

DEVELOPMENT OF BIM BASED REHABILITATION AND MAINTENANCE PROCESS FOR ROADS

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ABSTRACT

The utilization of Building Information Modeling (BIM) and model based 3-D control of work machines have increased a lot in new road construction in Finland as well as in other Nordic Countries. Up today, much less attention has been paid into the development of maintenance and rehabilitation processes. As a part of a large research and development program RYM PRE Infra FIN BIM in Finland, a focused research project of the BIM with experiments in total five (5) pilot projects has been performed. A main idea of the new BIM based process has been to utilize mobile laser scanning method for initial data acquirement, the use of novel 3-D analyze and modelling methods for point cloud processing, the use of new type optimization method for the planning of geometric and structural improvements needed for the existing uneven road surfaces, and further, through the creation of 3-D machine control models apply the newest 3-D machine control systems for continuous 3-D control of practical construction work using milling machine and asphalt paver. Finally, an evaluation is made between the new process model and the traditional way of working.

KEYWORDS

Automation, Roads, Information modeling, Mobile Laser Scanning, Maintenance.

INTRODUCTION

The utilization of Building Information Modeling (BIM) and model based 3-D control of work machines have increased a lot in new road construction in Finland as well as in other Nordic Countries. This development has been much slower in the field of road maintenance and rehabilitation. In Finland, as a part of the Infra FINBIM research work packet a special effort to study and develop the process of road maintenance has been active since 2010.

Automation for road maintenance has earlier been studied by a few projects and papers. Skibniewski and Hendrickson (1990) have studied general possibilities in automation and robotics for road construction and maintenance. They saw that automated road construction and maintenance equipment will provide attractive alternatives for the execution of routine work tasks in the future. The main reason for that is the repetitiveness and relatively moderate sensory requirements in many tasks. In the study, they considered a variety of continuously performed tasks including snow removal, road painting, grass moving, brush cleaning, sign placement, pothole and crack filling, and others. Numerically controlled equipment were seen to have the capability of execution repetitive, large-volume tasks with little or no operator assistance. In the paper, they did not describe more accurately the process needed to produce numeric data or information model for automated controlling tasks.

Heikkilä et al (2010) have performed a calibration for a stop & go scanning system developed in Finland for the geometric surface measurement tasks of existing roads. When using 20 m vehicle stopping intervals, the accuracy of the measurement was $-1 \text{ mm} \pm 8 \text{ mm}$ (average, standard deviation), and with 30 m intervals $-3 \text{ m} \pm 9 \text{ mm}$.

METHODS

The Maintenance BIM research has been done in a part of PRE InfraFINBIM work packet. As a part of a large research and development program RYM PRE Infra FIN BIM in Finland, a focused research project of the BIM with experiments in total five (5) pilot projects has been performed. A main idea of the new BIM based process has been to utilize mobile laser scanning method for initial data acquirement, the use of novel 3-D analyze and modelling methods for point cloud processing, the use of new type optimization method for the planning of geometric and structural improvements needed for the existing uneven road surfaces, and further, through the creation of 3-D machine control models apply the newest 3-D machine control systems for continuous 3-D control of practical construction work using milling machine and asphalt paver.

Three different road parts (Mt116, Kt51, Vt6) were used for the experiments in Finland. The first mobile scanning test was done for the Mt116 pilot. The road Kt51 is a main road from the capital Helsinki to west. In this pilot, a special road part selected was first measured using the mobile mapping equipment (Trimble MX8), then the survey results were analyzed and modelled using the software and tools provided by Terrasolid Oy (TerraScan, TerraMatch), after that a design optimization was done using Tekla Civil road design software and the imported 3-D initial data models from the previous phase, and then the optimized machine control models were created for the milling machine. In the test machine, an automated 3-D control system of Trimble GSC900 was used. Finally, the final surface after cutting work was measured using a total station equipment.

The road Vt6 is a main road from the capital Helsinki to east. In this pilot, three special road parts near city of Parikkala (each of 500 meter) selected were first measured using the mobile mapping equipment (Trimble MX8), then the survey results were analyzed and modelled using the software and tools provided by Terrasolid Oy (TerraScan, TerraMatch), after that a design optimization was done using Tekla Civil and Novapoint road design software and the imported 3-D initial data models from the previous phase. Further, optimized machine control models were created for the milling and paving machines. In these test machines, an automated 3-D control system of Trimble GSC900 was used. Finally, the final surface after cutting and paving work was measured using a total station equipment.

RESULTS

Using the mobile laser scanning for the initial data acquirement task, measured 3D initial data model from the existing and uneven road surfaces including 3D point cloud as well as digital photos were produced. The basic observations had to be calculated through a special error analyse and modeling process to achieve the demanded level of the accuracy of measurement. As a basement, the method included the use of reference points been measured using accurate robotic total stations or in one of the pilots a high precision levelling device. The final accuracy of measurement of the mobile scanning method after the calculation and optimization process by Terrasolid tools used was $+ 0,002 \text{ m}$ (average), $0,004 \text{ m}$ (standard deviation), $-0,0012 \text{ m}$ (minimum) and $+0,005 \text{ m}$ (maximum). In the table 1, the accuracy of measurement varying the spacing between the reference points using is presented. Furthermore, the laser scanned points and digital photos can be combined together creating very illustrative coloured point cloud can be produced.



