Methodology for Infrastructure Site Monitoring using Unmanned Aerial Vehicles (UAVs)

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***Abstract*—Monitoring a work of infrastructure allows one to know the state of this and the efficiency of the workers. The follow-up is a work carried out by the auditor, which sails to correspond with the design in planes. It takes fulfillment in the budgeted one and complies with the established times. This work uses classical topography elements, which demand time and money and the implications on the safety issue of non-construction personnel. To avoid this, this project implements a methodology capable of carrying out the task of monitoring civil work. An unmanned aerial vehicle or drone is used, which are small remotely controlled flying devices that in recent years have become an extremely useful tool in activities that human beings cannot perform or that threaten their integrity. For the realization of this work, a drone Quadcopter Phantom 3 Standard is used, responsible for taking photographs; these are loaded in the software Agisoft Metashape Professional that by photogrammetry techniques allows digital processing of images, generating a 3D vision, cloud of dots, digital surface model and distance measurement. By obtaining this information, it is possible to make a match with the work schedule and detect delays or advances in a precise way.**

Keywords—Topography; unmanned aerial vehicle; infrastructure work monitoring; digital image processing component; construction site

I. INTRODUCTION

The construction industry is relevant to the development of countries. This industry is related to the development levels of each government and is an important source of jobs. Despite its relevance, the sector is characterized by low productivity levels. Construction projects often exceed planned costs and times [1]. This situation is associated with a series of factors specific to the working conditions, such as the worksite, the multiple teams, the fragmentation of the sector, and the low industrialization and digitalization of its processes [2]. Thus, project management and incorporating new technologies are key to improving these indicators. Construction 4.0 is a new paradigm that promotes the sector's digitalization, automation, and industrialization. Thus, working with digital models of projects, tools for capturing the territory, and sensorization are key aspects [3].

Monitoring the progress of a project is key to its effective control. The constant review of the project's progress according to the planning and the supervision of the quality and scope are aspects of interest for project managers [4]. This activity is regularly performed based on the observation of the project managers, supported by traditional surveying tools. In the surveys of infrastructure works with classic topographic elements and visual inspections, the personnel must be inside the worksite to collect data. This displacement takes time and presents discontinuity since there are areas of impossible or difficult access, exposing possible accidents [5].

Site surveys have benefited from technological advances, currently using instruments for measuring different terrain variables, 3D scanners, and technology that uses GNSS systems are some examples. Unmanned aerial vehicles (UAVs) are presented as an efficient alternative for job site surveillance and inspection within these new technologies [6]. They have been used for military, agricultural, and urban management purposes. The use of drones for construction site surveys offers a series of benefits that reduce the risks and problems of traditional methods. It is possible to obtain continuous, accurate, real, and fast data of the entire surface under construction without accidents [7], [8].

While there are existing works that use drones for job site monitoring, it is necessary to advance in the establishment of methods and workflows to systematize these applications and increase the number of success stories to demonstrate the benefits [9]. To meet these objectives, the methodology presented in this research is a tool aimed at efficiently and accurately streamlining the work of construction site monitoring. It reduces the presence of experts within the construction, reducing the time in data collection and the risks of a possible accident. In addition, it provides digital elevation models for a complete analysis, using as base instruments a Phantom 3 standard drone and Agisoft Metashape Professional software. The information must be collected to recognize the differences between surveys with classic elements and surveys using drones for its creation. Based on this, a detailed methodology is designed, which has the final objective to compare the data collected and the data provided by the intervenor in an estimated time of 7 months.

This article is organized as follows: Section I is the introduction, describing the research problem, Section II presents the background and a contextual framework for a better understanding of the topic addressed. Section III contains the research methodology developed in this work. Section IV describes the proposed solution. Section V presents the results and analysis, and finally our conclusions in

Section VI are shown. Translated with www.DeepL.com/Translator (free version).

II. BACKGROUND

Topographic surveys can contribute greatly to identifying previously unseen surface features and can be used to produce three-dimensional computer models of the surveyed area, which can be manipulated in a variety of ways. *Surveying* is the science that studies the set of procedures for determining the positions of points on the earth's surface using measurements according to the three elements of space. These elements can be two distances and an elevation, or a distance, a direction, and an elevation [10]. This plan is essential for the correct location of any work to be carried out and for the elaboration of any technical project. To know the position of points in the area of interest is necessary to determine their location using three coordinates: latitude, longitude, and elevation [11]. We will analyze two site surveys for this methodology: surveys with classic elements and surveys using a drone.

