Using Unmanned Aerial Vehicles (UAVs) to analyze the urban environment

Efthimios Bakogiannis
Transportation Engineer & Urban Planner, Ph.D., Sustainable Mobility Unit- Department of Geography & Regional Planning, National Technical University of Athens

Charalampos Kyriakidis
Ph.D. Candidate, Urban & Regional Planner, Transportation Engineer, Sustainable Mobility Unit- Department of Geography & Regional Planning, National Technical University of Athens

Vasileios Zafeiris
Surveying Engineer, Sustainable Mobility Unit- Department of Geography & Regional Planning, National Technical University of Athens

Abstract

Over the last decades, the evolution of technology has helped us to facilitate various types of works 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 modeling of geospatial information in more than two dimensions depicted in traditional projects, until then. This has contributed to address a series of issues related to intense urbanization, as well as challenges in identifying complex ownership and building structures. A relatively recent such method is the mapping of buildings and wider spatial units by using Unmanned Aerial Vehicles (UAVs) that has contributed to the production of 3D models by using the appropriate software. This technology finds resonant in recent years in Greece. However, it has not been applied to the mapping of large spatial units such as urban areas. This research paper performs a wide area mapping using UAV. Its purpose is to investigate to what extent the UAVs 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 behavior.

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 urbanism" of the Athenian architect Takis Zenetos, who presented a series of futuristic urban planning proposals (see Yiannoudes, 2016), on an era that was possibly not compatible, with such bold ideas.

In the course of time, urban space is transforming into a digital one. Thus, emerging planning ideas 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 tools and technologies utilized by urban planners and practitioners for data collection, analysis and understanding of the specific characteristics of an area as well as the conceptualization and depiction of the proposed interventions.

Sure enough, new methodological tools, like crowdsensing and crowdsourcing techniques come to the forefront of collecting, urban mobility data, environmental data and cadastral information (Basiouka and Potsiou, 2012; Bakogiannis, *et.al.*, 2017; Bakogiannis, *et.al.*, 2018; Delitheou, *et.al.,* 2019). In fact, web-based platforms, such as Open Street Map (OSM) (Basiouka, *et.al.,* 2015; Bakogiannis, *et.al.*, 2018), have been successfully used to collect urban planning data resulting in the production of Open Source Data, creating a new type of geographic view, which is named '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 as well as the need for combined information regarding space and time, resulted in 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 in planning process. The increased use of new technologies is clearly related to the simplification of traditional design and planning practices. However, an important parameter is the cost reduction which, in times of economic crisis, the exploitation of alternative practices becomes an 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 capturing a building or a monument could be implemented by collecting a sufficient number of appropriate photo shoots. Thus, at the same time, measurable and qualitative information is collected (Neitzel and Klonowski, 2011) that can be utilized in various types of analysis. However, the point that differentiates this particular research project is the use of UAVs in a real city environment that consists of an innovation for urban studies in Greece.

In this way, it is expected to collect information on both the physical characteristics of urban space and the dynamic characteristics associated with road traffic. Therefore, it is possible to study the existing traffic –provided that a video is recorded- and proposals for its optimization could be suggested.

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

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 in terms of data quality, implementation timeframe and their operational costs.

Methodology

In order to address the research topics presented above, a decision was made. A pilot study took place on March 2017, as a part of a Sustainable Mobility Unit research project (2017-2018). Study area is located in the city of Kozani, Greece, and includes the Old Railway Station (ORS) area and Olympou Street.

Primary reason for opting in a road on a close proximity to the ORS area was that the use of UAVs in studying mobility parameters should be examined. Moreover, according the regeneration plan of the ORS area, a new cycle path is going to be developed across Olympou Street. In that way, information collected through this research can be used for the implementation of this construction works.

Moving a step further, UAV flight plans were developed. This specific plan was based on the size of the study area, the terrain which had been measured through Google Earth, and finally the technical characteristics of the UAV used. In order to optimize the outcome, the final plan was developed by using an open source software (PiX4dCapture). Flight paths were developed as Figure 1 presents.

