JOURNAL OF SPATIAL INFORMATION SCIENCE

Using UAVs to analyse the urban environment

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Abstract: The evolution of technology in recent decades has helped to facilitate a series of work in areas related to land and property management as well as spatial planning. The exploitation of new tools and methods has prompted the international interest in the recording and modelling of geospatial information in more than two dimensions depicted in traditional projects, by then contributing to addressing a series of issues related to intense urbanization and the creation of complex ownership and building structures. A relatively recent such method is the use of UAVs in the mapping of buildings and wider spatial units, contributing to the production of 3D models with the help of appropriate software. This technology has been very resonant in recent years in Greece, but has not been applied to mapping large spatial units such as urban areas. This work performs a wide area mapping using UAV. Its aim is to investigate the extent to which it can do it successfully. For this reason, a brief evaluation is attempted, taking into account the accuracy of the data as well as the cost and time required in relation to traditional techniques. The result justifies the specific technique that appears to produce good quality metering and quality data while helping to save resources.

Keywords: UAVs, orthomosaic, 3D mapping, urban planning, parking habits, people behaviour.

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1 Introduction: Transition from conventional to digital urban planning

From the early 19th century and onwards, numerous models of cities characterised by the concept of futurism, have been presented. They attempted to provide solutions on a series of problems and improve the quality of life of city residents. One characteristic example in Greece was the "electronic urban planning" of the Athenian architect Takis Zenetos, who presented a series of futuristic urban planning proposals, on an era that was possibly not compatible, with such bold ideas.

In the course of time, space tends to become more digital with basic element emerging design ideas which incorporate technological advances. In addition to the proposed plans and planning models, new technologies are gaining ground in the design process, following a series of new instruments and technologies utilized by the urban planners and practitioners for data collection, analysis and understanding of the specific characteristics of a region and the depiction of the proposed interventions.

Sure enough, new methodological tools, like crowd sensing and crowdsourcing techniques come to the forefront of collecting, primarily, urban mobility data environmental data and cadastral information (Basiouka and Potsiou, 2012; Bakogiannis, *et.al.*, 2017; Bakogiannis, *et.al.*, 2018). Indeed, for their successful application web-based platforms are utilized, like Open Street Map (OSM) (Basiouka, *et.al.*, 2015; Bakogiannis, *et.al.*, 2018), that contribute in the production of Open Source Data, producing a new type of geographic view, which is called 'Neogeography'. This term was proposed by Di-AnnEisnor, during the decade of 2000 (Haklay, *et.al.*, 2008; Stamatopoulou, 2013), in order to describe a process in which people feel free to participate in data gathering processes, apart from traditional consultations (Somarakis and Stratigea, 2014).

Also, the needs for increased information in fields like cadastre and land information management system, and even the need for combined information regarding space and time, resulted to the development of multidimensional models, beyond the two dimensions (Ioannidis, *et.al.*, 2000; Dimopoulou, 2015; Doulamis, *et.al.*, 2015 a; Doulamis, *et.al.*, 2015 b). However, even the simplest procedures were implemented through traditional methods, such as the study of urban development through sequential map layout (maps presented different information were used as different layers), today is a process that is simplified through specific applications in a variety of design software (Stamatopoulou, 2013). In addition to the work done in the field and office, new technologies have also entered the sphere of information dissemination, since the need for citizens' access to information, especially information on urban and societal resources, and their active participation in the design process is the core idea behind the "urban access" design (Nikitas and Rahe, 2013), which in turn forms the basis for promoting a combined urban planning and traffic planning (Christodoulopoulou and Kyriakidis, 2014).

The above are just a few examples of the transition from conventional to digital urban planning, both in the ideological context and, above all, in the implementation and planning process. The increased use of new technologies is clearly related to the simplification of traditional design practices. However, an important parameter is the cost reduction which, in a period of economic crisis, the exploitation of alternative practices becomes a very important parameter for the elaboration of studies and the implementation of urban interventions (Bakogiannis, *et.al*., 2018).

