Mobile Mapping System: Suitability for Building Information Modeling of Railway

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SUMMARY

The BIM (Building information modeling) technology has become interesting to scientists, engineers and designers at the beginning of 21st century. In traditional design, there are two-dimensional elements, while BIM implies a third dimension. This method allows achievement of sustainability in the design process, gather relevant information, and group them into a single coordinated model that enables different assessments in the early stages of design. There is no process that can be successfully implemented without the basis of spatial data, which must be collected accurately and efficiently. Such high standards require efficient and economically viable data collection. The one of such technologies is laser scanning - aero, mobile or terrestrial, depending on the type of project. The mobile mapping system opens up new possibilities so that huge amount of highly accurate, georeferenced spatial data are quickly collected and transformed into 3D infrastructure models.

This paper provides an overview of a project in which mobile laser scanning was applied. A 12km scanning process of the railway in the Germany was carried out. The obtained point cloud was used as an input data, and using the Revit Autodesk software package, a BIM model was created.

Key words: BIM, railway, mobile mapping system, scanner

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1. INTRODUCTION

BIM approach can be presented in two directions - as a technology and as a methodology. BIM as a technology is a digital representation of the physical and functional building characteristics, and as a methodology enables the collaboration of different participants at different stages of the building life.

BIM is not based on the ordinary digital drawing but on complete detailed object modelling that allows automatically registration of changes. BIM can represent the entire life of a building - from the construction process to the use and maintenance phase. The transition to BIM is not a change from one software to another but requires a completely different approach to the design process and far greater interactive data sharing (Vujaković, 2019).

Most modern companies use BIM to manage and coordinate projects in three dimensions. With the help of 3D models and their inspection, many construction issues and dilemmas are solved very successfully. The benefits of BIM usage are numerous, from project running and managing, detecting possible errors to the visual identity of the building itself. This could prevent most of the possible problems during construction work.

The aim of this paper is to present the basic characteristics of BIM technology, with an emphasis on data collection as an initial step. Contemporary surveying is briefly described, and then an railway in Austria is presented as a case study, from data capturing to the 3D smart model creation.

2. THE APPLICATION OF BIM TECHNOLOGY

In scientific terms, BIM is a concept of early 21st century. Thus, authors (Chung et al 2013) applied BIM technology for 34 floors of a house. Scientists have explored the full potential of BIM such as 3D, 4D and 5D BIM.

The authors (Barazzetti et al 2015) illustrated and discussed a real case study proving that a rigid workflow enables the creation of accurate historical BIM from a point cloud obtained by laser scanning technology. Structural simulation of geometry irregularity impact on the castle was performed. The advantages and disadvantages of the proposed approach are presented in the paper as well.

In the paper (Redmond et al 2012) development of BIM is mentioned, where the problem of using different non-synchronized BIM applications is highlighted. A "Cloud BIM information exchange mechanism" application is proposed to provide architects, surveyors and civil engineers cooperation, ie. work with the model on the same platform.

In the paper (Wang et al, 2015) method for the automatic extraction of individual elements from the raw point cloud obtained by laser scanning technology is proposed. The raw collected data primary goes through reduction, boundary detection and categorization of building components, which is why building components are recognized as single items.

In practical terms, many imposing objects have been built using BIM technology. Some of them are shown below.

The control tower of Indira Gandhi International Airport is located in the centre of the airport complex and is designed to have an open centre, a cabin at the top that connects the control room to the ancillary facilities and two smaller towers to support the cabin. From the BIM perspective, the most significant part of this project was extensive use of conceptual mass functionality in Revit which allowed engineers to design the tower shape and to analyze the facade panels. Parts of this project have been completely implemented using BIM approach and various 3D models have been developed to ensure better project coordination. The tower is shown in Figure 1 (Vujaković, 2019).

Bird's Nest Stadium in Beijing (Figure 2) is a project that was created in 2003. The stadium is constructed of 50,000 tonnes of steel, its length is 320 m and height is 60 m. It has been built for 4 years with over 17 000 hired workers and the main used technology was BIM (Vujaković, 2019).

