages of technology adoption were evaluated accordingly.

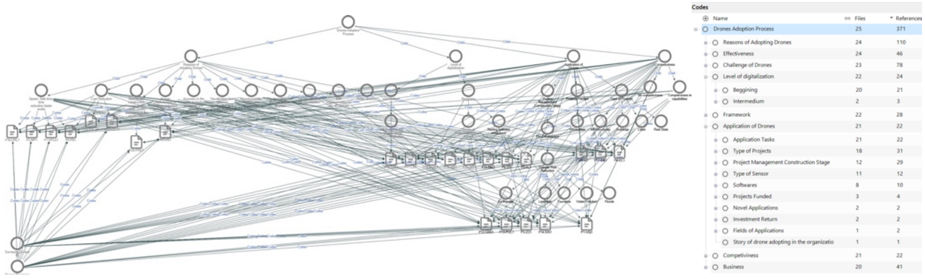

Fig. 4. Code Relationships, subtopics and references. In this figure is presented the codes and relationship between them and the actual transcripts.

4.1 Framework Generation

The set of ideas identified were evaluated in Nvivo and summarized in a text query for presentation purposes. The need of developing a framework or document to evaluate the adoption of UAS were hold by improving or creating new standards, manuals and workflows of the current practice of construction. Some airspace regulations should be modified in order to assure safety with in the UAS operations for medium and large companies.

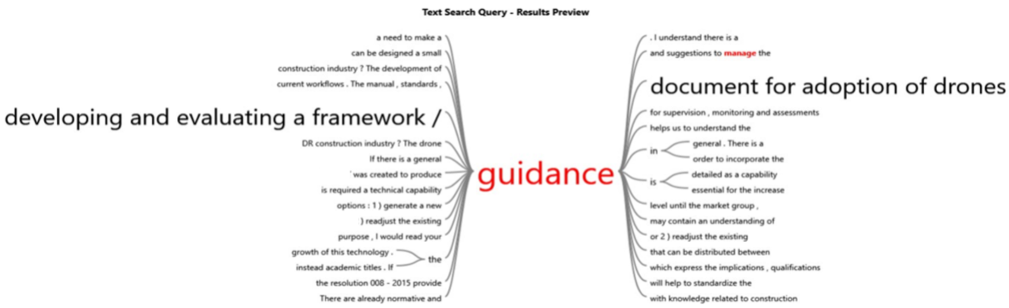

Fig. 5 Text Search Query – Results. In this figure is presented how the words connect the idea if guidance with the type of improvement or creation required for UAS operations for construction.

Furthermore, different hypotheses were built to understand the adoption process and identify the key drivers to consider its adoption as the figure below.

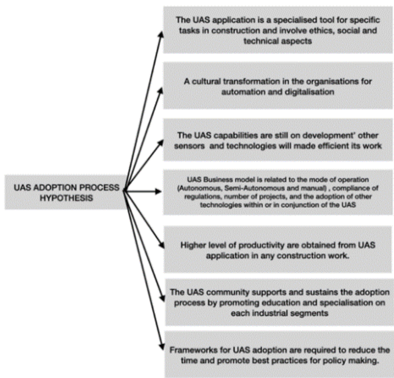

Fig. 6 Hypothesis Generated from the ground theory analysis. These hypotheses were used to identify the patterns that connect and provide ideas on how the adoption process should be proceeded.

Finally, the ideas were intertwined and added 2 layers or hierarchical levels that covered the governance and combined DOI, learning organization theory, community drivers, and task-fit theory with the Socio-Technical Systems approach by encompassing the answers to the questions related to who adopts the artefact, where/when it comes from, how to govern it and finally, how it works. However, this approach can change if artificial intelligence or the integration of other emerging technologies substitutes human operations for autonomous ones. It means that human skills influence the UAS operations and, perhaps, the ontology outside of a decentralized autonomous organization. In this attempt, all the key information concerning the stages of technology adoption were evaluated accordingly.

