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MOBILE LASER SCANNING (MLS)
in transport infrastructure documentation and research

SUMMARY: *The importance of a resource-efficient transportation model was recognized by the European policy makers as one of the most relevant issues for the future. Thus, transport infrastructure was included into the Europe 2020 strategy under the Resource efficient Europe flagship initiative. This is an indicator to professions related to the issue of what is expected and of how they need to adjust to accommodate the needs of the market. With regard to geodesy, this means adoption of new business models that ensure gathering of data in an efficient and cost-effective manner which encompasses all relevant information regarding transport infrastructure as well as its presentation in a simple, comprehensible, easily accessible yet accurate manner. This paper focuses on those issues through relating new hardware and software solutions emerging on the market that have the potential to provide a comprehensive solution to these problems. Thus, mobile laser scanning systems bundled with other sensors relevant to transport infrastructure survey as well as software solutions for representation, analysis and management will be presented.*

KEYWORDS: *Recourse Efficient Europe, transport infrastructure, Laser Scanner (LS), Mobile Laser Scanning (MLS), Building Information Modelling (BIM), ICT*

1. INTRODUCTION

Development of new technologies, simplification of their use and their adoption by the general population is influencing many scientific and professional fields. Geodesy is no exception and it might even be considered as one of the most affected. The availability of low-cost GPS positioning devices, publicly available satellite imagery like Google earth, public access databases and information sites like Land Parcel Information Systems (LPIS) as well as the transition from 2D to 3D (or even 4D) spatial information are drastically changing the geodesy paradigm.

The first significant paradigm shift, with regard to the measurement techniques, occurred with the introduction of GPS just a few decades ago, while the second, more recent one, can be attributed to laser scanning. But the measurement techniques are not the only ones that changed and caused those shifts. Advancements in ICT brought along an evolution of the information society, and that, now ubiquitous, information society demands a redefinition of information and of the manner in which it is conveyed. Hence, adoption of new technologies and a shift from the present business-as-usual models is a must for all geodetic research organizations and small and medium enterprises (SME) in a competitive and ever evolving market.

The first issue in researching transport infrastructure is collecting raw data from the physical locations and objects that comprise the infrastructure being researched. Data needs to be collected precisely, accurately, efficiently (in terms of cost and in terms of the ease and repeatability of measurements) and within a sensible, rational framework of storage, archival, collation, meta-data and context. Such high demands require extensive, efficient and economically sound inspection and data acquisition methods to bring the proposed strategy to fruition, and application of MLS in transport infrastructure documentation and analysis projects has the potential to serve that purpose.

But, since new methodologies and technologies require an in-depth analysis of prerequisites and applicability for their successful implementation, it is the responsibility of the research community to produce competent, comprehensive and, therefore, relevant assessments preceding their inception. Realizing the need of SMEs and industry for the former, Faculty of Geodesy researchers are continuously monitoring and assessing new market driven trends in geodesy with Mobile Laser Scanning (MLS) being the most recent one.

With regard to transport, for Europe to fulfil its economic and social potential rooted in its history and geopolitical location, it is essential to identify missing links and remove bottlenecks in transport infrastructure. Europe, in view of the accessions that formed the EU27 and the accession under way of Croatia, needs to plan in an economically responsible, cost-effective way the extension, intensification, advancement and innovation of the transport network. The EU needs to assure the sustainability of current and future transport networks by taking into account the needs for energy efficiency, and challenges posed by climate change, introduction of renewable energy sources into the Europe-wide electrical energy supply.

Resource efficient Europe, as one of the flagship initiatives of the Europe 2020 strategy (COM(2010) 2020), emphasises development of »green«, safer and energy efficient transport solutions, which requires an evaluation of the current conditions as well as a detailed analysis of potential improvements.

2. TRANSPORT INFRASTRUCTURE

Transport infrastructure is fundamental for the smooth operation of the internal market, for the mobility of persons and goods and for the economic, social and territorial cohesion of the EU (URL-2). Especially in the context of the European Union and the Common Market, transport infrastructure is the circulatory system that binds the geographical Europe together into a sensible, coherent, geopolitically well-defined whole. Thus, it is important for the EU to be able to assess how well this circulatory system functions, and whether it extends as far and branches out as pervasively as it needs to:

- help bring about social cohesion
- further liberalise and intensify internal and export commerce
- and balance and harmonize the quality of goods and the availability of the labour force across the European continuum.

