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Road Rehabilitation Using Mobile Mapping System and Building Information Model

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Abstract

Road rehabilitation is considered as one of the most important infrastructure projects worldwide. Road rehabilitation requires the Building Information Model (BIM) at different project phases. The most important step in road rehabilitation is building the existing 3D model to be used in the project phases. BIM will help to follow the advancement of the reconstruction field operations, and control the quality and performance of the project based on a predefined time schedule and an approved design. The objective of this research is to obtain optimal quality of a 3D model using state of the art technologies. Mobile Mapping System (MMS) and the number of control points will be used to achieve an accurate 3D model. The 3D model will be used as initial data in the BIM. The Scan to BIM process using laser scanning technology for building the road 3D model and connecting it to the BIM, is becoming an essential part of most engineering projects.

Keywords: lidar technology, Building Information Model, Mobile Mapping System, GNSS technology, right of way, Virtual Reference Station.

1. Introduction

Mobile Mapping System (MMS) is becoming a well-known technology for corridor surveying and for the creation of 3D models in most engineering projects. Lately, several researches have discussed the accuracy, capability, and speed of the lidar technology in field surveying (El-Sheimy, 2005; Klaus et al., 2012).

The accuracy of MMS is based on the GNSS technology. Consequently, the integration between different sensors of MMS is affected directly by the quality of the GNSS data which may create some difficulties regarding accuracy (less than 3cm) in the final survey results. This is caused by a GNSS failure due to some obstacles along the roads including trucks, buildings, trees, etc. Integration between different sensors in MMS such as GNSS/IMU and DMI, in addition to the usage of known control points to reach a reliable combined solution that could be used in the road project life cycle (Sairam et al., 2016).

The current research focuses on the quality of MMS data for BIM and the correct methodology to adjust the obtained Lidar Data (point cloud) using some additional classical survey measurements.

1.1. Building an Information Model and a Mobile Mapping System

Presently, there has been an increased interest in using BIM in engineering project life cycles (Design phase, construction phase, and maintenance period). BIM is defined as a process to share and use data during the life-time of a structure including the maintenance period. A BIM is an intelligent 3D model-based process that provides physical and functional characteristics for a facility (Fernandez, 2015).

MMS is considered one of the best methods to create the initial data requirement for Roads BIM based processes. However, a BIM-based process needs a 3D model of a high quality to be used in the automation process during the construction or maintenance of roads such as using milling machine and asphalt paver (Heikkilä and Marttinen, 2013; Schwarzbach, 2014).

The field operations of MMS are not complicated and most of the field work can be done in automatic steps using a good field operation software installed on the system, However, data processing is the most critical issue in MMS in order to get perfect results in a quick and efficient manner (Sairam et al., 2016). Generally, no single solution is used to obtain the final results including feature extraction and a final 3D model. Mostly, more than one software is used to get the desired results of the 3D model and the extracted road features.

There have been many benefits for using MMS or laser scanning in surveying to BIM. The scanning operations bring the real scanned site into office desktop and extract the 3D model and all the required features without going back to the field. It delivers, as well, a wide variety of formats to accommodate the workflow of the BIM model, solid model, 2D cad files, sections etc.

The planning of field works is important for determining the number of missions, number of GNSS reference stations that are needed to complete and cover the ROW of the road, and to define the Level of details (LOD) of every scanned element.

1.2. Quality of Data and Building Information Model Projects

It's well-known that a quality BIM project requires a quality information sysetem. The increase interest in using work machines in road construction and maintenance requires a good quality 3D model of an existing road to be used as a reference model in BIM.

MMS helps create the 3D model for an existing road. However, any created model needs a preprocessing procedure

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in order to be of a good quality and enough accuracy to be used in BIM process. This process needs to combine classical topographic surveys, by means of total station measurements, for identified points or cross sections along the roads to adjust the point cloud before extracting the features and creating the 3D Model from the lidar survey data.