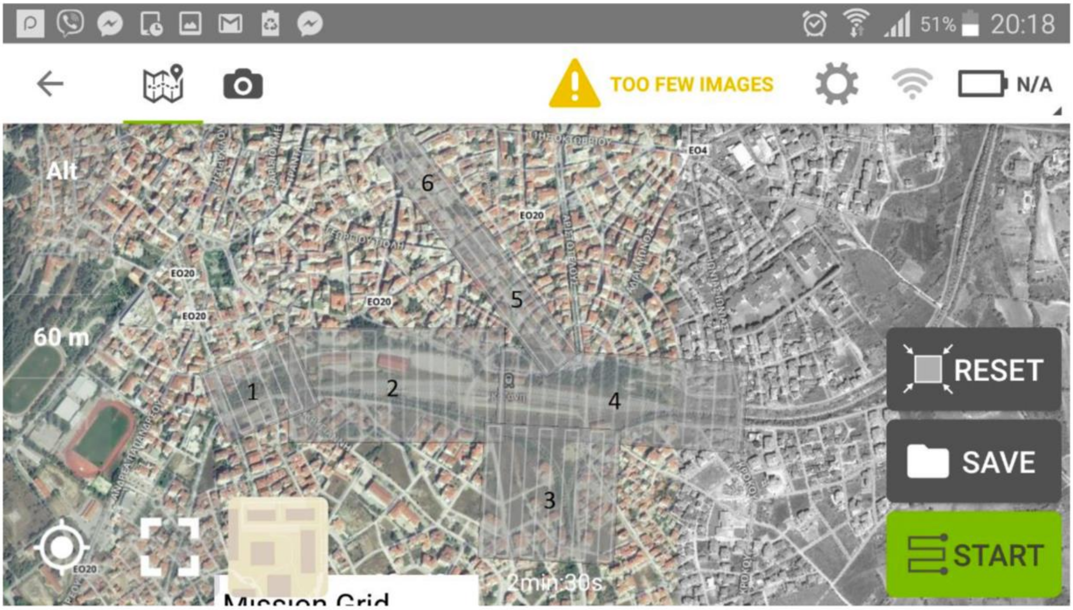

Figure 1. Design of flights by using the free software PiX4d Capture. Source: Own elaboration.

Figure 1 presents the six (6) different flights took place. The number of flights is explained by drone's small autonomy. For safety reasons the maximum flight duration was decided to be that of 15 minutes. The flights were fully automated: PiX4dCapture software served as autopilot. On the automated flights, the flight altitude was defined in sixty (60) meters above the ground, so the Ground Sample Distance (GSD)[1] is estimated to be 2.5 cm.

Front overlapping in aerial photographs, that are geolocalized, was selected at 80%, based on the research of Giang, *et.al*. (2017). Finally, It should be noted that, in addition to these photos (1,297 photos), other photos were taken with aerial ramps (239 photos), angled at 45 degrees, so that buildings can be visualized in a 3D model. At the same time, an additional videographer has produced a video of the study area.

In order to collect quantifiable data effectively, Ground Control Points (G.C.P.) were defined. G.C.P. are 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 Elevation Model (DEM). GlobalMapper, another open source software, has also been used for gaining this goal.

Figure 2. The produced point cloud. Source: Sustainable Mobility Unit Archive (2017). And the point cloud presented in Figure 2. Moreover, a series of issues related to traffic and parking management were studied, through the videos produced.

[1] GSD is how big each pixel is on the ground.