One of the key components of the long-term European framework of transport policy is to present a vision for a low-carbon, resource-efficient, secure and competitive transport system by 2050 that removes all obstacles to accessing and leveraging European transport in the creation of economical and societal added value on Europe's internal markets, promotes clean technologies and modernises transport networks (COM(2011) 21). Any innovation that aspires to such a high standard must be rooted in methodologically sound, globally relevant and high-quality, active, technology-empowered research.

Croatia has a specific geographical position because it is situated on the important Pan-European transport corridors as well as on the Adriatic sea. Due to this particular location, the development of transport and its supporting activities has a great potential for being a relevant driver of the economic growth (CODSC 2010).

Croatian transport network in 2010 consisted of: 29333 km of public roads, of which motorways comprised 1126 km; 2722 km of railway tracks (URL-12); 804.1 km is the total length of inland waterways within Croatia's border, of which international inland waterways' take up 539.2 km while state and inter-state inland waterways' amount to 264.9 km (figure 2.1). The Republic of Croatia has seven international airports and two smaller airports, and a 1400 km-long coastline and a maritime system with 7 major ports, which makes the development of maritime transport and seaports of major importance for the country.

With respect to the overall regional and local needs for a well functioning transport infrastructure, attention has to be given to modernisation and development of roads (e.g. construction of bypasses) local sea ports and local airports as well as regional railways.

In the urban transport sector, the main challenge is financing of public transportation facilities as well as modernisation of the rolling stocks (fleets) in order to develop a clean urban transport system. In order to reconcile the economic development of towns and cities and their accessibility with improving the quality of life and environmental protection, additional financial and human effort is required to make possible the encouragement of the search for innovative and ambitious urban transport solutions with a view to arriving into a situation where towns and cities are less polluted and more accessible and where traffic within them flows more freely.

3. DATA ACQUISITION AND ANALYSIS SYSTEMS

3.1. MMS

A key area of research of highly integrated transport infrastructure sensing platforms is the non-contact sensory survey, like the Laser Scanner (LS). LS doesn't just collect data on small segments of the transport infrastructure object but has a complete area coverage which includes neighbouring (buildings, vegetation, etc.), as well as overhead objects (power cables, tunnel ceiling, overpass and bridge span structures, etc).

Though MLS systems (figure 3.1) are often referred to as Mobile Mapping Systems, it is, in fact, not mapping because a map is created through some cartographic works (i.e. determining the scale/level of detail and content of map database, entry criteria and symbol specification for geospatial data, layout design etc.). In other words, the acquisition of data with (geographic) coordinates directly from terrain or imagery does not mean mapping but surveying (URL-3). Thus, Mobile Measurement System (MMS) might be a more appropriate term. This term can then uniformly describe a much wider range of systems collecting diverse data from either single or a multisensory platform (aeroplane, vessel or land-based vehicle).

The first operational land-based MMS was developed by the Center for Mapping at the Ohio State University. Their system – called

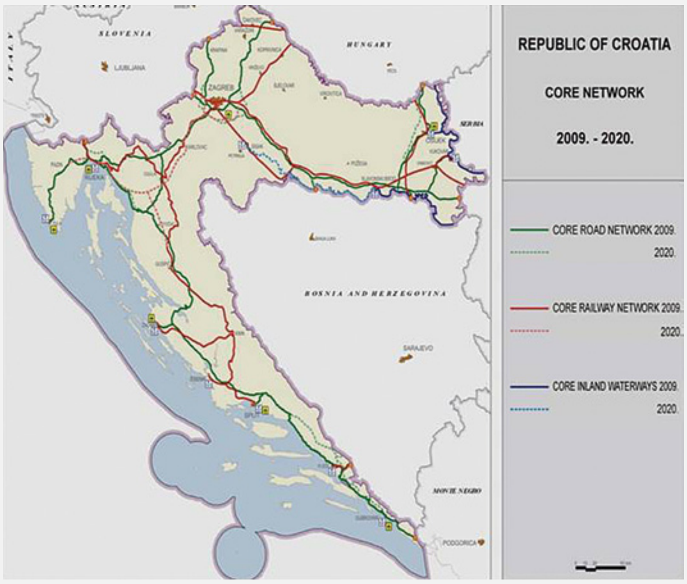

Figure 2.1. Croatian core transport network

Figure 3.1. Land-based MLS platforms: 1-Trimble MX8, 2-Riegl VMX-450, 3-Topcon IP-S2, 4-MDL Dynascan