Several experiments will be needed to test data quality and define the minimum number of the identified cross sections needed to get a reliable 3D model to be used for BIM.

GNSS trajectory is considered as one of the most important elements of data quality. Thus, in order to have a reliable GNSS solution, the distance between the MMS car and the GNSS reference station should not exceed 10 km in each mission. Moreover, more than one reference station should be used during the field operation to avoid any failure of data.

1.3. Mobile Mapping System Project Workflow

Using MMS in road surveying is not a strait forward technique that can provide a high quality point cloud and a 3D model without using well-known control points along the surveyed corridor. The number of control points or known cross sections depend on many factors such as the requested accuracy and the quality of combined GNSS/INS trajectory (Kennedy et al., 2006; Qian et al., 2017).

Many researchers explained the work flow to get a good quality point cloud using MMS (Soininen, 2012; Yang et al., 2016; Gandolfi et al., 2008; Barbarella et al., 2011; Al-Bayari, 2018). The current research employs the general procedure for GNSS/INS data processing using the Inertial Explorer software from Novatel (Waypoint Products Group, 2018), in addition to using the terrasolid package (terrascan and terramatch), for pointcould adjustment, processing, and classification (Soininen, 2018). This research also uses the ORBIT software (Orbitgt, 2018) or TopoDot software (TopoDOT, 2018), for data extraction and the exporting of the extracted data to be used in Civil 3D for the BIM process.

The Terramatch software package is used for point cloud pre-processing to correct the drift of the trajectory at locations, where the accuracy of the trajectory solution is weak due to failures in the GNSS signal. A good number of control points are needed in order to achieve accurate results (Soininen, 2018).

2. Case Study: Rehabilitation of Amman-Aqaba Desert Highway

This case study is part of the reconstruction and rehabilitation project of Highway 15 (Amman-Aqaba Deseret Highway). The project involves a complete reconstruction of 220kms of the road, which runs from Queen Alia airport intersection to Maan governorate (Figure 1).

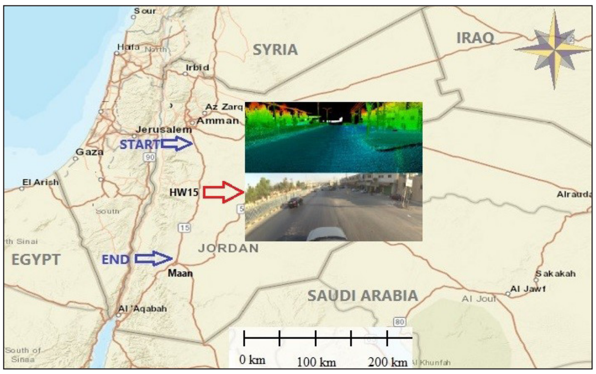

Figure 1. Amman-Aqaba Deseret Highway (Highway 15), in Jordan

The MMS technology for surveying started twenty years ago. Unfortunately, this is the first time for this technology to be used in Jordan. Maverick MMS from Teledyne Optech is used in this pilot project to survey the first section of the Deseret highway (Teledyne Optech, 2017). Figure 2 presents the main component of the Maverick system used in this pilot project.

The quality and testing of MMS results were possible because the whole Highway has been surveyed using highly-accurate surveying techniques in addition to MMS.

Figure 2. Maverick Mobile Mapping System Used for Pilot Project in Jordan

2.1. Highway Surveying Techniques

This research has used a general surveying procedure that guarantees highly-accurate spatial data information for the design and construction phases. This procedure is summarized as follows:

1- Establishing a highly-accurate static GNSS traverse network along the road right of way (ROW). The spacing distance between the established points is 500m and is connected with the National Jordanian network.

2- The highly-precise geometric leveling of traverse Bench mark points is done using digital level. The accuracy of loop closure is 3mm*√km (First order class I).

3- Surveying of the cross sections every 25m along the Highway using highly-precise Total Station, based on Traverse network (Figure 3).

