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CONTEMPORARY METHODS OF SPATIAL DATA ACQUISITION – THE ROAD TO "E-GOVERNMENT"

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IZVLEČEK

Sodobno upravljanje prostora zahteva učinkovito, zanesljivo in kakovostno pridobivanje prostorskih podatkov. Napredna geodetska oprema zagotavlja prožnejše in učinkovitejše postopke zbiranja podatkov, ki končnemu uporabniku ponujajo večje možnosti za kakovostno poslovno odločanje. Takšni podatki so tudi podlaga za izvedbo GIS-sistema, katerega uporaba v poslovnih sistemih lokalne samouprave je temelj za vzpostavitev e-uprave. V članku so predstavljeni rezultati in primerjalne prednosti zbiranja podatkov s sistemom za mobilno kartiranje (MMS). Predstavljeno je tudi izvajanje zamisli glede učinkovitega upravljanja prostora v direktoratu za gradbeništvo občine Bačka Palanka v Srbiji.

ABSTRACT

The modern approach to area management in recent times implies an efficient, reliable and qualitative acquisition of spatial data. Modern surveying equipment provides more flexible and effective procedures for data collection that provide increasing opportunities for qualitative decision-making of end users. Simultaneously, these data represent the spatial basis for the implementation of GIS systems, whose successful utilisation in business systems within local government paves the way for the establishment of "e-government". This paper presents the results of the comparative advantages of data acquisition using the mobile mapping system (MMS) and the method for realization of the idea of effective area management, based on the example of the Directorate for Construction of the Municipality of Bačka Palanka, Serbia.

KLJUČNE BESEDE

sistem za mobilno kartiranje (MMS), e-uprava, upravljanje prostora

KEY WORDS

mobile mapping system (MMS), e-government, land management

1 INTRODUCTION

Information in IT society as it stands at present no longer represents merely statistics that generates a reaction that is optimally adjusted to the emerging situation. In contemporary times information represents a resource and a comparative advantage over the competition which results in a better competitive position, fast and timely decision-making, which today, as never before, is unmistakably in correlation with the success or proficiency in the business world. Like no other known strategically important matter, information has one component that transforms it from being valuable to becoming completely irrelevant: time. In the function of time, which can sometimes be differentially minimal, information can change the reality and in the business world this time factor can make the difference between a winner and a total loser. Furthermore, information has no value unless there is an appropriate infrastructure that can accept it, process it and react to it.

As such, information, information infrastructure and users comprise an unbreakable chain in decision making that is a prerequisite for business success. If any of these components is not at an adequate level it can represent a weak link that completely nullifies the quality of other factors. In other words, no successful business decisions can be made in an inconsistent decision-making chain. Spatially-orientated business activities, as an important component in the business system management, have a set of spatial information for geo-referencing all relevant information that significantly influences the decision-making process. Likewise, spatial information serves as a foundation for generating decisions on the basis of spatial attributes or relations among the components of a business system. Beginning with a completely practical view of the problem of managing a group of physical structures (e.g. infrastructure facilities), the process can be viewed through four basic questions: (1) What do we have (the structures we manage)? (2) What do we want? (3) What do we do? (4) Which activities are included (what has been done, what is in progress and what is to be done)? In order to answer these questions, we require relevant, qualitative and up-to-date data.

In this paper special attention is paid to the structure, acquisition and significance of spatial data, as a prerequisite for the efficient work of local government, with special emphasis on contemporary methods of acquiring spatial data as a support for successful area management and the foundation for establishing "e-government".

2 PROBLEM DEFINITION

Public enterprises – Directorates for Construction, as well as all similar business systems within local governments in Serbia, conceive their main business activities using spatial data to a significant extent. As a rule, in every phase they conduct analysis, analytics, planning, design, realization and exploitation, as required activities on the part of the Directorate that are spatially determined. The quality of spatial data directly influences the quality, i.e. efficiency, of area management, as well as the organizing of the life and work of local government. The most common problems related to spatial data relate to:

- institutional distribution (data is stored in several different locations: municipal cadastre agencies' premises, local government bodies, republic and provincial institutions),
- inconsistency of data formats,
- quality (accuracy and reliability),
- availability.

