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UAS APPLICATION FOR URBAN PLANNING DEVELOPMENT

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ABSTRACT

The field of Unmanned Aerial Systems or Drones is still under development by the challenges of regulation and technology readiness for certain applications. The application of emerging technologies and robotics incites the growth of productivity on repetitive and exhaustive tasks for human and represent a rapid solution for data collection methods. The UAS presents opportunities to contribute and carry out urban planning tasks in a reduced time and risks, and appropriately supportive for COVID-19. Therefore, a case study is presented to illustrate the process of UAS data collection and conclusions drawn for delimitating urban communities.

INTRODUCTION

The COVID-19 pandemic has significantly changed the values and methods to live life. Nowadays, humans are plugged into technology to survive and generate economic contributions to society. Therefore, strategies underpinned on solid automation cases for the significant contributors to nations' GDP levels aligned to the Sustainable Development Goals shall be designed along with emerging technologies as the concept of Society 5.0 and Industry 4.0.

The concept of Society 5.0 has been defined by the Japanese government as merging the real-world and cyberspace to promote wealth by scientific and technological innovation migrating from "smart cities" to "super-smart cities". Therefore, this vision stimulates research on robotics and technologies that can contribute to the adequacy of well-being facilities; and pursue the faculty of sustainable happiness (Deguchi, et al., 2020). Another strategy is Industry 4.0 by Germany. The strategy is looking to improve the rate of emerging technology adoption to overachieve a comprehensive transformation of the industrial production. The last strategy has been tested in countries such as Brazil (Siltori, et al., 2021). However, the strategy of Society 5.0 is oriented to the specific case to be covered in this paper.

A recent redesign on the traditional user-experience models of aerial robots such as Unmanned Aerial Systems (UAS) or Unmanned Aerial Vehicle (UAV) has provoked explorations on its potential for diverse fields. The research for possible UAS applications within urban planning development is emerging given the several needs that the specified aerial robots and technologies can address. The change management in learning organisations occurring with UAS and urban planning is related to cost-benefit solutions against actual workflows and image resolution obtained from satellites. The UAS covers a real-time smaller range of area than satellites. In other words, UAS assists satellites in enriching the spatial analytic components of accurate geospatial data by monitoring the development of cities and human mobility.

The accuracy of geospatial data allows urban developers and policymakers to improve citizen experience-oriented to well-being and happiness. For instance, some typical applications related to this purpose with UAS target the monitoring of urban development (Gallagher & Lawrence, 2016), identification of vulnerable communities for disaster recovery (Wu, et al., 2020), measurement of the solar irradiation level potential (Nelson & Grubesic, 2020), precision agriculture (Hu, et al., 2019), smart contracts for city development (Alladi, et al., 2020), city heritage preservation (Templin & Popielarczyk, 2020), and law enforcement (Li & Liu, 2020).

However, the challenges listed in the literature address different management levels.

On the low-level workers or technical aspects of UAS implementation, there are significant challenges concerning design and fabrication, power supply, endurance, and radio control distance (Hassanalian & Abdelkefi, 2017). These challenges directly affect the cost-benefit plans and the micro aerial robot tasks operation (Duffy, et al., 2017). In addition to the weight, dimensions, materials, and operation boundaries hindering the agility process of deployments and, in a particular context, the implementation of UAS in urban and rural areas (Norzailawati, et al., 2016). In high and middle levels of management, it is essential to keep awareness of the regulations applicable to UAS applications—as these could lead to strong limitations.

Understanding and Contrasting of UAS Regulation Limitations

The UAS regulatory bodies of the European Union Aviation Safety Agency (EASA) provide a detailed account of limitations. The EASA's regulations are conveyed in UAS design and operations with the (2019/945) & (2019/947) respectively. The proactive regulations imposed for the circumstances of operating in proximity to assembled people aim to protect the privacy of residences and maintain national security. However, the "specific" category, in which it is possible to operate in urban areas, could be an arduous process for experienced research pilots to re-adequate and recognise the UAS qualification from outside the EU zone. Therefore, the harmonisation process of UAS qualification is an internationally ongoing process and might take several business cases to accomplish. For example, The UAS regulations of the United Kingdom have a similar structure to the EU regulations to fluently evaluate authorisations.