4- Surveying the existing features and terrain points using total Station and the GNSS RTK observation technique (to create a good digital terrain model of the Road ROW).

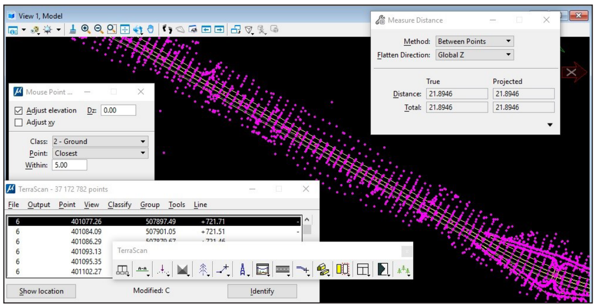

Figure 3. Cross section points measured using Total station every 25m along the Road.

3. Data Processing and Building the 3D Model

Due to high traffic on the road, the surveying of 65kms of the Deseret Highway was done over the period of two days; peak hours were avoided. The total working hours were less than seven hours. Moreover, the road was divided in sessions based on six GNSS reference stations (Three main and three auxiliary stations).

Figure 4 presents the GNSS Reference station used during the MMS surveying. Instead of VRS stations, separate GNSS reference stations were used placed on the same traverse network established by the contractor. This is to avoid any errors in data processing due to datum shift, and to get a better ambiguity resolution in the GNSS data processing, where the baselines do not exceed 10km between the reference stations and MMS.

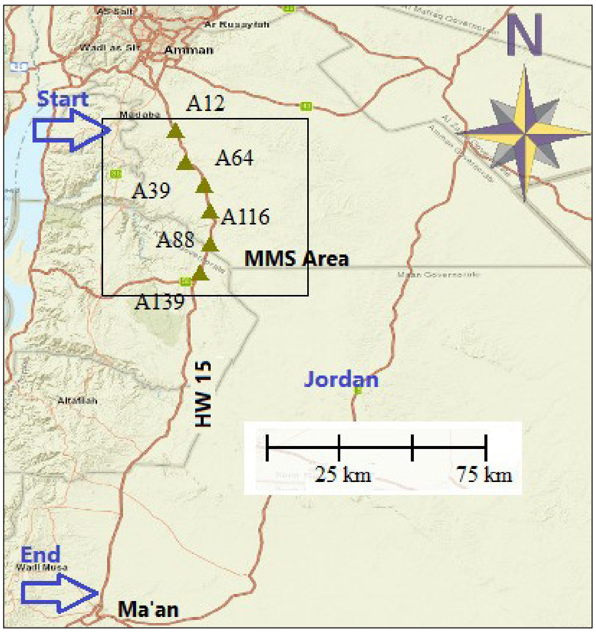

Figure 4. GNSS Reference stations used during the MMS survey.

Data processing of trajectory had been done using the Inertial explorer software package by Novatel to produce a combined GNSS/INS solution and then the Distillery software package was used to process and adjust the trajectory and lidar data and finally to export georeferenced point cloud and images (Figure 5).

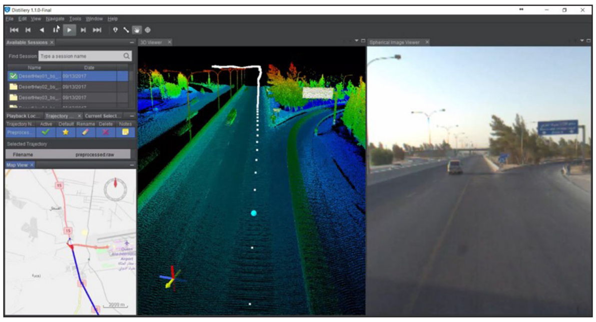

Figure 5. Distillery software for lidar data processing and image visualization

Strip adjustment and matching from different missions were done using Terramatch software package by Terrasolid. Some problems were encountered due to false ambiguity resolution in some places caused by the loss of look of GNSS data (Al Madani et al., 2016). Apparently, the loss of look was caused by heavy traffic of trucks, or when the MMS car passes under steel bridges. Figure 6 presents the difference in different strips due to error in GNSS solution.

