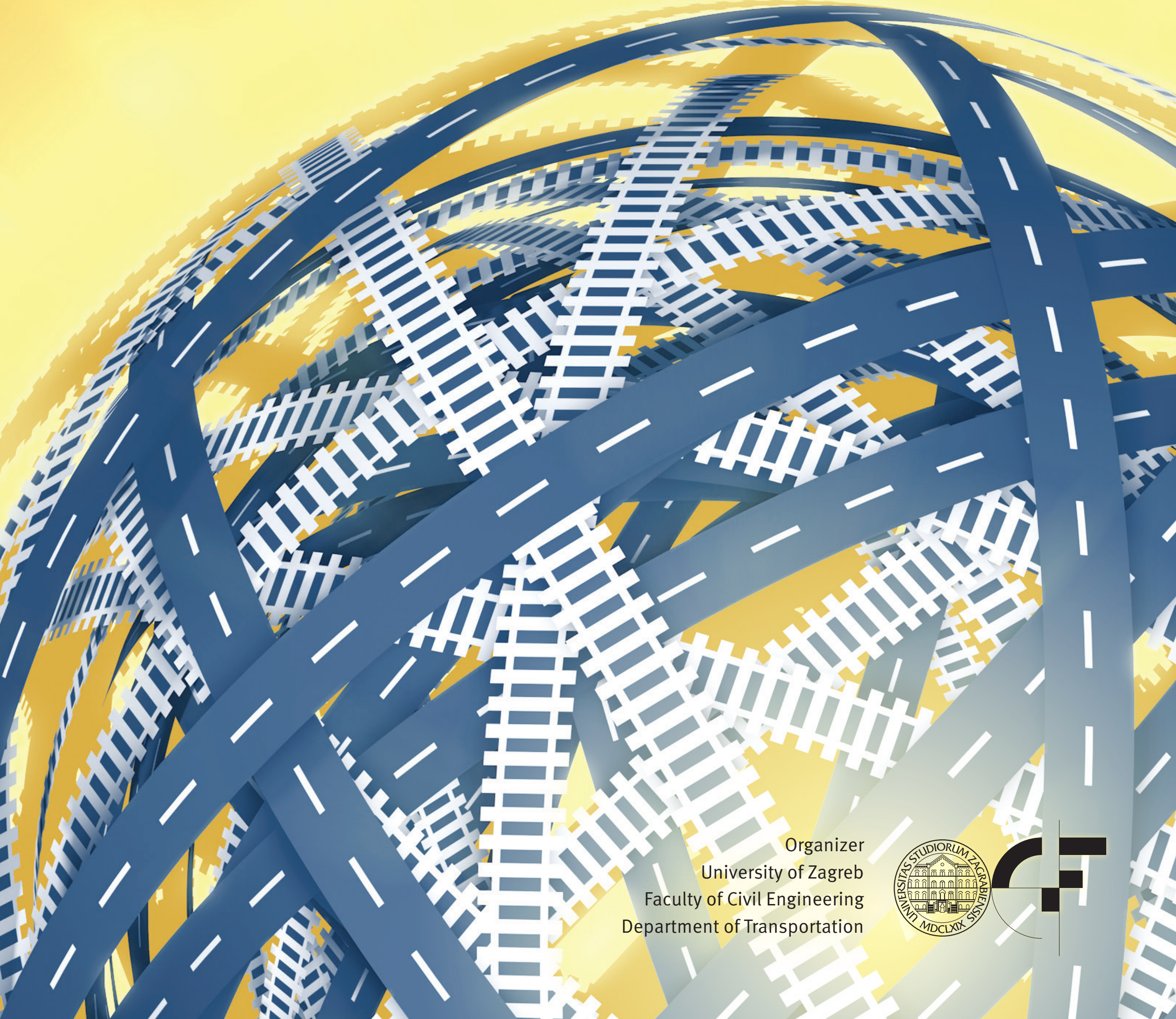
CETRA[2016]

4[th] International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA[2016]
4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

TITLE
Road and Rail Infrastructure IV, Proceedings of the Conference CETRA 2016

EDITED BY
Stjepan Lakušić

ISSN
1848-9850

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Marko Uremović · Matej Korlaet

PRINTED IN ZAGREB, CROATIA BY
"Tiskara Zelina", May 2016

COPIES
400

Zagreb, May 2016.

