Accuracy analysis of LiMAP mobile mapping services

PROJECT:	Mobile mapping services analysis
ADDRESS:	Lithuania & Estonia
SERVICES:	LIDAR data collection and feature extraction analysis
CLIENT:	For public purpose

Document prepared by LiMAP CEO, Andrius Aponas.
More than 15 years' experience in the surveying field.

INTRODUCTION

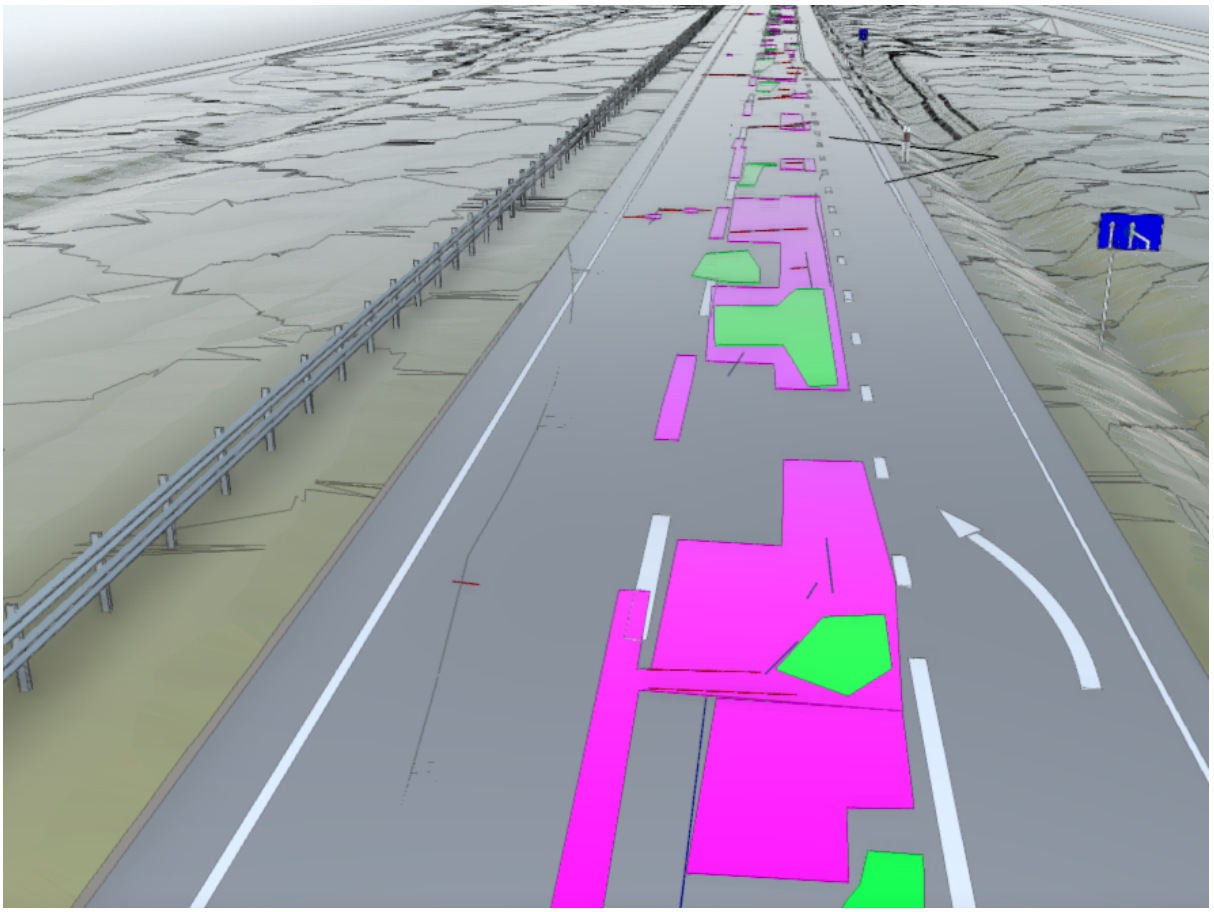
For more than 5 years the company LiMAP, UAB provides mobile mapping services to all Baltic and other foreign countries. Every client wants to be sure that provided data and services can assure the quality expectations and their needs.

We have chosen 3 projects, which we did in the year 2021, and made LIDAR data accuracy analysis:

- First **SUNRISE VALLEY SCIENCE & TECHNOLOGY PARK, LITHUANIA**. We chose it because in this area we have a calibration base and a lot of accurate control points. It's an urban area.

- Second **STATE MAIN ROAD 6 VALGA - UULU 10,019-24,714 KM, ESTONIA**. Chosen because it is a quite common project area, when a detailed surface needs to be prepared for road constructors, the project length is bigger than average.

- Third project - **STATE MAIN ROAD A6 KM 25,848 - 26,3284, LITHUANIA**. A highway, chosen because of it's bad surface conditions. It's extremely important to know how the Mobile LIDAR system (MLS) works in bad conditions, when big vibrations, bumps occur.



I. SUNRISE VALLEY SCIENCE & TECHNOLOGY PARK, LITHUANIA

I.I. Project description

Customer of this project: none. It was done for LIDAR data analysis purposes.

Location: This is an area near Sunrise Valley Science and Technology park, LiMAP head office. WGS84 coordinate - 54.7233, 25.3375

Situation description: near the project area from the East side stands an 8 floors building with glass material and can cause unreliable signals of the GPS unit, which is integrated into the mobile mapping system. From the West side stands a 15 m height forest area.

I.II. MLS survey

In this project we have done 2 scans, forward and backward. Usually we do 2 runs only on the projects where there is no need for a high precision data. More runs, more precise data we get.

Both scans were done as close as possible to the building to be sure that the condition of the survey was lower than medium.

Base station: Our own base station was used. For this one we used the Trimble R12 GNSS unit, which can track all the available satellite signals.

I.III. Reports of MLS survey

From Atlans A7, IMU data a report was generated to identify surveying conditions' qualities:

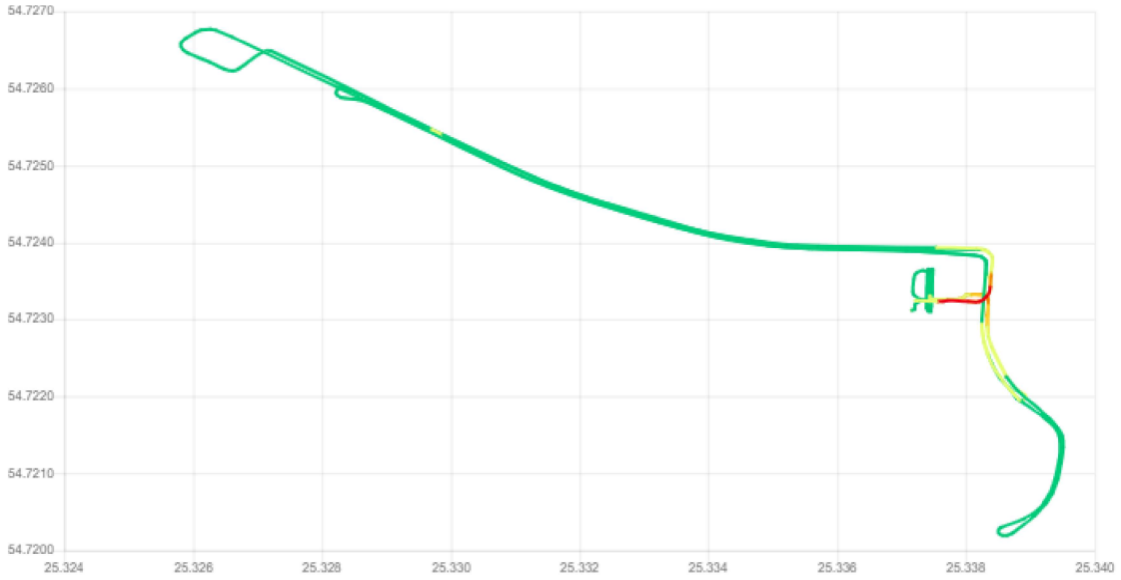
LiMAP Advanced post-processing software

PROJECT OVERVIEW (POST-PROCESSED)