Figure 1. Trimble MX8 mobile mapping system was used for the laser scanning and photogrammetric measurements. As driving speeds in the pilots Mt116, Kt51 and Vt6, the 50-65 km/h, 40-50 km/h and 50-70 km/h, were used, respectively. The speeds were varied due to different road, traffic and environment conditions.

The combined final initial data model of the old road (Fig. 2) was an accurate and illustrative 3D point cloud, from which the different existing unevennesses of the road surface could be found and mathematically modelled. The orange areas in the Figure 2 describe the ruts and potholes, deeper than 20 mm compared to the reference line, were automatically founded using the Terrasolid software tools. In the Fig. 3, an illustration of water flow possibilities on the road surface is presented. The Fig. 4 describes the adjusted parameters using 20 m intervals of the road geometry based on the same point cloud.



Figure 2. An example of the analyzed and modelled 3-D point cloud. The geometric pits and deviations have been coloured (Terrasolid). There were observed many new useful possibilities to detect and model useful information for road improvements from the point cloud.

Table 1. The accuracy of 3D measurement (ETRS.G30FIN - N2000 coordinate system, [mm]) of the mobile laser scanning method used in using the different intervals (100 m, 200m, 300 m) between the reference points (Maintenance BIM research project, Vi6 pilot, Table by Terrasolid Oy).

Control spacing	100 m	200 m	500 m
Z average magnitude	0.003 m	0.005 m	0.025 m
Z standard deviation	0.005 m	0.007 m	0.019 m
XY average magnitude	0.013 m	0.018 m	0.024 m

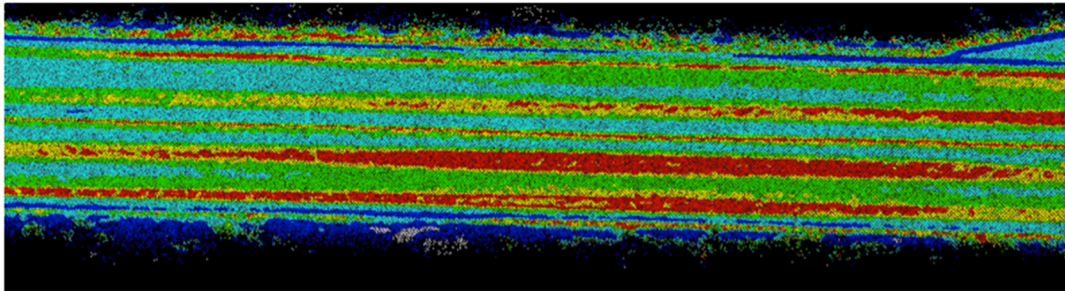


Figure 3. Illustration of water flow possibilities on the existing road (Terrasolid).

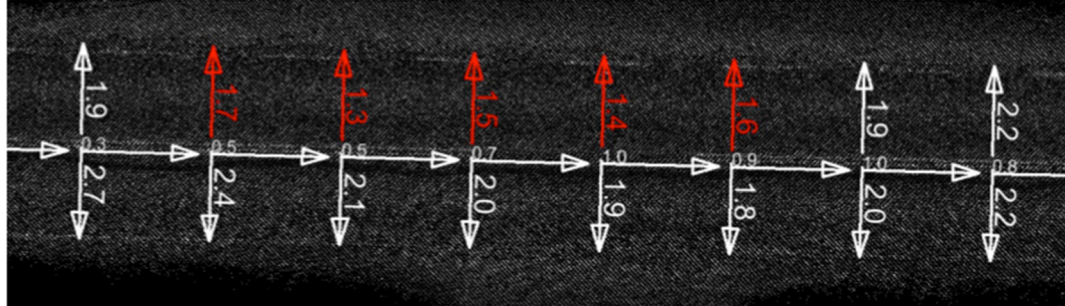


Figure 4. Adjusted parameters of the road geometry (Terrasolid).

The point cloud was imported to the Tekla Civil software, where a road designer made an optimization for the surface repairing. The optimization of the milling and paving work amounts were considered in the Tekla Civil and thus first time using 3-D method in Finland.

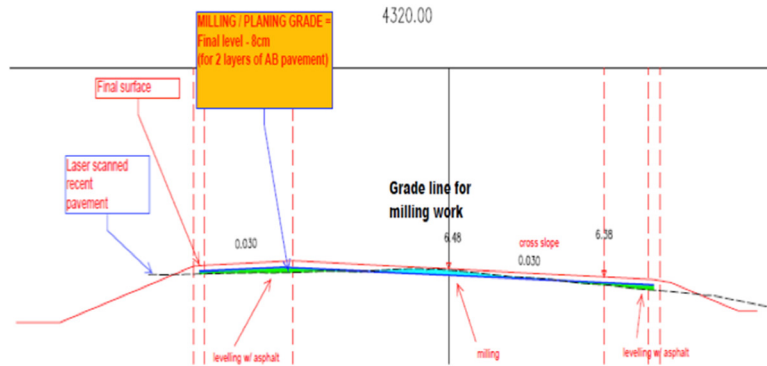


Figure 5. BIM based optimization of the road rehabilitation. The milling and paving works are to be optimized in 3-D through the economic calculations.