A. Inspection of the Construction Site with Classical Methods

To carry out the site inspection, it is very necessary and indispensable to have a topographic map of the site of the work project, to make a respective marking of points on the ground, in order to make measurements for the calculation of soil movements, to have a record of measurements to check the situation of sections of work already done and to determine the volumes of soil moved (excavated and transported) and of course to have at hand the chronogram of the work.

Topographic maps or charts are the results of a cartographic projection, which are mathematical transformations that allow representing (project) the sphere on the plane, and converting the geographic coordinates (latitude and longitude) into Cartesian coordinates (X and Y). This process entails distortions of the original three-dimensional surface, which is converted to a flat two-dimensional surface [12].

B. Drone Inspection

To perform surveys with drones, a technique (or collection of techniques) called photogrammetry is used to determine objects' geometric and spatial properties in a given area from aerial images. The main objective is to convert two-dimensional data into cartographic information. To obtain a faithful reconstruction of the data, the objects in the reconstruction area must appear in a sufficient number of images [13]. This information is the one that allows extracting its structure. To obtain this extra information, an overlap is made between consecutive images. The UAV pilot must plan the route or mission so that in each image, there is an element that also appears in the previous, following images [14].

The flight of a remotely piloted aircraft (Drone) is performed at an altitude that must be calculated taking into account the desired scale and the focal distance of the camera, but also must take into account the parameter of "correlation," which indicates that a certain territory must be covered with images. Each photo must have an area in common with the photograph taken previously. To comply with this, the RPAS must have an absolute flight altitude and a constant speed to perform shots with regular intervals that correspond to equal paths and thus ensure a percentage of correlation between the succession of images. To obtain excellent results, it is necessary to ensure that the longitudinal overlap is greater than 80% and the transverse overlap is greater than 60% [8].

Some elements are relevant to understand for the correct use of drones. Focal length is the basic description of a photographic lens. It is not a measure of the actual distance of a lens but "is a calculation of the optical distance from the point where the rays converge to form a sharp image of an object for the digital sensor of the camera's focal plane". On the other hand, the pixel is the smallest unit of the pictorial elements that constitute a digital image, projecting the color spectrum. Color pixels are generally believed to have red, green, and blue components. A digital image is obtained from a matrix of pixels distributed in rows and columns. As a result, the sum of all the pixels distributed in the rows and columns is its size in pixels. The greater the number of pixels in an image, the higher its resolution. In addition, the ground sampling distance (GSD) is the distance between two consecutive pixel centers measured on the ground. The higher the value of the image GSD, the lower the spatial resolution of the image and the less visible details [15].

The GSD is related to the flight altitude: the higher the flight altitude, the higher the GSD value. Even when flying at a constant altitude, images from one project may not have the same GSD. This is due to differences in terrain elevation and changes in camera angle while shooting. Since the orthomosaic is created using the 3D point cloud and camera positions, an average GSD will be calculated and used. Finally, in photogrammetry and Drone flights, the scale is a parameter of great importance, this is data that in many of the cases is known before the flight is performed, but it can also be known after the flight has been performed. It is required to find the appropriate height at which the Drone should take the photographs when the scale at which the work is required is known, in case if the height is known. However, not the scale [16]. We must find it using a calculation between the focal distance and the flight height (later on, we will detail how to calculate the flight heights) [17], [18].

C. Digital Image Processing

Digital image processing can extract useful information from images and build digital models. The decreasing costs of computer equipment, the increasing amount of image digitizing equipment available on the market, and new technologies that tend to promise great advances in image processing are factors that combine to indicate the future trend of digital image processing. Image processing aims to improve the appearance of images and make certain details more evident in them that are desired to be noticed [19]. The image may have been generated in many ways, such as photographically, electronically, or through television monitors. The processing of the images can, in general, be done by optical methods or by digital methods on a computer [20].

