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EVALUATION OF TRAFFIC PARAMETERS AND UNDESIRABLE INCIDENTS USING UAV TECHNOLOGY

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ABSTRACT

Vehicles reposition analysis is a key feature in a process of forming the traffic behaviors and managing the specific urban area issues. The anti-congestion or anti-incident activities contribute to the improvement of living conditions in modern cities. In cases when preventing the adverse incidents is impossible, it is essential to correctly evaluate the scale of a problem and take the best decisions in terms of the traffic. The purpose of the study is analyzing the possibilities of road safety improvement and refining the process of managing or modeling the traffic and infrastructure by using the UAV's.

KEYWORDS

traffic analysis, urban area, UAV, traffic parameters

INTRODUCTION

In the beginning, UVAs like another modern technologies were only used by the military. In the course of time, their smaller versions have become widely used by civilians. Currently, UVA technology is used in many areas such as environmental protection (measurements of air pollution and biomass), public safety and geo-spatial and surveying activities in addition to commercial use. UVA become also helpful during traffic measurements and control. Increasingly, they are also involved in smart cities activities.

1. TRAFFIC MEASUREMENTS AS AN ESSENTIAL TOOL FOR EFFECTIVE TRAFFIC MANAGEMENT

The constant development of automotive sector leads directly to the growth of traffic density and expansion of road network. Managing more and more advanced transport systems, particularly in urban area, becomes the serious challenge. In years 2005-2015 Annual Average Daily Traffic (AADT) in Poland increased about 35%, as the consequence of growing number of vehicle on the roads and significant role of commercial road transport. It is worth mentioning that traffic measurements are important source of social mobility characteristic and demand information. The analysis are also helpful in identification of road users behaviors tendencies and dependencies between them and infrastructure.

Effective traffic management process requires complex, honest, actual and very detailed information about road traffic characteristics. Data describing the real-time volume of road network density and its transformation are obtained by traffic measurements and analysis. Implementation of Urban Traffic Management and Control System (UTMC) cannot be effective without knowledge about type and specificity of vehicle movement in selected area. To select best solutions infrastructure authorities must conduct very time-consuming and capital-intensive studies. Classical measurement methods, usually engaging a great amount of human recourses (as traffic observers), are encumbered with significant errors. Usually there is a need to convert paper form data into the digital format. Consequently the drawbacks of those methods are not only limited human divisibility of attention, but also a very long duration of gathering, analysis, interpretation and publication of traffic measurement results.

Traffic data in statistical terms refer to[1, 2],:

- Annual Average Daily Traffic (AADT),
- daily distribution of different vehicle categories in the traffic volume,
- traffic density on Road Network in local or national coverage,
- time interval distribution of traffic volume changes,
- changes and tendencies in road traffic.

The biggest and most expansive traffic measurement (covering entire national road network) is General Traffic Measurement. The study is conducted by General Directorate for National Roads and Motorways every 5 years. Recommendations concerning traffic measurements indicates the significance of frequent data acquisition. The examinations should be perform cyclically with brief time intervals between them.

Increasingly, the importance of continuous analysis is emphasized. Nowadays the appreciable facilitation in that area are Intelligent Transportation Systems (ITS). Modern solutions not only collect useful data itself but also may share the technical infrastructure for traffic analysis purposes. ITS may be the great support for discussed issues. Information provided by those systems can be source of essential data for calculating coefficients and volumes used in traffic analysis. The continuity of conducted research allows to select arbitrary duration and time intervals. Frequent and complex traffic parameter study is a key factor in early traffic tendencies and hazardous event identification. Awareness of those processes enables to develop an appropriate transport policy in the area, implementing adequate traffic organization. It is also helpful tool in road network development planning. [3]

Unfortunately using ITS infrastructure in traffic analysis is not the perfect solutions. Usually the vehicle registration sensors mounted in the road surface, on the roadside gantry or holder. Because of that fact measurements may only take place in strict localization. The process of moving the equipment is very stifled or in worst case

scenario impossible. The constant growth of traffic density compels the authorities to monitor the complete road network not only the selected parts. Need for control is particularly recognized on the busiest communication routes, so primarily in urban areas. Therefore, the mobile measurements requirement is identified.

