Mobile Laser Scanner Technology to Detect Road Settlement in Sodong Bridge, Trans Sumatera Toll Road

Idwan SUHENDRA, Ragil.W. KARIM, Billy SILAEN, Darmawan E. WICAKSONO

SUMMARY

Based on Presidential Regulation Number 117 of 2015, PT Hutama Karya (Persero) received an assignment in accelerating the construction of the Trans Sumatra toll road, the assignment consists of funding, technical planning, construction implementation, operation, and maintenance. Maintaining and monitoring toll roads is essential in preventing traffic accidents on toll roads and providing comfort and safety for toll road users.

One of the activities carried out is monitoring the settlement of toll roads by comparing data from mobile laser scanners (MLS) on Sodong Bridge at Terbanggi Besar – Pematang Panggang toll road. Data scanning is carried out on 2 track A and track B on 2 acquisition period.

The acquisition data was processed to reference the data to the base station and eliminate shifting between acquisition tracks. The processing results are then used to create a high-resolution DTM surface and sampling point from the DTM. Road settlement value was extracted through a comparison of the MLS surface data between two periods.

The extraction result from toll road settlement showed variations on the road surface at an elevation from 0 to –0.07 m. From this result, an onsite check must be executed and a necessary action plan must be carried out to solve the settlement issue of the road.

Keywords: Mobile Laser Scanner, Settlement, Trans Sumatera Toll Road

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1. INTRODUCTION

Based on Presidential Regulation Number 117 of 2015, PT Hutama Karya (Persero) received an assignment in accelerating the construction of the Trans Sumatra toll road, the assignment consists of funding, technical planning, construction implementation, operation, and maintenance.

The total length of the Trans Sumatra toll road is ± 2770 km. Until 2022, Hutama Karya has operate 546 km of Trans Sumatera toll road. Under these conditions, PT Hutama Karya (Persero) as a BUJT has the responsibility to carry out the monitoring and maintenance process to meet the Toll Road Minimum Service Standards, which consists of monitoring the International Roughness Index (IRI), cracks, potholes, and monitoring road surface settlement.

In the process of toll road maintenance, areas with unstable soil conditions, are very important to monitor the stability of the road face, slopes, bridge structures, etc. Road monitoring activities will later be used as mitigation to provide comfort and safety for road users.

2. SCOPE OF WORK

The study area is 500 m sectiion of Sodong bridge, which located at Terbanggi Besar – Pematang Panggang Kayu Agung toll road. It is one example of an area that needs to be monitored for road settlement because the area has a soft clay type with a depth of 6-8 m. In this area, the construction process is carried out using the Prefabricated Vertical Drain and Vacuum method.

In the maintenance process for the 2020-2021 period, the surface of the toll road in the Sodong bridge area has been overlaid with asphalt 4 times due to settlement in the road surface.

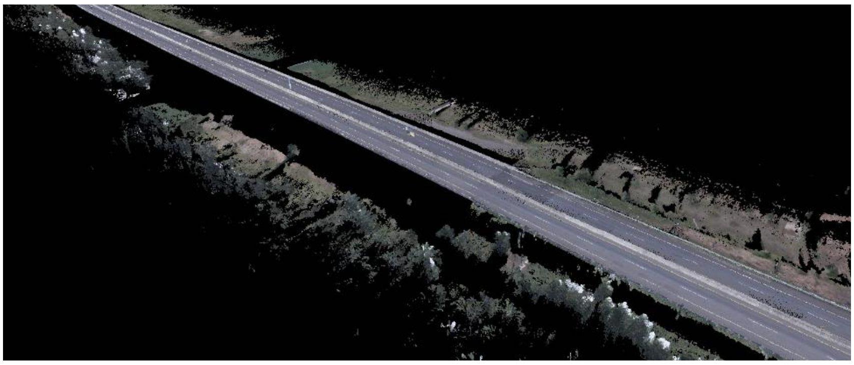

Figure 1: Location of the Sodong Bridge

3. METHODS

3.1 Periodic Mobile Laser Scanner Acquisition

Mobile laser scanner acquisition is carried out annually on operating segments. This periodic acquisition is carried out to obtain information on any changes that occur in the location of the toll road, such as cracks, holes, etc. In the Sodong bridge area, there are two periods of data from the results of mobile laser scanning in 2021 and 2020

3.2 Base Station

The base station is measured with static geodetic GPS observations during MLS acquisition. Each base station covers 10 km for each acquisition, The purpose of observing the base station is to bind to the local reference used, and improve trajectory accuracy when making MLS acquisitions.

