

# Point Cloud Based Road Surface Modelling and Assessment

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## Abstract

Creating digital twins of the built environment based on point clouds broadens its application area; point clouds of buildings support BIM (Building Information Modeling) while the digital twins of road surfaces support transportation applications. Point clouds acquired by current TLS (Terrestrial Laser Scanning) or by MLS (Mobile Laser Scanning) systems represent the road surface with high accuracy, and resolution (i.e. with small point spacing). In particular applications extreme high accuracy and robustness is required; the paper discusses surveying and assessment of vehicle test track, including a braking platform. Both the surveying method (TLS supported by Total Station measurements) and the data processing workflow are presented. The potential evaluation results are discussed in detail; semi-automatically created 2D sections and deviation maps shows how the current state of the pavement differs from the as-designed geometry. The investigations proved that point-cloud based data acquisition methods enable deriving high accuracy and high-resolution road surface models.

**Keywords:** MLS, OpenCRG, point cloud, TLS

## 1 Introduction

As-built documentation reconstruction planning of roads are based on geodetic surveying of sections in every 25 meters [1]. These surveys fulfil the general construction requirements (earthworks calculations, accuracy assessment) but do not provide sufficient, detailed information to vehicle dynamics simulations or for detecting minor failures of the pavement. In such cases applying surface-based data acquisition technology is recommended that generally provide point clouds of the surveyed object/area. In engineering practice imagery-based spatial reconstruction (e.g. SfM – Structures from Motion) and laser scanning are the most widely used technologies to capture high accuracy, high resolution geometry of structures. The end products of such surveys enable creating the digital twins of the particular structures/facilities.

Application of point clouds to various engineering purposes has been investigated for years, e.g. engineering geology [2], cultural heritage protection [3], reverse engineering [4]. Abby et al (2015) captured road profiles and analyzed the IRI (International Roughness Index) values [5]. El Issaoui et al (2021) assessed the potential of MMS (Mobile Mapping System) to detect pavement failures [6]. Égető et al (2020) discussed how point clouds can support road construction works, they used total station measurements as reference [7]. Guan et al (2015) developed a method to automatically extract road features (road surface, road markings, pavement cracks) from MLS (Mobile Laser Scanning) datasets; the resolution of the point cloud limited the detection of small cracks [8].

Current paper discusses investigations for both TLS and MLS data sets from the ZalaZone Aquaplaning braking platform. The surface of the track was assessed by TLS data and the general applicability and reliability of MLS data is presented.

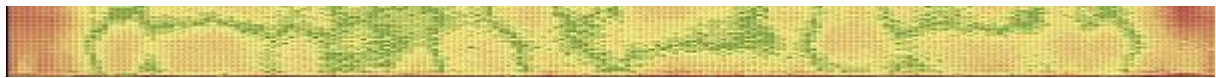
## 2 TLS based road surface modelling and assessment

The applied Surphaser 400 laser scanner enables high accuracy geometric assessment due to its technical capabilities: 1 mm ranging accuracy and 0.1 mm ranging noise. During pre-processing of the point cloud farthest points reflected with low intensity or by low incident angle has been filtered out therefore reducing the risks of certain errors. The aquaplaning test track is a 200 m long road segment; in order to achieve robust registration of point clouds captured from different scan positions, we applied control points all over the area that have been

measured by a Leica TS16i total station. This also enabled georeferencing the data set; further measurements from the same area can be compared to each other this way. The maximum residual value in the control points was 4 mm during the registration.

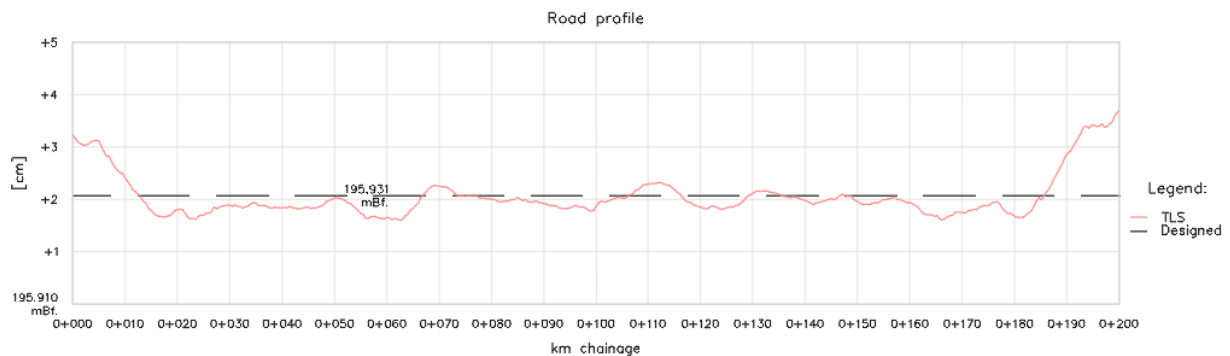
Based on the design plans the reference model has been created. The aquaplaning track starts with a 15 m long, 1% slope, then it has a 180 m long horizontal segment, closed by a 15 m long slope at the end. The reference surface composed by 3 planes enables to create a deviation map that shows the differences from the as-designed model.