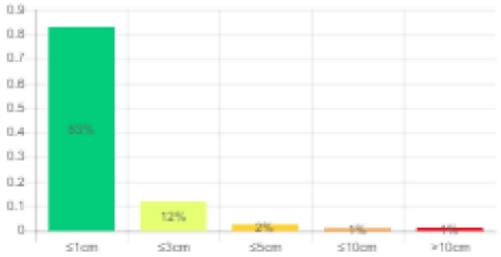
zf_forward_cam_forward_VGTU-replay

NAVIGATION - Positioning quality overview - Northing / Easting (POST-PROCESSED)

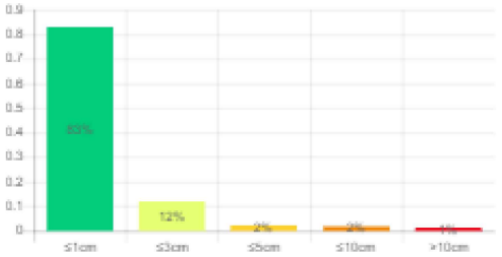
Trajectory (Northing Standard Deviation)



Northing Standard deviation

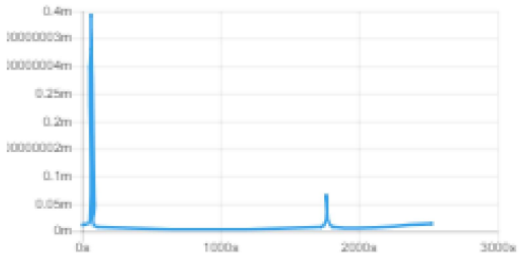


Easting Standard deviation

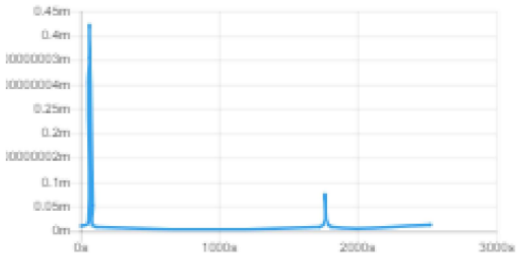


NAVIGATION Positioning quality overview - vs Time (POST-PROCESSED)

Northing Standard deviation



Easting Standard deviation

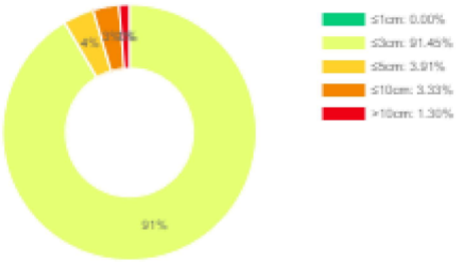


Alignment Status

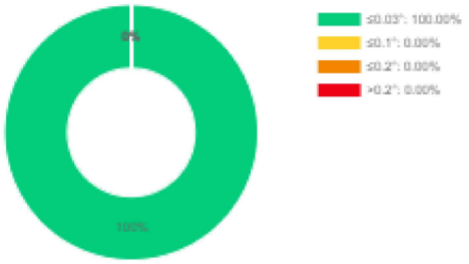
✓ Heading performance shall be reached.

INERTIAL NAVIGATION SYSTEM (POST-PROCESSED)

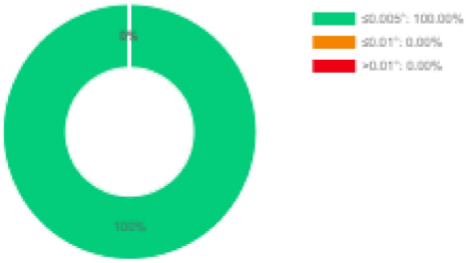
Altitude Standard deviation



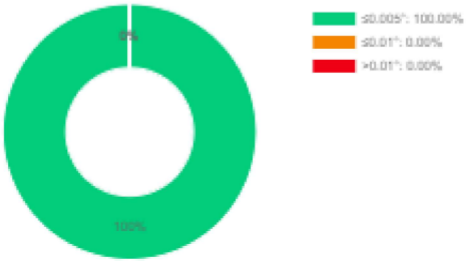
Heading Standard deviation



Roll Standard deviation



Pitch Standard deviation



I.IV. Matching scans together

Every drive-by is individual and is different. No two measurements in geodesy will ever be the same. Those rules apply for mobile mapping as well.
For each project we match both or more drive-bys and decrease the possibility of an error.

Mismatches:

Average 3d mismatch: 0.00667
Average xy mismatch: 0.00547

Statistics for internal observations

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0 ground points
4 xy points
0 elevation points
0 ground lines
0 section lines
0 roof lines

	X	Y	Z
Average magnitude	0.005	0.004	0.005
RMS values	0.006	0.005	0.007
Maximum values	0.012	0.012	0.023
Observation weight	48.0	48.0	7407.0

Average magnitudes per line

Line	X	Y	Z
1	-	-	-
2	-	-	-
3	-	-	-
4	-	-	-
5	-	-	0.005
6	-	-	-
7	0.009	0.002	0.010
8	-	-	-
9	0.006	0.004	0.003
10	-	-	-
11	0.004	0.004	0.005
12	-	-	-
13	0.003	0.004	0.004
14	-	-	-
15	-	-	-
16	0.005	0.005	0.005
17	-	-	-
18	0.003	0.004	0.004
19	-	-	-
20	-	-	-
21	-	-	-
22	-	-	-
23	-	-	-
24	0.007	0.004	0.004
25	-	-	-
26	0.004	0.003	0.005
27	-	-	-
28	0.005	0.003	0.002
29	-	-	-
30	0.001	0.004	0.005
31	-	-	-
32	0.005	0.006	0.011
33	-	-	-
34	0.006	0.002	0.006
35	-	-	-
36	-	-	-

Average magnitudes per scanner

Scanner	X	Y	Z
0	0.005	0.004	0.005

I.V. CP measurements with traditional surveying methods

For the traditional survey we used total station Leica TCRM 1203+. Measurements were done in the LKS-94 coordinate system. Total station was orientated on the resection method to 6 base points, which were done on a RTK GPS method, 60 sessions / 3 times a day, results averaged. All control points (CP) on the perpendicular surface were measured with RL function, others with Leica mini prism 360 GRZ101. Using this methodology, CP should reach a precision of +-2 mm, accuracy +-15 mm.

