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Use of Aerial Images as Support for Cost Analysis of Sewage Collection Networks

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***Abstract*— *The present work aims to analyze the applicability of aerial images obtained with Unmanned Aerial Vehicle (UAV) in decision making regarding the choice of sewage collection network in a sector of the city of Palmas - TO. In order to arrive at a cost comparison between simple and double network that meets the necessity of sewerage of the sector studied. Through orthorectified images, it was specifically pointed the types of coverings, quantitative, for the items of demolition, removal and restoration of pavements and sidewalks. The usage of these images aimed to assess the accuracy in the budget of projects of these networks, since the practice used for the preparation of the budgets is made through visual inspection in loco or by estimation, being an expensive, slow and imprecise practice. The studied tool proved to be efficient, as it is possible to verify, with the resolution adopted for the images, the types of coating, precision in the quantitative survey through the orthomosaic.*

***Keywords*— Unmanned aerial vehicle (UAV), budget, sewage collection network, sewer.**

I. INTRODUTION

Among the existing alternatives for the operation of sewage collection network, the destructive method is the traditional and the most used alternative. This method consists of excavating trenches along the entire length of the projected network, where the piping system is installed directly in the trench over a cradle with suitable materials [1].

The conditions for the operation of these networks are established by [2]. The standard establishes guidelines for removing the pavement, opening the trench, sewering, shoring, laying, filling the trench and recomposing the pavements and sidewalks.

Besides the choice regarding the practice of operation of networks, using the destructive or non-destructive method, it should also choose simple network or double network. According to [2] the pipes of simple network must be located in the third most favorable to the connections, while the double nets must be elaborated as close as possible to the curb, with space available, preferably on the sidewalk.

According to [3], the characteristics of each existing covering, be it asphalt, sidewalks, interlocked pavers, etc., dictate the removal and recomposition practices, which consequently reflect on the cost of the works. The identification and the quantitative of paved sections and sidewalks where the projected network will intersect, precedes the preparation of budgets and is done through visual inspection in loco, an expensive and slow practice.

Considering that construction budgets consist of transforming the details of the project into costs, it must be prepared before the execution of the work, since through it there is a forecast of the cost of the work, thus providing the basis for viability of the object in question [4].

Included in this scenario, the use of technologies, the survey of geographical information and aerial imaging, have emerged as an auxiliary tool for civil and scientific purposes. According to [5], unmanned aerial vehicles (UAVs) present themselves as a potential alternative in the process of obtaining images that assist in the identification and characterization of surfaces, coverage and land use.

Initially, UAVs were used for military purposes, however, their use is becoming increasingly attractive for commercial and governmental applications due to the enormous potential for property monitoring and inspection [6].

In recent years, the use of UAVs for civilian purposes has started to increase thanks to technological advances, cost reduction and the size of sensors related to the Global Positioning System (GPS), pre-programmed flights, IMUs (inertial motion units) and auto-pilots. In this way, technology can fill some knowledge gaps, improving the spatial and temporal resolution of the most common current remote sensing systems [7].

[8] relates that the cost-effectiveness, ease of use, flexibility of flight planning and deployment, the availability of a range of high resolution sensors and post-processing software give this tool the superior potential over images satellite images and images of manned planes.

In a work developed by [3] using aerial images for the budgeting of network, the author finds that the refinement of the resolution used in the process of obtaining the images brought richness of details that allowed in some cases, in addition to the specification of the material, the distinction of the shapes of the pieces used in interlocked pavers and even their state of conservation.

As a sample unit for the development of this research, it was considered a sector in the southern region of the city of Palmas - TO, not yet contemplated with projects of water supply and sewer sytem. On the aerial image of the area overflown, two network routing models were created, one with a simple network arrangement and the other with a double network arrangement, all serving the same sub-basins.

Dimensions and identifications of the types of coating of the sidewalks and roads obtained by the images orthomosaic were compared with the field data, aiming to evaluate the reliability of the referred quantitative and specifications extracted by the sensor attached to the Unmanned Aerial Vehicle (UAV).