Photogrammetry is the process of generating a 3D model from 2D images; the resulting model can be scaled and used to measure distances between objects. Since archaeologists have used the early 1980s terrestrial photogrammetry, the high cost of hardware and processing equipment meant that it was not a viable technique for most projects. In the 2000s, with the advent of low-cost digital cameras and improved computer processing, photogrammetry became a more viable option for small-scale site analysis and assessment. With the rapid development of drones in recent years, architects and archaeologists have benefited greatly, as photogrammetry has become easier [21], [22].

III. Research Methodology

To develop this research, Design Science Research Method (DSRM) is used as a basis. Thus, the research methodology contains five stages: 1) identification of problems and motivations; 2) definition of objectives and potential solution; 3) design and development; 4) demonstration; and 5) evaluation. Fig. 1 shows the activities and tools for each stage.

In the first stage, a literature review was conducted to identify construction site inspection issues, along with the advantages of using drones and technical specifications for their use. Web of Science and Scopus databases were used. With this, in the second stage, the research team defined the objective of a potential solution: the use of drones and photogrammetry can improve construction site inspection processes. Thus, in the third stage, a workflow was proposed. It contains the stages, characteristics, technical elements, and processes to perform the inspections. A series of recommendations are given so that the method can be replicated. With this, the fourth stage demonstrates the method's usefulness in a case study. Finally, in the fifth stage, the results are analyzed, and the effectiveness of the proposed method compared to the traditional method is discussed first.

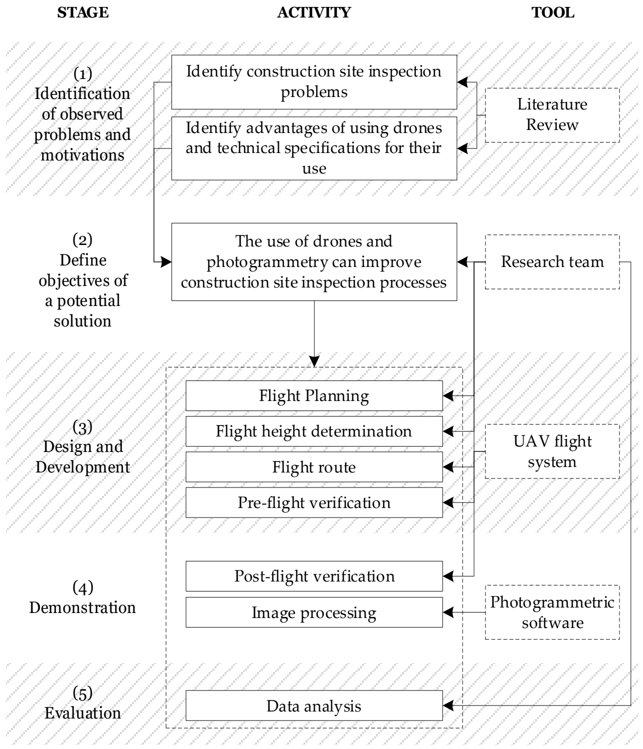

Fig. 1. Research Methodology.

TABLE I. Applications of UAV in Construction

Applications	Methodology processing	Methodology Aircraft	References
monitoring construction progress	Change detection using point clouds	No defined	Huang et al,2022 [23]
Comparison modeling software	3D reconstruction modeling techniques	No defined	Keyvanfar et al, 2022 [24]
Monitoring road base	3D reconstruction modeling techniques	No defined	Lo et al, 2022 [25]
construction progress monitoring and inspection	3D reconstruction modeling techniques	No defined	Amir et al, 2022 [26]
Dynamic site layout planning	3D reconstruction modeling techniques	No defined	Ahmed et al 2021 [27]
Impact on workers' health and safety	No defined	Define safety operation, and describe potential risks	Jeelani & Gheisari [28]
safety inspections in construction	Image capture	For manual flight using check list pre and post flight	Oliveira et al., 2021 [29]
Monitoring the work cycles of earthmoving excavators	Video	No defined	Yiguang et al, 2021 [30]
monitoring work in a construction project	3D reconstruction modeling techniques	No defined	Kaamin et al, [31]

Table I indicates some applications of UAV technology utilized by civil engineering in the construction process. As shown in the table, since only two studies define the methodology for aircraft and the other studies realize 3d reconstruction modeling techniques for several applications.

IV. Proposed Methodology

In order to achieve the research goals, a methodology is proposed. Fig. 2 shows the proposed workflow. It considers seven stages: A) Flight Planning, B) Flight height determination, C) Flight route, D) Pre-flight verification, E) Post-flight verification, F) Image processing, and G) Data analysis.