2. THE CHARACTERISTIC OF UAV'S USED AS TRAFFIC MEASUREMENT SUPPORT

The most current response to discussed demand is the usage of unmanned aerial vehicle (UAV), so called drones. Most important advantages of proposed solution are:
- unhampered selection of localization,
- unhampered selection of measurement duration,
- real-time operations,
- relatively low operation coasts,
- low human recourses commitment,
- wide range of observations,
- direct research of hard to reach area,
- focusing on current traffic events,
- ability of moving faster than the observed vehicles,
- ability of conducting measurements in adverse weather conditions,
- ability of supporting the crisis situations.

Fig. 1 Example of unmanned aerial vehicle [4]

Additionally, UAVs may be used for following processes [2, 5]:
- traffic conditions monitoring,
- identification of traffic congestions,
- vehicle counting,
- parking lots utilization monitoring,
- road network control,

- undesirable events detection,
- vehicle accidents or disaster area examination,
- evaluation of infrastructure and technical equipment condition,
- road surface quality evaluation,
- emergency vehicle routing,

Recommended UAV's tools[6]:
- day and night video cameras,
- infrared cameras,
- infrared sensors,
- multi-spectral and hiper-spectral sensors,
- laser scanners,
- thermal sensors,
- moving target indicator,
- chemical or biological detectors,
- rain radars,
- wind sensors,
- visibility sensors,
- wireless communication hardware.

It is worth mentioning, that within the UAVs all the sensors and detectors may be easily added, removed and replaced. Equipment manipulations enable to enlarge and upgrade the device functionality. The usage of UAVs gives the traffic engineer a great flexibility in tool selection and offers precise adjustment to environment and adverse weather conditions.

3. POTENTIAL OF UAV TECHNOLOGY USAGE IN TRAFFIC ENGINEERING

UAV technology is currently gaining the popularity as traffic measurements support tool in small and medium areas. Drones are used by the engineers investigating dependencies on appearing on urban road networks. In those cases high quality camera recordings, correct devices calibration and dedicated software play a crucial role in the process. Video recorders allow automatic detection and recognition regardless of the meteorological conditions. The only UAVs limitation is changeable angle of sun reflections. Shadow cast by a vehicles on the road surface may cause video detection and measurement interpretation errors. The study carried out in 2015 [7] show that current technology can reach about 65% vehicle counting accuracy. Additional application of dedicated shadow-removing graphical filters allows to accomplish 100% accuracy.
However, using drone for vehicle counting is not the only UAV technology application in traffic engineering. Described devices also perform a supervisory function. Road Network monitoring successfully support detecting hazardous drivers behavior. Driver behavior studies [8] mostly focus on vehicle optical trajectory tracking using high resolution digital cameras. The vehicle movement trajectory is examine paying special attention to driver misbehavior. Carefully monitored driving style may provide enough information for driving when intoxicated (DWI) presumption. It can be assumed that UAVs are able to perform the potential DWI drivers preselection. Appointing certain vehicles allows to achieve rapid law enforcement reaction. Preventive actions do not limit itself only to identification of DWI drivers. Drones are increasingly used for detecting the red light violation, parking in restricted area violation or right-of-way violation. [9] Mentioned actions are not the only work towards safety improvement. Road network monitoring allows to react quickly ,identify and examine a potential accident scene.

It is particularly significant when it comes to hard to reach or dangerous area. It is worth mentioning that not only a location coordinates, but also information about the accident or adverse event severity is crucial for emergency services effectiveness.
UAVs may be also widely used as a support for Road Weather Information Systems (RWIS). Equipping the device with meteorological sensors changes a drone into mobile weather station. Mobile station can be used to obtain thermal maps, that are source of detailed information about road weather conditions and potentially dangerous situations (like slippery surface). The mobile weather control concept seems to be particularly useful in urban areas. It enables to monitor weather conditions in the real-time and variable locations. It is worth mentioning that UAV mobile measurements provides precise and accurate data for winter maintenance services. The complex information allows the authorities to react quickly and effectively in cases of danger. The road network administrator can also generate warning messages to the drivers, by analyzing the system thermal maps on time. [10]

4. UAV - POLISH LEGAL RESTRICTIONS AND LICENSES

All UAV operators, regardless of the nature of the operation, are required to comply with the aircraft law. The rules for drone using may vary if operator have a UAVO certificate. UAV operators are required by ordinance, which cancel some aircraft laws.
Responsibility of operators of unmanned flying objects are set out in Annex 1 and Annex 2 to the Regulation of the Minister of Infrastructure and Construction dated 8 August 2016 year. Attachments determine the requirements for civil responsibility of UVA operators and owned by them license.
The airspace over the territory of the Polish space is divided into classified and unclassified. The classified space is divided into two basic classes of space:

- uncontrolled space - Class G; reaching from the ground (GND) to FL095 (9500 feet or approx. 3000 m above the ground),
- space controlled - Class C and D; extends from FL095 to FL660.