In any case, other countries may manage the regulatory aspect throughout the council's governance or unrestricted the usages of UAS. The last alternative could deliver wisdom on the practices of its implementation (Grubesic & Nelson, 2020) as could be the case of the Dominican Republic. The regulation in this country is more flexible than the aforementioned countries—where the operations with UAS in urban areas are carefully monitored and unrestricted (Vanderhorst, et al., 2021).

Therefore, the aim of this paper is to illustrate the applications of UAS in a flexible context so that its exploration for a council can assist during the delimitation process of urban municipalities and extend its versatility in the Dominican Republic.

LITERATURE REVIEW

Understanding of Society 5.0

The emerging concept of Society 5.0 is based on scientific cases, and for the case of UAS, successful cases make easier its integration. Adopting emerging technologies and robots could generate apprehension for different governments and citizens by the triggering involved in the change management such as generational relief and capabilities requirements (Demir, et al., 2019). For these reasons, the triggers that the adoptions of multiple technologies (Industry 4.0) for super-smart cities or the Japanese concept of Society 5.0 will be needing technical and ethical frameworks for the adoption process in overseas countries. The vision underlies the reduction of human alienations and productivity enhancement throughout the implementation of cyber and physical robots. Thence, humans can be specialised in innovative and creative tasks aligned with their Ikigai (Kumano, 2018). Therefore, the understanding, ethics, frameworks, and cases of technology assisting humans could be extrapolated in the built environment in order to allocate the areas of improvement and replicate the model in other countries. For example, in the European Union is taken the concept of industry 5.0 as a coherent integration of technologies towards sustainable resilience and satisfying life of workers (Breque, et al., 2021). This vision makes reference to the society 5.0 adding updates regarding COVID-19 and resilience variable for the society. The vision assumes that economic recovery would be lead by applying technologies in a more fulfilling and human-centered way. However, how these concept would be seen and applied in cities?

The concept of smart cities has been generally related to improving the experiences of humans with technologies in terms of transport and energy. However, the introduction of technologies onto the existing infrastructure facilities and systems of cities is a challenging process; in contrast, to building them with an government technological vision of the city. For instance, the 2011 Tohoku earthquake produced significant changes in the Kashiwa-no-ha government vision of smart cities. The government vision allowed to guide the city towards an eco-friendly urban development, focused on longevity and new industrial developments. The vision and changes made to the urban structures were based on the lessons learned from the spatial distribution between infrastructures and their interconnections of data, information, monitored shared services, and traffic flow divergences in the city (Deguchi, 2020). In these cases, of traffic and infrastructure a system as the Unmanned Aerial System (UAS) was required for the acquisition and integration of data as well as softwares for its analysis and coordination processes.

Some of the most relevant reasons to apply emerging technologies as the UAS are the need of innovation and competitive advantage (Otala, 1995), risk reduction in humans, rapid data collection process, requirements of high-resolution images, accuracy of data and digitalisation of the real-world with the integration of Building Information Modelling (BIM). In terms of the general adoption rate of technology, innovations can be seen as disruptive or progressive. In the case of the UAS, the rate tends to be disruptive by the substantial productivity increment in data collection process experienced in the field (Vanderhorst, et al., 2020).

However, the "how" of the innovation adoption seems to be a gap to explore in the scientific field, especially for urban planning oriented to improve the decision-making process of councils regarding to data-driven desicions, mobility, resilience and energy. Figure 1 illustrates a vision to be developed while digitalisation and aerial robots of the environment are achieved.