The processing of GNSS/INS data using separate reference stations for different missions and adjusting the point cloud using Terramatch can give better results than processing the data using all reference stations and producing one trajectory. This is attributed to the positioning accuracy of the trajectory, which can vary a lot during one drive mission. Thus, the dominant error source for inaccurate data is that the trajectory positioning will increase using more than one reference station in different missions.

Figure 6 presents the difference in trajectory processed with respect to different reference GNSS stations. The significant differences are just in the height component (1-2cm), but this could produce a larger error in the point cloud and this error is not acceptable for quantity surveying in road rehabilitation and maintenance in BIM process.

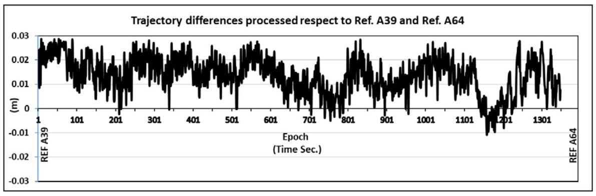

Figure 6. Differences in the Height of trajectory processed using different Reference Stations with a 10km-distnace from each other

Terrascan software package provided by Terrasolid company has been used to adjust the point cloud to known points of cross sections. The cross sections have been surveyed using total station every 25m, then the point cloud has been exported for feature extraction to Orbit software (Figure 7) and TopoDOT software package by C3D (Figure 8). Civil 3D software package by Autodesk was used to create the 3D model using extracted features (Figure 9), and to export the final model to BIM software.

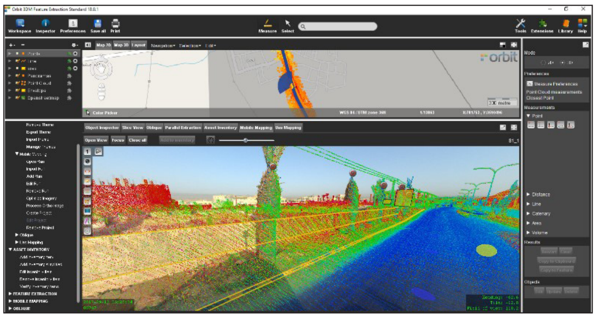

Figure 7. Orbit Software and feature extraction

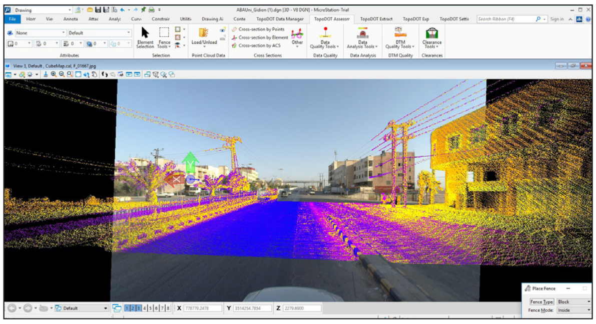

Figure 8. TopoDOT software point cloud overlaid over images

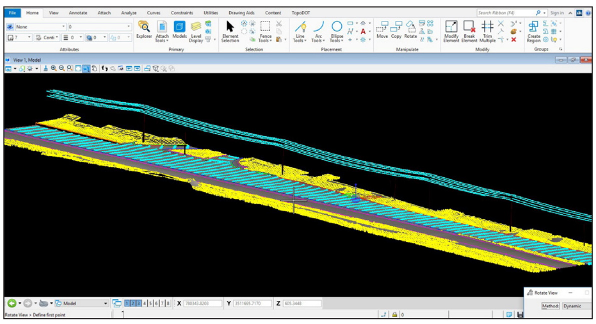

Figure 9. Road extracted features in CAD format

4. Results and Discussion

Several tests have been performed along the road to define the quality of the extracted 3D- model (to be used in the BIM process) and to minimize the effort of control points surveying using classical topographic surveys and/or GNSSRTK observation techniques. The point cloud has been adjusted using different cross sections at different spacing (25m, 50m, 100m, 150m, and 200m). Table 1, Figure 10 and Figure 11, present the differences between point clouds and total station results.