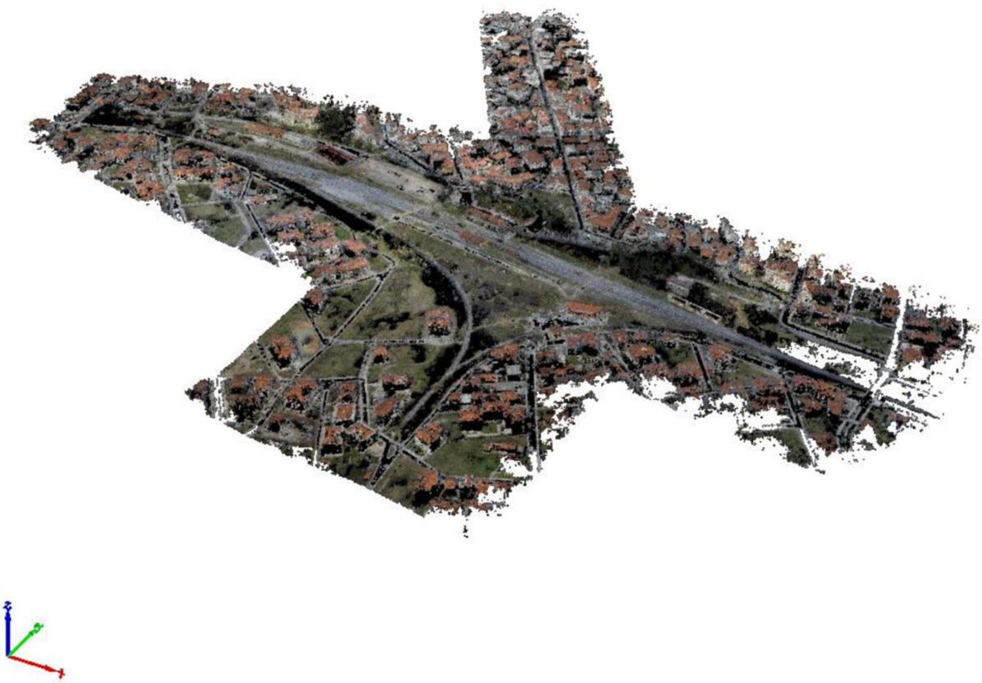

Figure 2. The point cloud developed. Source: Own elaboration.

Overall, in order to assess the quality of the produced results, the new orthomosaic has been compared to the old one as well as to the official urban plans. In that way, the quality of the new orthomosaic was evaluated and the evolution of the spatial form of this area was also recorded, over time. Moreover, deviations from the official urban plan were checked, demonstrating buildings constructed earlier or in an informal way. This information could be a first means of assessing the legality of structures, saving up human and financial resources.

Method assessment

Following the implementation of the aforementioned processes, a new orthomosaic was developed. For the evaluation of the method, it was decided to investigate the reliability of data, the photo resolution and the interpretation of the urban space as well as the feasibility of work.

In order to evaluate the reliability of the data obtained, it was decided to compare the produced orthomosaic with the pre-existing one and with the layout of the existing urban plan. Following the comparisons, a common conclusion was extracted: there were slight variations between the new and old orthomosaic and the layout coincided to a large extent. As mentioned in the previous section, differentiations were expected due to the fact that the urban form could be changed over time and informal housing could be developed. However, such phenomena have not been observed. Figure 3 shows the match between the layout of the buildings and the new orthomosaic, demonstrating that urban planning regulations were followed to a sufficient extent. This observation is related to the fact that: (a) the area studied was constructed decades ago and (b) the general trend in Greek urban planning system is to recognize and legalize the pre-existing urban morphology.

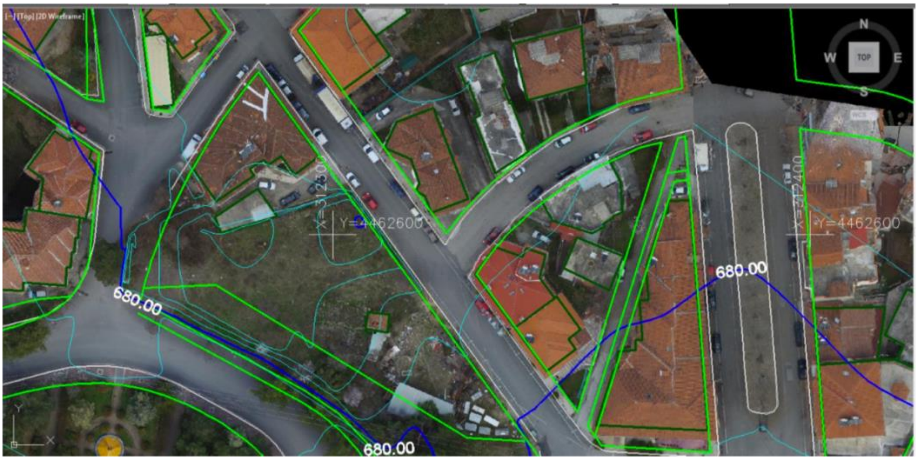

Figure 3. Comparing the new orthomosaic with the official urban plans. Source: Sustainable Mobility Unit Archive (2017).