Figure 1: Urban city with the adoption of technologies and robotics

While this vision is in process, the current capabilities of UAS and the pandemic make to consider to work with the current matured and low risk UAS and operations. In the future, UAS, artifitial inteligent and quantum computing could made possible sophisticated operations and assessment. For example, (i) Rights of the sensitivity artificial intelligence to mirror, erase or monitor recorded behaviors of people on social media, (ii) the impact and concerns of autonomous 360° live-streaming reality capture of inaccessible vulnerable communities after biological disasters; (iii) the social and economic implications of eatable parts and threats of a biological quantum UAS for the animal and human realm without mentioning the discussion of UAS and propulsion methods for transport people and goods. Nevertheless, the following section describe the UAS and its role in urban planning.

Unmanned Aerial System and Urban Planning

UAS are designed in accordance to the task to be addressed. There are different UAS categories according to the aerodynamic design, weight, and context in which it is developed. According to the design (Greenwood, et al., 2019) a hierarchy of UAS is established. Aerial robots have three types: fixed-wing (as an airplane), VTOL (hybrid between airplane and helicopters) and rotorcraft (as quad-copters). Differences can be identified in regards to the design, the flight time, price, and manoeuverability for each type. Fixed-wing and VTOL UAS have more energy efficiency on the flight time than rotorcraft models. However, the energy efficiency compromises the manoeuvrability of the UAS on confined and complex data collection spaces, for example, building and bridge inspection. In extended areas, fixed-wing and VTOL UAS are the most suitable solutions. (Siebert & Teizer, 2014) describe parameters in applying photogrammetry with UAS , which is recommended to be between 100 m^2 to 100,000 m^2 during the operation. Furthermore, the determination of the most appropriate tool for the assessment can be affected by the cost level linked to the implementation of UAS and the implications of its operation. Therefore, the utilisation of UAS is still under exploration for certain tasks and subcategories of urban planning; frameworks for adoptions and applications for COVID-19 still on development.

Reviewing the literature systematically as (Vanderhorst, et al., 2019) on UAS applications for urban planning, through a text mining approach with Scopus database, less than 600 manuscripts referring to “UAV” and “Urban Planning” were found and the visual data mining tool expressed 4 clusters or topics related urban planning (as shown in Figure 2). Moreover, detailed keywords referring to the technical aspects of urban planning were found as shown in the green cluster (Figure 3). Additionally, implementations were observed in several subcategories within urban planning such as Construction (Faris Elghaish, et al., 2020), Infrastructure (Greenwood, et al., 2019), Traffic (Barmpounakis, et al., 2016; Hubbard & Hubbard, 2020), and Agriculture (Tsouros, et al., 2019).

However, the link between urban planning and those fields should be investigated in detailed for councils. Furthermore, cases on urban planning are still under evaluation due to the contemporary issues of urban areas regulations and capability of the sensors to address tasks mentioned in (Noor, et al., 2018). For example, radio frequency legal distance transmission power, zoom UAS lens, thermal and infrared cameras regulations, and ethics on substance carriage. Tasks related to disaster management, law enforcement, search and rescue were also identified as seen in Table 1.