Figure 1: The control tower of Indira Gandhi International Airport

Figure 2: The Bird's Nest Stadium in Beijing

There are many other projects where BIM is also used: Seoul Design Square Project, Hong Kong Oceansheigs Project, Beijing Poly Corporation Headquarters Project, Kuala Lumpur

Sunrise Tower Project, 2014 FIFA World Cup Brasil "Arena das Dunas Project" in the city of Natal, etc.

3. DATA COLLECTION METHODOLOGY

The BIM application begins with the production of high-quality 3D terrain bases such as digital terrain models and digital surface models. Then, it proceeds with modelling based on relevant information about the project, design and object location. This leads to the development of an intelligent 3D model whose elements are linked dynamically, not only by points, surface and planes but also by a rich set of shared data. All of these steps depend largely on the quality of the collected data.

Surveying technologies are developing as well as other technical disciplines. Today, traditional surveying methods are outdated and in many aspects modern technology including radar, UAV, photogrammetry and laser scanning is used. This paper gives a brief overview of laser scanning technology, with an emphasis on mobile laser scanning, that was used in the case study.

Light Detection and Ranging (LIDAR) is an accepted method for generating precise and directly georeferenced spatial data about the characteristics of the Earth's surface. This method enables data that are more accurate, precise and dense. What makes LIDAR particularly attractive is the high spatial and temporal data resolution, as well as the ability to observe the atmosphere and cover the altitude from the ground to more than 100 km. LIDAR instruments collect land surface data at a frequency of about 150 kHz. The resulting product is a dense network of georeferenced points, called the point cloud. Also, by surveying with UAV technologies (Unmanned Aerial Vehicles), the product is the same-point cloud. The LIDAR method can be classified as an active data collection method, since it does not use solar light, but the LIDAR system itself is the source of the laser light pulse. This feature allows data to be collected at night, when air is cleaner and less polluted by traffic. One of the main advantages of the LIDAR system is the ability to register multiple reflections of the emitted laser beams (Davidović et al, 2018).

The working principle of LIDAR is based on determining distance from the sensor to the object in space by using the laser light. The technology is based on the collection of three different sets of data. Position of the sensor is determined by using GPS phase measurements in a regime of relative kinematics, while the use of an inertial measurement unit (IMU) provides known orientation. The last component is a laser scanner. The laser sends an infrared beam to the ground and it is reflected to the sensor. After fieldwork, data are processed, after which the coordinates for each point on the surface are obtained. It is essential to focus the laser beam in a certain direction, which is done in most LIDAR systems by using a mirror that oscillates or rotates. This system is the most flexible in terms of point density on the ground (Davidović et al, 2018).

There are different types of laser scanning, and which one will be used is determined by characteristics of the object that is going to be recorded:

- Terrestrial Laser Scanning (TLS),
- Airborne Laser Scanning (ALS),
- Mobile Laser Scanning (MLS)

MLS surveying is performed by moving the vehicle on the ground, while the laser scanner collects data about the environment, and navigation system based on GPS and IMU tracks the vehicle trajectory. This enables 3D scanning of roads, buildings and trees (Ninkov et al, 2017).

It has to be pointed out significantly lower costs of the MLS system when compared to the ALS. With appropriate software solutions, MLS can automate key processes such as: creating or extracting surface models, road signs, urban trackers, curbstones, track geometry and increase the cost-effectiveness of the mapping process. It also provides integration with the most popular geoinformation systems in terms of cartographic databases and applications (Vasić et al, 2018).

The main output data of the MLS surveying are dense sets of points, where their density depends on the device, and with the advancement of technology, the density increases. Millions and billions of collected points are available for all subsequent work, and in that manner, the productivity is increased (Vasić et al, 2018).

Besides a very wide scope of point cloud data manipulation, its great side is that from point cloud can be produced another type of product. By using MLS, different terrain models can be obtained, and BIM as a 3D smart model is one of them.

4. CASE STUDY – RAILWAY

As mentioned above, MLS is a very convenient technique for obtaining high-quality data in order to create BIM. In this paper, a railway in Austria is surveyed with MLS. The surveying is accomplished by mounting scanner on train (Figure 4), and 12 km of railway and its environment is covered.