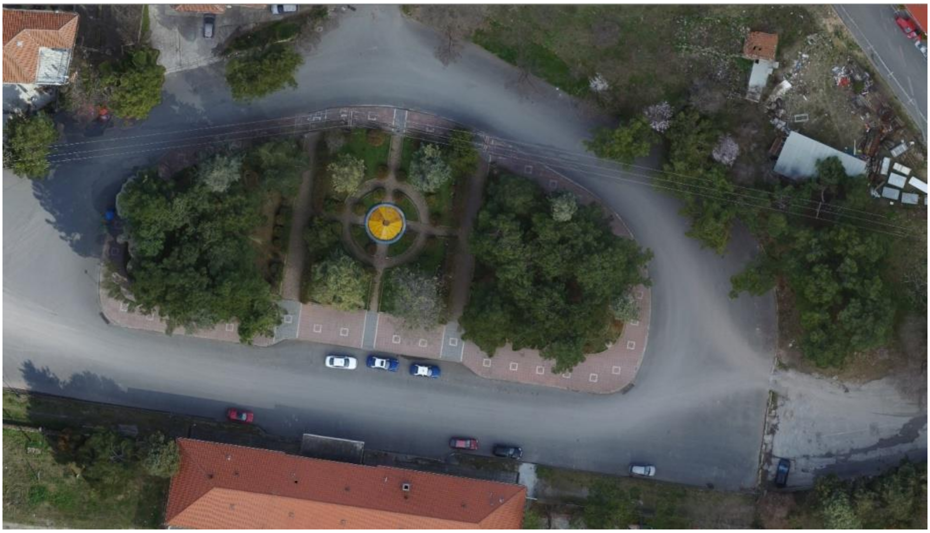

Figure 4. Part of the study area presented in the new orthomosaic (2017). Source: Sustainable Mobility Unit Archive (2017).

Figure 5. Part of the study area presented in the old orthomosaic (2007-2009). Source: Sustainable Mobility Unit Archive (2017).

The next parameter to be evaluated was the resolution of the orthomosaic produced. For this purpose, the quality of the new orthomosaic was compared with the old one (the official one) that was developed during the period 2007-2009. The GSD in the new orthomosaic is estimated to be 2.5 cm (Figure 4) as opposed to the old one that the GSD is estimated to be 30 cm/pixel (Figure 5). Therefore, the clarity of the new map is 12 times better than the clarity of the old one. As a result the information collected is of better quality. Meanwhile, more accurate measurement data have been obtained, validating the accuracy of recorded data. The equipment used was contributed to that, since the resolution could vary depending on the camera used. However, nowadays, good resolution cameras are available in the market at tempting prices. Thus, modern photos are of better quality than the old ones (2007-2009). The results are different when comparing the new orthomosaic with the urban plan produced by using traditional techniques. In the second case, the measurements are of better accuracy and the plan presents much more detail (Table 1). Nonetheless, in cases of large urban areas, like the one studied in this paper or even settlements and towns, the precision provided by this technology is particularly adequate.

	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 2. Comparing traditional techniques with UAVs method.