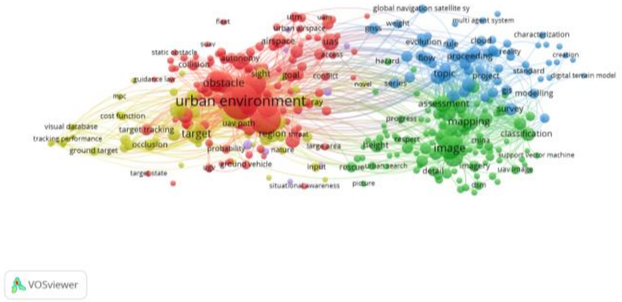

Figure 2: Literature text mining approach

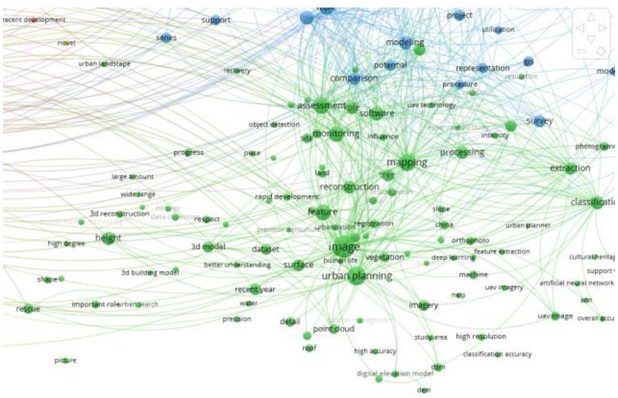

Figure 3: Literature for UAS outcomes

Table 1: Application of UAS within Urban Planning

Field	Tasks	Literature
Construction	Monitoring, inspection and safety Surveyings 4D BIM Progress reports	(Faris Elghaish, et al., 2020; Vanderhorst, et al., 2019)
Infrastructure	Bridge inspections Monitoring Infrastructure Inspection of Infrastructures	(Greenwood, et al., 2019)
Traffic	Traffic Flow monitoring and management Vehicle detection Traffic incidents Travel time measurement Monitoring connectivity and security issues	(Barmpounakis, et al., 2016; Hubbard & Hubbard, 2020)
Agriculture	Weed Mapping and Management Vegetation Growth Monitoring and Yield estimation Vegetation Health Monitoring and Diseases Detection Irrigation Management Corps Spraying	(Tsouros, et al., 2019)

Urban Planning	Swarm of Drones Rapid monitoring, assessment and mapping of natural resources Cadastral Applications Land Management Land consolidation Disaster Monitoring 3D reconstruction to Historical buildings	(Noor, et al., 2018; Kuru, 2021; Sadhasivam, et al., 2020).

The urban planning tasks are addressed with technological tools such as satellite images, google earth, airplanes, helicopter LiDAR, and photogrammetry. Nowadays, the gaps and challenges faced by the tools for making an efficient and accurate result have been reduced with the UAS; mainly with the purpose of data capturing, where UAS offers a feasible solution depending on the sensors used for data capturing. For example, measuring traffic flow (Gattuso, et al., 2021), particle matter (PM2.5) (Li, et al., 2019), radiation in drinking water (Salmirinne & Hyvönen, 2017), koala and primate identification (E.corcoran, et al., 2019; Spaan, et al., 2019) and conditions of the cities as previously discussed. The data acquired helps to build a more real cyberspace that (in the future) could feed unmanned autonomous robots accessing a cloud-quantum computing-based to support human activities. Thus, leading to big-data analysis and artificial intelligence solutions for human problems to be more efficiently addressed. For instance, the identification of feasible aerial taxi routes, ideal UAS heliport locations, UAS houses, building re-adaptation for UAS noise, post-pandemic urban planning designs, seasonal land-use changes, and elder villages allocations, sharing social development amongst communities, and climate change risk plans will be some tasks that the futurist vision intends to solve. In addition, the 3D reconstruction of exoplanets and space-time travel may be possible in a distant future.

However, UAS for the mobility of citizens appears to be a possibility for the next post-pandemic generation.

Barriers of Society 5.0 and Unmanned Aerial Systems

Despite the benefits that the concept of Society 5.0 and the application of UAS present, there is a factor which produces doubt and scepticism from different management perspectives on its execution. In terms of the society 5.0 concept, the identified barriers for its adoption in society are oriented by legal aspects, acceptance of working along robots, mental disorders, human substitution, organisational changes on human resource departments, ethics on robots, human competition with robots and business cases (Ivanov, et al., 2020; Demir, et al., 2019; Deguchi, 2020).

However, the adoption of robots in the Dominican Republic has been sluggish in respect to countries where research, development and entrepreneurship initiatives are a fundamental aspect of their society.