I.VI. MLS data analysis compared with traditional surveying methods

After comparing results between total station and MLS we got such results:

Number	Easting	Northing	Known Z	Laser Z	Dz
70	586154.651	6066042.918	137.722	137.736	+0.014
71	586157.254	6066048.376	137.583	137.598	+0.015
72	586154.368	6066053.069	137.426	137.440	+0.014
73	586157.015	6066064.135	137.103	137.113	+0.010
75	586164.121	6066049.164	137.584	137.596	+0.012
76	586164.127	6066050.291	137.553	137.565	+0.012
77	586164.180	6066051.390	137.521	137.535	+0.014
78	586164.183	6066052.083	137.497	137.510	+0.013
79	586164.160	6066053.059	137.460	137.474	+0.014
80	586164.151	6066053.825	137.430	137.444	+0.014
81	586164.135	6066054.677	137.406	137.420	+0.014
82	586164.118	6066055.567	137.382	137.395	+0.013
83	586164.008	6066056.552	137.356	137.371	+0.015
84	586164.028	6066057.295	137.338	137.351	+0.013
85	586164.063	6066058.011	137.319	137.333	+0.014
86	586164.067	6066058.925	137.299	137.311	+0.012
87	586164.082	6066060.496	137.254	137.268	+0.014
88	586164.084	6066061.335	137.229	137.242	+0.013
89	586164.120	6066062.271	137.200	137.211	+0.011

90	586164.117	6066063.016	137.172	137.183	+0.011
91	586164.126	6066063.879	137.148	137.157	+0.009
92	586164.106	6066064.555	137.116	137.128	+0.012
93	586164.097	6066065.580	137.086	137.096	+0.010
94	586164.105	6066066.767	137.050	137.061	+0.011
95	586164.100	6066067.423	137.032	137.044	+0.012

Average dz	**+0.013**
Minimum dz	**+0.009**
Maximum dz	**+0.015**
Average magnitude	**0.013**
Root mean square	**0.013**
Std deviation	**0.002**

I.VII. MLS data combined with traditional methods

Number	Easting	Northing	Known Z	Laser Z	Dz
92	586164.106	6066064.555	137.116	137.119	+0.003
94	586164.105	6066066.767	137.050	137.052	+0.002
71	586157.254	6066048.376	137.583	137.584	+0.001
73	586157.015	6066064.135	137.103	137.104	+0.001
87	586164.082	6066060.496	137.254	137.255	+0.001
95	586164.100	6066067.423	137.032	137.033	+0.001
88	586164.084	6066061.335	137.229	137.230	+0.001
72	586154.368	6066053.069	137.426	137.426	+0.000
77	586164.180	6066051.390	137.521	137.521	+0.000
85	586164.063	6066058.011	137.319	137.319	+0.000
70	586154.651	6066042.918	137.722	137.722	+0.000
80	586164.151	6066053.825	137.430	137.430	+0.000
81	586164.135	6066054.677	137.406	137.406	+0.000
83	586164.008	6066056.552	137.356	137.356	+0.000
90	586164.117	6066063.016	137.172	137.172	+0.000
93	586164.097	6066065.580	137.086	137.086	+0.000
76	586164.127	6066050.291	137.553	137.552	-0.001
78	586164.183	6066052.083	137.497	137.496	-0.001
79	586164.160	6066053.059	137.460	137.459	-0.001
84	586164.028	6066057.295	137.338	137.337	-0.001
86	586164.067	6066058.925	137.299	137.298	-0.001
91	586164.126	6066063.879	137.148	137.147	-0.001

89	586164.120	6066062.271	137.200	137.198	-0.002
75	586164.121	6066049.164	137.584	137.582	-0.002
82	586164.118	6066055.567	137.382	137.380	-0.002

Average dz	**-0.000**
Minimum dz	**-0.002**
Maximum dz	**+0.003**
Average magnitude	**0.001**
Root mean square	**0.001**
Std deviation	**0.001**

I.VIII. Final point cloud and control points

Final LIDAR data and CP can be shared on your request.

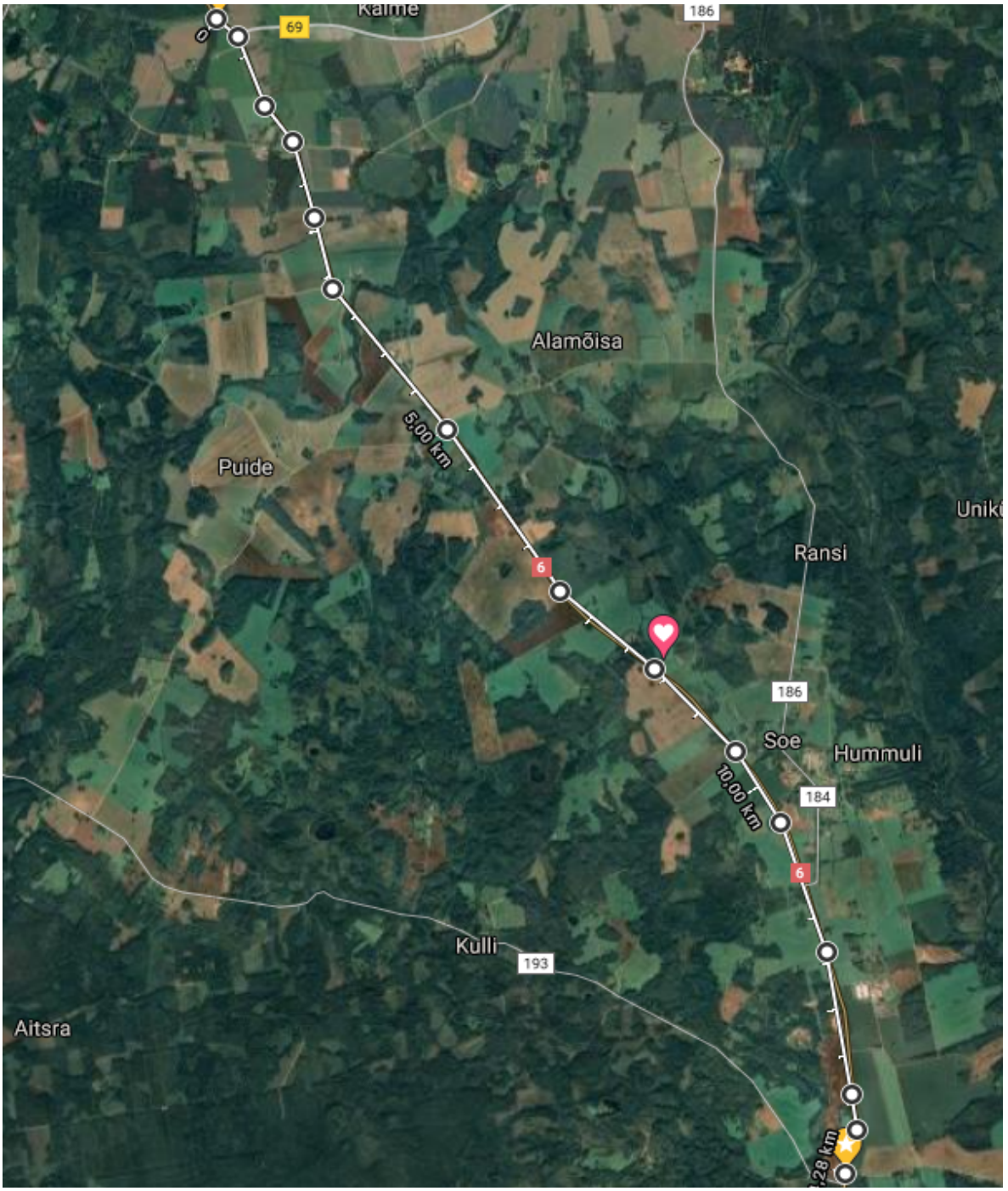
II. STATE MAIN ROAD 6 VALGA - UULU KM 10,019-24,714, ESTONIA

II.I. Project description

Customer of this project: TREV-2 GRUPP. One of the biggest road constructor companies in Estonia.

Location: This is an area located near the Latvia and Estonia border.

WGS84 coordinate - 57.9254, 26.0091



Situation description: length of project is more than 14 km. More than 80 % of the situation is a wide-open area, the other 20% are covered with forest and big trees.

II.II. MLS survey

In this project we have done 6 scans of which 3 forward and 3 backward. We are doing 6 scans where higher precision is required.