Table 1. Analysis of MMS point cloud and known cross sections measured at different spacing.

Known points Cross Section Spacing	25m	50m	100m	150m	200m
Standard Deviation (m)	0.006	0.007	0.008	0.015	0.026
RMS (m)	0.006	0.007	0.008	0.015	0.026
Min dz (m)	-0.005	-0.007	-0.008	-0.019	-0.028
Max dz (m)	+0.006	+0.007	+0.012	+0.022	+0.027

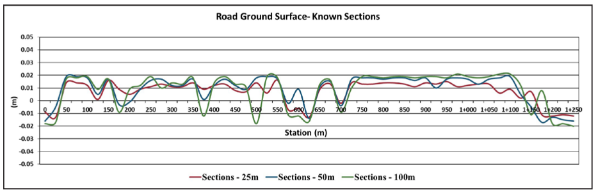

Figure 10. Differences between Ground Road Surface and known points measured at different spacings (25m, 50m, and 100m), road surface match the surface at 25m.

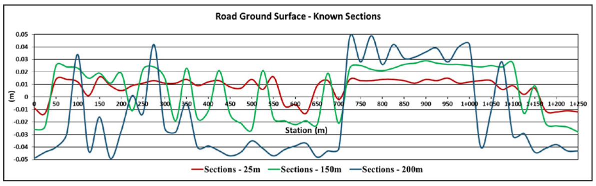

Figure 11. Differences between Ground Road Surface and known points measured at different spacing (25m, 150m, and 200m), road surface match the surface at 25m

Using known cross sections every 100m gives good results and is efficient for adjusting the MMS point clouds to create a reliable and accurate 3D model and road surface that could be used for all road applications in the BIM processes. The created model should be used as initial data model for BIM process, and the easiest way to start utilizing BIM in maintenance is to connect the already existing databank information to geo-spatial locations such as the model created by MMS.

The created Road surface model by MMS permits to perform many analyses related to the road condition such as road surface damage: ruts, cracks, and potholes that will be useful to be integrated in BIM process for maintenance and road rehabilitation:

1- Road surface damage analysis: Figure 12 presents damage on the road surface and the field verification using images of the road.

2- Cross sections could be created and compared with the designed drawing and calculation of quantities for the needed materials in the construction or rehabilitation phase (Figure 13).

3- Feature extraction: point cloud supports the extraction of all features and objects such as bridges, road signs, electrical poles, etc. Figure 14 presents extracted features and a bridge model created using MMS data.

4- Moreover, the Deseret road is in the phase of reconstruction, but the MMS survey revealed an urgent need for renewing the asphalt. Therefore, the original 3D model could be thinned and used for creating a new design surface which could be imported into a machine control system and used for resurfacing the road (Schwarzbach, 2014).

5- Finally, the data allowed an accurate estimation of the quantities of materials needed for the surface renewal (Marttinen and Heikkilä, 2015).

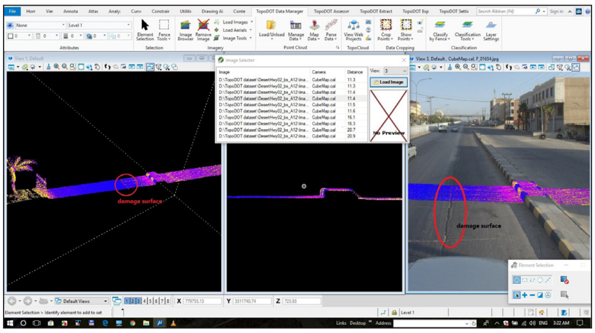

Figure 12. Road surface condition analysis and verification using point cloud and images