A. Flight Planning

It is important to know the place where the flight will take place. The orography, branch of the study of the physical geography that is in charge of studying and describing the relief of a region in particular, forces to value the opportunities and risks. Depending on this, the way of carrying out the work will be defined. To do so, we will start working with a small-scale cartographic map and a real survey of the terrain. It is necessary to determine whether it is legal to fly in the chosen area (whether or not it is controlled airspace, restricted airspace, photographic flight prohibition, etc.).

Then, a take-off and landing point is defined, this must be a relatively flat place, far from the frequent passage of people and without obstacles around it, since, in case of any failure, an RTH manoeuvre (Return to the point of origin) must be executed, and it is likely that the landing of the aircraft will not be in the precise point.

B. *Flight Height Determination*

The main natural and artificial obstacles found on the route to and from the site are explored in this stage. It is important to know the heights of these obstacles since the drone may not have sensors to avoid collisions.

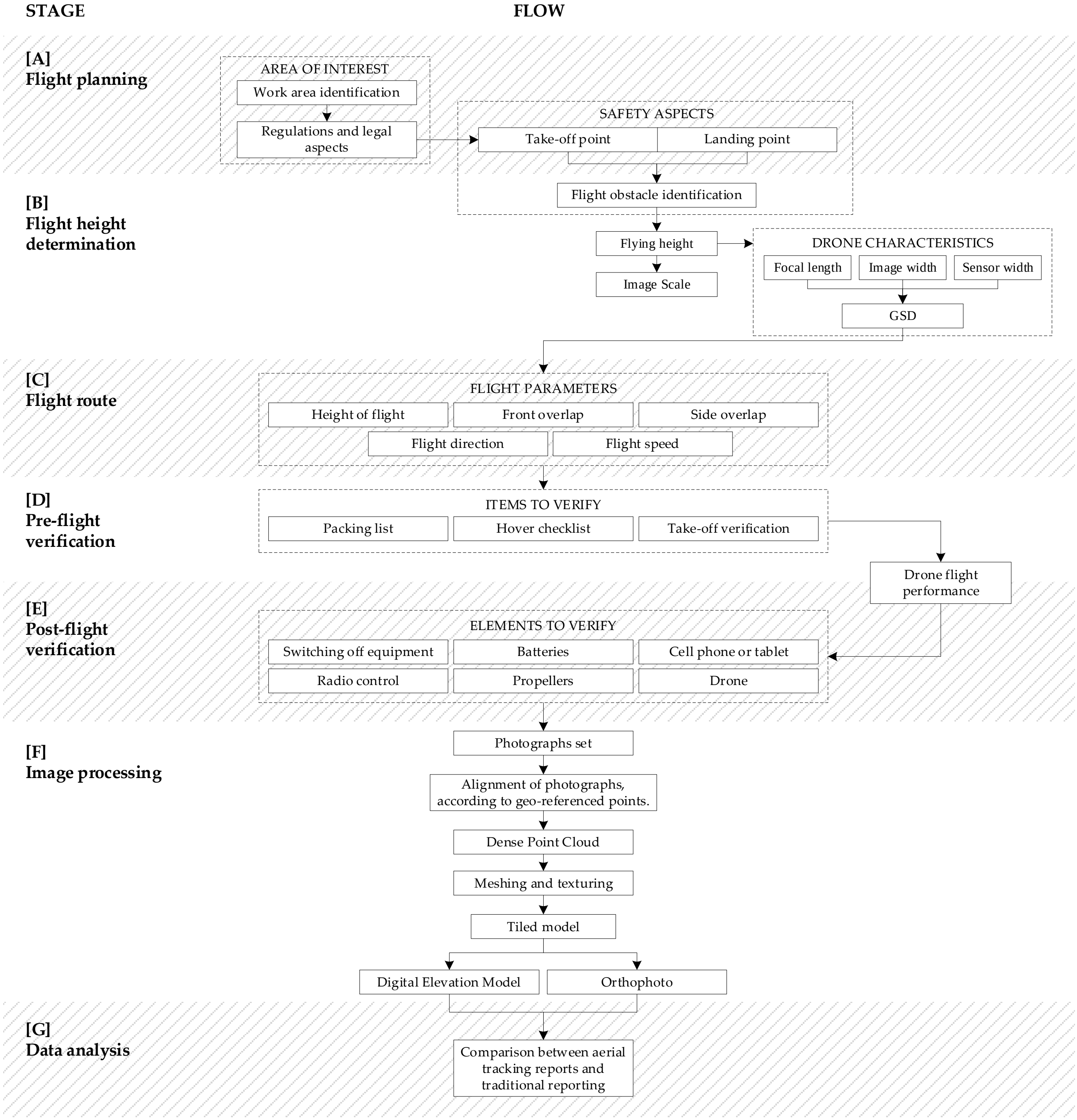

Fig. 2. Proposed Workflow.

The structure with the highest height is the construction site crane, 35 meters high for the case study. Therefore, a safe flight height of H=75 meters is defined. It is possible to determine the flight height to respond to a given scale. Equation (1) allows us to choose the average flight height, where Zm is the mean flight height, f is the focal length, and Em is the Image scale.

$$Zm = f \times Em \tag{1}$$

In addition, the scale of a photograph is determined by equation (2), where f is the focal length, H is the height of flight over the ground, ab is the distance over the frame, and AB is the distance over the ground.

$$E = \frac{ab}{AB} = \frac{f}{H} \tag{2}$$

On the other hand, the ground sample distance (GSD) is calculated by equation (3).

$$GSD = \frac{Flying\ heigth\ (H) \times Sensor\ width}{Focal\ length\ (f) \times Image\ width} \tag{3}$$

Table II shows the parameters used according to the DJI Phantom 3 Standard drone.

TABLE II. FLIGHT HEIGHT PARAMETERS

E	Image width	Sensor width	Focal length	Flying height	GSD
-	*[px]*	*[mm]*	*[mm]*	*[m]*	*[cm/px]*
1/3750.93	4,000	6.17	20	75	0.578

C. Flight Route

The flight route to be flown must be planned. The Waypoint flight mode is proposed. This consists of recording a series of geo-located points that the aircraft will fly autonomously, freeing the pilot from its control and allowing him to focus his capabilities on other aspects such as battery level, remote connection status, and altitude number photos taken. This step is carried out for the case study using the DroneDeploy mobile application. The following flight parameters used are shown in Table III.