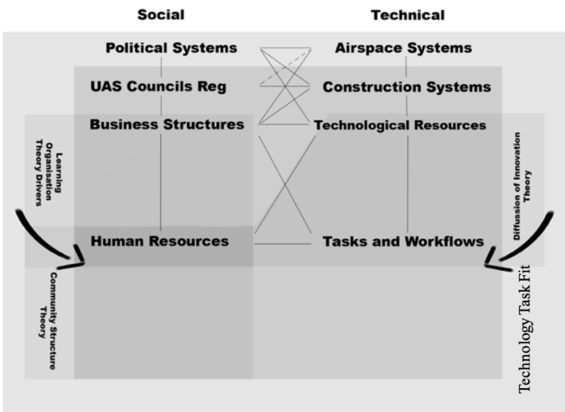

Fig. 7. Socio-Technical System Framework and modifications. The ontology describes the layers in which the social and technical aspects are merged when discussing the application of UAS in a national level. The rows reflect on the changing regulatory environment that the UAS face thru political and airspace systems inflicting the boundaries of operations.

For example, if UAS are banned due to a country's legislation or due to privacy issues, another technology would emerge in order to overcome the challenge. In other words, the evaluation of UAS acceptance, in organizations requires an understanding of the dynamics in the regulatory boundaries, business models, and processes within the UAS operations. Other remarkable examples are the types of operations that may influence the feasibility of the UAS adoption according to the size of the organization. Therefore, UAS applications are seen in organizations for automatizing employee productivity by improving the actual workflow. In terms of structure, organizations are changing the way of delivering products and services. Organizations are taking the knowledge obtained from UAS to provide business-to-business services by opening a new industry concerning to quality assurance and additionally providing the path for autonomous organizations with the internet of things. Finally, the model was evaluated by asking professionals to fill their perspectives on each specific feature and assess their relevance. Improvement in the aspect of political and airspace were highlighted to fulfill the gap in knowledge referencing the UAS.

Therefore, this model supports any type of organization to allocate a department of UAS for special projects. This type of projects, where budget and quality assurance are vital should be monitored utilizing UAS according to the stipulated standards of infrastructure inspections, record of construction process, human resource skills and sustainability. Furthermore, the policymakers can understand the implications and changes with the regulation for cases that contribute more to the economy than the possible harm or mal used could arise. In addition to investors, projects related to improve productivity are encouraged in acknowledgement of the UAS community as a guidance for standardizations.

5. CONCLUSION

The aim of this study was to develop an ontology for public, private, and non-profit organizations that explain the epistemological implications of the implementation of UAS for the construction industry in the Dominican Republic. The 2 studies (4 interviews and 30 surveys) and the 24 semi structured interviews provided an overview of the adoption process as well as underlining the basis of social-technical theory. The Nvivo software for ground theory coding, thematic and content analysis allowed to identify, the social aspects of politics, governance, business and community as well as their relationship with the technical aspects of airspace, technicalities of construction operations, technology availability and the tasks in which the UAS influence the workflows. The need of guidance was reflected by the improvement, modification or generation of a new standards, workflows and practices for UAS operations for construction. Then, the hypotheses generated from the 3-coding process related to productivity, business and frameworks were validated utilizing thematic and content analysis for the cases elaborations. The problem of governance was addressed by developing a model in which elaborates the epistemological implications or hypothesis founded in linkage theories of community structure, learning organization, diffusion of innovation and task fit. Therefore, any type of organization can understand the adoption process and implications of UAS within their workflows. Validation of the framework were assessed with 3 professionals of the field providing their perspective on benefits to the policy makers and politicians regarding the adoption of UAS.

However, it is wise to consider, in future works, 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, building a digital twin can interact with a multiple UAS as part of a personalized human behavior digital replica 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 with workshops by OpenBIM group and others. The efforts are towards digitalization and elevate industrial practice covering some of the technical frameworks for UAS adoption. Furthermore, works on the land surveying frameworks 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. Infrastructure manuals can be updated for inspections processes in the future.

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