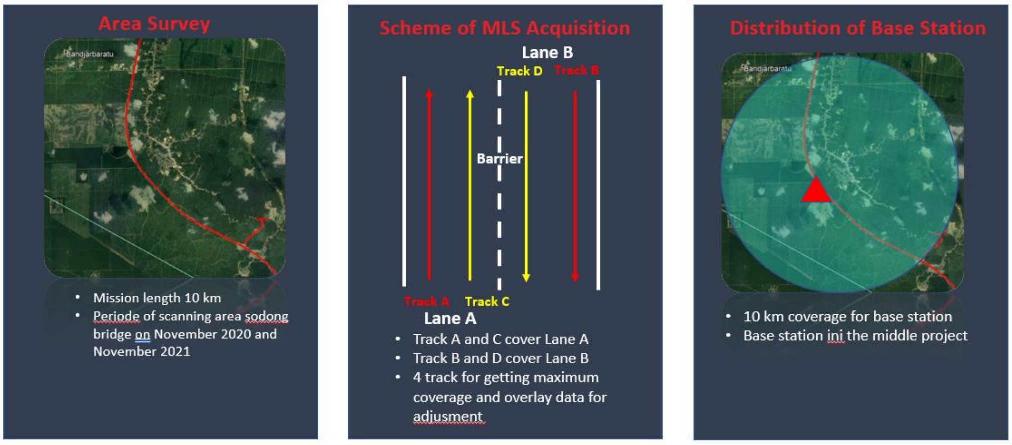

Figure 2: MLS Acquisition Scheme

3.3 Data Processing

3.3.1 Trajectory Adjustment

Trajectory of acquired mobile laser scanner data is tied to the GPS geodetic base station observation data so that the quality of the trajectory can be improved

3.3.2 Generate-Georeferencing Image and Point Clouds

Next step is to generate images and point clouds and then georeferencing the acquired trajectory. In this process of generate image and point clouds, coordinates are defined based on trajectory data from observations in the field and also trajectory data resulting from adjustments with the base station.

3.3.3 Tie Point Measurement-Adjustment Point Clouds

Tie points are automatically generated in the area of overlapping data between tracks. Tie points are used to make adjustments based on overlapping areas. Defining tie points can also be done manually on objects that are easily identified in the survey area such as road markings, premarks, barrier ends etc. .

Furthermore, after defining the tie point, a point cloud adjustment process is carried out to eliminate shifting between data in the overlap area

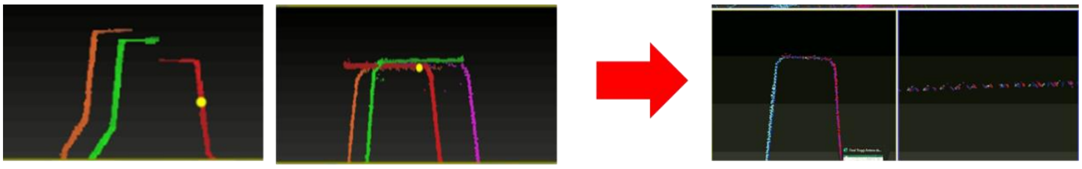

Figure 3: Adjustment process to eliminate shifting between tracks in the overlap area

3.3.4 Independent Check Point (ICP)

ICP points is sampled at the project location with GPS static observations using 30 minute rapid static method of observation. ICP points are used to see the quality of processing results, this value describes the accuracy achieved from point clouds

In the Sodong bridge mission project area there are 4 independent check points (ICP), to measured the accuracy results achieved in the results of mobile laser scanner (MLS) data.

Figure 4: ICP point distribution on the Sodong bridge

Table 1: MLS data accuracy value achieved against the ICP point

ICP	Elevation ICP	Elevation LiDAR	Accuracy
A33	7.646	7.646	0
A34	8.142	8.137	0.005
A35	4.715	4.709	0.006
254A	5.068	5.072	-0.004

3.3.5 Mobile Laser Scanner Data Analysis

The data obtained from the acquisition of mobile laser scanners are in the form of point clouds and images which will later be extracted to obtain an analysis of road grades or IRI values, crack detection, holes, and surface elevation for settlement monitoring.