TABLE III. FLIGHT PARAMETERS

Height of flight	Correlation zone (Front overlap)	Correlation zone (Side overlap)	Flight direction	Flight speed (mapping)
[m]	*[%]*	*[%]*	*[°]*	*[m/s]*
75	75	65	6	15

Providing this data in the DroneDeploy application automatically displays a calculation of flight time, area to be covered, number of photos to be taken, and how many batteries will be needed. Similarly, if the pilot prefers, a manual flight can be performed to maintain the flight parameters. Before making the flight, several aspects must be taken into account, such as:

- The time range (10:00 am - 3:00 pm). It is recommended to perform the flight at noon because the sun's position avoids excessive shadows.
- To be within the operating temperature range of the drone (0° to 40° C).
- Not to exceed the maximum service ceiling above sea level (6000m).
- Have optimal battery charge level (Drone, remote control, and cell phone).
- To establish a connection with enough satellites.
- Ensure that there is no interference between the Drone-Control connection.
- It is not recommended to fly the drone if the wind speed is 8-10 m/s or more.

Also, avoid proceeding if weather conditions are not suitable (Rain, thunderstorm, fog). It is recommended to monitor weather measurement data, temperature, wind speed and direction, precipitation probability, cloud cover percentage, visibility distance, available satellites, and KP level. The latter measures the geomagnetic disruption caused by solar activity, with 0 being the minimum level, nine being the maximum, and 3 or 4 being safe to fly. If this index is high, it generates inaccuracy in the global positioning system and a decrease or fluctuation in the number of blocked satellites.

D. Pre-flight Verification

Before starting the flight, a checklist should be considered to certify that the initial variables guarantee a safe flight. This process is facilitated by using the DJI mobile application for the case study. The following aspects should be verified:

- Packing list: this starts by checking the application update, downloaded maps, cell phone, and radio control battery charged, SD card with enough space, propeller condition, lens cloths, and UAV pilot license.
- Hover checklist: The drone is inspected for defects, battery correctly positioned and sufficiently charged, propellers adjusted, camera protector removed, SD card in position, monitor brightness at maximum, and antennas in position.
- Take-off verification: Check for the presence of other drones in the area, warn the spectators that the drone is going to take off, look for/listen for defects in the drone, monitor battery power, and signal strength.