The proactive demand of innovation, feasible and viable applications of robots for reduction of human alienation allows societies to understand and prioritise the true meaning of human essence and achieve sustainable wealth (Wendling, 2009). In a more profound sense, the development of viable business cases to innovate methods of transport, data collection, and data analysis would contribute to the progress and establishment of the vision in Figure 1 of a society 5.0. Different countries have different rates of encountering innovation with robots, but the UAS have tended to be modest and expensive in some extend.

The challenges of UAS deployment are influenced by specific regulations in each country. The responsibility to regulate UAS weighing less than 25 kg is from the national civil aviation authority. In the Dominican Republic, the past UAS regulation (Resolution 008-2015) used to frame and authorise operations with aircraft weighing less than 2 kg based on the level of risk involved. However, the regulation required updates related to the training methods for pilots and, in addition, to the correspondent permissions for operation beyond the digital reconstruction and inspection as UAS for cargo. For these reasons, a new regulation was released covering those topics. Nevertheless, the industry around UAS and its professionalism could be evolving to an "adolescence period" in which the standardisation of risk mitigation accelerates and outpaces the safe adoption process. In the same aspect, the technical challenges faced in adopting UAS on urban deployments are the visual distance from the pilot during operations, interferences, the complexity of the urban and suburban areas regarding infrastructure, weather conditions, battery power, and ground sampling distance (Grubesic & Nelson, 2020).

In the case of the Dominican Republic, currently only one city (Santiago) has started developing a plan towards the goal of becoming a smart city (INTEC, 2019; CDES, 2020). In essence, the city aims for an improvement in culture, urban planning, and social cohesion. Furthermore, the UAS has been tested for other applications such as UAS for desinfection during COVID-19 restrictions, UAS for cargo of medical samples and fertilizer distribution in agriculture. However, these applications are still in development for the future due to technology readiness, sufficient supporting business cases and effectiveness of the methods. Nevertheless, technology and robotics are fields yet to be developed and promoted—in order to speed up the decision-making process from a technical and management perspective.

Implementing the concept of society 5.0 in the Dominican Republic will require significant changes in technologies from the aspect of data collection, processing, analysis, and management based on the amount of real-time data on cloud computing as described by (Shibasaki, et al., 2020). In addition to the social implications of perception in case of UAS taxi. Frameworks for adequate transition between traditional and novel method should need to be established previous the adoption. For example, building a model quantification of infrastructure assets in a community or city, economic assessment of urban areas, 3D simulation for forecasting urban expansion, maintenance of buildings and infrastructures as well as policies to data interoperability access are cases that contribute to the vision.

However, the actual implementation could present barriers of funding, knowledge management, acceptance, open and big-data storage, as well as specialized software for data analysis. Therefore, the UAS cases help define the pipeline of digital data reconstruction for these purposes.

METHODOLOGY

The aim of this paper is to illustrate the case of UAS application for urban areas in the Dominican Republic, intending to use UAS data for urban planning development. A qualitative approach was used to recreate the case through semi-structured interviews with the (2) main institutions involved in the pilot study in the Dominican Republic. The data shared was analysed, evaluating the documents and vision regarding the applications of UAS. Finaly, the details and conclusions regarding the experiment were reported.

The experiment was carried out in an urban area which presented a significant population growth, and providing evidence of it was required. The main purpose of the UAS implementation was to identify the most populated areas and provide a big picture of the population growth as well as the house distribution to the council since it could not be appreciated via satellite images. In the country, this type of task is carried out by physically visiting the places with or without 2D maps as well as using census data. The major challenge is that it is only possible to understand any explanation regarding the urban area on-site. The benefit of the UAS in these tasks is the possibility to hold 2D lines, visually update maps in colours, and accurately identify the current community conditions. This approach makes safer and more efficient the exhausting tasks of ground-workers.

The approach to analyse the potential of UAS implementattion was assessed based on the responsabilities of the council such as traffic management, public spaces, disaster risk reduction, land use, infrastructure facilities, rural markets, and heritage conservation. Therefore, the database generated for the municipality was developed utilising UAS reconstruction followed by CAD platform modeling to visually describe the population growth of the community area. Nvivo 2020 software was used to identify the segment of the experiences shared. Quad-copters weighing less than 2kg were utilised in order to assure safety on the deployment. DJI Phantom 4 and Mavic Pro were used in the early mid-2018.