Unclassified space is above FL660 and numerous elements of space, which are specifically separated from the space both controlled C / D and uncontrolled G eg. zone D (Danger Area), P (forbidden zone), R (Restricted Area), EA (Exercise Area) and others.
Besides, in uncontrolled airspace G isolated elements controlled airspace:

- CTR - (Control Zone) area controlled airports,
- TMA - (Terminal Control Area) area controlled airports (a),
- MCTR - Military Control Zone,
- MTMA - Military Terminal Control Area.

The airspace is not uniform either in the area of controlled airspace C (may contain many elements of the unclassified) or in the area of uncontrolled airspace G (which contains a lot of zones of the CTR / TMA, which are zones C communication airports).

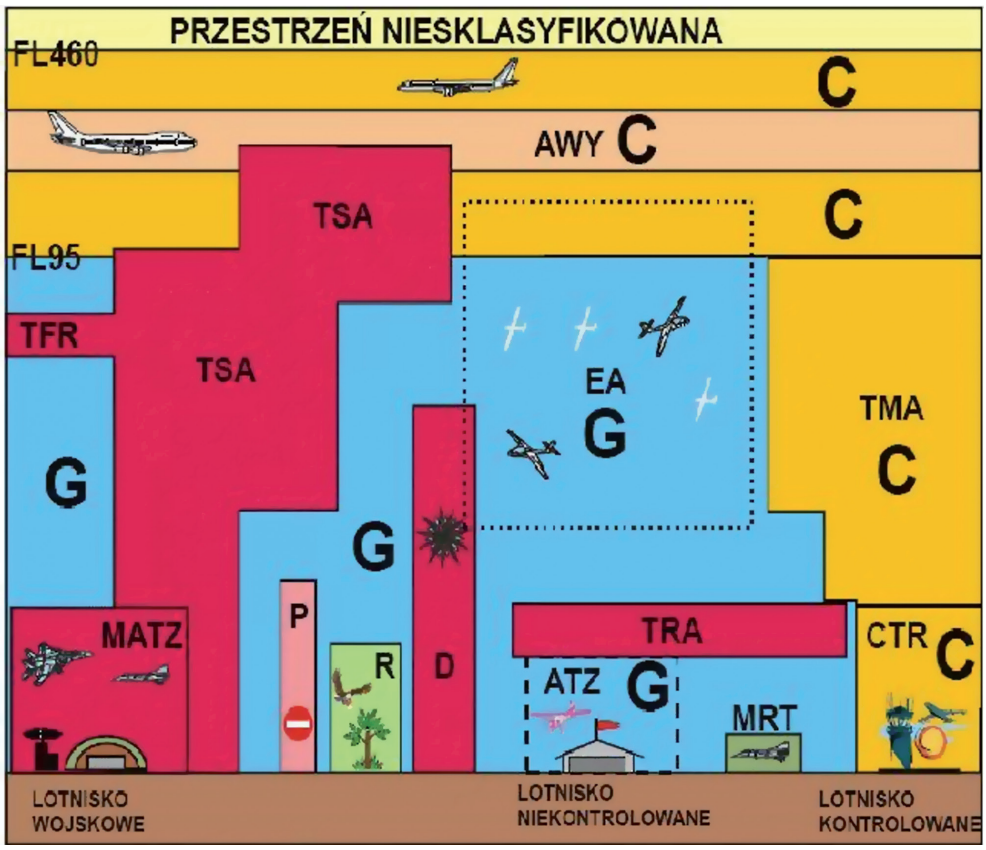

Fig. 2 Airspace split [10]