Monitoring the elevation of the road surface is done by comparing the data for 2 measurement periods from the survey results of the Mobile Laser Scanner (MLS), this process is carried out by point-to-point comparison, which comparing the elevation of the same point or also can be done with surface-to-surface comparison, by comparing the object shape from 2 or more observational data.

4. RESULT AND ANALYSIS

4.1 Data Subtraction

The primary purpose of subtraction analysis is to determine the deviation for each measuring surface's epoch. The elevation datum of all surfaces has been synchronized using MSL elevation.
As shown in Figure 5, the deviation is affected by environmental and operational issues by subtracting two different generated surfaces from the point cloud from two periods acquired from 2020 and 2021. We acquired the data at the exact location. The two surface data are generated using the Triangulate Irregular Network methodology with 1cm resolution. Thus, considering the resolution value of the data in use, the result of surface data should represent the actual condition.

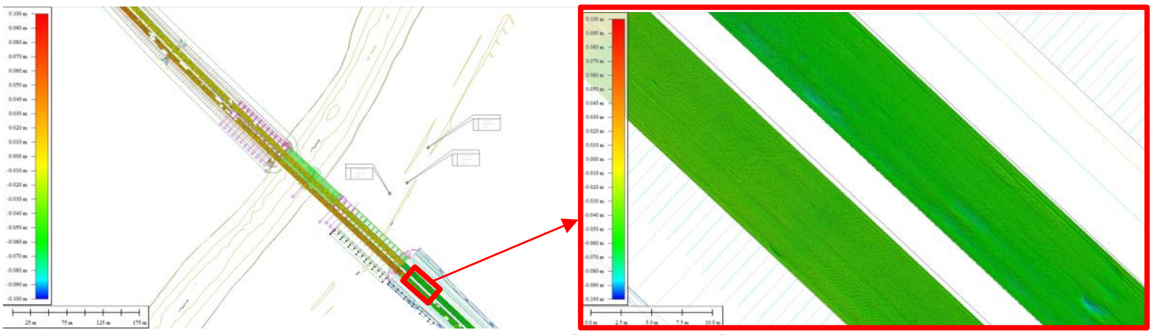

Figure 5: Subtraction Analysis

Moreover, we can focus on the surface settlement that will be separately researched by mainly considering two different conditions, subsidence and stability. As shown in Figure 5, the surface analysis emphasizes that subsidence occurs almost 100 meters before the bridge structure, around 3-5 cm.

4.2 Sampling Point

The sampling point analysis has been taken from subtraction processes. Next, we must generate the gridding processes from the subtraction surfaces to obtain the exact surface value in point form. The sampling point analysis has 1m resolution by means that the point has a distance of 1 meter from one point to another. Those results can be seen in Figure 6, and the range, minimum, maximum, and mean calculation is attached to table 2

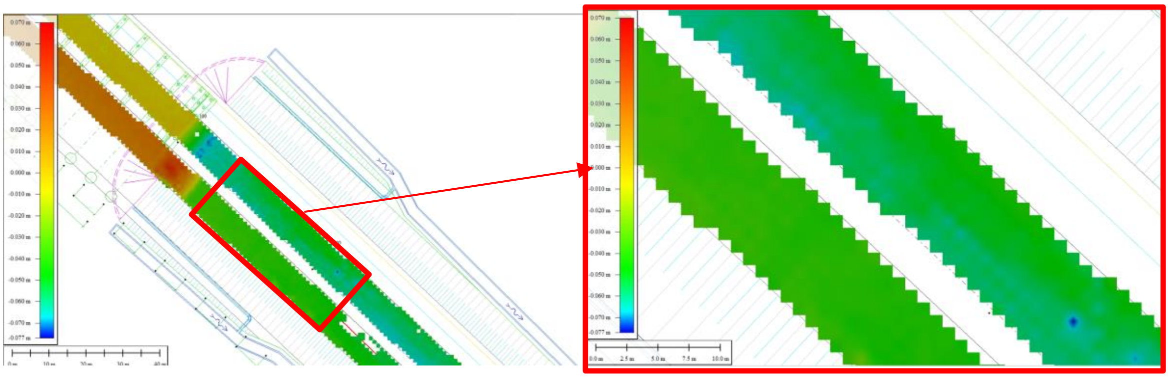

Figure 6: Sampling Point

From Table 2, the elevation value has been classified into different specific numbers. Each number represents the subsidence level which is visualized

Table 2: Table Sampling Point

No	Range	Colour
1	0	
2	-0.02 to 0	
3	-0.04 to -0.02	
4	-0.06 to -0.04	
5	-0.07 to -0.06	
6	<-0.07	

4.3 Gridding Surface

As mentioned before, settlement or deformation analysis can be handled using both visualization and statistical methods. We can see on figure 7 and table 3 the surface experienced a settlement which is reinforced by evidence from visualization and statistics.