Base station: we have used a public GPS base station, which can track GPS and Glonass signals. Distance to the base station was around 30 km.

II.III. Reports of MLS survey

From Atlans A7, IMU data a report was generated to identify surveying conditions' qualities:

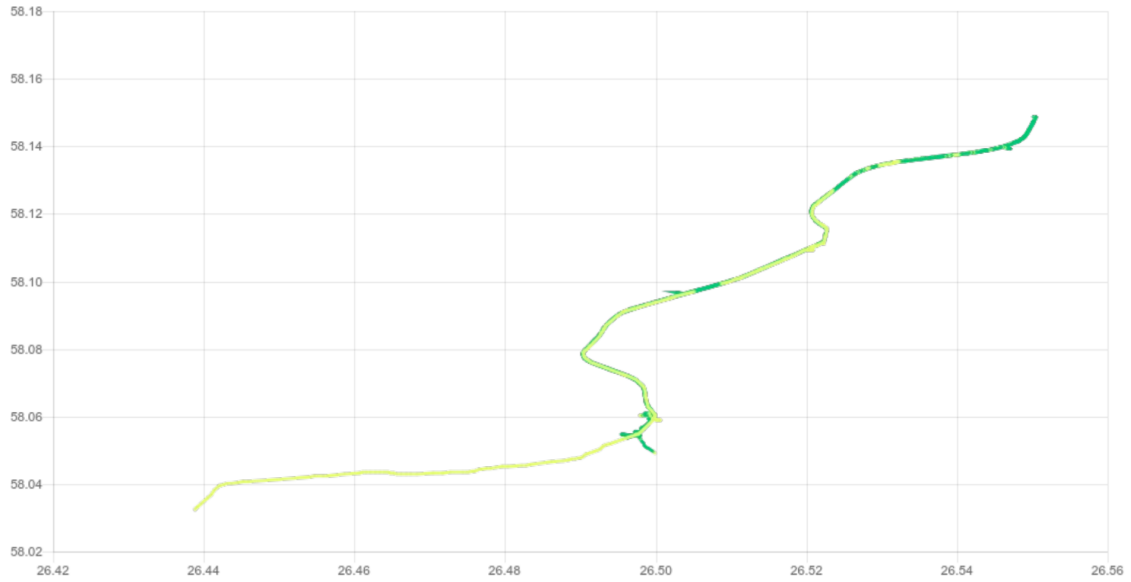
LiMAP Advanced post-processing software

PROJECT OVERVIEW (POST-PROCESSED)

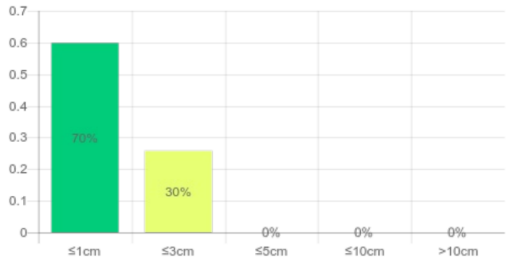
LIM-21-SCAN-120-EE-0617D-replay

NAVIGATION - Positioning quality overview - Northing / Easting (POST-PROCESSED)

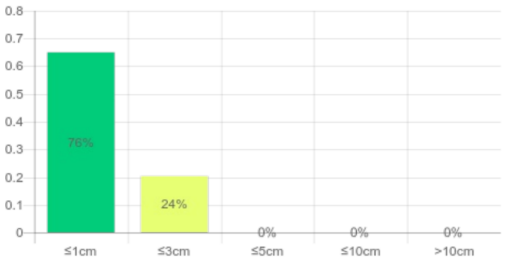
Trajectory (Northing Standard Deviation)



Northing Standard deviation

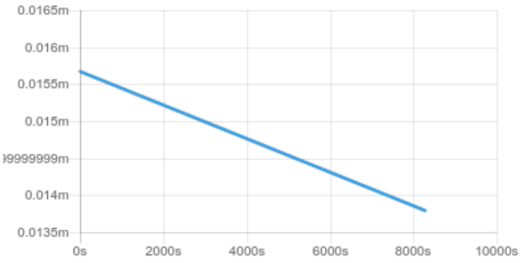


Easting Standard deviation

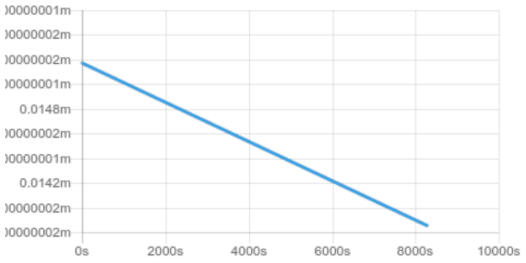


NAVIGATION Positioning quality overview - vs Time (POST-PROCESSED)

Northing Standard deviation

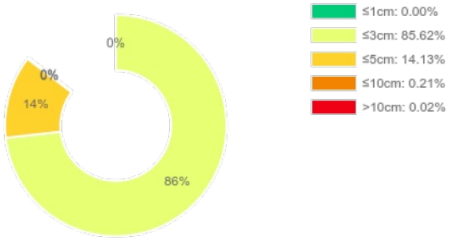


Easting Standard deviation



INERTIAL NAVIGATION SYSTEM (POST-PROCESSED)

Altitude Standard deviation



Heading Standard deviation

Roll Standard deviation

Pitch Standard deviation

II.IV. Matching scans together

Every drive-by is individual and is different. No two measurements in geodesy will ever be the same. Those rules apply for mobile mapping as well.
For each project we match both or more drive-bys and decrease the possibility of an error.

Mismatches:

Average 3d mismatch: 0.00751
Average xy mismatch: 0.01764
Average z mismatch: 0.00749

Statistics for internal observations

0 ground points
266 xy points
0 elevation points
0 ground lines
106436 section lines
0 roof lines

	X	Y	Z
Average magnitude	0.008	0.014	0.007
RMS values	0.010	0.016	0.010
Maximum values	0.050	0.061	0.066

Average magnitudes per line

Line	X	Y	Z
1	0.016	0.009	0.015
2	0.013	0.018	0.003
3	0.007	0.012	0.006
4	0.009	0.015	0.009
5	0.006	0.017	0.007
6	0.009	0.018	0.009
7	0.009	0.008	0.007
8	0.008	0.007	0.003
9	0.007	0.006	0.008
10	0.006	0.015	0.007
11	0.019	0.020	0.004
12	0.008	0.011	0.006