Figure 4: Mounted scanner on the train

The laser scanner that was used is Trimble MX8, and its main characteristics are shown in the Table below (URL 1):

Specifications	MX8
Accuracy	8 mm
Maximum measurement rate	600 000 points/sec
Camera	20-35 MP
Range	800 m

Table 1: Characteristics of Trimble MX8 laser scanner

The data collection result, dense point cloud is presented in Figure 5.

Figure 5: Point cloud of surveyed area

After preparing the point cloud for further work, ie. point cloud matching, reduction of the points to facilitate manipulation is performed. Even after these steps, the area of interest was large so it has to be divided into sectors and modelled part by part. All of these steps were performed in MicroStation software package. That is a CAD platform that generates 2D and 3D vector graphic elements, including BIM modelling (URL 2).

The format required for importing data into Revit is a .rcs file, obtained by certain conversion steps. First, it was necessary to adjust the input parameters, choose measurement units, perform georeferencing, and define the levels at which further processing is performed.

Then, modelling is conducted in a few phases.

At first, an axis was made from the trajectories obtained from the point cloud. That axis is duplicated and moved in the way that directions of rails are obtained. Between the rails, beams are modelled and situated. The beam modelling process is performed by utilizing the characteristics of Deutsche Bahn manual. That is a specification for all German and Austrian rails, consisting of different types with different measures. One beam with all its details, such as screws and additional small elements is modelled according to that specification. Afterwards, it is just multiplied at a certain distance, measured from the point cloud, and checked in the manual. Figure 6 presents the point cloud rail beams and its model.

Then entire railroad is attached to the ground model, that is previously obtained from the point cloud in MicroStation software.

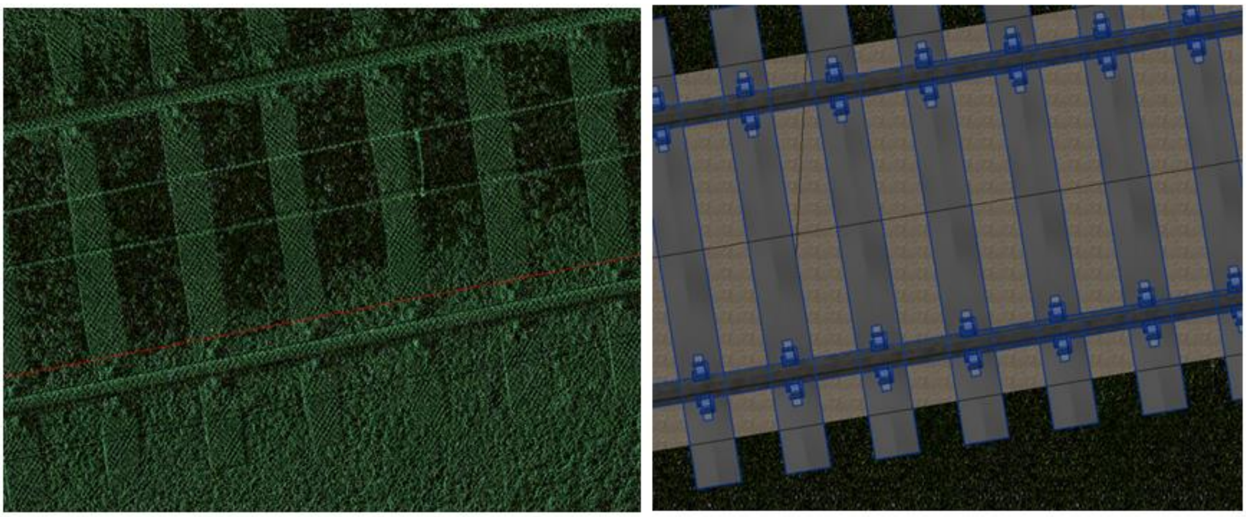

Figure 6: Rails - point cloud and BIM model, from the left to the right

After that, details surrounding the railway, such as houses, buildings, stations and ramps were modelled. The distance from the rail to which the BIM model was created depended on the MLS range. So, if the scanner reached, the length would be up to 25m. On the other hand, if the forest is near the railway, the scanner could not record further.