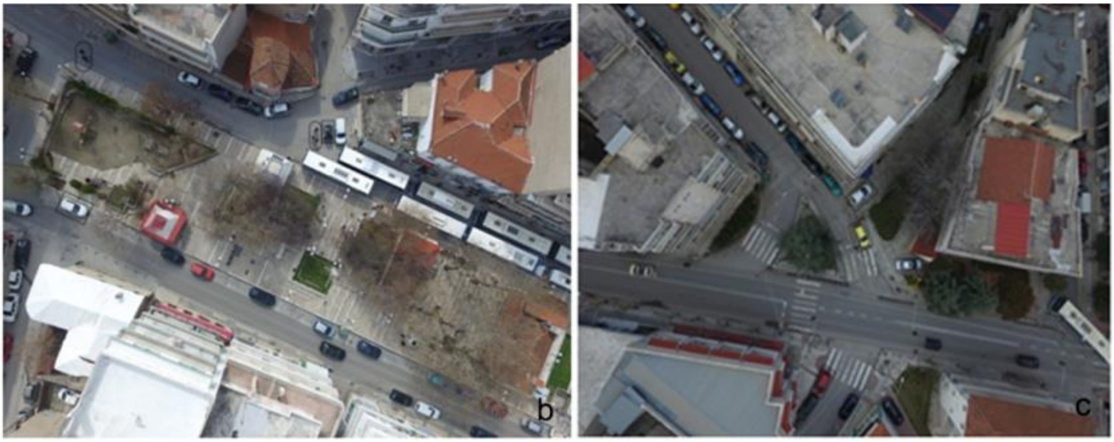

Figure 6. Mobility and parking behaviors. Source: Sustainable Mobility Unit Archive (2017).

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) and it was conducted by a two-man workshop. This work is divided into two parts:

(a) Office work: the flight plan developed.
(b) Fieldwork: the definition of the G.C.P. and the flights took place.

After that, it was decided to compare the cost of work performed in relation to the cost of the same work in case it was conducted by traditional mapping methods. 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 to the duration of the work. According to our assumptions, the number of persons required is twice as high (2 topographers and 2 workers as support staff) that will have to work for 4 days. On the basis of the above data, it was proved that implementing the work by using UAVs is more efficient in economic terms than conducting the same project by using traditional techniques. Volkmann (2017), who carried out a comparative analysis between traditional methods and UAVs focusing on economic terms, reaches a similar conclusion.

Given the fact that the precise calculation of the cost is a procedure that is also affected by a series of other criteria (*i.e.* the area that has to be captured), 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.

Finally, it should be mentioned that through this project it was also possible to create a data base concerning street behavior. More specific, traffic and parking habits were recorded, as presented in Figure 6. Moreover, pedestrians' behavior was also studied by analyzing the videos. In a different case, this could be possible only by observation, id est researchers who would observe people's behavior in specific street sections. Such traditional techniques are economic inefficient due to the fact that the number of researchers required is higher.

Conclusions

Technological evolution 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 planning proposals. UAVs are such tools that can make a significant contribution to mapping cities.

In the context of this study, UAVs used to map an urban area that is going to be regenerated; the Old Railway Station of Kozani and a road located in a close proximity to the station. The results derived helped us in comparing this method with traditional methods. More specific:

- 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.
- Using UAVs seems to be a cost-effective procedure comparing to traditional methods, since the demands on time and people were considerably reduced.
- Mobility patterns and street behavior was also recorded.
- Apart from 2D topographical diagrams, 3D mapping can also be developed. 3D capture provides better understanding of the study area.

The above findings resulting from this application of a UAV could be 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 recording that UAVs can provide, it is believed that their use in urban planning can be extended to fields like traffic management and study of human behavior, contributing to a better understanding of the parameters influence the function of urban spaces.

References

[1] Bakogiannis, E., Kyriakidis, C., Siti, M., Iliadis, F. and Potsiou, C. (2017). Toward a methodology for noise mapping using VGI. In: *VGI: Emerging applications in public science and citizen participation-FIG Commission 3 Annual Meeting*, Lisbon, Portugal, 27-30 November 2017.

[2] Bakogiannis, E., Kyriakidis, C., Siti, M., Kougioumtzidis, N. and Potsiou, C. (2017). The use of VGI in noise mapping. In: *GeoPreVi 2017*, Bucharest, Romania, 14-16 September 2017.

[3] Barrile, V., Gelsomino, V. and Bilotta, G. (2017). UAV and computer vision in 3D modeling of cultural heritage in southern Italy. In: *IOP Conference Series: Materials science and engineering*, New Delhi, India. Available at: https://iopscience.iop.org/article/10.1088/1757-899X/225/1/012196 (Accessed January 2018).