E. Post-flight Verification

After landing, the drone should be turned off. Place the camera protector, put the batteries away, recharge them, and remove the cell phone or tablet. In addition, the radio control should be turned off and put away. The propellers should be removed, cleaned, and put away. Cables should be disconnected, the photographs taken should be downloaded to the computer, and, finally, the drone should be cleaned and put away.

F. Image Processing

Photogrammetry techniques are used to reconstruct the 3D model from photographs. In the case study, Agisoft Metashape Professional software was used to process the images taken. In the first instance, these are aligned, a process consisting of joining each photograph's geo referenced points. The result is dependent on the correlation percentages used in the flight. The "Dense Point Cloud" is created, a set of vertices in a three-dimensional coordinate system. These vertices are identified as X, Y, and Z coordinates and represent the external surface of an object. It is possible to make the "Mesh", which is the basis for generating a texture completely created in the next process called "Texture", now the three-dimensional model is obtained. If a detailed texture is required, the process called "Tiled model" is applied, created from the dense point cloud. This 3D model is useful to observe structures that are not accurately detailed in a simple photograph. Finally, the "Digital Elevation Model" and the "Orthophoto" are generated. The first one provides information about the different heights presented in the terrain, being an important tool to assess the vertical evolution of the work. At the same time, the second tool is the pairing of all the photographs represented in a new composite image. Because these maps accurately illustrate the land, it is possible to measure real distances.

G. Data Analysis

In the case under study, at the beginning of the monitoring of the work indicated, it was provided by those in charge, the schedule called "Construction of mixed superstructure" of the Postgraduate Building, which began on August 15, 2018, and ended on July 8, 2019, with a duration of 266 days. Based on this, the analysis and comparison with the software-generated models were started. This process consists of taking each item, specifying whether it is built within the defined dates, and then writing a report.

Finally, a comparison was made between the aerial monitoring reports and those provided by the construction supervisor to determine whether the proposed methodology is more efficient than the one used traditionally.

V. RESULTS AND ANALYSIS

This section presents the results obtained with the applied methodology. Fig. 3 shows a comparison between the initial day of aerial monitoring to the site (August 2, 2018) and the last day (May 24, 2019). A total of 8 months were considered in the investigation, excluding December 2018 and January 2019.

Table IV shows the activities corresponding to the work development processes.

The analysis of the processed models and their comparison with the work schedules are presented in Table V. In addition, observations of the status of each activity are shown with their respective dates.

The success cases presented in [9] show applications in the construction industry of RPAS in passive mode, i.e. only the images are acquired and the reconstruction of the site is performed. In our work, in addition to delivering the orthophotomosaic, an on-site measurement of the quantities of executed work is performed.

In [11] was described basic method for photogrammetry orientation. This paper is result of case study to automate the whole process of construction project. In our job was considered characteristics of vehicle and flight conditions, safety and chronograph actualization used measurements from flight data, this information beyond automate monitoring construction process.

As shown in Table IV, the construction site presents some delays observed in the photographic records obtained in the proposed methodology. In addition, a contrast can be made between what was built (an aerial photogrammetric record) and what was established in the schedule.

Due to these delays in phase 1 of the work (Underground), the contractor reprogrammed times and presented a new schedule of the same stages initially exposed (Construction of composite superstructure). The stakeout began on March 18, 2019, and ended on July 15, 2019. This generated that part of the data obtained in the aerial monitoring did not present the construction of the items. In addition, the new dates exceeded the estimated monitoring time range (8 months). The weather is against the methodology presented, but it is also against the construction progress, so the monitoring process is not affected.

Some of the reasons for the delays were: Restricted hours of use of the crane tower due to its noise and proximity to a residential area. The rains, the water table, and shallow water that drained over the excavation caused flooding. Based on the results obtained and the comparisons made with the supervision reports of the work, it can be deduced that the methodology created is efficient, safe, fast, and accurate, facilitating the preparation of reports and other supervision activities.