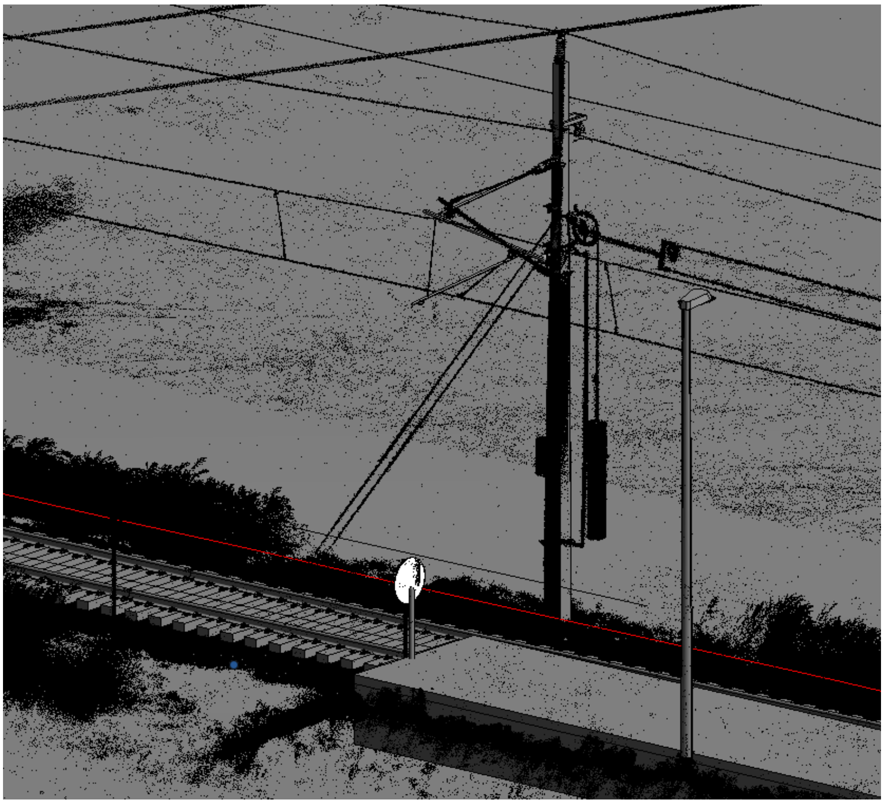

Figure 7. Overlapped BIM model and point cloud

Figure 8 shows one part of rendered BIM model- railway and its environment. This model provided plenty of views and renders, such as wire-frame model, intensity model, classifications by height and other characteristics. Also, this 3D smart model is varying, ie. some dimensions or materials could be changed, and that will affect the calculations and further processes.