To control un Unmanned Aerial Vehicle operator have to get a certificate of drone operator. As part of the certificate UAVO can get permission to fly drone in sight reach or out of reach, the certificate also shares drones in terms of weight classes: to 5 kg to 25 kg and 150 kg.
In the European Union there is no uniform approach to the use of unmanned aerial vehicles. The European Commission has published a map maid integration of drones in the airspace over Europe. Element discredit drones may be right to privacy, which by their mobility can significantly limit. [10]

5. TRAFFIC MEASUREMENTS BY UAV

Traffic monitoring and measurements of movement can be difficult to implementation in the situation to perform a study on the whole city. The use of unmanned aerial vehicle to monitor and collect data on traffic, due to the possibility of covering a large part of the land on which the measurements are carried out, it is more useful.
The use of drone to conduct a study should be preceded by preparation, especially the preparation of the equipment, appropriate overlay and appropriate software. Measurement area should be divided into smaller areas due to the equipment possibility.

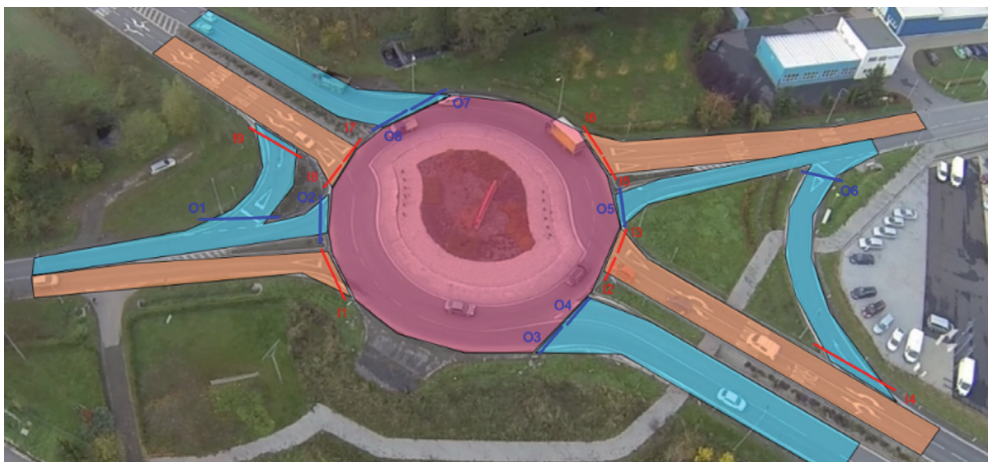

Fig. 3 Example of covered area [11]

Drones operating is possible due to unmanned aerial system, both in real time and pr-planning route of flight. Data collection systems are based on different method of data streaming. One of the data streaming method is the transfer via mobile phone transmission. Broadcasting stations cover areas along roads and cities areas, which is beneficial for the possibility of using this method of information transmission. [11]
Another way is to use a satellite positioning system (eg., GPS or GLONAS). The route of flight and drone control should be possible for the recipient of the information in real time. It is possible to connect the UAV monitoring system and traffic monitoring system using sensors mounted on roads, which after processing can become a valuable source of information for ITS and Smart Cities.
The condition for the integration of UAV systems and traffic management is knowledge and a number of parameters related to UAV:

- UAV design parameters (eg. mass, speed range, endurance),
- equipment (sensors, control data link),
- operational environment (control station).

Due to the lack of pilot on board the unmanned aircraft requires a high reliability data link and high autonomy of the UAV in case of bug or loss of communication.