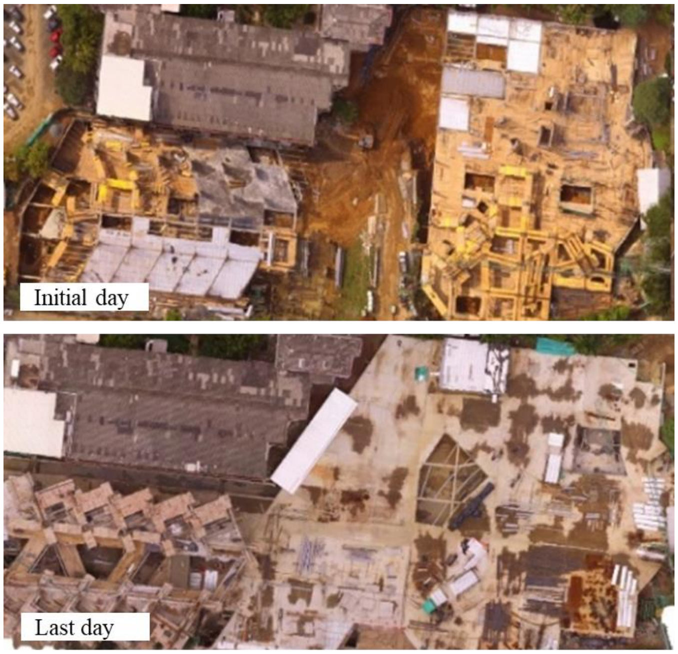

Fig. 3. Research Methodology.

TABLE IV. WORK DEVELOPMENT PROCESSES ACTIVITIES

Activity	**Description**
1	Columns-screens in concrete LEVEL +1.50 to LEVEL +6.00. SOUTH SIDE.
2	Concrete columns-screens LEVEL +1.50 to LEVEL +6.00. NORTH SIDE
3	Beams and solid mezzanine slab. LEVEL +6.00. SOUTH SIDE - Metal structure slab and classrooms LEVEL +6.00. SOUTH SIDE
4	Concrete columns-screens LEVEL +6.00 to LEVEL +9.70. SOUTH SIDE.
5	Beams and solid mezzanine slab LEVEL +9.70. SOUTH SIDE. - Metal structure slab and classrooms LEVEL +9.70. SOUTH SIDE.
6	Beams and solid mezzanine floor slab LEVEL +6.00 NORTH SIDE - Metal structure slab and classrooms LEVEL +6.00 NORTH SIDE - Circulations and bridges LEVEL +6.00.
7	Concrete columns-screens LEVEL +6.00 to LEVEL +9.70 NORTH SIDE - Metal structure slab and classrooms LEVEL +9.70 NORTH SIDE
8	South side stage 1: Beams axes 4, 5, 6 and 7.
9	South side stage 1: IP profiles, classroom metal structure, classroom connectors axes 7-6, 6-5, and 5-4.
10	South side stage 1: Casting of classroom slabs axes 7-6, 6-5, 5-4.
11	South side stage 1: Screens MP-1 level + 8.30 to +11.20
12	South side stage 1: Screens CP-1 level +9.70 to +11.20
13	South side, stage 2: Beams axes 2, 3 and 8.
14	South side, stage 2: IP Profiles, Classroom collaborating sheet, Classroom connectors axes 8-7, 4-3, and 3-2.
15	South side stage 2: Casting of classroom slab axes 7-6, 6-5, 5-4
16	South side stage 2: Screens MP-1 level + 8.30 to +11.20
17	South side stage 2: Screens CP-1 level +9.70 to +12.60
18	Stage 3: Bridges and circulations
19	North side stage 1: Beams axes 7, 6, 5 and 4
20	North side stage 1: IP Profiles, Collaborating sheeting classroom, Connectors classrooms axes 8-7, 4-3, and 3-2
21	North side stage 1: Casting of classroom slab axes 7-6, 6-5, 5-4
22	North side stage 1: Screens MP-1 level + 8.30 to +11.20
23	North side stage 1: Screens CP-1 level +9.70 to +12.60