All of these inconsistencies, as well as problems occurring as a result of the inefficient work of system institutions, provide the following characteristics for the working environment:

— lack of planning documentation,
— outdated cadastre substrate forms,
— unresolved property ownership issues and legal problems related to public land,
— inefficient decision making systems based on incomplete and unreliable data,
— inefficient responses to potential investor initiatives,
— iInadequate IT support, outdated communication infrastructure,
— poor quality strategic documents for the development of local government from the aspect of development strategies, planning, objectives and the creation of an environment for doing business as a foundation for the overall development of the city,
— unplanned investment in infrastructure, particularly in roads, without orderly priority lists for interventions (regular maintenance, increased maintenance, rehabilitation, repair, reconstruction).

A lack of spatial data or their poor quality has generated a set of problems that directly lead to a dysfunctional system, i.e. inadequate area management. In order to overcome this problem, it is necessary to have a systemic approach for acquiring spatial data and ensuring their mutual interaction.

3 OVERVIEW OF CONTEMPORARY SYSTEMS FOR THE ACQUISITION OF SPATIAL DATA

3.1 State of the art

The purpose and methods of utilising spatial data most commonly have a significant impact on the optimization of selecting geodetic methods, instruments and tools, but also the level of accuracy and reliability of spatial data. This selection has a direct impact on the dynamics and costs of geodetic works. Developmental technological path from classical optical and mechanical theodolite, via electronic distomats and total stations, all the way to the contemporary electronic total stations, digital levelling tools and global positioning systems has also had a significant influence on the possibility to establish contemporary methodologies in road infrastructure management. This possibility is primarily observed in a significantly shorter time period and lower cost of spatial data acquisition, but also in a greater reliability. A list of some of the systems available in North America is provided in Table 1 (sources are from the literature and the website information of companies) (Tao, 1998).

With the advent of the Global Positioning Systems, as well as video imaging technologies, cumbersome photo-logging systems were replaced by GPS-based video-logging systems. It has been demonstrated by many projects that the GPS-based video-logging systems offer a fast and low-cost approach to highway inventory (Lapucha, 1990; Schwarz et al., 1990). The evolution of mobile mapping systems from video-logging systems was mainly contributed by the efforts of two research groups in North America, The Center for Mapping at The Ohio State University, U.S.A. and the Department of Geomatics Engineering at The University of Calgary, Canada (Bossler et al., 1991; Schwarz et al., 1993). Compared to video-logging systems, mobile mapping systems are able to offer full 3-D mapping capabilities that are realized by using the advanced multi-sensor integrated data acquisition and processing technology (El-Sheimy and Schwarz, 1995; Li, 1997; Novak, 1995; Tao, 1997).

Table 1: Some of video-logging and mobile mapping systems in North America (Tao, 1998)

System	Developer	Positioning Sensors	Mapping Sensors	Website References
ARAN (Automatic Road Analyzer)	Roadware Corp., ON, Canada	Accelerometers/IMU (Inertial Measurement Unit)/ GPS (Global Positioning Systems)	1 VHS (Video Home System), 2 or more CCD (Charge Coupled Device), Laser	www.roadware.com
GeoVAN	GeoSpan Corp	GPS/DR (Dead Reckoning)	8 CCD, voice recorder	www.geospan.com
GI-Eye	NAVSYS Corp., CO, USA	GPS/IMU	1 CCD	www.navsys.com
GPSVan	The Ohio State University, Columbus, OH, USA	GPS/Gyro/wheel counter	2 CCD, voice recorder	N/A
GPSVision	Lambda Tech Int'l Inc., WI, USA	GPS, INS (Inertial Navigation System)	2 colour CCD	www.lambdatech.com
ON-SIGHT	TransMap Corp., OH, USA	GPS, INS	4 colour CCD	www.transmap.com
Roadwiew	Mandli Communications, Inc, WI, USA	GPS/IMU/Inclination Odometer/Barometer	Progressive Scan CCD	www.mandli.com
Road Radar	Road Radar Ltd., Canada	GPS	Ground Penetrating Radar, 1 Video	www.rrl.com
TruckMAP	John E. Chance and Associate, Inc., LA, USA	Multi-antenna GPS/gyro	Laser range finder, 1 Video	www.jchance.com
VISAT (Video images, an INS system and the GPS Satellite system)	The Univ. of Calgary and Geofit Inc., Canada	GPS/INS/Anti-Brake System	8 B/W CCD, 1 colour SVHS (Super Video Home System)	www.visat.com
TOPCON	TOPCON, USA	40 satellites, all-in-view, L1 GPS, L1/L2 GPS, L1/L2 GLONASS (Global Navigation Satellite System), L1/L2 GPS + L1/L2 GLONASS, WAAS (Wide Area Application Services), MSAS (Multi-functional Satellite Augmentation System), EGNOS (European Geostationary Navigation Overlay Service)	CCD, Video	http://www.topconpositioning.com