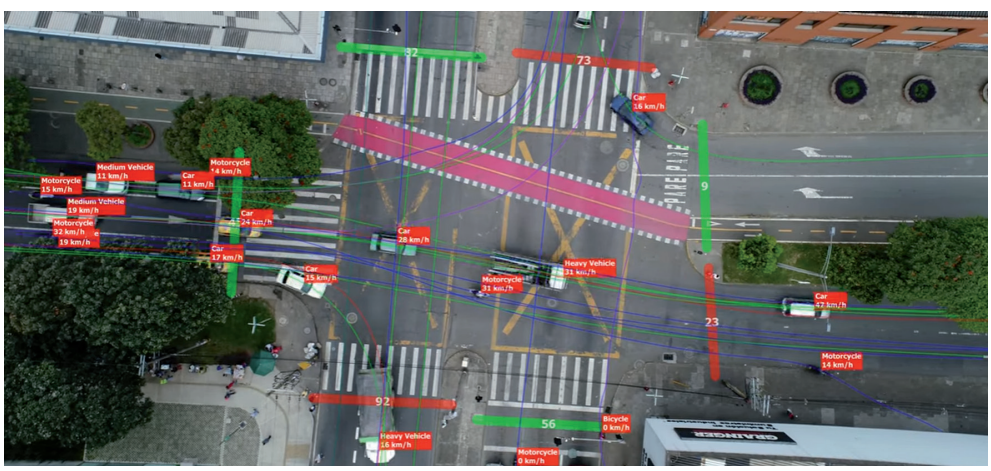

Fig. 4 Example of UAV traffic measurements [12]

UAV control stations - person controlling the operation of the aircraft should be responsible for the following tasks [13]:
- flight planning,
- control over the device during the flight, takeoff and landing,
- control motion sensors,
- distribution of images for those interested.

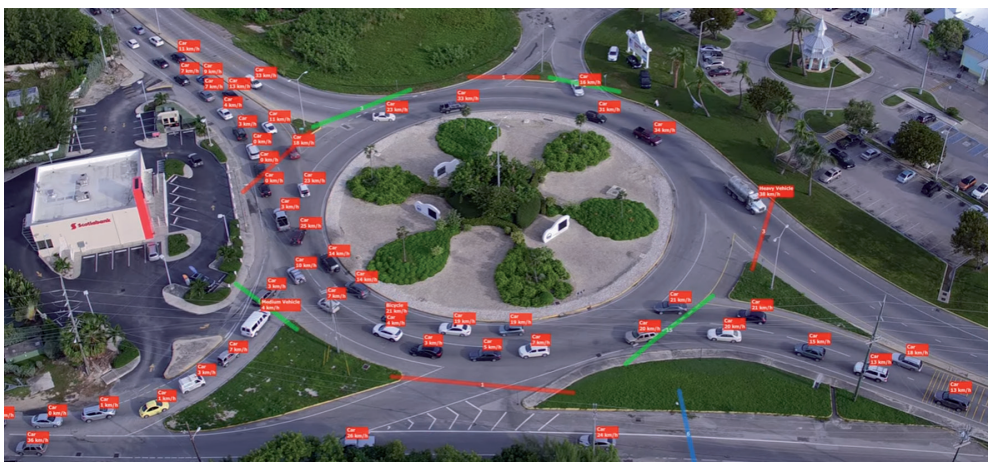

Fig. 5 Example of UAV traffic measurements [12]

5.1. TRAFFIC COUNTING AND FLOW

Counting of road vehicles is the most basic task, which can be done with UAV's, using a dozen or so clicks. To make a measurement, apart from the hardware and sensors, it is required to have software specialized in reading necessary data. In order to read information about amount of vehicles on the road, in virtual environment, it is necessary to set possible traffic trajectories and sample counting places – gates, which count a vehicle when one is in range. In addition to vehicles counting, there is a possibility to retrieve information about i.e. speed of certain vehicles or their average speed. At more sophisticated intersections, manual vehicle counting is technically difficult. However, due to UAV technology, it doesn't differ from traditional manual measurement. In case of intersections, it is possible to download and filter data i.e. from one or more trajectories defined beforehand.
Traffic engineers need reliable and detailed data on all aspects of the traffic movement. Some of the needed data to make traffic model is the intensity, consisting of individual vehicles on the preset road sections. Analyzing all possible trajectories, with the help of UAVs, can be assessed at the macro level the following features of the flow of vehicles:
- Occupancy – the location was occupied by a vehicle in fraction of time,
- Density or concentration – number of vehicles per kilometer/mile,
- Flow – number of vehicles during a given time interval,
- Mean speed – at a cross-section at a specific time.

In addition to these parameters, there are a number of other possible to read , which are need in the traffic engineering, such as gap acceptance, critical gaps, capacity, and capacity estimations.