Such high-resolution deviation map becomes easy to be managed if elevation data is structured in a regular grid, applying conditional formatting for color coding. Fig. 1 shows a grid with 1 m longitudinal- and 1 dm cross-resolution; elevation values have been interpolated with nearest neighbor method from the point cloud.



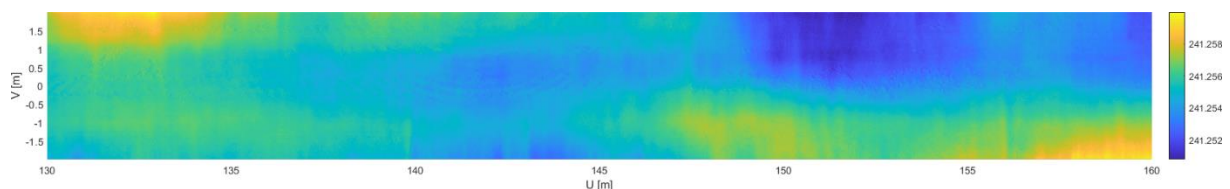
**Fig. 1** Regular grid elevation map

From the pre-processed point cloud different engineering products have been derived. Cross-sections in every 5 meters, while points of longitudinal sections (Fig. 2) in the track axis and crossfall values have been defined by 1 m spacing using semi-automated technique. Annotations have been added in CAD environment.



**Fig. 2** TLS - Longitudinal section

Although point clouds have multiple application opportunities, deriving surface model is beneficial in multiple cases. TIN (Triangulated Irregular Network) enables effective data storage and manages interpolation between measurement points [9]. CRG (Curved Regular Grid) models can be created using the surface model and the as-designed model; such CRG models can be applied in vehicle simulation environments (e.g. IPG CarMaker) (Fig. 3) [10, 11]. According to OpenCRG standard road surface elevation data is to be structured in cm-resolution in a grid along the road axis. Having the axis line, the primary ( $x$  and  $y$ ) coordinates can be defined, and the elevation ( $z$ ) values can be interpolated on the surface model.



**Fig. 3** TLS OpenCRG model UVZ map, section 0+130.00-0+160.00

The derived products show the potential of investigating road surfaces is such high accuracy and high-resolution point clouds are available. Cross-sections enable detecting small differences, while OpenCRG models support simulations with extreme accuracy requirements.

### 3 MMS data assessment

MMS data was captured by a Leica Pegasus 2 resulting connecting point cloud swaths. During pre-processing these datasets have been merged and the area of interest has been extracted. Compared to TLS data one main difference is in the number of points: MMS dataset contained 17 million, while that of TLS had 130 million points.

Regarding point distribution, TLS point cloud spacing is smaller close to the scan positions, while MMS produce more evenly distributed points.

One way to assess geometry is creating deviation maps; most of the differences between the TLS and MMS data lie in the 0-8 mm range (Fig. 4, Fig. 5)

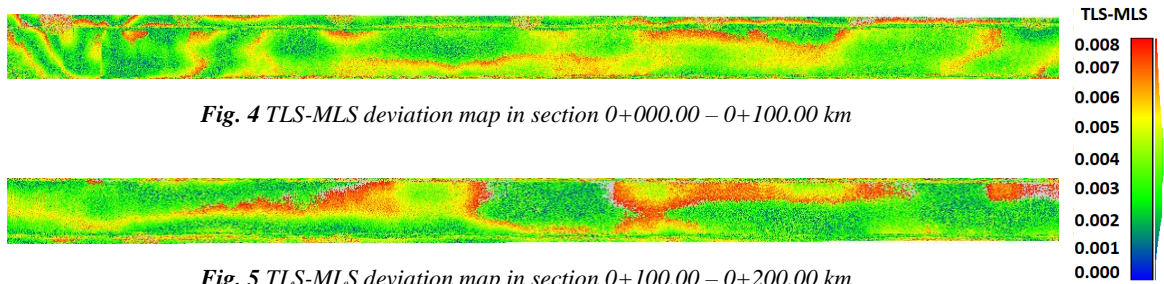


Fig. 4 TLS-MLS deviation map in section 0+000.00 – 0+100.00 km

Fig. 5 TLS-MLS deviation map in section 0+100.00 – 0+200.00 km

In order to further evaluate the MMS data quality, same products have been derived as it was shown in case of TLS. Crossfall values were computed from the longitudinal section points; the trend is similar, however, reasonable difference can be observed in some sections (Fig. 6).