The increasingly intensive development of digital sensors and their qualitative and quantitative efficiency in the collection of spatial data and their processing is a precondition for creating high-quality, reliable, efficient and integrated systems for collecting spatial data. Such systems nowadays provide a large amount of data of high accuracy and reliability in a short time, further emphasising the analysis and interpretation of the data and not the primary acquisition. The following table shows some of the most advanced systems for the collection of spatial data from the area of Europe (Table 2).

Table 2: Some of the most advanced Europe's mobile mapping systems

System	Developer	Positioning Sensors	Mapping Sensors	Website References
IPM	The Fraunhofer Institute	GNSS (Global Navigation Satellite System), inertial measurement system	Laser	http://www.ipm.fraunhofer.de/
Trimble UX5	Trimble	GNSS	Digital camera inclination sensors	http://uas.trimble.com/ux5
Riegl VZ-400	Riegl	GNSS	SyncTimer; laser plummet, compass (optioinal)	www.riegl.com
Aibot x6	Aibotix/Leica Geosystem	GNSS	Digital camera	www.aibotix.com

The large autonomy of a system for mobile mapping, efficiency, low costs of mobilisation of such system, a large amount of reliable spatial data, intensive development of software tools for processing and presenting these data are just some of the features of these integrated systems that have ranked them among the most popular systems for the mass collection of spatial data. Merging data gained through laser scanning of geo-referenced digital images creates a very high quality, reliable and convenient spatial basis for primary collection of spatial data, but also for various types of analysis and decision-making based on the reliable spatial information. At present such systems are used on a daily basis to evidence and control the quality of transport infrastructure and mapping structures along roadways, but also for the establishment of the cadastre of traffic signs, public lighting, bridges, fences, walls, protection against noise pollution, 3D models of objects and collecting numerous other data in the function of safety consideration.

Recent years have witnessed the growth of demand for road monitoring systems based on image or video analysis. These systems usually consist of a survey vehicle equipped with photo and video cameras, laser scanners and other instruments. Sensors mounted on a van collect different types of data while the vehicle moves along the road. Recorded video can be geographically referenced with the help of global positioning systems (Barinova et al. 2009). Barinova et al. (2009) presented a tool for efficient interactive mapping of road defects and lane marking on rectified images of road pavement surfaces. A group of authors from Japan presented an automatic road mapping technology by fusing vehicle-based navigation data, stereo images and laser scanning data for collecting, detecting, recognizing and positioning road objects, such as road boundaries, traffic markers, road signs, traffic signals, road guide fences, electric power pylons and many other applications important to people's safety and welfare (Shi et al., 2008).

The other intelligent techniques for improving object space accuracy were to use more intelligent data processing of multiple navigation sensors like GPS and IMU. These works can be found in Geomobil

(Talaya et al., 2004) and *StreetMapper* (Hunter et al., 2006). The Geomobil system uses a POS/LV (Position and Orientation System for Land-based Vehicle applications) navigation sensor and its corresponding software - Pospac. *StreetMapper* uses Riegl 2D laser scanners integrated with an IGI (Ingenieur Gesellschaft fur Interfaces) TERRAControl GPS/INS system. This system has been used on a number of projects, including highway asset measurements, indivisible abnormal load route planning and 3D city modeling. *StreetMapper* provides detailed data on the facades of buildings and high resolution measurements of power cables beside streets. The accuracy trials under normal conditions resulted in an RMS (Road Mobile System) error between *StreetMapper* data and ground control points better than 30mm (Hunter et al., 2006).