RESULTS

In the Dominican Republic, the UAS regulation was flexible for government operations. However, regulation parameters such as clear 20 m x 30 m deployment area, do not exceed 80% of battery charge, maintaining a visual line of sight and checks of the air traffic were considered in the operations in class G. In technical aspects, the UAS only covers a certain amount of land for ground sampling distance.

The application of UAS for urban planning is still unknown for councils. A short introduction regarding UAS was required to define the expectations of the outcomes and sharing a different point of view concerning their requirement. Challenges during the deployment were concerned with peak hours of transit and school times. The first deployment was made in open spaces of the city centre.

The software used for processing the imaging data was Recap Autodesk which converts them into an orthomosaic. The UAS altitudes and the RGB sensor settings of the UAS were different which provoked higher contrast in one area of the orthomosaic as presented in Figure 4. Moreover, environmental assets of the community were identified such as a river, new roads and farmhouses from Figure 5 and 6.

Figures 4 and 5 show the decoding of urban grids, the socioeconomical status of the zone, road conditions and emerging ones. Figure 5 shows with rectangles on green ( ) the houses with zinc roof and ( ) on purple the concrete structural elements on the roof. The surveyed area covers a municipality with approximately 586,000 m^2 containing 529 zinc roofs and 256 concrete ones in 2018. The process of counting roofs was divided into 9 blocks according to the organic and suburban grids developed organically. From Figure 5, blocks 4 and 8 were evaluated to understand the possible decisions derived from the UAS data.

Figure 4. Visual Evaluation of Urban Growth

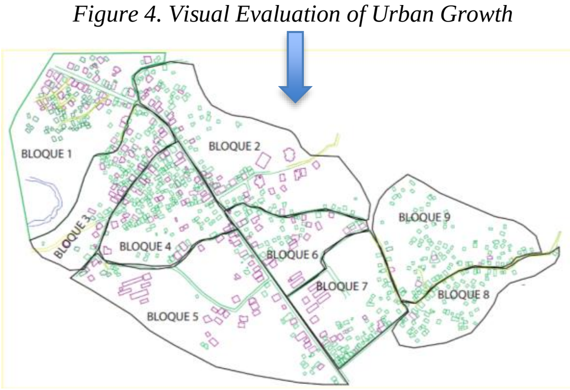

Figure 5. Analysis of Urban Area

In Figure 6, a visual assessment of the urban changes is presented. The experiment was conducted in 2018, but the authors complement the information of the comparison with 2020 satellite images. Figure 6 shows the period of 2017-2020 and the UAS images compared. Figures within

6abc present the changes and issues of maps available on a high resolution with satellites against UAS. The Figures 6a and 6b show the housing developments and changes in the zone in constrast to Figure 6c that does not provide visual data of the current state. In Figure 6def the construction of new houses and land-use changes from agricultural purpose to construction can be appreciated.

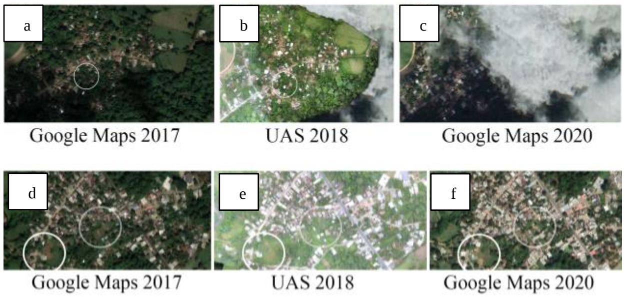

Figure 6. Visual Evaluation of Urban Growth

Furthermore, the challenges presented at the council during the process were related to the sustainability of UAS internally. The council was lacking in knowledge on UAS applications and its versatility in data collection and the implications of data processing. However, there was no resistance to change as long as the business case was feasible in the long term and funds were available for the adoption process. However, the regulations of this type of operation could be limited by the lack of specialised human resources and the required yearly update frequency. Furthermore, the usage of the data allowed the council to provide accurate information of the current location of the communities and assess COVID-19 measurements.