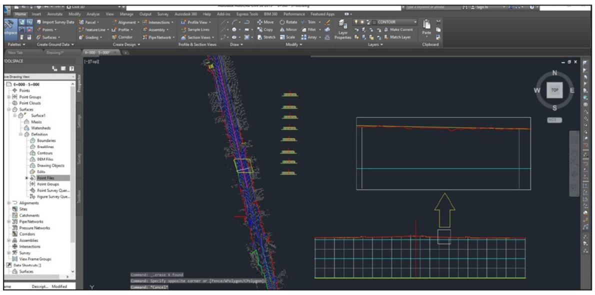

Figure 13. Road surface and Designed cross sections in AutoCAD Civil 3D

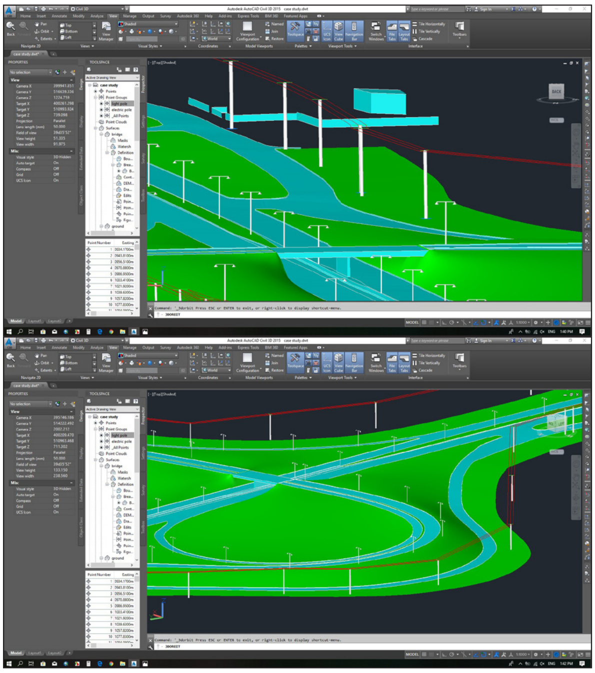

Figure 14. Extracted 3D Model in Civil 3D

5. Conclusions

MMS perhaps constitutes the best technique to create roads 3D model to be used in BIM, but there are important considerations that have to be taken into account during the surveying and data preprocessing phase, and these include:

1- Strip matching and adjustment is an essential step in point cloud data pre-processing and it should be done for different missions and different surveying directions as well as for overlapping between different strips and missions.

2- To get a reliable precise 3D model to be used in the BIM process, the point cloud for this purpose should be adjusted and corrected with known cross-section points distributed every 100m along the road corridor.

3- Processing the GNSS/INS data to create an MMS trajectory should be done based on the nearest GNSS reference station. To avoid corruption in the ambiguity resolution, the processing of data for baselines with more than a 15km-distance between the MMS car and the GNSS reference station must be avoided.

4- Finally, the Scan to BIM process in the road project is efficient and accurate to create the initial 3D model to be used in the BIM process, but, often, the office work and production time are relatively long.

References

Al Madani, S., Sadoun, B., Al Bayari O. (2016). Continuously operating reference station and surveying applications in KSA. International Journal of Communication Systems, Volume 29, Issue 6, pp 1046–1056

Al-Bayari, O. (2018). Mobile mapping systems in civil engineering projects (case studies) Appl Geomat (2018). Volume 11, Issue 1, pp 1-13

Barbarella, M., Gandolfi, S., Meffe, A., Burchi, A. (2011). A Test Field for Mobile Mapping System: design, set up and first test results, Proceeding of the 7th International Symposium on Mobile Mapping Technology, 13 – 16 June 2011, Cracow, Poland

El-Sheimy, N. (2005). An Overview of Mobile Mapping Systems. In Proceedings of the FIG Working Week 2005 and GSDI-8, Cairo, Egypt, 2005; pp. 16-21.