In that context, this paper focuses on spatial framing processes using UAVs. The specific technique is now widespread for plotting buildings or monuments (Barrile, *et.al*., 2017) since it is possible the collection of a sufficient number of photos and appropriate downloads for the detailed capture of a building or monument. At the same time, in this way, measurable and qualitative information is collected (Neitzel and Klonowski, 2011) that can be utilized in various analysis. However, the point that differentiates this particular research project is the use of UAVs in a real city environment that consists an innovation for urban studies in Greece. In this way, it is expected that information will be collected on both the physical characteristics of the urban space as well as the dynamic features related to traffic on the streets. Consequently, through the recording of information it is supported that it is possible to study the existing traffic as well, if video is taken, and in that way suggestions can be made to optimize it.

2 Case study: The wider area of the former railway station in Kozani, Greece

2.1. Aim and objectives

Aim of this paper is to explore the usefulness of UAVs on the capture process of an urban area, with the objective of collecting qualitative and quantifiable information. More specific, the research question could be expressed as: How UAVs can help urban planners in order to better understand and analyse urban environment (urban form and urban mobility)? This occurs through the comparative analysis of methods on the quality of the data, the implementation time frame and their operational costs.

2.2. Methodology

In order to appropriately address the research topics presented above, a decision was made to place a pilot application on March 2017, as a part of a research project, implemented by the Sustainable Mobility Unit[1]. Study area is located in the city of Kozani, and includes the site of the old railway station of the city and Olympus Street.

Primary reason for opting a road on top of the old station area is explained by the fact that the road is associated with the study of movement, as the usage of UAV for surveying in urban areas could be studied only in the area of the station. Additionally, this area of study is particularly important because there is provision for regeneration in the area of the station and proposed intention for the development of a cycling network, which will pass through Olympus street, linking the development area with the city centre.

Moving a step further, drone flight plans were developed. This specific design was based on the size of the study area, the terrain which had been measured approximately through Google Earth, and finally the technical characteristics of the used drone. In order to optimize the outcome, the final design of the flights took place with the help of free software (PiX4dCapture), each time beneficial to developing the flight paths and the coverage area.

Figure 1 projects the six (6) different flight plans. High number of flights is explained by drone's small autonomy and for safety reasons the maximum flight duration was decided to be that of 15 minutes. The flights were fully automated, with the software stated above, serving as autopilot. On the automated flights was selected as flight altitude of sixty (60) meters above the ground, so the size of the pixels of the final outcome accounting for 2.5 cm.

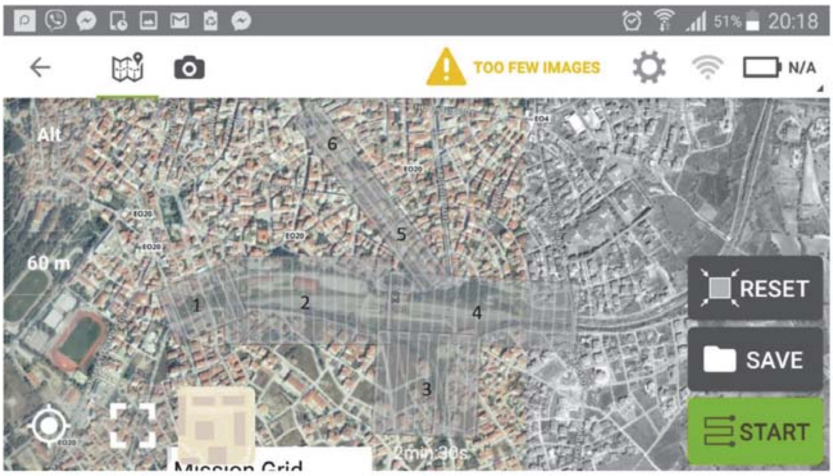

Figure 1. Design of flights by using the free software PiX4d Capture.