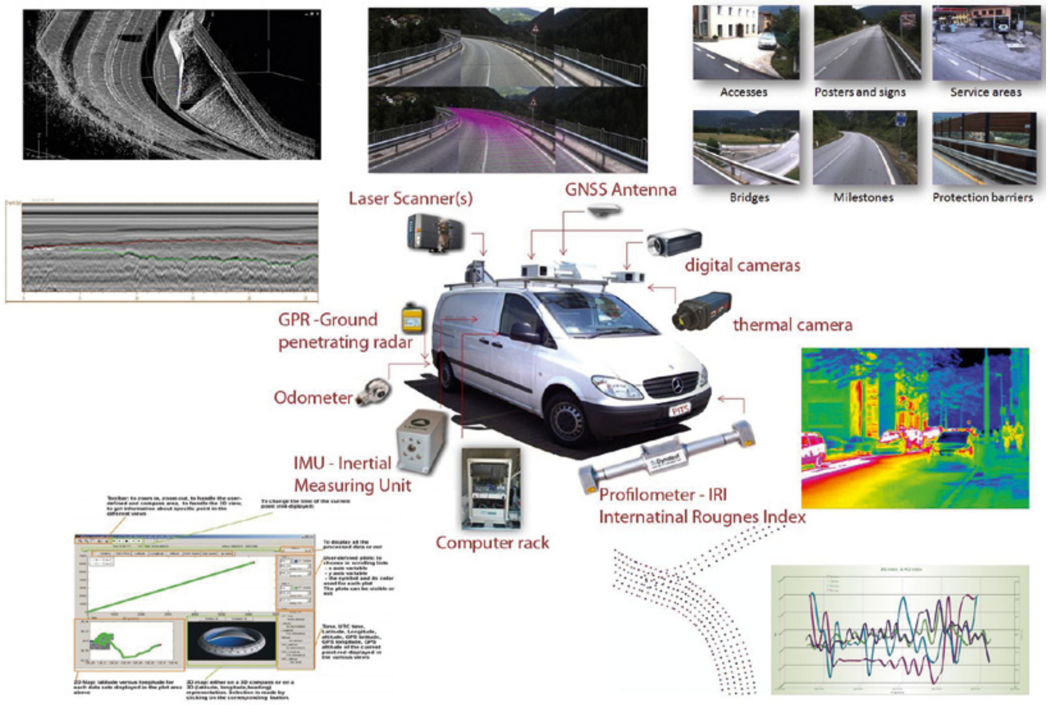

Figure 3.2. Mobile Measurement System for acquiring diverse relevant infrastructure data

GPSVanTM – integrated a code-only GPS receiver, two digital CCD cameras, two colour video cameras and several dead-reckoning sensors. All components were mounted on a van the GPS provided the position of the van and the images from the CCO cameras were used to determine the positions of points relative to the van (Goad, 1991; Novak, 1991).

Later independent implementations of land-based MMS added dual-frequency carrier-phase differential GPS (most recently even GNSS), more accurate Inertial Measurement Units (IMUs), and more sophisticated processing techniques (Ellum and El-Sheimy 2002). In most current systems, a wheel-mounted Distance Measuring Indicator (DMI), that provides accurate vehicle velocity updates, is also integrated in the navigation sensor set. The increase of accuracy, provided through integration of multiple navigation and positioning sensors, pushed the application of MMS forward.

As concerns land-based transport infrastructure, relevant structural information is provided with the integration of additional sensors including Ground Penetrating Radar (GPR), Laser Crack Measurement System (LCMS), thermal (IR) cameras and profilometer (International Roughness Index IRI) (figure 3.1).

Current airborne and land based laser scanning systems rely almost solely on time-of-flight LSs (URL-4; URL-5; URL-6; URL-7; URL-8; URL-9; URL-10; URL-11). In Puente et al. (2011) work, a review on land-based mobile laser scanning (MLS) to derive detailed topographical data was described. Mainly it distinguished some systems that are being used for cartographic mapping applications such as the TOPCON IP-S2 system or »The Google Car« versus those ones collecting data about the infrastructures (road, rails, bridges, tunnels…) that are needed for inspection, engineering and management purposes. The accuracy requirements for the map or survey data change considerably, so every scanner specification should be taken into account in order to obtain the best solution according to its aim.

Another emerging application of MLS is in hydrographical survey, where supplementation of multibeam echosounder data with LS data provides seamless comprehensive above-below water surface data set eliminating, or at least drastically reducing, the need for additional surveys of the coastal area, thus making it more efficient and cost-effective. With that said, a comprehensive naval and inland waterway application potential has actually yet to be fully explored and exploited.