Mobile Mapping System (MMS) is the latest technological product for mass spatial data acquisition with motion-imagery sensors. The system can be mounted on any moving vehicle on road, rail or water. The system provides geo-referential spatial high-resolution images, i.e. 3D point clouds. Apart from great autonomy and efficiency, this system is characterised by the great accuracy of its collected spatial data, as well as their homogeneity. Even though it can be used in almost all conditions, its higher efficiency and comparative advantage in relation to all other systems is achieved in densely built-up areas, tunnels, bridges and urban roads with high traffic loads. The system is modular in design and its standard structure usually contains the following components: system core – it presents a sophisticated solution for a control unit, GNSS receiver, IMU and external odometers installed on a vehicle's wheels and serving to determine the position of MMS and collected data from sensors, laser scanners, cameras, thermal sensors, radars and three 2D scanners. Depending on the project task and monitoring conditions, as well as the natural surroundings, this system can utilise some of its components or can record with a discrete selection and a combination of components. The product of the corporation TOPCON, model IP-S2, which was used for data acquisition for the project described in this paper, consists of the following:

- GNSS receiver (L1/L2 GPS + GLONAS) – for MMS positioning;
- IMU (gyro degree 1°/h) – system for MMS orientation;
- 2 odometers – for measuring speed and length;
- 3 laser scanners (40 000 point/sec) – for forming a 3D model in a radius of 30m;
- Spherical camera (15 img/sec) – for collecting high resolution panoramic images (5400x2700).

In general, two primary types of sensors involved: positioning sensors and mapping sensors.

Positioning sensors are (Tao, 1998):

a) environment-dependent external positioning sensors: GPS, radio navigation systems, Loran-C and cellular positioning devices etc.
b) self-contained inertial positioning sensors: INS or IMU, dead-reckoning systems, gyroscopes, accelerators, compasses, odometers and barometers etc.

Mapping sensors are (Tao, 1998):

a) passive imaging sensors: video or digital cameras, multi-spectrum or hyper-spectrum scanners etc.
b) active imaging sensors: Laser range finders or scanners and a synthetic aperture radar (SAR) etc.

Until recently, spatial data for urban areas were collected by using terrain geodetic methods and aero-photogrammetry, i.e. remote detection. In relation to the aforementioned methods, the greatest advantage of MMS is in time and cost reduction for data acquisition with good data quality. The power of MMS lies in the possibility of direct geo-referencing with system sensors. Once geo-referenced, system sensors provide positioning of all other points gathered during the process, without the necessity of indirectly geo-referencing in order to provide additional measuring or orientation of certain points. MMS achieves accuracy from 3 to 30cm when integrating GPS/IMU systems, sequential stereo images and point clouds obtained with a 3D laser scanner.

Another advantage of MMS is a flexible mode of linking MMS products to other spatial databases. The extraction i.e. vector spatial data with geo-referenced video material provides the user ability to select time moment and structures data. The user can present them on the vector substrate at any given moment. A great choice of standard formats for data exchange also places this system into the flexible spatial environment suitable for integration with spatial data with a diverse level of detail, as well as diverse format and structure of the presented content.

4 POSSIBILITY OF APPLYING MMS IN GIS AS A PREREQUISITE FOR "E-GOVERNMENT"

There are a lot of projects that have implemented GIS logic and technology. This often causes a slow implementation of Geographic Information Systems because of investors's need to put all informations systems that have any relation with spatial data into a GIS. So, there is a need for bridging this gap between the complete lack of a systematic approach in spatial data management and the demand for the integral and functional management based on all available spatial information in just one generation.

The example of the public land management scheme using the information system is presented in Fig. 1 (Černe et al., 2010).