[4] Basiouka, S. and Potsiou, C. (2012). VGI in cadastre: A Greek experiment to investigate the potential of crowdsourcing techniques in Cadastral Mapping. *Survey Review*, 44(325), 153-161.

[5] Basiouka, S., Potsiou, C. and Bakogiannis, E. (2015).Open Street Map for Cadastral Purposes: An application using CGI for official processes in urban areas. *Survey Review*, 47, 344 (2015), 333-341.

[6] Christodoulopoulou, G. and Kyriakidis, C. (2017). *Using a combined urban and traffic planning for promoting sustainable mobility in the Municipality of Piraeus*. Available at: http://www.citybranding.gr/2014/12/blog-post_9.html (Accessed September 2017).

[7] Delitheou, V., Bakogiannis, E. and Kyriakidis, C. (2019). Urban planning: Integrating smart applications to promote community engagement. Heliyon, 5(5), e01672.

[8] Dimopoulou, E. (2015). *nD Cadastre: Planning-Development-Standards-Modeling* [e-book]. Kallipos, 2015. Availabe at: https://repository.kallipos.gr/bitstream/ 11419/3661/1/nd_cadastre.pdf (Accessed January 2018).

[9] Doulamis, A., Soile, S., Doulamis, N., Chrisouli, C., Grammalidis, N., Dimitropoulos, K., Manesis, C., Potsiou, C. and Ioannidis, C. (2015a). Selective 4D modeling framework for spatial-temporla land information management. In: 3rd *International Conference on Remote Sensing and Geoinformation of the Enviornment,* Paphos, Cyprus, 16-19 March 2015.

[10] Doulamis, A., Doulamis, N., Ioannidis, C., Chrysouli, C., Grammalidis, N., Dimitropoulos, K., Potsiou, C., Stathopoulou, E. and Ioannides, M. (2015b). 5D modelling: An efficient approach for creating spatiotemporal predictive 3D maps of large-scale cultural resources. In *25th International CIPA Symposium*, Taipei, Taiwan, 31 August-5 September 2015.

[11] Haklay, M., Singleton, A. and Parker, C. (2008). Web mapping 2.0: The neogegraphy of the GeoWeb. *Geography Compass*, 2(6), 2.011-2.039.

[12] Ioannidis, C., Potsiou, C., Soile, S. and Badekas, J. (2000). Detailed 3D representation of aerchaelogical sites. *Proceedings of the International Archives of Photogrammetry and Remote Sensing (ARPS)*, Vol. XXXIII, Part B5. Amsterdam 2000, 642-649.

[13] Neitzel, F. and Klonowski, J. (2011). Mobile 3D mapping with a low-cost UAV system. In: *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, Zurich, Switzerland, 2011, 37,1: C22.

[14] Nikitas, A. and Rahe, U. (2013). Designing the metropolitan future of Shanghai: A local interaction platform looking to incorporate urban access design considerations in planning for a faier, denser and greener Mega-City. In: *10th European Academy of Design Conference «Crafting the Future»,* Gothenburg, Sweeden,17-19 April 2013.

[15] Stamatopoulou, C. (2013). *3D representation for the exploitation of touristic routes in the Municipality of Lamia* – M.Sc. Thesis University of Thessaly. Available at: http://ir.lib.uth.gr/bitstream/handle/11615/41528/11416.pdf?sequence=2&isAllowed=y (Accessed January 2018).

[16] Somarakis, G. and Stratigea, A. (2014). Public involvement in taking legislative action as to the spatial development of the tourist sector in Greece – The «OpenGov» platform experience, *Future Internet*, 6 (2014), 735-759.

[17] Sustainable Mobility Unit (2017-2018). *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.

[18] Volkmann, W. (2017). *Small unmanned aerial system mapping versus conventional methods.* CTA Working Paper 17/07. Wageningen: CTA. Available at: https://publications.cta.int/media/publications/downloads/1987_PDF.pdf (Accessed January 2018).

[19] Yiannoudes, S. (2016). *Architecture and adaption. From cybernetics to tangible computing*. New York, NY; London,UK: Routledge.