Average magnitudes per scanner

Scanner	X	Y	Z
0	0.008	0.014	0.007

II.V. CP measurements with traditional surveying methods

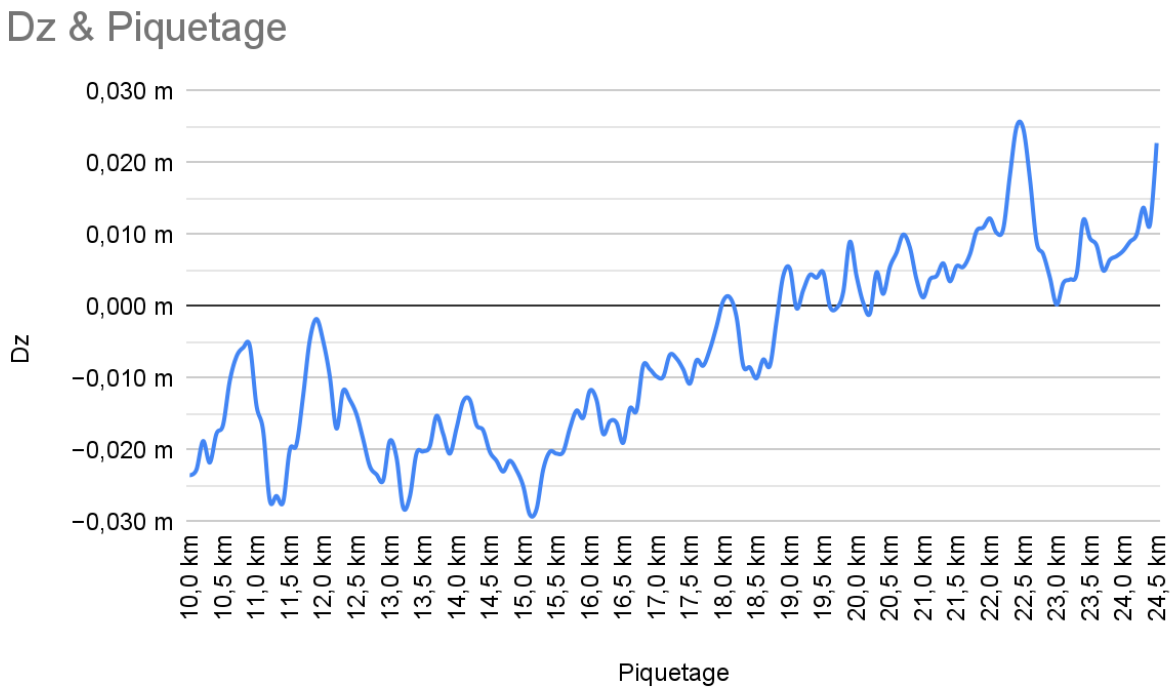
For this task we have chosen a levelling method combined with RTK solution. It was extremely important to get the best results in elevation. We used a Leica sprinter 250M. Levelling points were marked with paint on asphalt every 50 m by sections. 1 point on each roadside. Levelling was done in both ways Forward and Backward. It was divided into 4 parts to get the best results. Final accuracy was reached 2 mm on elevation. To measure XY values, a GPS unit was used.

II.VI. MLS data analysis compared with traditional surveying methods

After comparing results between leveling and MLS got results:

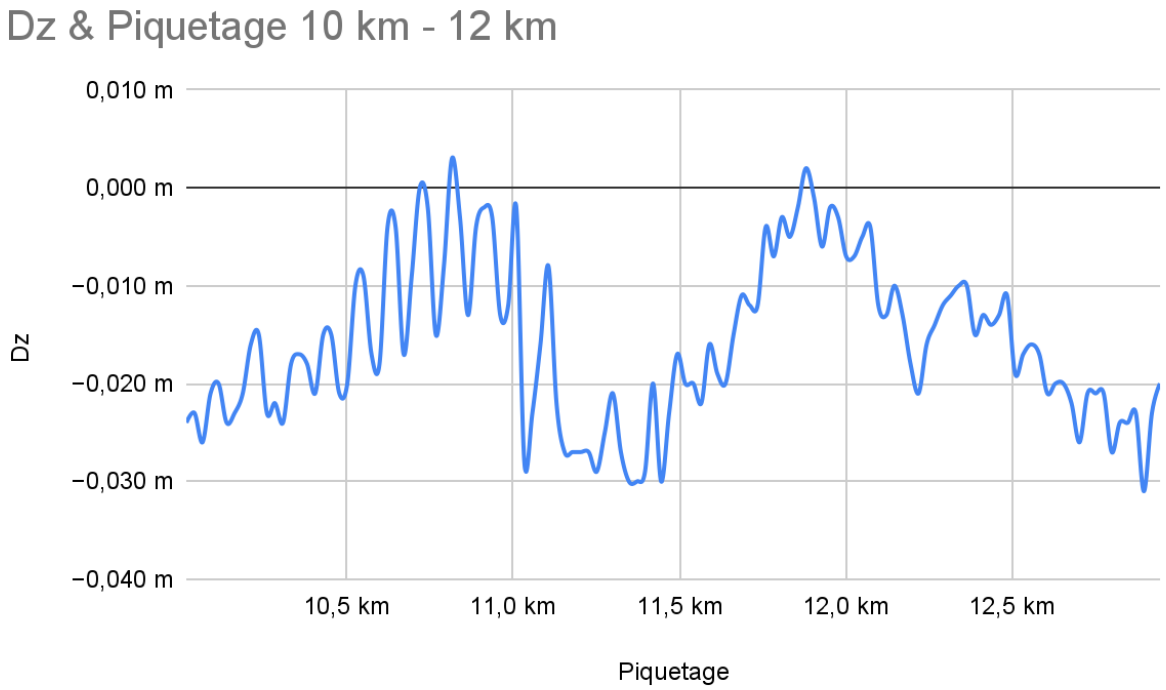
Average dz	**-0.006**	**Average magnitude**	**0.012**
Minimum dz	**-0.036**	**Root mean square**	**0.015**
Maximum dz	**+0.031**	**Std deviation**	**0.013**

More detailed statistic:

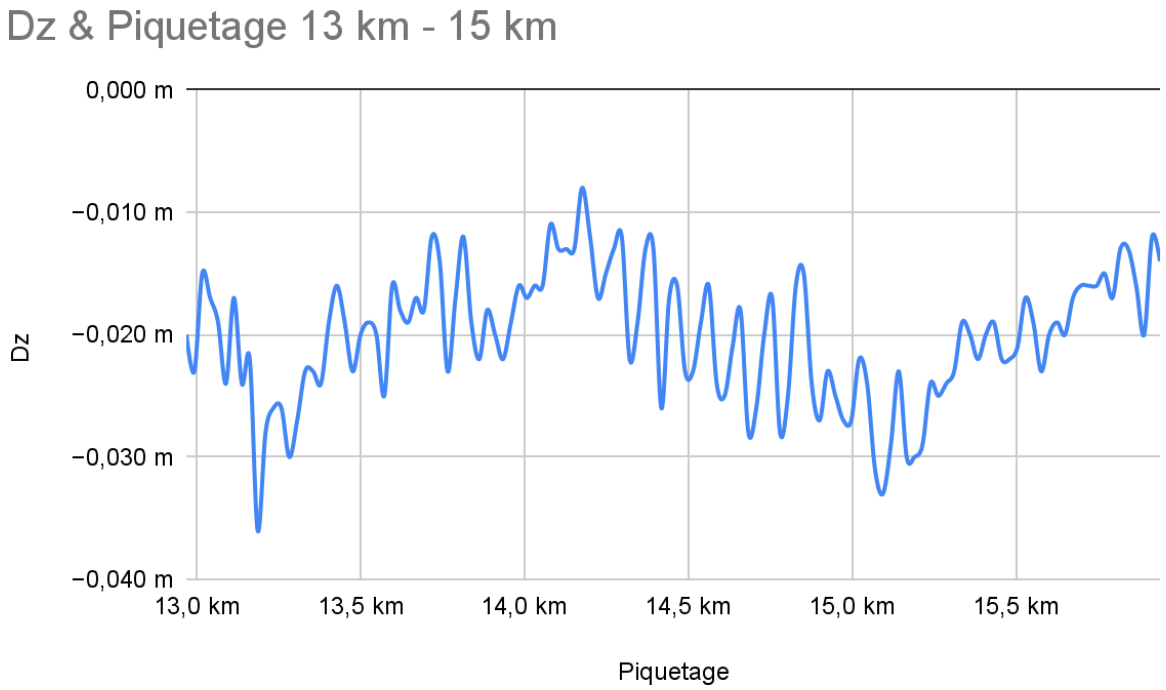


As we see from the diagram above, in all project lengths, the difference between levelling and MLS data is from -36 mm to +31 mm, its 67 mm interval per 15 kilometers, or 4,5mm per kilometer.