II. METHODOLOGY

In order to achieve the proposed objectives, the applied experimental methodology compared costs of sewage collection networks, budgeted based on quantitative and specifications obtained by aerial image.

2.1 Field of study

For the development of this research, it was considered a sector in the southern region of the city of Palmas - TO which hasn't yet been contemplated with sewage collection network projects. Even without a previously elaborated project, two hydraulic collection network arrangements were elaborated on the same area, one simple, serving both sides of the roads, and the other, double arrangement serving both sides of each road.

In order to isolate the design variables, the same direction of flow was adopted, the same internal neighborhoods to be served, a standard distance of 50m between manholes, a minimum diameter of 150mm and an average depth of 1.60m for the network.

Bertaville sector, an area defined as the object of this research, has an area of approximately 60 ha and is located in the southern region of the city of Palmas - TO. The choice is justified by the fact that it is an area in the initial occupation process and with infrastructure services, such as asphalt and pavement already executed, thus subsidizing the achievement of the proposed objectives.

2.2 eBee UAV and softwares for flight and image processing

To collect the images, eBee model aerial vehicle, was used, with registration certificate Nº PP-220920032 (Figure 1), of Swiss manufacture, 96 cm (38 in) wingspan and flight range of around 30 min. It has a propeller at the rear and its foam construction allows flexibility and lightness (700 grams -1.5 lbs), resulting in reduced energy consumption. The aircraft contains a platform with specific sensors attached, which allow photographic images and videos obtention. The aircraft has built-in sensors that enable the stability of the equipment on mission, as well as the transmission of data that guarantee the direct monitoring of the flight opetarion.

Fig.1: Unmanned aerial vehicle eBee.

Flight planning is carried out by the base station, developed by the same aircraft manufacturer (senseFlay),

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with the following set: eMotion 2 software, responsible for the flight preparation and operation of the aircraft's path, and a transmission antenna, which allows the real-time monitoring of the overflight, as well as the sending of landing commands, changes of direction or obtention of images. The program interface shows important information about the battery level, ambient temperature, altitude, position, duration and speed of the flight, wind speed, resolution and longitudinal and latitudinal overlap of the area to be overflown, altitude and radio link.

For image processing and creation of orthorectified mosaics, the aircraft also has a specific software, Pixel4D (senseFlay). In this process, the points captured by the aircraft's GPS are related with the correspondent image.

2.3 Image capture device (camera)

The camera used to capture images, model Canon RGB S110, brought together suitable features compatible with the eBee system and the orthomosaic assembly application. It has a 12.3 megapixel Live MOS sensor, with an ISSO range of 100 to 6400, with capacity to record images in RAW (12-bit lossless compression), JPEG, JPEG + RAW, image stabilizer and a maximum speed of shutter of 1/4000s, being able to shoot 3 frames per second.

2.4 Flight planning and image obtention

The plan established for this research aimed the obtention of images that would guarantee better distinction of objects on the surface and greater accuracy in the survey of sidewalk and pavemented areas. For this purpose, a single overflight was carried out at a height of 120 m with overlapping of images on the order of 60% in the longitudinal, 75% on the side and a resolution of 3.4 cm/pixel, resulting in an overflight with a duration of 30 min approximately.

The method seeks to ensure that the stripes may be "tied" by the connection points determined in the common area and form a block.

2.5 Orthomosaic assembly

The georeferenced mosaic was obtained after a series of steps, which involved the removal of errors and distortions caused by the image acquisition process, and aimed to guide the images in relation to each other and in relation to the complete scene.

This image processing was done using the UAV GPS information and its own algorithms, capable of automatically finding the linking points between the photos, generating orthomosaics in tif format, DEM (Digital Elevation Model), triangular model 3D and georeferenced point cloud.

Its obtention allows the survey of measurable data, such as area and volume, making easier the identification of imagined points.

2.6 Survey of data in the field and by way of the mosaic

Considering that the wastewater collection network can be located both under the sidewalk and under the street, in order to obtain the data collected in the field and via the mosaic, 10 points were randomly chosen in the recorded area, with 5 sections on streets and avenues and 5 sections on sidewalks, so that the sample unit brought different types of coating, thus subsidizing the assessment of the tool reliability in the proposed survey.