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[1] "Research for the Municipality of Kozani for preparing an action plan towards Sustainable Mobility: Framework for a strategy to raise people awareness and enhance local community towards environmental and traffic problems". Scientific director: Vlastos Thanos.

Front overlapping aerial photographs, which have geolocation, was selected at 80%, proportionately Giang, *et.al*. (2017) research. It should be noted, finally, that, in addition to these photos (1,297), other photos were taken with aerial ramps (239), angled at 45 degrees, so that buildings can be visualized in 3D and extra videographer with manual flight of drone, to produce video of the study area.

Coextending, in order to efficiently collect quantifiable data, Ground Control Points (G.C.P.) were set on the ground, *i.e.* points with known coordinates which are highlighted before the aerial photography. These points were distributed internally and around the region. In order to be measured, duplex GPS using Base-Rover indicators (for points on the ground) and Total Station (for points in buildings) were used.

Following the collection of data, using the PiX4dMapper software, photos were aligned and placed in the correct shooting position to produce point cloud and then the Digital Elevetion Model (DEM) with the help of the freeware application of GlobalMapper for the creation of the terrain image.

Subsequently, surveying the study area took place on the final orthomosaic of the along with the projection of the buildings through the point cloud (Figure 2). Moreover, a series of issues related to traffic and parking management were studied, through the videos produced.

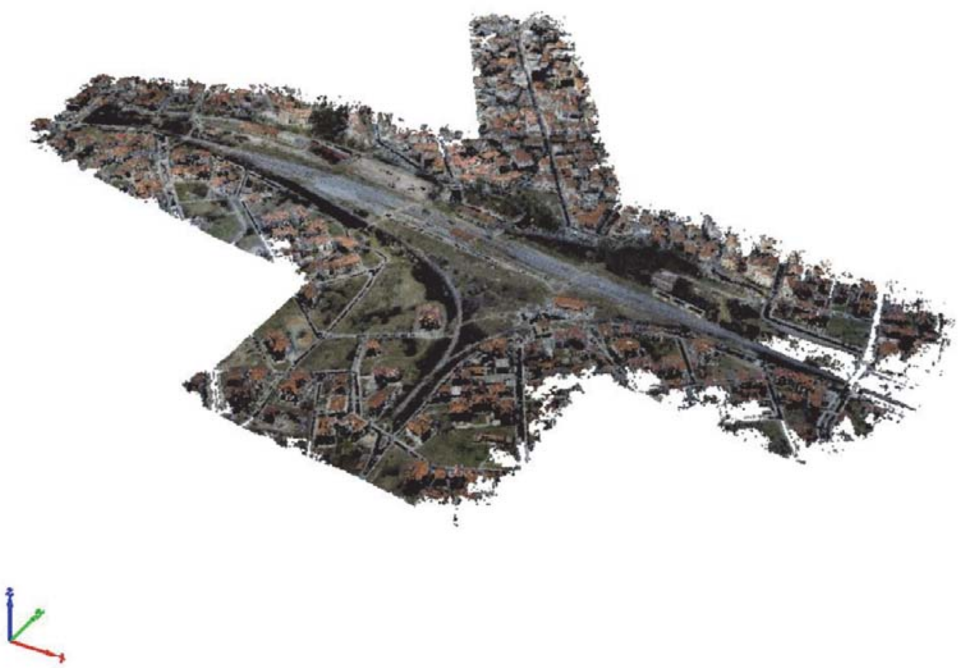

Figure 2. The produced point cloud.

Overall, in order to assess the quality of the produced results, it was decided for a comparison with the existing backgrounds, such as existing orthomosaics of such areas and urban plans of studies. In this way, beyond the control of the reliability of research, spatial development of the studied area of Kozani was recorded following the additions of buildings. Moreover, deviations from existing urban study were checked, demonstrating buildings constructed earlier or arbitrarily. This information could constitute a first mean for assessing the legality of structures, saving up human and financial capital in the context of compliance with the building regulations.