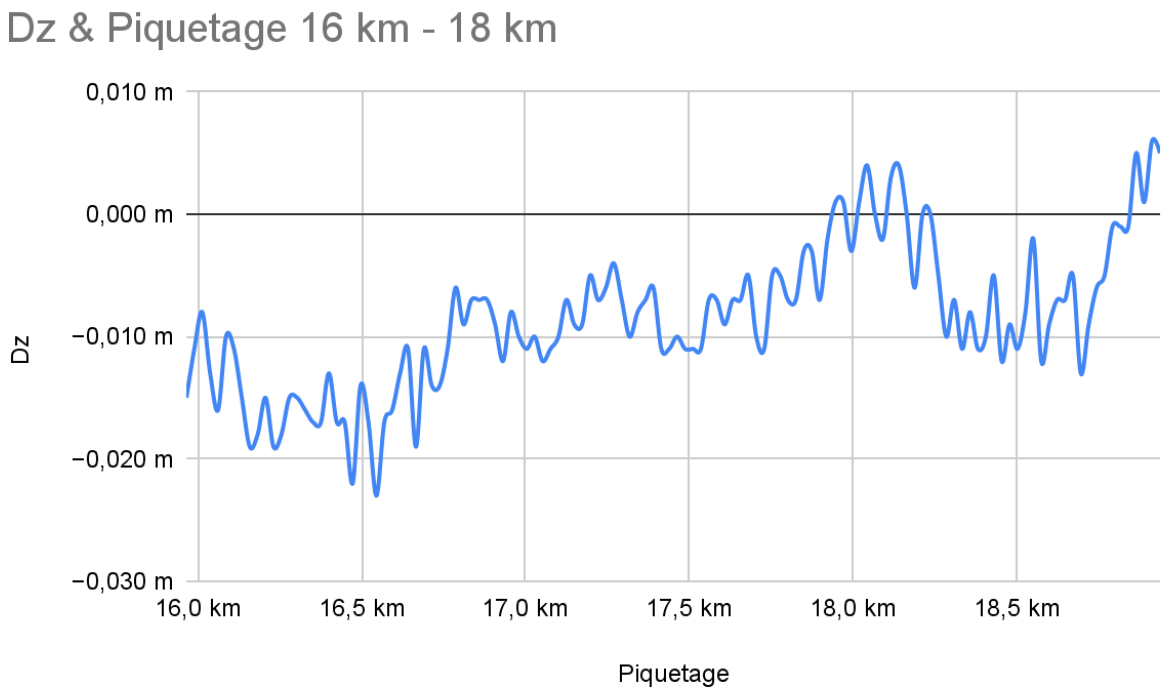
For a better investigation we divided the 15 km path into 5 parts every 3 km, and we got results. In the first section it goes from the -30mm to +0mm.

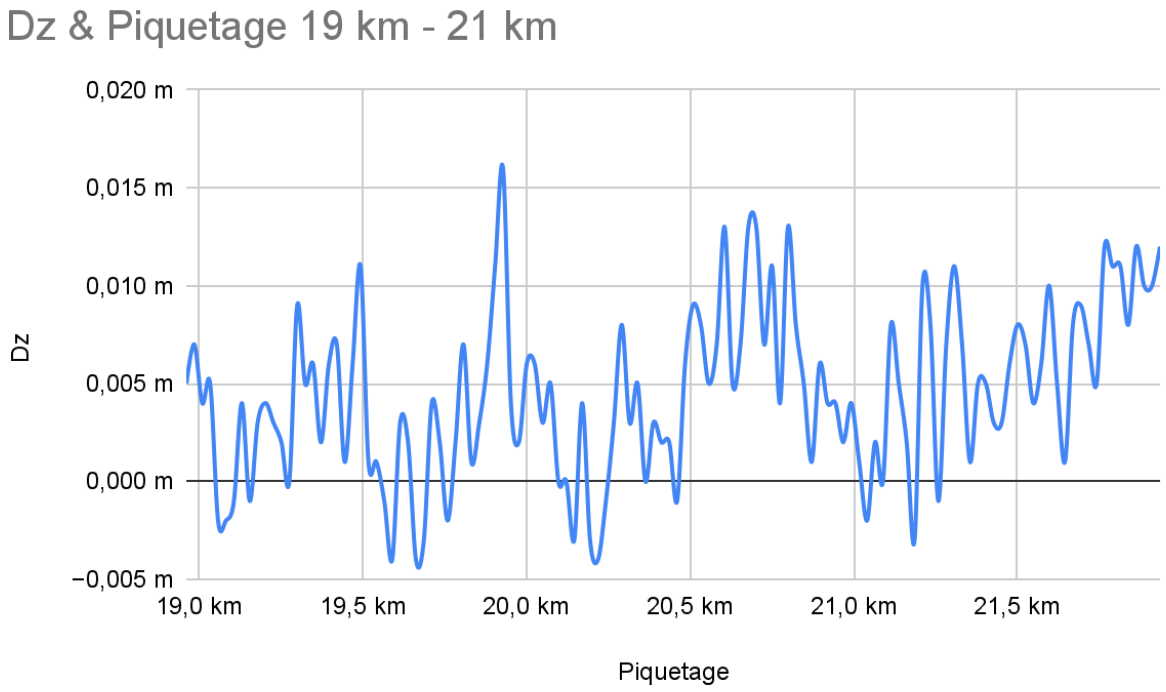


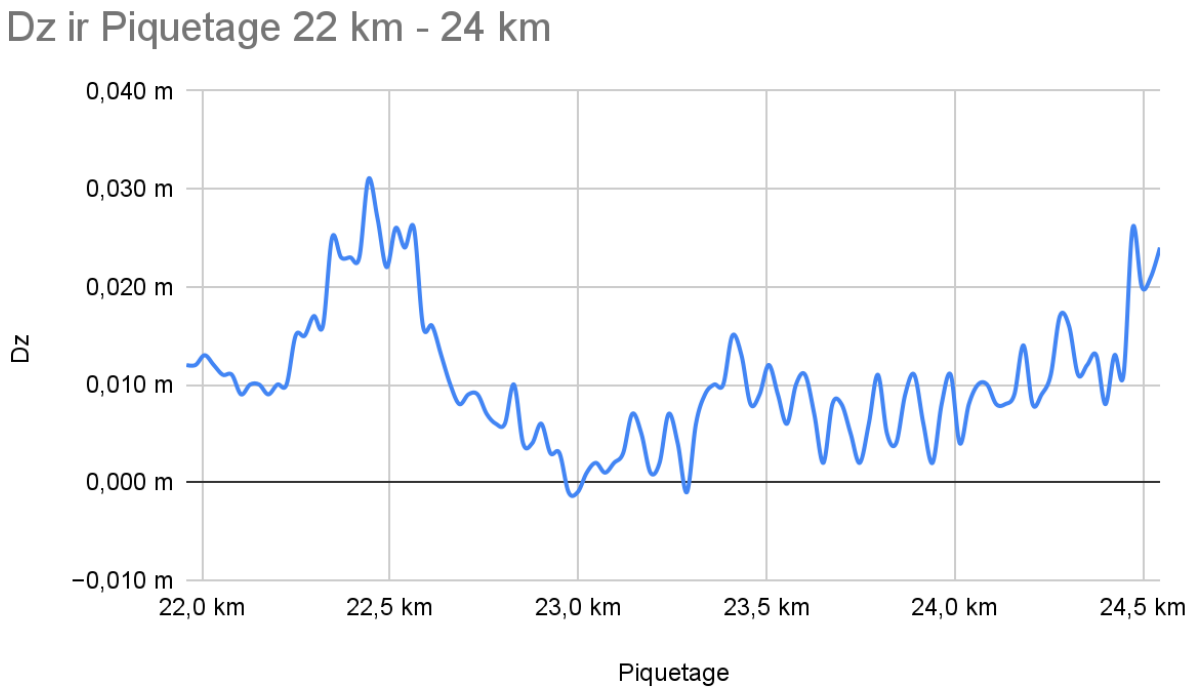
The same situation we see in other diagrams:



We can notice that in the diagram below at piquetage 16-18 km: if we divide data every 1 km, we can get precision intervals from -5 mm to + 5mm, regarding the average trajectory.