An abundance of numerical measurement acquired leads naturally to an important question of how to automate and make autonomous as much qualitative, semantic reasoning about the observed transport infrastructure.

3.2. MAPPING AND ANALYSIS

As mapping technology progresses, new and improved methods of on-the-fly, real-time data representations are being implemented into progressive analytical processes. The importance and benefits of on-the-fly 3D data representation and of the machine-facilitated 3D situational awareness-building contemporaneously with the performance of the survey are an important research topic. Research and professional work (management, studies, expertise treatises, consulting) conducted in a 3D virtual environment produces results in significantly increased quality, speed and comprehensiveness of the analytical tools. Super-inducing the fourth, temporal dimension adds an immeasurable value to the models, allowing efficient and relevant use in civil planning, urban development planning and management etc.

Relatively recently a Building Information Modelling (BIM) began its rapid expansion on the spatial information market. While it has its roots in architecture, the principles of BIM apply to everything that is built, including roads and highways, and the benefits of BIM are being experienced by civil engineers in the same way they are enjoyed by architects (Strafaci, 2008). BIM is the process of generating and managing building data during its life cycle. Typically it uses three-dimensional, real-time, dynamic building modelling software to increase productivity in building design and construction. The

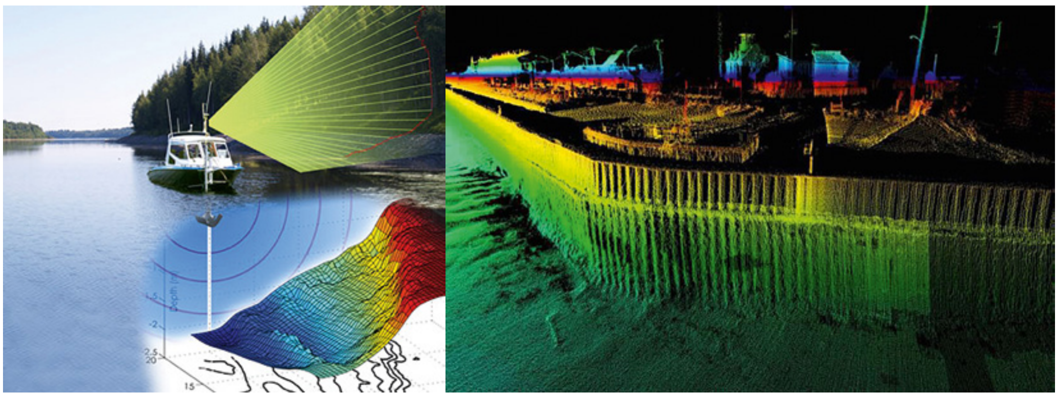

Figure 3.3. Multibeam and LS on a vessel – principle of operation (left); integrated multibeam and LS point cloud (right)

process produces the BIM, which encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components (figure 3.4). Pieces can carry attributes for selecting and ordering them automatically, providing cost estimates and well as material tracking and ordering. This method of management is more practical and efficient that the business-as-usual models of how building management is pursued nowadays.

On those lines, MMS is opening new possibilities by enabling enormous amounts of highly accurate, georeferenced spatial data to be rapidly collected and transformed into information-rich 3D infrastructure models. However, raw data collection alone is neither practical nor complete. MMS solutions need to be bundled with specialised software solutions to control raw spatial data collection and automate key processes such as creating or extracting surface models, roadway signs, utility poles, roadside edges, pavement markings, horizontal and vertical clearances and road geometry to raise cost-effectiveness of the mapping process. MMS software solutions are designed to serve that purpose and to provide integration with the most popular GIS, in terms of cartographic databases and application environments. These solutions can even be equipped with WEBGIS that allows users to access the database through any Internet browser, which, in light of the ICT development, makes it undoubtedly the future for relaying and managing information.

4. CONCLUSION

It needs to be said that MLS does not replace but rather dovetails current surveying techniques, because some tasks cannot be performed using MLS. Still, the proliferation of LSs throughout the geodetic community, as a result of new market demands, calls for an urgent redefinition and adaptation of surveying standards and legislation which accommodates laser scanning in all its forms. We need to accommodate this and future technologies in a way that ensures quality of service and products provided, just as we did with GPS.

The research community must play a major role in their inception. Assessing accuracy and precision of MMS is one issue to address, but making cost-benefit analysis for specific applications is just as important, since not all projects can benefit equally from MMS. Only after verification will we be able to address the problem of gathering data on the transport infrastructure in a cost-effective yet precise, reliable and verifiable manner.