Proceedings of the
4th International Conference on Road and Rail Infrastructures – CETRA 2016
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COMPARISON OF DIFFERENT SURVEY METHODS DATA ACCURACY FOR ROAD DESIGN AND CONSTRUCTION

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Abstract

For road design and construction, survey data play very important role as a basic tool and a starting point for the development of the design. In addition to the quality of project design, accuracy and precision of survey data is also essential for project-to-field data transferring within road build. In this paper, survey methods and its precision will be presented in a view of two commonly used methods (GPS and total station) and some new technology (unmanned aerial system-drone). Special emphasis will be given to the potential use of drones in survey data for road design and construction, with presentation of the field research results on the example of urban roundabout.

Keywords: survey data, accuracy, GPS, drone, total station

1 Introduction

Road design is a complex activity involving the analysis of field conditions and evaluation of alternative solutions in order to obtain the best possible quality of the final product – the road. For quality project, accuracy of input data is essential. The accuracy of survey data will reflect on a road build conditions. Geodetic survey, as the basic input data for the development of road project is extremely important in terms of its precision and detail. Therefore, the issues around its development and content are defined by the relevant laws and regulations. Within the survey, it is important to know horizontal and vertical accuracy of provided data, particularly if there are also used for structure stake out.
Geodetic survey consists of two equally important parts whose accuracy equally affect the overall accuracy of the project: digital map or plan (usually digital cadastral plan – DCP) and topographic survey. DCP is usually obtained by digitizing analog cadastral maps and its vectoring [1]. Precision of this process is presented in Figure 1 on the example of the building from Vodenička Street in Osijek.
DCP is supplemented and overlapped by survey data. Points 1 and 2 are derived from the survey data while points 1' and 2' are within DCP. It can be seen that the differences in position are not negligible, and they can be 0.5 meters or more. It should be noted that DCP gained by digitalizing (scanning) of analog cadastral maps can not be increased by magnification of scanned plan detail or by using higher resolution [2].
In making surveys for the road design, particularly in urban areas, it is necessary for parcel boundaries on vectored DCP to be corrected by field survey data which will greatly increase its precision. Also, DCP does not contain terrain altitude data nor a sufficient number of detailed points for quality road design. Therefore, it is necessary to supplement it by field survey so the comparison of commonly used survey methods (total station and GPS) and new technology (unmanned aerial system-drone) are presented in this paper.

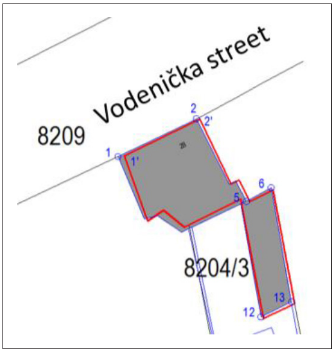

Figure 1 Comparison of vectorised DCP and survey data

2 Total station and GPS

The total station is a combination of electromagnetic distance measuring instrument and electronic theodolite. It can be used to measure horizontal and vertical angles as well as sloping distance of object to the instrument so it has been used for many engineering and construction applications. Besides that, it is proven to be an excellent tool for mapping complicated fault zones in vegetated and cliffy areas in geologic mapping [3]. Accuracy of this method in positioning detailed points is within 1 cm which is very important when displaying strictly defined surfaces on geodetic layers such as asphalt and concrete surfaces or within larger and more demanding projects. However, there are some external factors affecting accuracy of this method. As described in [4], for total stations using laser beam, type and colour of the reflecting surface will substantially affect the energy of the reflection of the laser beam, increasing the distance between the total station and the target leads to increase the errors in measuring the slope distances, accuracy of measured slope distance for the white surface is higher than the accuracy of any other surface colour and modern electronic surveying instruments may be affected by the capacity of instrument battery which may be worked for long time in the field.

The use of GPS (Global Positioning System) for surveying begun in the 1980s with data being post-processed as one of its main disadvantages. But during that time it was the only way to obtain centimetre-level positioning. In the early 1990s, RTK (Real-Time Kinematic) methods were used to obtain centimetre-level positioning in real-time making former GPS survey method very efficient [5]. However, even with the use of modern instruments, by GPS survey there is a possibility of local displacement of the entire recording (because of the point of view accuracy) so the best accuracy can be achieved by using relative relations within the area of one recording.

As an answer to continues tendencies in geodetic science and practice for a high accuracy and reliability of data with minimal material costs, GNSS (Global Navigation Satellite System) system is developed. This concept of networked reference GNSS stations include GPS – American system (Global Positioning System), GLONASS – the Russian system (Global Navigation Satellite System) and the European Galileo system which is still inactive. CROPOS (CROatian Positioning System) system consists of 33 GNSS reference station at a distance of 70 km distributed in a way to cover the entire Croatian territory for the purpose of collecting data from satellite measurements and calculating the correction parameters. This networked reference station systems allows the determination of points with an accuracy of 2-3 centimetres and for the vast majority of geodetic measurements, this precision is sufficient. However, accuracy on a level less than one centimetre can be obtained by a combination of GNSS RTK system with the use of laser sensors and transmitters.