Other divided diagrams show that in 3km length, between levelling and raw MLS data precision is from 0 mm to 30 mm. As per 1 km it is from 0 mm to 20 mm, in some cases it can be reachable from 0 mm to 10 mm per km.

II.VII. MLS data combined with traditional methods

To eliminate MLS data mismatch to leveling data (interval from -36 mm to +31 mm) we are using leveling points to force point cloud data into precise position. With specialized software MLS data and leveling data are being matched in sophisticated ways. It is not a straight line force match, but instead software takes into consideration accuracy of point cloud trajectory and uses weighted force displacement.

After combining results MLS and leveling data, report:

Average dz	**-0.000**	**Average magnitude**	**0.001**
Minimum dz	**-0.002**	**Root mean square**	**0.001**
Maximum dz	**+0.002**	**Std deviation**	**0.001**

II.VIII. Final point cloud and control points

Unfortunately the final LIDAR data and CP can not be shared due to an ongoing client's project and will be available only after construction will be over and data will lose it's sensitivity.

III. STATE MAIN ROAD A6 25,848 - 26,328 KM, LITHUANIA

III.I. Project description

Customers of this project: 3 road construction companies before the Yellow FIDIC tender (design and build asphalt resurfacing). These 3 companies are few of the biggest road construction companies in Lithuania. Data was ordered to check asphalt, required to level road volume scope before tender.

Location: This project is located in the middle of Lithuania.

WGS84 coordinate - 55.0405, 24.2242

Situation description: length of project is around 1 km. On both sides of the road there is high forest, but basically a lot of satellites were available.

III.II. MLS survey

In this project we have done 5 scans, 5 forward and 0 backward.

Base station: was used as a VRS base station, which can track GPS and Glonass signals. Distance to the base station was up to 1 km.


3 scans
E262
2 scans

III.III. Reports of MLS survey

From Atlans A7, IMU data a report was generated to identify surveying conditions' qualities:

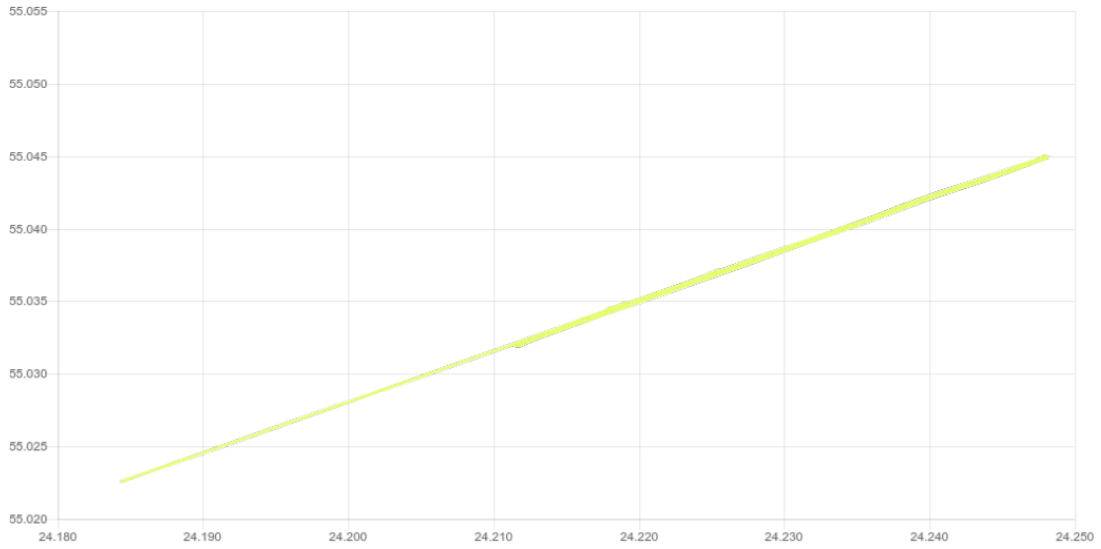
LiMAP Advanced post-processing software

PROJECT OVERVIEW (POST-PROCESSED)

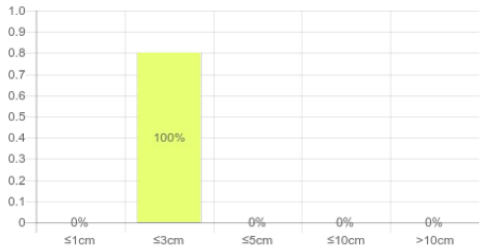
LIM-21-SCAN-083-LT-0415D-replay

NAVIGATION - Positioning quality overview - Northing / Easting (POST-PROCESSED)

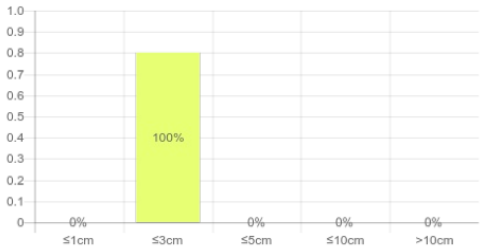
Trajectory (Northing Standard Deviation)



Northing Standard deviation

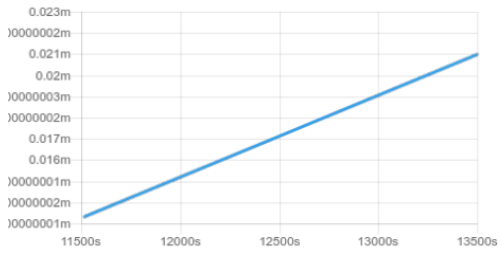


Easting Standard deviation

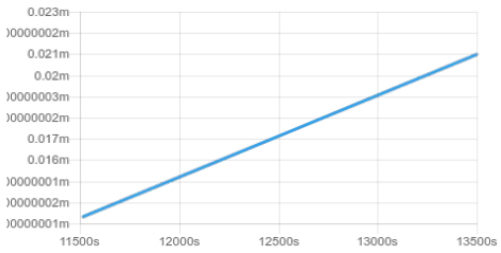


NAVIGATION Positioning quality overview - vs Time (POST-PROCESSED)

Northing Standard deviation

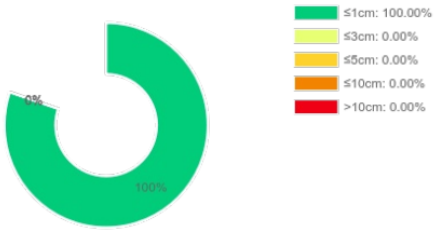


Easting Standard deviation



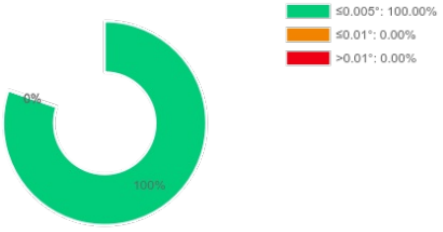
INERTIAL NAVIGATION SYSTEM (POST-PROCESSED)