III. RESULTS AND DISCUSSIONS

3.1 Photointerpretation of images

The result of the image processing resulted in a mosaic with good resolution quality, which facilitated the identification of the types of coatings and precision in the measurements. With the mosaic it was possible to obtain details of the material specification and even the distinction of the shapes of the pieces used, as it can be observed in Figure 2.

Fig.2: Detail, in mosaic, of interlocking pavers.

In another section extracted from the mosaic, it is possible to observe the presence of painted concrete sidewalks (Figure 3).

Fig.3: Painted concrete sidewalk.

3.2 Measurement of sections of road and sidewalk

The lengths of roads and sidewalks adopted as sample units to verify the accuracy of the survey are shown in table 1.

Table 1. Variations in dimensions adopted as sampling

Nº	COATING	DIMENSION (m) (field)	DIMENSION (m) (image)	VARIATION (m)	DIFFERENCE (%)
1	Asphalt	6.80	6.84	-0.04	-0.59%
2	Asphalt	6.00	5.95	0.05	0.83%
3	Asphalt	6.60	6.58	0.02	0.30%
4	Unpaved	4.85	4.87	-0.02	-0.41%
5	Unpaved	6.62	6.59	0.03	0.45%
6	Unpaved	6.53	6.57	-0.04	-0.61%
7	Concrete	6.82	6.86	-0.04	-0.59%
8	Concrete	7.65	7.68	-003	-0.39%
9	Interlocked	6.34	6.38	-0.04	-0.63%
10	Interlocked	6.39	6.35	0.04	0.63%

When comparing the data on asphalt crossings and sidewalks, it is noticed that the maximum variation between the values of sidewalks and crossings on the pavement was of the order of 4.0 cm, which may be caused by the projection of the shadow of obstacles, making difficult the survey of measurements at some points in the mosaic.

In some situations, the aforementioned aspect can interfere and become the limiting factor in the accuracy of the obtention of measurements, that is, the position of the sun in the flight schedule is responsible for the projection of the shadows, whatever be the surface. As a way to restrain such interference, it is possible to plan flights with greater overlap of the route and at schedule between 10 am and 11 am.

Even with the difficulties found, it can be observed that the individual percentage variation did not exceed 1.0%, which attests to the degree of reliability of the use of images obtained by UAV in the survey of the quantitative of services, for works of wastewater collection network.

3.3 Network costs

Taking as a cost base the composition tables of the local sanitation concessionaire and the numbers of cut and recomposition of sidewalks and pavement, the budgets for the two network models were obtained. In their conceptions the simple and double networks have lengths of 8,132m and 12,575m respectively.

The neighborhood studied is all paved and with 80% of its sidewalks in natural terrain with the remaining 20% of pavements in: concrete, interlocked paver and grass. Such quantitative were obtained in the mosaic generated by the images.

The global cost of the network to be implanted varies considerably in cost. The double network is more expensive, with a percentage of 14% above the cost of the simple network, covering the same area. Table 2 shows the synthetic budget of services for the execution of the work.

Table 2. Synthetic budget of network elaborated in the mosaic.

ITEM	R$ DOUBLE NETWORK	R$ SIMPLE NETWORK
PRELIMINARY SERVICES	R$ 21,063.29	R$ 21,063.29
TECHNICAL SERVICES	R$ 84,507.00	R$ 71,558.96
SIGNALING / WARNING	R$ 14,580.11	R$ 9,294.53
EARTHMOVING	R$ 697,081.16	R$ 512,486.46

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PAVEMENT REMOVAL / REPAIR IN STREETS AND AVENUES	R$ 37,916.88	R$ 693,524.63
SOIL REPLACEMENT FOR RECOMPOSITION OF PAVEMENT	R$ 8,490.45	R$ 174,374.22
REMOVAL / REPAIR OF SIDEWALK	R$ 647,582.56	R$ -
DITCHING SHORING	R$ 275,599.43	R$ 173,802.52
MAINTENANCE HOLES	R$ 577,271.04	R$ 369,814.26
LOADING, TRANSPORT AND UNLOADING (L.T.U)	R$ 11,465.70	R$ 35,535.53
INSTALLATION	R$ 55,743.72	R$ 35,535.53
HYDRAULIC PART	R$ 34,320.10	R$ 21,873.73
TOTAL	R$ 2,465,621.44	R$ 2,118,863.66

Even though there is a difference in cost between the networks, it's necessary to think about the extensions of connections that interconnect the network itself with the home to be served.