On a parallel track, software solutions for sharing information, updating the database, monitoring, analyzing, rationalizing, optimizing and managing transport infrastructure assets from one integrated framework (figure 4.1) over the internet are mapping a direction which geodesists and their services must also adopt in future business-as-usual models.

With the challenges the forthcoming accession of Croatia to the European community (EC) will bring about, it is imperative to raise competitiveness of Croatian geodetic community in the European Economic Area (EEA). In order to empower the dynamics of economic growth, job creation and incentives to knowledge-based SME, special emphasis has to be placed on unlocking the innovation potential, securing the methodologically sound, globally relevant and high-quality, active, technology-empowered research and development (R&D). This can only be achieved through both major investments in material and human research resources and promoting an active communication and collaboration of the research community with SMEs and industry.

Hence, in light of the Digital Agenda for Europe (COM(2010) 245) and introduction of LTE (Long Term Evolution) 4G standard or better, investments in human resources through lifelong learning programmes, along with new technologies, are an imperative for all SMEs (which are predominant in geodesy) struggling to remain competitive in an ever evolving market.

Figure 3.4. BIM model of a multi-level intersection

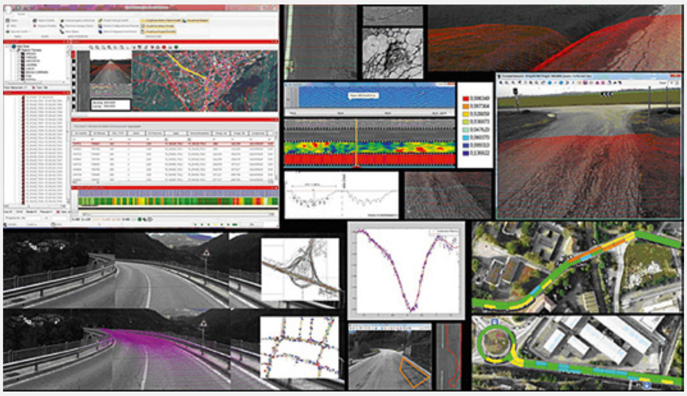

Figure 4.1. Various data gathered and derived from numerous sensors integrated in a singular measurement system

REFERENCES

- COM(2010) 2020: Europe 2020: A strategy for smart, sustainable and inclusive growth, ec.europa.eu
- COM(2011) 21: A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy, ec.europa.eu
- COM(2010) 245: A Digital Agenda for Europe, eur-lex.europa.eu
- Central Office for Development Strategy and Coordination of EU Funds – CODSC (2010): National Strategic Reference Framework 2012-2013, http://www.strategija.hr/
- Ellum, C., El-Sheimy, N. (2002): Land-Based mobile Mapping System, Photogrammetric Engineering & Remote Sensing volume 68, number 1, pp. 15-28
- Goad, C. C. (1991): The Ohio State University Mapping System: The Positioning Component, Proceedings of the 47th Annual Meeting, pp.117-120.
- Novak, K. (1991): The Ohio State University Mapping System: The Stereo Vision System Component, Proceedings of the 47th Annual Meeting, pp.121-124.
- Puente, I., González-Jorge, H., Arias, P., Armesto, J. (2011): Land-Based Mobile Laser Scanning Systems: A Review, ISPRS Archives Volume XXXVIII-5/W12
- Strafaci, A. (2008): What does BIM mean for civil engineers?, CE NEWS, pp. 62-65
- URL 1: http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=tsdec320&plugin=0, (16. 1. 2012.)
- URL 2: http://ec.europa.eu/transport/infrastructure/index_en.htm, (16. 12. 2011.)
- URL 3: http://en.wikipedia.org/wiki/Mapping, (20. 1. 2012.)
- URL 4: http://www.riegl.com, (21. 1. 2012.)
- URL 5: http://www.optech.ca/, (21. 1. 2012.)
- URL 6: http://www.leica-geosystems.com, (21. 1. 2012.)
- URL 7: http://www.blomasa.com/, (21. 1. 2012.)
- URL 8: http://www.flimap.nl/, (21. 1. 2012.)
- URL 9: http://www.trimble.com, (22. 1. 2012.)
- URL 10: http://www.sitecoinf.it, (22. 1. 2012)
- URL 11: http://www.mdl.co.uk, (22. 1. 2012.)
- URL 12: http://www.dzs.hr/ (23. 1. 2012.)