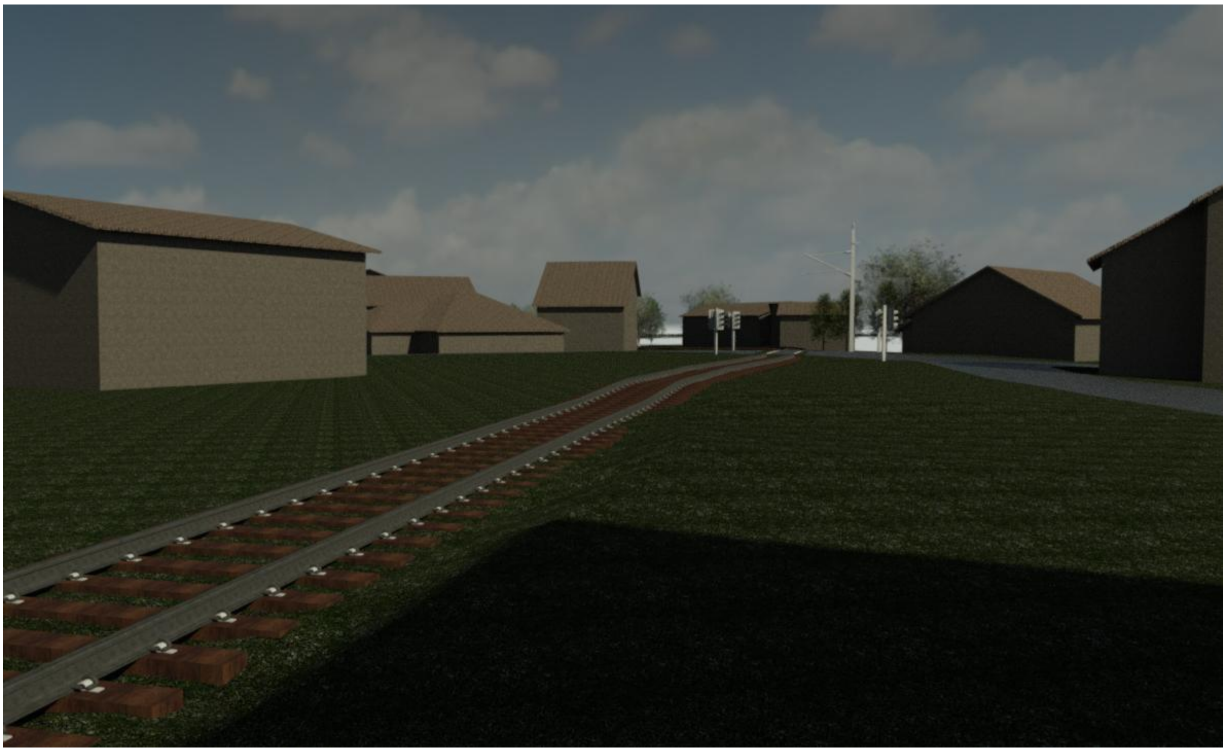

Figure 8: Rendered BIM model- railway and its environment

4. CONLUSION

Open communication enhances the relationship between the members of the project team and influences on the creation of a mutual trust, so its importance is exceptional. Better communication, with no doubt, allows BIM access. The biggest advantage of BIM is the more reliable transfer of information between different project teams, designers, contractors and those who maintain the facility.

According to (Vujaković, 2019), some of the other advantages are: better visualization, improved productivity due to easy information modification, better coordination of all project documents, adding and linking key information (material specification, the position of details for ordering and cost calculation), faster design, cost reduction, etc.

Even BIM benefits are quite obvious, there are still barriers that make it more difficult to use the BIM approach. Some of them are (Davidović et al, 2019).

- Price: The BIM implementation leads to a reduction in overall costs, but before it is necessary to invest some resources for technical training and for the education of professional staff
- Lack of demand: The generally accepted view "the client did not ask us for BIM" is still expressed.
- Lack of knowledge - many people have heard of this technology, but few are aware of its many benefits

In order to obtain a high-quality BIM model, accurate and precise data on the area of interest is a precondition. Such high standards require extensive, efficient and cost-effective inspection and data collection methods to deliver the proposed strategy, and the MLS application can serve this purpose (Davidović et al, 2019).

With laser scanning and BIM, surveyors can embrace and expand their significant role in construction projects. At any place where the redevelopment of existing facilities is planned, architects and civil engineers will need information on their existing condition to begin the redevelopment process. Ensuring the rapid collection of accurate data on often complex and abandoned structures is the job of surveyors. Surveying experts are the ones who will have to deal with often complicated objects and provide reliable data on their real state and create 3D models suitable for further development of the BIM process (Bečirević et al, 2019).

This paper presents a methodology for creating an existing state BIM model based on laser scanning data. All things considered, it can definitely be concluded that this methodology, in particular the use of laser scanning in the whole BIM process, is very applicable. Quite simply process of collecting large amounts of high-quality spatial data and their better visualization and presentation are certainly important determinants that positively affect the greater efficiency of BIM process, especially in the segment of recording the existing state.

Note: Project presented in paper is published with kind permission of the contributor. The original data were provided by DataDev company, Novi Sad, Republic of Serbia.

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BIOGRAPHICAL NOTES

Dejan Vasić was born in Sarajevo, Bosnia and Herzegovina, in 1980. He received the Ph.D. degree in geodesy and geomatics from the FTN, UNS, Novi Sad, Serbia in 2018. Currently, he is an Assistant Professor at the FTN, UNS. His areas of interest are 3D terrestrial and airborne laser scanning, BIM modeling and Engineering Geodesy.

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