3 Unmanned aerial system – drone

Photogrammetric method is very cost-effective for producing survey maps of long and narrow objects such as roads. Altitude component accuracy obtained by this survey method is about 10 cm. However, the basis for achieving desired accuracy level is carefully performed survey. Survey should be carried out within low vegetation season, when the ground and all objects are clearly visible, survey measure should be adjusted to the required accuracy and to make ground preparation for aerial survey by setting fotosignals (crosses) or clearly marking defined details and measuring and calculating their coordinates [6].
Today, in photogrammetric survey, unmanned aerial systems (UAS) or drones are increasingly used [7] from simple drones with elevation accuracy of approximately 10 cm to unmanned aircraft equipped with GNSS RTK system with elevation accuracy around 2-3 cm.
UAS were developed when navigation and mapping sensors were integrated onto radio-controlled platforms to acquire low-altitude, high-resolution imagery for military purposes [8]. Today, UAS have a range of potential environmental or commercial applications (emergency response, pollution detection, crop spraying, etc.), they can be deployed in surveillance applications against civilians, such as applications in policing and border surveillance or as a weapons [9]. Due to the low cost, fast speed, high manoeuvrability, and high safety of UAS systems for collecting images [10], there is also possibility for its various use in civil engineering.
Investigating potential use of UAS for surveying earthwork projects, Siebert and Teizer [10] described different influences on UAS performance and its characteristics. According to their research, UAS required only 3% of the conventional RTK GPS-based data acquisition time but evaluation of the UAS-generated photos for errors (blur and obstructions) required more time and the UAS photogrammetric mapping approach required about one third of the time a RTK GPS survey. The main advantage of an orthophoto from the UAS is a geometrically corrected aerial photograph that is projected similarly to a topographical map, displaying true ground position with a constant scale throughout the image. This can be very helpful for field engineers for the direct measurement of distances, areas, and positions, and in particular when creating cross-sectional views or other terrain map information. There are also some issues within UAS survey. Stronger thermal winds can cause air turbulences for the UAS resulting in some blurred photos. Finally, UAS operation in highly populated areas can be unsafe or unsecure for any bystanders (pedestrians or other traffic).

4 Field measurement

Within this research, UAS type Phantom 2 Vision+ (Figure 2) equipped with 14MP camera was used in order to obtain photogrammetric images and to evaluate accuracy of different survey methods. It is a Class 1 aircraft system according to valid Croatian regulations [11] with total weight about 1,3 kg.

Figure 2 UAS Type Phantom 2 Vision+

Survey was conducted on roundabout in Trpimirova Street in Osijek. On the curbs on all four roundabout legs and on central island, 50 detailed point was marked and determined by four methods: a) survey by total station; b) survey by GPS RTK method using two satellite receiver TOPCON HIPER V type; c) survey by GPS CROPOS method using one satellite receiver TOPCON HIPER V type and d) survey by UAS photogrammetry with 60 m flight level. For aerial images processing, Quantum GIS software was used and four control points. Areal image with marked control points is presented in Figure 3 while resulting digital terrestrial model (DTM) is presented in Figure 4.

Figure 3 Aerial photo with marked control points taken by UAS

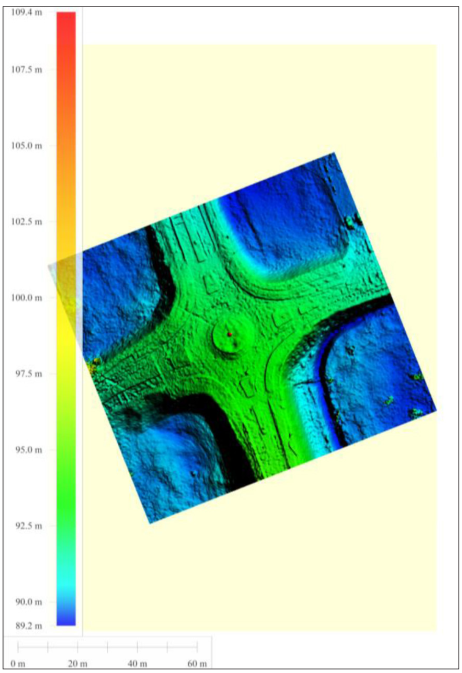

Figure 4 DTM obtained by UAS images processing

5 Comparison of survey results

In order to compare accuracy of different survey methods and potential use of UAS for survey, results of UAS, GPS RTK and GPS CROPOS methods are analysed in terms of total station method. Elevation of detailed points obtained by a total station method are determined by trigonometric method with an accuracy of about 5 mm. Due to the fact that this method is the most accurate one, results of other used methods are compared in terms of total stations results. Results of UAS, GPS RTK and GPS CROPOS survey are presented in Figure 5 in terms of total station results. As it can be seen, the highest deviation is obtained for UAS method. GPS RTK and GPS COPOS methods presented similar deviations. However, GPS RTK method seems to have more reliable results due to continues values of deviations for all measured points.