Simple network extensions are longer, considering that a single line of piping installed in the street should serve both sides of the road. Starting from the network, located on the asphalt, following up to the limit of the land lot, the installation of the branches generates cutting and recomposition on both asphalt and coated sidewalks, which does not occur in the double network installed on the sidewalks. Figure 4 shows the difference in length between the two situations.

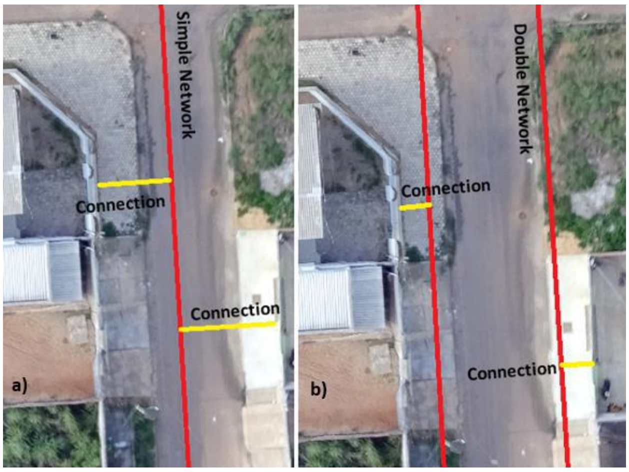

Fig.4: Connections outflowed in simple (a) and double network (b), showing the variation in the length of extensions

Both concepts were elaborated to serve 1,100 potential connections, that is, with buildings generating domestic effluent. The lengths of branches for each network design were 6.0 m for simple network connections and 2.0 m for double network connections, variation caused by the distance between the network and the points to be outflowing.

Budgeted home connections with their respective branch lengths, cut-off numbers and pavement restoration, it was arrived at the values per connection unit presented in table 3.

Table 3. Total cost of home connections.

	QUANTITY OF CONNECTIONS	R$ / CONNECTIONS	TOTAL
SIMPLE NETWORK CONNECTION	1,100.00	R$ 990.71	R$ 1,089,781.00
DOUBLE NETWORK CONNECTION	1,100.00	R$ 439.04	482,944.00

Home connections are installed in a associated way with the networks, that is, their values are incorporated into the total value of the sewer system of the inhabited sectors.

The total values of each of the network budgeted here with their respective connections can be observed in table 4.

Table 4. Total cost with network and connections.

	R$ TOTAL CONNECTIONS	R$ TOTAL NETWORK	TOTAL
SIMPLE NETWORK	1,089,781.00	R$ 2,118,863.66	R$ 3,208,644.66
DOUBLE NETWORK	482,944.00	R$ 2,465,621.44	R$ 2,948,565.44

The double network in its complete design, including connections, is approximately 8.1% cheaper than the simple network.

IV. CONCLUSION

The usage of aerial image for the purposes proposed in this research added agility and accuracy in the quantification of services for the operation of sewerage network, maximizing the information through georeferenced images, which can be consulted at the appropriate time, enabling the clarification of uncertainties present in the budgeting of works stage.

For the situation described, considering the same depth of trenches, hydraulic material, diameter of piping, conditions of coating roads and sidewalks, the double network proved to be a more economical and viable solution.

It is important, therefore, to point out that situations of unpaved roads and more expensive sidewalks, with ceramic coating, tiles and ornamental stones, can interfere with the cost of the network and must be analyzed in a specific way.

The methodology proved to be promising, presenting fast and accurate results, which can be used as a subsidy in the practice of decision making for projects and work budgetings of sewage collection networks.

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