2.3. Method assessment

Following the implementation of the aforementioned processes, a new orthomosaic was created. For the evaluation of the method, it was decided to investigate the reliability of data, analysis of photos and the possibility of interpretation of the urban space and finally the feasibility of work.

For the evaluation of the reliability of the data obtained, it was decided to compare the produced orthomosaic with the preexisting one and the layout of the existing planning study in the study area. Following the comparisons, a common conclusion was extracted: there were slight variations between the new and old orthomosaic and the layout to coincide to a large extent. As mentioned in the previous section, from the beginning, it was considered that there was a possibility of differences for the sake of amending the urban situation and owing to possible arbitraries. However, it was not examined to such degree in order to raise questions for further exploration of the issue. Figure 3 shows the match between layout and the new orthomosaic, demonstrating how urban planning regulations were followed to a sufficient extent. This was probably observed due to the oldness of the study area and the general trend of Greek urban planning regulations to recognize preexisting urban form through the various planning studies, aiming to save up built capital.

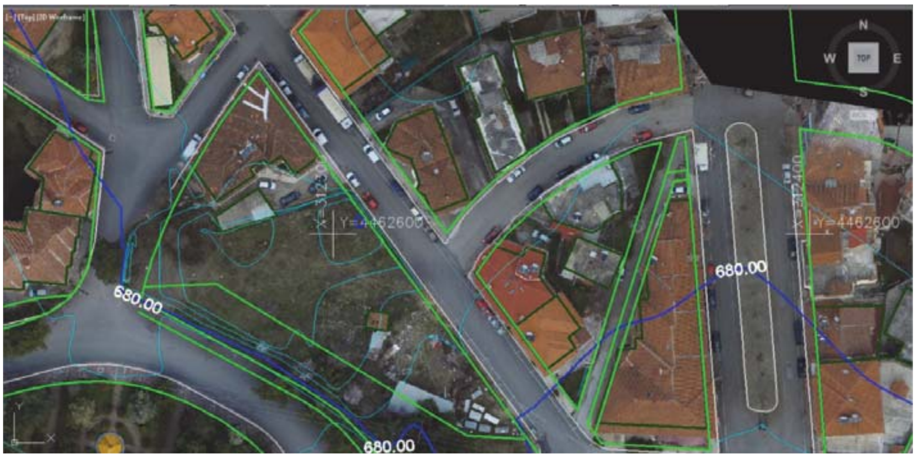

Figure 3. Comparing the orthomosaic with urban planning regulations.

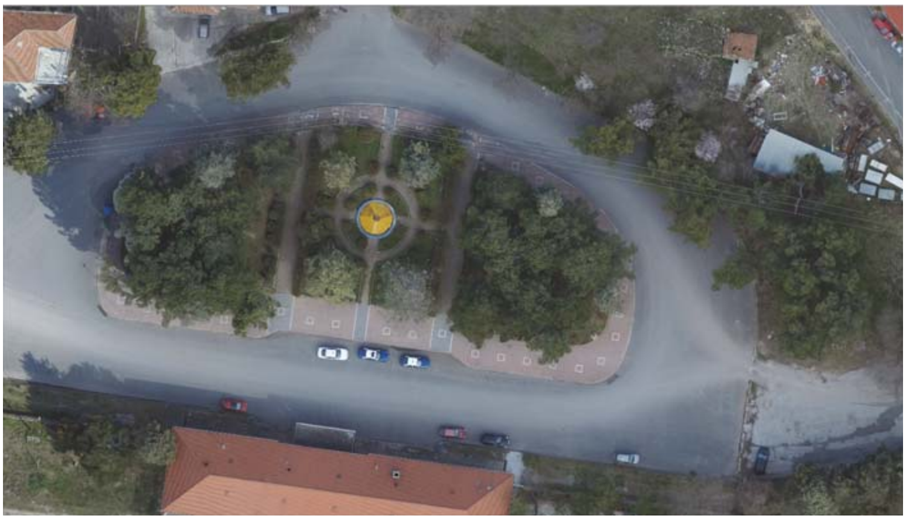

Figure 4. Part of the studied area presented in the new orthomosaic (2017).