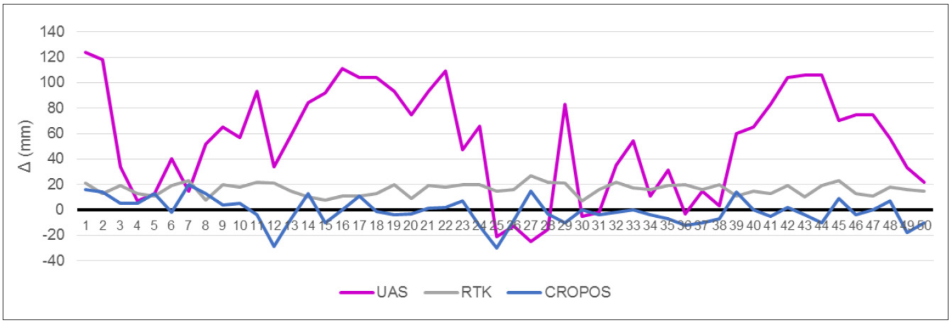

Figure 5 Survey results from different methods in term of total station method

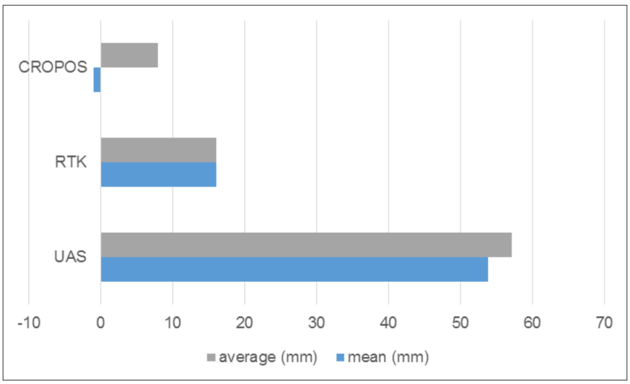

Figure 6 Average and mean deviations in term of total station method

In order to compare accuracy of different survey methods, in Figure 6 average and mean values of elevation deviation in term of total station results is presented. For GPR CROPOS method, mean value of deviations is -1 mm (measured elevations are in average 1mm lower compared to elevations determined by total station method). This result presents very high compatibility with total station measurements. However, average value of deviations is slightly higher, 8 mm, meaning that average deviation of this method compared to total station is 8 mm. For GPS RTK method, average and mean values of deviations are the same, 16 mm, meaning that this method gives the most uniform deviations. UAS method results have the highest deviations compared to total station results making this method the least accurate one. Average and mean elevation deviation is 54 mm and 57 mm respectively which also presents very reliable result. Even though this is significant loss of accuracy, it presents the potential of using UAS as alternative, relatively cheap and fast survey method with applicability in projects which do not require highly accurate measures. In order to increase accuracy of any photogrammetric survey, it is necessary to select level of desired accuracy and on that basis, we can define survey parameters such as flight level, image overlapping and ground sampling distance (GSD) which defines recording resolution. Particularly, flight level adjustment could be used for increasing UAS survey accuracy but the safety issue must be addressed since UAS operation in highly populated areas can be unsafe or unsecure for any bystanders (pedestrians or other traffic) or for the UAV equipment itself.

6 Concluding remarks

For road design and construction, survey data play very important role as a basic tool and starting point for design development. Accuracy and precision of survey data is also essential for project-to-field data transferring. So, in order to define accuracy of different survey methods and defining its potential application, comparison of the results of four different survey methods were used. Results of this field study has shown that GPS RTK and GPS COPOS methods presented similar deviations from the total station results taken to be referent one. However, GPS RTK method seems to have more reliable results due to continues values of deviations for all measured points. On the other hand, UAS method results have the highest deviations comparing it to total station results making this method the least accurate one. Even though this is significant loss of accuracy, it presents the potential of using UAS as alternative, relatively cheap and fast survey method. UAS are growing new technology with increase market for small photogrammetric and remote sensing projects to which it offers an unbeatable price-performant service and product.

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