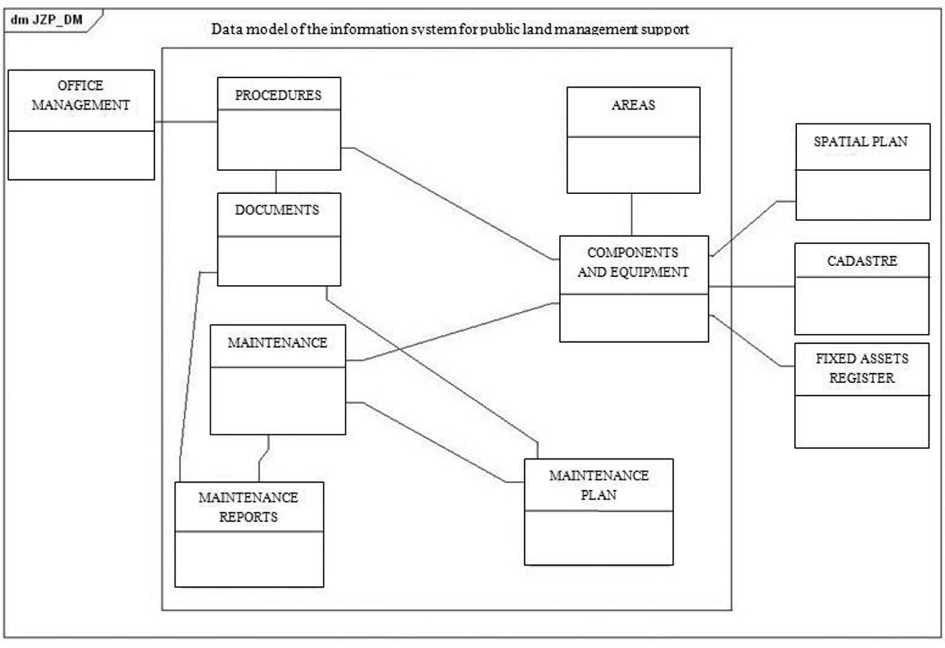

Figure 1: Illustration scheme of the data model of the information system for public land management support (Černe et al., 2010).

As a rule, the informatics component (hardware) does not present system limitations nowadays. Moreover, the implementation of some commercially available GIS applications usually satisfies the most demanding users. At the same time, generating, designing, processing, usage, presentation and distribution of spatial data presents the GIS component that most commonly influences success of the system usage. Remote detection, aero-photogrammetry, altimetry, permanent monitoring systems, laser scanners and, in recent times, MMS with software tools for automatic data processing and analysis can respond to the requirements of the most demanding users, who require spatial information almost in real time. Using MMS the collected spatial data can be used for:

- mapping street infrastructure elements and vegetation (horizontal and vertical signalisation, curbs, posts, lamps, ground infrastructure, aerial masts, trees), Fig. 2;
- providing catalogues of damaged pavements;
- data acquisition on structure facades;
- visualisation of planning documentation;
- providing an economic base to elaborate SWOT analyses;
- data acquisition for completing spatial databases;
- integrating the existing spatial bases with MMS images and comparing old and new conditions;
- collecting integral spatial information on the travelling band zone;
- mapping waterways;
- mapping railroads;
- tourism – unique city or state presentations;
- information on real estate;
- GIS elaboration.

Figure 2: Possibility to insert additional content (aerial masts, trees etc.).

MMS provides a multidimensional possibility of using its products for the elaboration or usage of GIS environments. Namely, MMS products can be used as a spatial component of the system, which is in that case used as a spatial landform to geo-reference all other elements and entities of the relational database. On the other hand, these products can be a medium for data extraction and transfer to other formats suitable for further usage within the existing systems, as well as a foundation for the visualisation, i.e. interpretation, of results on examining certain data in the database.

5 CASE STUDY – DATA CENTRE AS A STEP TOWARDS "E-GOVERNMENT" OF THE LOCAL MUNICIPALITY OF BAČKA PALANKA

Within the realisation of the business strategy and with the objective of increasing operational efficiency and functionality for the Directorate of Construction in Bačka Palanka has begun the realisation of the idea to create a data centre of the local government as a first step towards the goal of introducing "e-government". The data centre is designed as a modular GIS system to provide the possibility of integrating more independent business systems into a unique institutional framework. In this sense, the planning and realisation of all system components began systematically, with special attention to the dynamic realisation plan of individual phases.