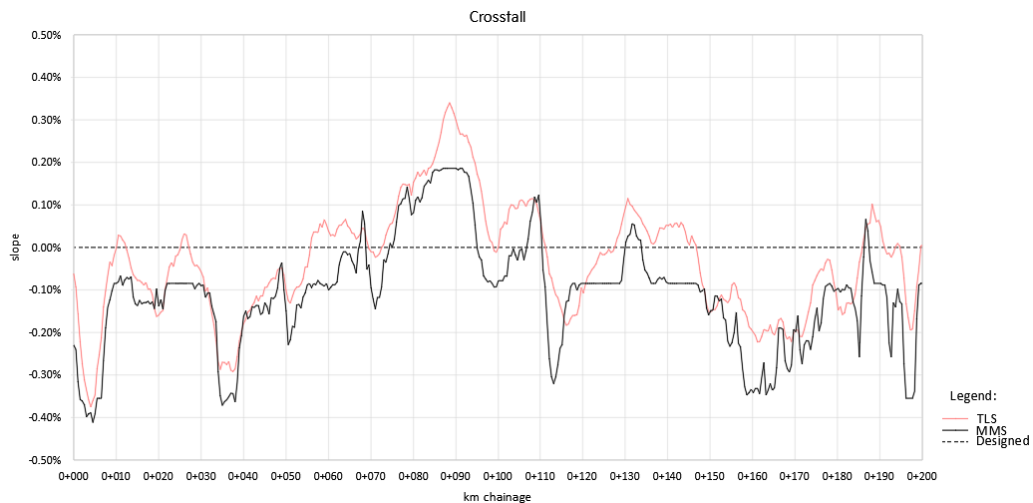


Fig. 6 TLS-MLS crossfall values

Analyzing the cross sections, no such small differences can be observed, as in case of TLS, however, the general trend of the road geometry seems to be correct (Fig. 7).

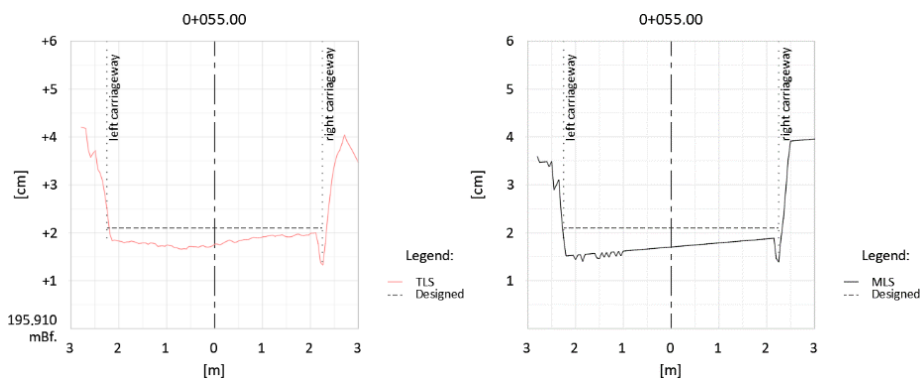
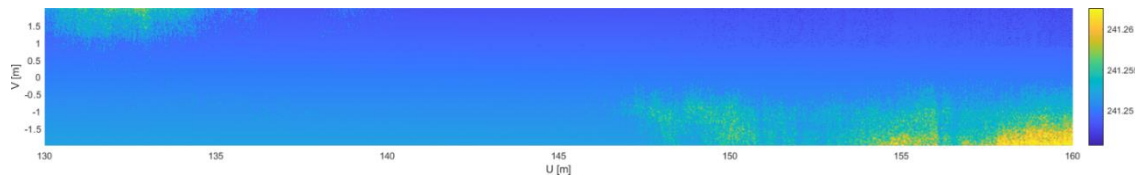


Fig. 7 TLS (left) and MMS (right) cross sections in 0+055.00 km

OpenCRG models derived from both data sources show similar results as in case of cross- and longitudinal sections. CRG models from MMS are less detailed compared to TLS-based models (Fig. 8).



*Fig. 8 MLS OpenCRG model 0+130.00-0+160.00*

#### 4 Conclusion

The results proved how high-resolution, accurate point clouds can effectively support road surface investigations, detecting pavement failures (e.g. potholes, cracks), differences compared to the as-designed models (e.g. in crossfall values). MMS data can describe the overall road geometry, shows the trends of changes, but TLS is to be recommended in case of extreme accuracy and resolution demands. Data acquisition method is to be chosen according to the requirements of the desired end products.

#### Acknowledgement

The research reported in this paper and carried out at the Budapest University of Technology and Economics has been supported by the National Research Development and Innovation Fund (TKP2020 National Challenges Subprogram, Grant No. BME-NC) based on the charter of bolster issued by the National Research Development and Innovation Office under the auspices of the Ministry for Innovation and Technology.

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