DISCUSSION

According to (Siebert & Teizer, 2014) UAS could cover areas between 100 – 100,000 m^2. But, in this case, 2 UAS were used to cover a bigger range of area; however, given the accuracy of less than ±10cm the deployment was tolerable for the main purpose. Geospatial data was collected in order to identify the socio-economic status of the area. The population living under zinc roofs was approximately double of the concrete ones, allowing to understand the possibility to take actions on social projects or aids for enhancing quality of life in the community. In addition, the identification of a small river in block 1 shows the community may face risk during rainfall periods, as mentioned in the literature (Noor, et al., 2018). The overall visual urban analysis of the grids was useful to confirm the empirical data held by the council, but thanks to the implementation of UAS it became physically and cybernetically sharable with other stakeholders and institutions as the 911 —National System of Attention to Emergencies and Security— in a 2D printed format. The initiative for taxing illegal construction and inappropriate land use emerged during the discussions. The information presented may allow road restoration and quantification of construction work in the community and produce faster, cheaper workflows by reducing bureaucratic processes during the supervision and confirmation of land space.

In other aspects, the information gathered allowed other institutions and stakeholders to understand the opportunity to apply UAS for the office of statistics. However, the lack of knowledge in technical aspects confirmed that the alliance of public and private partnership in terms of technology adoption should be included for the initial stages until the technology could be integrated into the organisation. In addition, this approach promotes the adoption of emerging technologies for small and medium organisations.

Furthermore, the map generated was used as a visual aid for the identification of community needs. The data of the community was more manageable in print-based rather than electronic format. It means that the printed version was effortlessly shared at meetings and avoided issues of specific computational requirements. The high-resolution images were capable of presenting the community status in council meetings for internal requests and evaluating the decision to upgrade the municipality circumscription. In terms of implementing the society 5.0 concept, other UAS applications shall be tested, such as urban traffic and monitor the mobility of the citizens in inaccessible areas and the pandemic context. The use of other technologies are encouraged to carried out and assess the site conditions. Apps and other data should be integrated for the visual assessment of the UAS application and generate the useful information for the councils such as Geographic Information Systems (GIS) and layers of land use. These UAS applications may seem as indicators of society 5.0 implementation as mentioned in the introduction section by (Deguchi, 2020). Another possible usage of the digital data of the communities could be for promoting solar energy programs by identifying the applicable roof area for these purpose (Grubesic & Nelson, 2020). And, as a consequence, it will regulate the vertical growth of the community.

Therefore, the data collection can provide the baseline for future technology adoption as big data management and Artificial intelligence for point cloud classification and simulations. The integration of those technologies will directly influence the 3D reconstruction of buildings with the Building Information (BIM) methodology and their attributes. On a long term basis, the adoption of the emerging technologies will contribute to heritage conservation and restoration in case of fire as well as hyper automation in forecasting the community growth behaviours.

CONCLUSIONS

In conclusion, this paper presented an example of how the UAS can be used to identify house growth for councils in the Dominican Republic. The model presented showed that UAS has the potential to provide visual information regarding the current state of the community and UAS applications from the council perspective. The model could be replicable in other countries with similar settings.

The integration process requires technical and social awareness regarding the UAS applications and the benefits to stakeholders. Incentives on adopting emerging technologies should be desirable to encourage business innovation in the country and raise the standards of automation and digital transformation. Therefore, the positive implementation of aerial robots contributes to reducing alienation in specific work tasks by improving productivity, reducing human exposure to risky environments, and identifying community needs for contributing to the well-being and sustainable happiness of the society. Further work on framework to develop an adoption process of UAS should be designed with the new normal and visions established.

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