For the purpose of elaborating and project documentation, apart from classic geodetic measurements, photogrammetric aerial monitoring was performed and high resolution digital orthographic photo landform has been established. Furthermore, integration of all mentioned data with data from the Agency for Cadastre of Real Estate (scanning of geo-referential cadastre plans, data from the Digital Cadastre Plan, known data from the Cadastre register on installations and wiring) was carried out, as well as integration with the data and operational documentation of the Directorate (planning documentation, project documentation). As a step forward in the overall survey of the town area, mapping was performed with the most contemporary technology for spatial data acquisition in motion – Mobile Mapping System. All listed spatial data was integrated into a GIS environment serving as a spatial system component for both the data acquisition process and the visualisation, in order to objectively manage the demands of the local government. Specialised GIS for traffic signalisation was completed as phase one.

5.1 Hardware and software

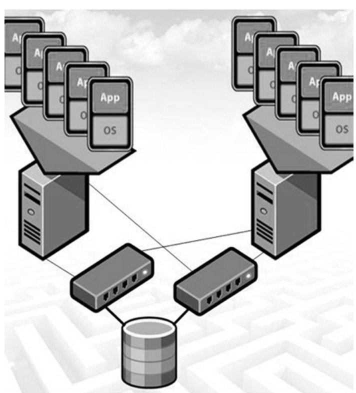

Figure 3: Data Centre in Bačka Palanka (phase one).

The project that is realised with help of hardware architecture system of Public Agency for Development of Bačka Palanka is based on cloud computing platform (Fig. 3). The central server, domain accessibility, high velocity database flow, accessibility to distant locations and adequate capacity for data storage are only some of the properties that generated the necessary conditions for efficient usage of the designed system.

Apart from the system and server software, software support in the project's realisation was provided with the use of several tools for preparing spatial data and creating a specialised GIS for traffic signalisation. Data extraction from MMS products was performed using Spatial Factory software. *Spatial Factory*® is an application that enables the manipulation of point clouds obtained by laser scanning in motion. The advantage is observed in the possibility to present the integrated imagery material from digital cameras and laser scanners, simplifying the process of measuring and mapping detailed points (Fig. 4). The programme provides the possibility to map dots, lines and polygons. It is additional possible to form a spatial database or load the existing databases in order to survey, update or analyse data.

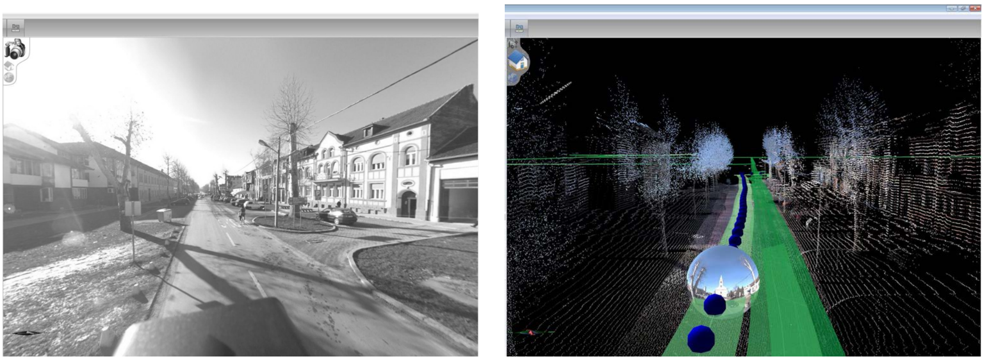

Figure 4: Spatial Factory® - digital image and trajectory from point clouds.

The existing spatial data from the operational documentation of the Bačka Palanka Directorate for Construction and the products of MMS have been integrated with PanoramaGIS software. *PanoramaGIS*® is an application that enables integration of diverse digital imagery (aerial image substrate forms, oblique images (PixoView), cadastre and topographic plans (Fig. 5), national maps and special purpose plans), the survey of video materials and the mapping of set points based on terrain photogrammetry (forward intersecting). Every mapped point can optionally acquire a determined set of attributes. An additional possibility is to form a spatial database or load the existing databases in order to survey, update or analyse data.

The selection of the software platform is achieved on the basis of future users' demands and will be adapted to users both formally and systematically, with the goal of considering all previous partial solutions that should be unified and functionally integrated. The pilot project of the specialised GIS for traffic signalisation has been realised within the Directorate using the software platform established on the open source philosophy. The selection of the OPEN GIS tool is in accordance with all advantages of the open source philosophy, as well as in accordance with all commercial benefits and the objective overview of the project complexity.