TABLE V. ANALYSIS OF PROCESSED MODELS AND COMPARISON WITH SCHEDULED

Activity	**Schedule**		**Observations**
	Start date	**End date**	
1	15/08/18	8/09/18	In the model produced from the photographs of the September 19, 2018 photogrammetric flight, it can be seen that 12 of the 14 concrete screens have been constructed.
2	25/09/18	19/10/18	On September 28, 2018, the placement of the +1.50m level metal structure is being completed. Between October 9 and October 18 of the same month, the established in this topic was built.
3	10/09/18	3/10/18	On September 19, construction had not yet started. This started on October 9, 2018 and was completed between March 12 and March 21, 2019.
4	4/10/18	29/10/18	On October 9, construction had not yet started. According to the photogrammetric record of February 22, 2019, this item is completed.
5	30/10/18	24/11/18	On March 21, 2019, the start of the beam work was observed. On April 25, the assembly of the metallic structure is being done and on May 3, the casting of the mezzanine slab will start.
6	20/10/18	15/11/18	On October 23, 2018, the construction of the columns-screens from +1.50m to +6.00m started. On November 16, 2018, i.e. one day after the completion of items 1, 2 and 3, the column-screens were completed. Between February 22 and March 28, 2019, items 1 and 2 were completed, item 3 is completed on April 25, 2019, in these items the work had an approximate delay of 3 months.
7	16/11/18	11/12/18	On November 16, 2018, despite being the same day that this topic should be started, the work presents a delay, due to the fact that on that day they were just finishing the +1.50m level screens. This item was completed between March 28 and April 3, 2019.
8	26/03/19	10/04/19	This issue in general includes the whole process of construction of the beams in shafts 4, 5, 6 and 7, it is concluded that the construction of these was completed on time.
9	10/04/19	23/04/19	On April 25, 2019, the work presents a delay due to the fact that only the metallic structure of axes 4-5 and 5-6 is finished, and that of axes 7-6 were implemented between April 25 and 28.

10	17/04/19	25/04/19	On April 25 (the same day that this item should have been completed), the metallic structure is being placed, generating a backlog in this item. The casting of the classroom slabs begins between April 28 and May 3, 2019.
11	10/04/19	25/04/19	Item completed within the time established in the schedule.
12	15/04/19	29/04/19	Topic completed within the time stated in the schedule.
13	29/03/19	15/04/19	This topic in general includes the whole process of construction of the beams in axes 2, 3 and 8, from the photogrammetric analysis, it is concluded that the construction of these was performed in the established time.
14	15/04/19	27/04/19	On May 3, 2019, the work presents a delay due to the fact that only the metallic structure of axes 3-4 is finished.
15	24/04/19	29/04/19	On May 3, the slab of the classroom that composes axes 8-7 is being cast, this should have been cast 4 days ago.
16	15/04/19	27/04/19	Item completed within the time established in the schedule.
17	27/04/19	07/05/19	Item done in the time established in the schedule.
18	27/04/19	09/05/19	On May 3, 2019, it can be observed that the circulation of the south side, which compose axes 8, 7, 6, 6, 5 and 4, are being finished, which generates that the work has a delay.
19	03/04/19	09/04/19	This issue includes the whole process of construction of the beams in axes 7, 6, 5 and 4, the elaboration of the beams started on May 3, 2019.
20	09/04/19	23/04/19	On May 3, 2019, only the profiles of axes 5-6 have been located.
21	16/04/19	23/04/19	Performing the photogrammetric analysis, it is observed that the work presents delay in this subject.
22	09/04/19	24/04/19	Item completed within the time established in the schedule.
23	13/04/19	29/04/19	Item completed within the time established in the schedule.

VI. CONCLUSION

This paper deals with the monitoring of infrastructure works using aerial photogrammetry. The use of the drone becomes an active tool in the task of monitoring the evolution of the work, since, with an overflight combined with image processing software, it is possible to evaluate the entire structural construction area, which reduces the displacement of personnel within it and the taking of specific photographs for each work activity. The methodology presented in this research is efficient and suitable for construction site monitoring. The management of the aircraft requirements, the identification of the flight zone, the safety conditions and the photogrammetry requirements allowed obtaining the final objective of comparing the data collected and the data provided by the supervisor in a civil construction. The data obtained showed the delay in the construction and there was a need to make modifications in the construction schedule of the work. Validation of the methodology is not achieved with a single case of application, so the conclusions presented here are limited to this study. To have an external validation, it is suggested the application of the proposed development and tested in different conditions.

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