Altitude Standard deviation

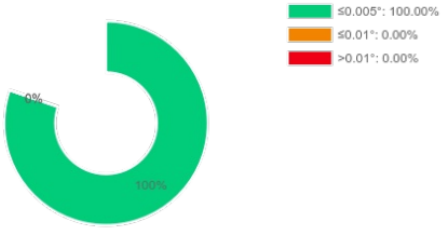


Heading Standard deviation

Roll Standard deviation



Pitch Standard deviation



II.IV. MLS data analysis compared with traditional surveying methods

Mismatches:

Average 3d mismatch: 0.00636

Average z mismatch: 0.00636

Statistics for internal observations

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0 ground points

0 xy points

0 elevation points

0 ground lines

10562 section lines

0 roof lines

	X	Y	Z
Average magnitude	0.000	0.000	0.006
RMS values	0.000	0.000	0.008
Maximum values	0.000	0.000	0.035

Average magnitudes per line

Line	X	Y	Z
1	-	-	0.009
3	-	-	0.009
5	-	-	0.005
7	-	-	0.004
9	-	-	0.006

Average magnitudes per scanner

Scanner	X	Y	Z
0	-	-	0.006

III.V. CP measurements with traditional surveying methods

For this task we have chosen a levelling method combined with RTK solution. It was extremely important to get the best results in elevation. We used a Leica sprinter 250M. Levelling points were marked with paint on asphalt every 50 m by sections 1 point in each roadside. Leveling was done in both ways Forward and Backward. Final accuracy was reached 0 mm on elevation. To measure XY values, a GPS unit was used.

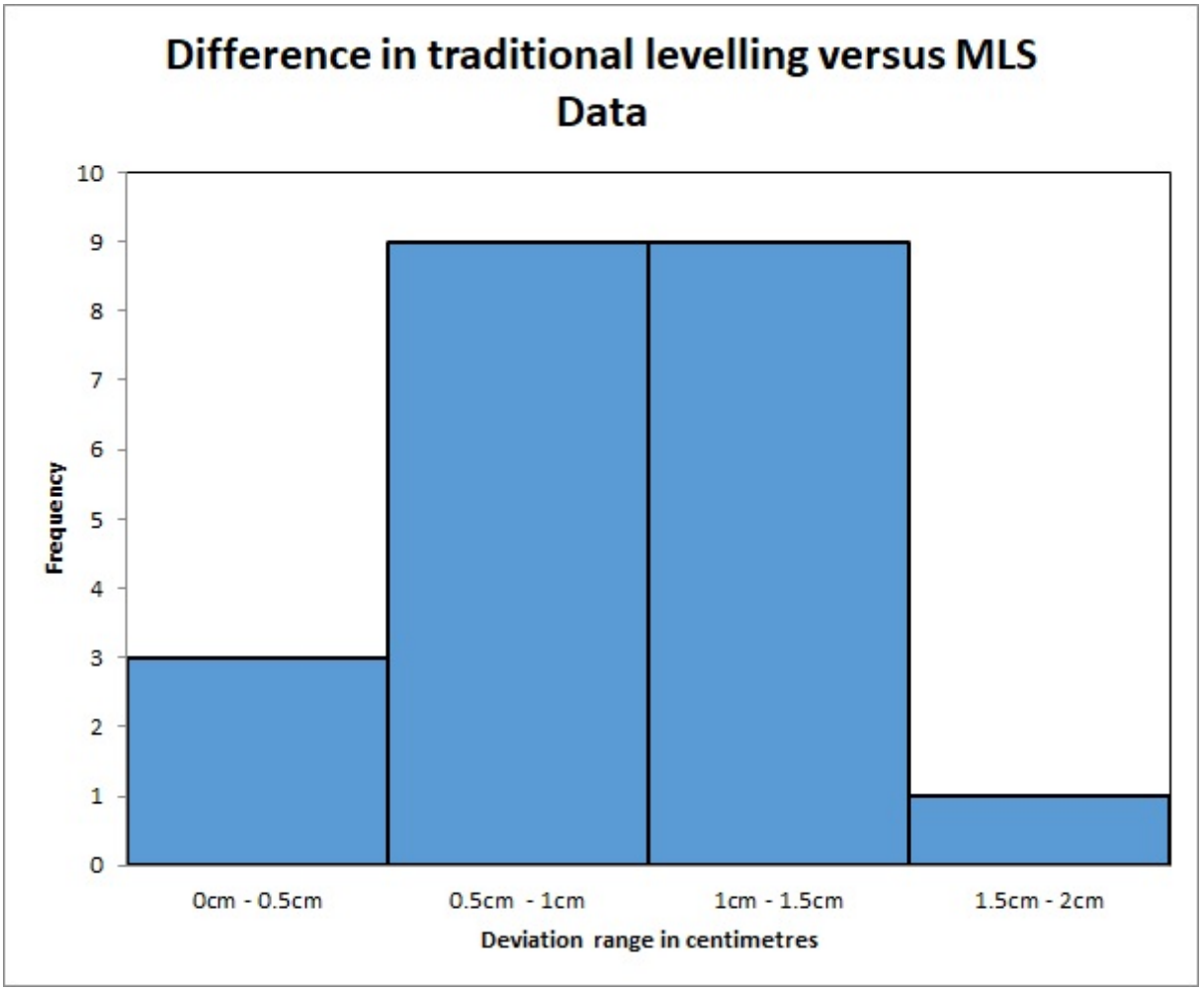
III.VI. MLS data analysis compared with traditional surveying methods

After comparing results between leveling and MLS got results:

Average dz	**+0.010**	**Average magnitude**	**0.010**
Minimum dz	**+0.003**	**Root mean square**	**0.011**
Maximum dz	**+0.016**	**Std deviation**	**0.004**

More detailed statistic:

Here we can analyse how deviation looks at the entire project.



If MLS data was shifted by distances ((16 mm+3 mm)/2=9,5mm) in +9,5 mm, MLS data accuracy was +-6,5mm.

On this project we reached high accuracy and precision, even without using CP. Even when we get good results, for resurfacing projects we need to combine MLS and levelling data.

III.VII. MLS data combined with traditional methods

To eliminate MLS data accuracy (interval from+3 mm to +16 mm) we are using leveling points to get precise data. In specialized software MLS data and leveling data are matching, making corrections for LIDAR data.

After combining results MLS and leveling data, report:

Average dz	**-0.000**	**Average magnitude**	**0.002**
Minimum dz	**-0.003**	**Root mean square**	**0.002**
Maximum dz	**+0.003**	**Std deviation**	**0.002**

III.VII. Final point cloud and control points

Final LIDAR data and CP can be shared on your request.

IV. CONCLUSION ABOUT THE RESULTS

The results of this study demonstrate **RAW (not corrected with control points)** MLS data results:

1. In very small road scan projects up to 1 kilometer, accuracy range is **+-10mm.**
2. In longer road scan projects, accuracy range is +- 33 mm per ALL project. In the **worst** cases seen here it would be **+-15mm per 1 kilometer.**
3. In shorter road scan projects up to 3 km, accuracy range is +-15mm per ALL project. In the **worst** cases seen here it would be **+-15mm per 1 kilometer.**

100% of all LiMAP projects are matched between 2 - 6 scans. It's additional security to get data in high quality and maintain selfcheck procedures. As we see from the results, comparing traditional methods CP and MLS data, especially on longer distance projects we get similar errors. Collectively, our results appear consistent with the geoid model we use for the project. I.e. in this project the geoid model has 5 cm accuracy, so we can assume that this 5 cm error can cause elevation data especially on bigger distances like 15 km and more. The only method to eliminate it, is levelling longer projects.

Next research about MLS data combined with CP shows that accuracy can be reached from -3mm to +3mm, no matter what size the project would be.

This MLS data analysis shows us that MLS services can fit the highest quality standards for road design, constructions, and other engineering tasks.