Figure 5. Part of the studied area presented in the old orthomosaic (2007-2009).

The next parameter to be evaluated was the analysis of the orthomosaics produced. For this purpose, the quality of the new one was compared with the old orthomosaic (the official one) produced during the period 2007-2009, for cadastral purposes. The accuracy of the new orthomosaic is plotted in 2.5 cm pixels (Figure 4) as opposed to the old one where its analysis is plotted in 30 cm pixels (Figure 5). Therefore, the clarity of the new map is 12 times better resulting in the quality information being collected being of better quality. Meanwhile, more accurate measurement data are obtained, validating the accuracy of recorded data. In this effect, of course, contributed the equipment that was used, since the analysis could vary depending on the camera used. However, today's technology provides cameras with very good resolution and low cost, resulting in high-resolution, better quality images than those of 2007-2009.

However, it should be noted that the accuracy of the measurements is better compared to the two particular cases of orthomosaics. When comparing captures produced using UAV and traditional techniques, it is found that the accuracy of the measurements of the second type is considerably better, as shown in Table 1. However, in cases of large urban areas such as the study area or even settlements or towns, the precision provided by this technology is particularly adequate.

It should be also mentioned that through the videos recorded, traffic and parking habits were studied. As Figures 6-8 depict, there are specific parts of Olympou Str. that function as parking areas, although they were not designed to address parking problems. Illegal parking was also found in other parts of the street and as a result pedestrians cannot walk in a comfortable way on the pavements. Finally, most of them usually prefer to cross the street in points in which no zebra crossings exist.

	Traditional Mapping methods	Mapping with UAV
Precision	Millimetres to centimetres	centimetres
Pre-processing time (Office)	1 hour	2 hours
Duration at field	3 working days	1 working day
Personnel	2 working groups	1 working group
Measurements processing (office)	2 hours	1 working day
Total processing time	3 working days	4 working days
Every working group is composed by 2 persons, one skilled engineer and one unskilled assistant		

Table 1. Comparing traditional techniques with UAVs method.

In addition to the quality features and the capabilities of the new orthomosaic, an important parameter for evaluating the method is its cost, measured both in money and in human resources. For that reason, during the survey, a calendar was kept, recording the times required for each individual job and the persons who had to work to complete it. The whole work lasted one working day (14/03/2017), from a two-man workshop, and included office work, where the organization of the flight plan took place as well as the fieldwork, where the taking of the G.C.P. and the flights required took place. After that, it was decided to compare the cost of this work in relation to the same work by conventional means. Given the fact that this work was not implemented by both methods in order to obtain a precise comparison, assumptions were made as to the number of people required as well as the duration of their work. According to these cases, the number of persons required is twice as high (2 topographers and 2 as support staff) who will have to work for 4 days. On the basis of the above data, it appears that the cost in the case of imprinting using UAV is an aliquot of the capture with traditional techniques, since time and human resources are saved. Volkmann

(2017) reaches a similar conclusion, who carries out an economic analysis of traditional methods with UAV.

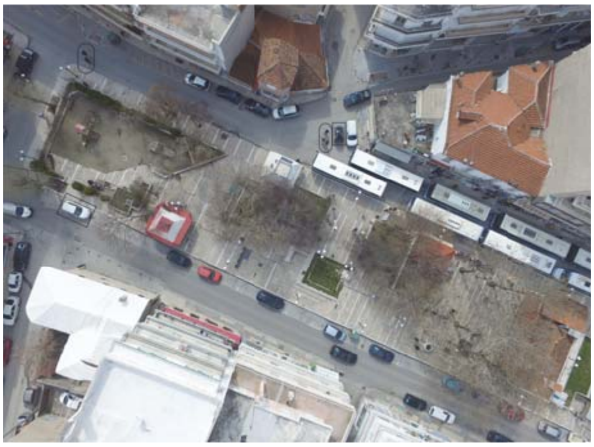

Figure 6. Mobility and parking behaviours.