5.2. SPEED, CLASSIFICATION AND EMISSION

Measurements done with UAV's help can provide detailed information about moving vehicles speed, which is more and more often used by police to monitor driver's adherence to traffic law. UAV's usage to determine vehicles speed brings benefits of real-time vehicle tracking. Data acquired with UAV's help is more precise than traditional measurements, moreover it is possible to make measurements over a wider area simultaneously. Additionally it is possible to discreetly observe traffic, without interfering with its free flow – traditional traffic measurements attract attention of drivers, which in turn makes their behavior less natural.
An important aspect of the measurements made with the help of drones is the possibility of the vehicles classification on the appropriate classes, eg. car, truck. Viewed from the side, measurement classification drone may seem vague, but through the use of innovative solutions based on weight, size, amount of used axles perfectly reflects reality.
The data gathered by the UAV can be used for example to construct O-D matrixes, which are useful in the traffic modeling.[12]

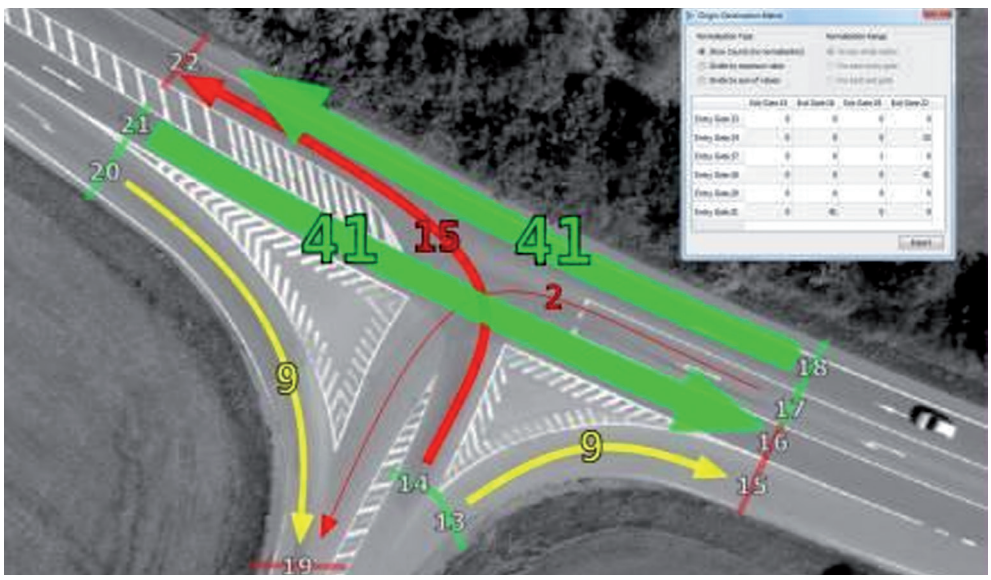

Fig. 6 Example of UAV traffic measurements

CONCLUSION

Effective traffic management process requires complex, honest, actual and very detailed information about road traffic characteristics. Using ITS infrastructure in traffic analysis is not the perfect solutions. Usually the vehicle registration sensors mounted in the road surface, on the roadside gantry or holder. The UAV use also have a barrier which can be a technological solution, however the use of modern solutions is able to eliminate errors. Thanks to this there are opportunity to obtain the detailed results of which could serve to further analysis and traffic models construction. Literary research has successfully proved that the use of drones is effective and can displace traditional measurement methods in the future. The iron measurement method eliminates human imperfections in measurements.

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OCENA PARAMETRÓW RUCHU DROGOWEGO ORAZ ZDARZEŃ NIEBEZPIECZNYCH ZA POMOCĄ UAV

STRESZCZENIE

Analiza sposobów przemieszczania się jest istotnym czynnikiem w procesie kształtowania zachowań komunikacyjnych oraz w procesie rozwiązywania problemów funkcjonowania obszarów zurbanizowanych. Działania zapobiegające kongestii czy niepożądanym zdarzeniom, przyczynią się przede wszystkim to polepszenia warunków życia mieszkańców miast. W przypadku, gdy zapobiegnięcie niepożądanej sytuacji jest niemożliwe, niezbędne jest prawidłowe oszacowanie skali problemu oraz podjęcie właściwych decyzji z punktu widzenia zarządzania ruchem. Celem artykułu jest analiza możliwości poprawy bezpieczeństwa ruchu drogowego oraz usprawnienie zarządzania infrastrukturą, poprzez wykorzystanie badań zrealizowanych przy pomocy UAV.

SŁOWA KLUCZOWE

analiza ruchu, obszar miejski, UAV, parametry ruchu