Fernandez D. (2015). National Building Information Model Standard Project Committee, USA) https://www.nationalbimstandard.org/files/NBIMS-US_FactSheet_2015.pdf, (accessed on 17 January 2019)

Gandolfi, S., Barbarella, M., Ronci, E., Burchi, A. (2008). Close photogrammetry and laser scanning using a mobile mapping system for the high detailed survey of a high density urban area, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences (ISSN: 1682-1750). Part B5, Beijing 3-11 July 2008, Vol. XXXVII, pp. 909-914:

Heikkilä, R., and Marttinen, M. (2013). Development of BIM based rehabilitation and maintenance process for roads. 10.22260/ISARC2013/0136. https://doi.org/10.1007/s12518-018-0222-6

Kennedy, S.; Hamilton, J.; Martell, H. (2006). Architecture and system performance of SPAN NovAtel's GNSS/INS solution. In Proceedings of the ION PLANS 2006, San Diego, CA, USA, 25–27 April 2006; pp. 23–25

Klaus, P., Schwarz, N., El-Sheimy, N. (2012). Mobile mapping systems-State of the art and future trends. Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. 2012, 35: 759–768

Marttinen, M., and Heikkilä, R. (2015). Relative Information Modelling Based Optimization for Asphalt Pavement Renovation. 10.22260/ISARC2015/0048.

Orbitgt (2018). Generic-Mobile-Mapping, https://orbitgt.com/wp-content/uploads/2018/10/2018-Generic-Mobile-Mapping-1.pdf [Accessed 11 November 2018].

Qian, C.; Liu, H.; Tang, J.; Chen, Y.; Kaartinen, H.; Kukko, A.; Zhu, L.; Liang, X.; Chen, L.; Hyyppä, J. (2017). An Integrated GNSS/INS/LiDAR-SLAM Positioning Method for Highly Accurate Forest Stem Mapping. Remote Sens. 9(3): 3-16.

Sairam, N., Nagarajan, S., Ornitz, S. (2016) Development of Mobile Mapping System for 3D Road Asset Inventory, Sensors (Basel) 2016 Mar; 16(3): 367. Published online 2016 Mar 12. doi:10.3390/s16030367

Schwarzbach, F. (2014). Road Maintenance with an MMS - Accurate and Detailed 3D Models Using Mobile Laser Scanning, GIM International, Vol. 28(7), July 2014

Soininen, A. (2012) Mobile Accuracy & Control https://www.terrasolid.com/download/presentations/2012/mobile_accuracy_and_control.pdf ; (accessed on 20 Dec. 2018).

Soininen, A. (2018) Terrasolid software, Available online: http://www.terrasolid.com/download/tscan.pdf, (accessed on 20 Dec. 2018), http://www.terrasolid.com/download/tmatc.pdf (accessed on 20 Dec. 2018).

Teledyne Optech, (2017). Maverick Mobile Mapping System. http://info.teledyneoptech.com/acton/attachment/19958/f-02bf/1/-/-/-/-/2017-09-19_Optech_Maverick-Spec-Sheet_Eng_web.pdf, [Accessed 15 December 2018].

TopoDOT (2018). TopoDOT Worflow. https://new.certainty3d.com/workflow/extract/process_section, [Accessed 10 December 2018].

Waypoint Products Group. (2018). ANovAtel Precise Positioning Product: Inertial Explorer 8.70 User Manual v4, March 2018. https://www.novatel.com/assets/Documents/Waypoint/Downloads/Inertial-Explorer-User-Manual-870.pdf

Yang, B., Liu, Y., Liang, F., Dong, Z. (2016). Using Mobile Laser Scanning Data for Features Extraction of High Accuracy Driving Maps. Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. 2016; XLI-B3:433–439. doi: 10.5194/isprsarchives-XLI-B3-433-2016.