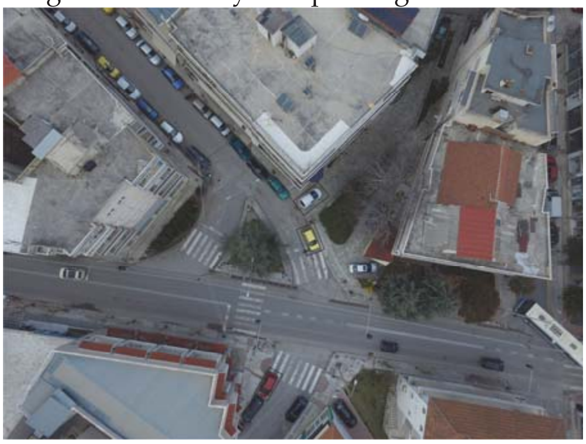

Figure 7. Mobility and parking behaviours.

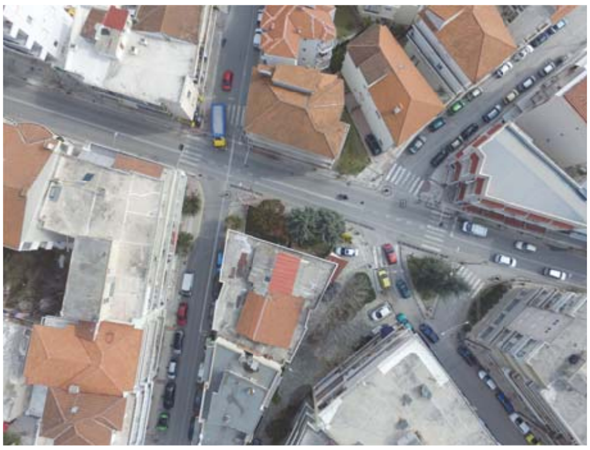

Figure 8. Mobility and parking behaviours.

Given the fact that the precise calculation of the cost is a procedure that is affected also by a series of other criteria (*i.e.* the area that was to be printed), beside the working hours, it was decided not to present specific budgets but rather a relation of expected cost of the two methodologies, as resulted by Table 1.

3 Conclusions

The evolution of technology has significantly impacted the design of research and the spatial planning process. A range of new technological tools are now widely used in data collection as well as in the depiction and evaluation of proposed designs.

The UAVs are such a tool that can make a significant contribution to capturing the topographical area that must now be implemented through systematic modeling and the spatial planning study of urban structures based on a three-dimensional modeling approach. This capture enables additional data to be collected during the study, such as planning data, as well as data collection on the road site.

In the context of this study, the use of UAVs to map an urban area was studied in order to compare data quality, timeframe and cost of implementation. The area chosen is that of the old railway station of Kozani and a road that is in the immediate vicinity of the aforementioned area.

The comparison between the orthomosaics performed showed that the resolution of the new orthhomosaic was quite better than the previous one. As a result, the accuracy of the qualitative and quantitative data will be high enough. However, the accuracy of the survey was also checked through the urban plan for the area, where the cartographic background was largely identified. An important point was the fact that the above method was found to be significantly more economical than conventional impressions since the demands on time and people were considerably reduced. Finally, the most important issue was that, in addition to the metering information that can be captured even in traditional 2D topographic diagrams, 3D capture provides better reading and understanding of the area to be studied, thus being studied in qualitative terms, and thus overall. The above findings resulting from the application of the UAV are a tangible proof of their usefulness in surveying in large urban environments, where the needs are more in relation to private ownership.

Finally, taking into account the possibility of video footage that UAVs can provide, it is believed that their use in urban space can be extended to study, control and traffic management and the study of human behaviour, contributing to a better understanding of the parameters which push in its expression, expanding geographic thinking.

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