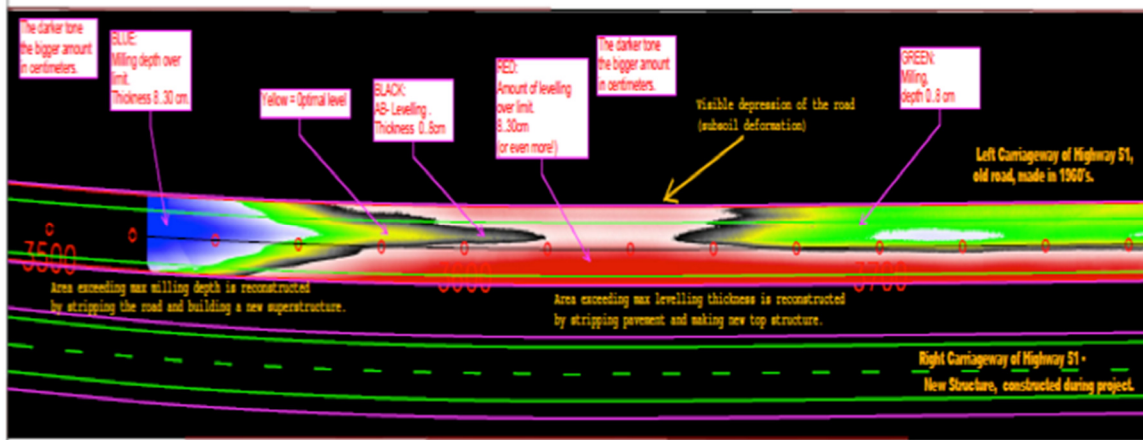


Figure 6. BIM based optimization of the road rehabilitation.



Figure 7. BIM based automated control of milling machine (robotic total station was used for 3D positioning, Trimble GSC900 system for the machine control).

In the 3D machine control of the milling machine, Trimble GSC900 system was used. The production model was created first in the Tekla Civil software, where four different files for the production phase were produced: road geometry (the file format was VGP), 3D break lines (GT), the 2D maps of the milling and paving work areas (VGP) and the known reference points for total station surveys from the work area (GT). Second, the final production models (machine control models) were created by the Trimble Business Center software and using SVD and SVL binary formats. The most important observation was that the location of the prism in the milling machine in relation to the road lane under milling work is critical in the automated controlling process. If the prism is located above another lane, which is not the existing work object, the control system can calculate wrongly the needed correction for the blade. Generally, the information model based automated control worked very well despite some blind spots between the total station used and the prism in the machine. The control surveys from the final milled surface of the road showed a very high accuracy or about $\pm 5... \pm 10$ mm (the most checking points, a separate total station was used for the quality measurements).

As general observations, the initial data model based on the mobile mapping was obtained quite quickly, however special new expertise was needed to perform this work phase. The information transfer from the initial data surveys to the BIM based road design was able to be done without significant problems or delays. The optimization of road repair works using in the BIM modelling was evaluated to be possible. There were seen some needs to have more advanced tools for that kind of optimization needed. In the utilization of the machine control there were not seen any special problems.

CONCLUSIONS

Based on the results, it was concluded that the use of reference points using 50 m maximum spacing makes it possible to achieve sufficient accuracy of measurement for 3D machine control in the coordinate system used. The table 1 shows the possible accuracy of measurements using different spacing. When using 500 m spacing, it was evaluated to be impossible to control milling of paving machines in practical road maintenance working tasks. It is recommended to use at least 100 m spacing for the reference points when using mobile laser scanning for that kind of purposes.

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There are a lot of different benefits, which can be obtained by applying BIM and machine automation into the process of road maintenance. The new concept of the BIM based road maintenance includes the utilization of mobile laser scanning with photogrammetric measurements, a special survey analyse and modeling work phase, the information transfer to road design software using BIM modeling principle, new optimization possibilities and methods for the maintenance and rehabilitation design – in this case to milling and asphalt paving works, and 3-D automated control of work machines, i.e. milling machines and asphalt paver. When comparing the new process to the traditional one, the most significant difference is the possibility to continuous optimization of road improvements utilizing more accurate and continuous information models obtained through the BIM process.

For the future research and development, this type of 3D initial data model offer some very interesting and potential possibilities. With mobile mapping we can create continuous surface models of old roads. Future challenge is to create such parameters and corresponding tolerances that we could automatically find and detect those road problems which remain to be fixed. Further using this type of compacted information, the optimization in the later road design phase could be performed much easier and more comprehensive way.

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