Figure 5: PanoramaGIS®- integration with the digital geodetic plan

5.3 Results

As previously stated, the main group of data applied consisted of spatial data as follows: scanned and geo-referenced cadastre plans, digital cadastre plan data, digital aerial imagery substrate forms and available topographic substrates. The main task of preparing spatial data included the process of collecting data from diverse sources and translating it into a unique coordinate system, thus enabling mutual integration. Data obtained by MMS were used as a spatial basis for data visualisation from the operational documentation, but also as a platform for data extraction and integration into the GIS environment. Considering the quality and totality of the visual approach, MMS data served to gather most of the necessary thematic and graphical attributes of the vertical traffic signalisation elements. The remaining set of attributes was stored in the base by direct input from project documentation, as well as all other available relevant sources. Table 3 provides a survey of designed GIS modules and their status from the aspect of their degree of realisation.

Table 3: Possibilities of applying MMS in GIS as a prerequisite for "e-government" and the establishment of a data centre

No.	Module title	Module description	Realisation status
1	Spatial data	Spatial system basis including: scanned and geo-referenced cadastre plans, digital cadastre plan, digital aerial images, topographic substrates, spatial and planning documentation, cadastre register of installation and wiring, mobile mapping images	Fully realised
2	Traffic signalisation	Cadastre register of vertical and horizontal traffic signalisation for the issues of recording and management	Fully realised
3	Parking service	Parking place mapping; zoning; billing; planning and maintenance	Partially realised
4	Street lights	Data and status of existing infrastructure, as well as on the planned developmental phases. Records and fault reports	Partially realised

No.	Module title	Module description	Realisation status
5	Planning and construction	Designing, planning, public presentations and providing necessary documentation (opinions, agreements, information on locations etc.)	Partially realised
6	Public greenery	Records on public green areas, picnic areas and parks	In progress
7	Real estate value assessment	Model for the mass assessment of real estate values in the function of objective and market assessment as a basis for billing taxes and other earnings from real estate properties	In progress
8	Cemeteries	Records and maintenance	In progress
9	Road infrastructure	Recording; classification; categorisation; planning; planned maintenance	In progress

6 CONCLUSION

The qualitative data for spatial management present the most valuable resource and, as such, are utilised for planning, arranging, exploiting and protecting the natural environment. In recent time, spatial data acquisition using contemporary geodetic technology provides a great possibility from the aspect of short-time decision-making processes based on the objective and reliable data. One such technology is MMS (this paper presents the model IP-S2 system of the TOPCON corporation). A large amount of spatial data and a link with GIS applications represents a significant quality of MMS, as this enables the generation of new spatial databases or the update of existing ones, which should be a foundation for traffic, infrastructure and urban planning and thereby a step towards the establishment of local "e-governments". The advantages of mobile data acquisition (for example MMS) aimed at establishing "e-government" are as follows:

- collecting real time data,
- collecting data on the speed of cars or other vehicle movements,
- gathering all data in one transit, thereby reducing collection time,
- reducing additional terrain trips – additional monitoring,
- providing security while working, with monitoring performed from a vehicle,
- accuracy – depending on the vehicle's speed (absolute accuracy: from 10cm to 30 cm)
- simultaneously, much more data is collected in relation to classical data acquisition methods – reducing field time,
- more economical than classic data acquisition methods,
- complete survey of road conditions,
- possibility to form spatial databases which update quickly and qualitatively and are economically feasible.

The possibilities for implementing MMS to establish "e-government" include the provision of overall information for making qualitative decisions in spatial planning; elaboration of spatial databases for infrastructure underground network; fast and easy establishment of road register with updated data on road conditions; elaboration of tourist maps, virtual city tours and providing logistic support for tourists prior of arrival; extraction of vector data and distribution into the traditional graphic or GIS database; implementation through all known worldwide commercial internet services: Google Maps, Google Earth, Bing, Nokia maps etc. and creating a spatial environment for an uninterrupted route to the realisation of the idea of "e-government".

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