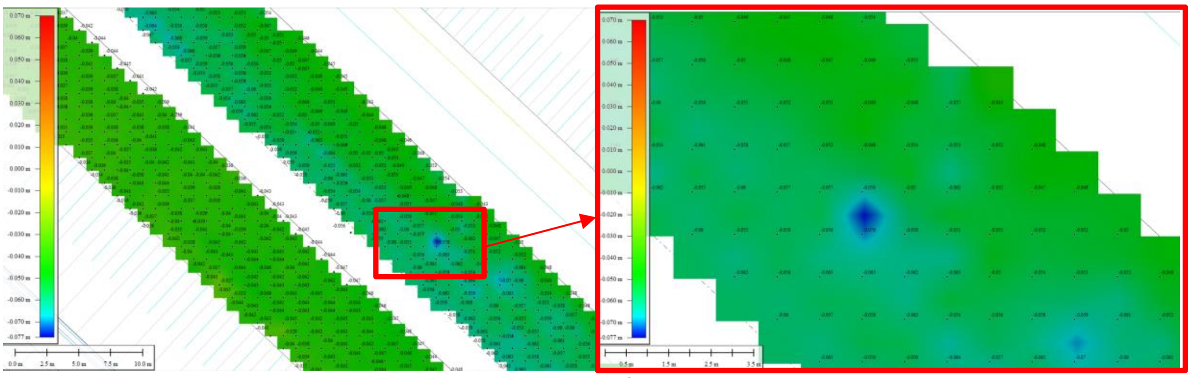
Figure 7: Figure Gridding Surface and Extracted Value

Based on the visualization, we can see that the point spread is taken on the degradation area, where it can be seen that all the areas settle in the span of 1 year. It can be shown that it can be possibly calculated with simple statistics to present the analysis more calculatedly.

Table 3: Road Settlement on All Tracks

	No	Range	Count	Percentage
ALL TRACKS	1	0 to 0.02	2673	30,12%
	2	-0.02 to 0	4056	45,71%
	3	-0.02 to -0.05	1064	11,99%
	4	-0.05 to -0.1	1079	12,18%
	5	<-0.1	0	0,00%
	TOTAL		**8872**	
	MAX		**0.083**	
	MIN		**-0.078**	
	STDEV		**0.025600229**	

Based on the calculation, the table concludes the surface settlement distinct into stable and subsidence conditions. The evidence of that conclusion is the percentage of subtraction elevation, where 30,12% occurs stable around 0 to 0.02 meters, and 45,71% of sample elevation shows the subsidence.

5. CONCLUSION

The visualization of Point Cloud from Mobile Laser Scanner could be utilized as the primary data for analyzing the surface condition. In this case, the point cloud data, which has been generated to the surface, can see the level of flatness and settlement of the toll road. It is because the point cloud from MLS has a high resolution and can accurately analyze the surface.

We understand that the settlement result varies completely based on the subtraction analysis from two different periods. It can be noticed from visualization and statistical method where the deviation ranges from -0.05 to 0.058 meters where the toll road surface experiences both subsidence and stable in different areas. That analysis can be compelling information for toll road engineers to maintain quality of toll road surfaces.

Additionally, it is concluded that point cloud features significantly impact the quality of analysis. Furthermore, although the point cloud data accurately represents the actual condition, it should be considered that advanced data processing is needed.

6. RECOMMENDATION

The acquisition scheme for settlement detection needs to be further studied to improve its acquisition and analysis. For acquisition improvement manufacture of monitoring benchmark points which then be used as base station periodically for consistency, ideal ICP distribution is also needed to be studied. More advanced and efficient point cloud comparison needed to be studied for data analysis.

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CONTACTS

Idwan Suhendra
PT. Hutama Karya (Persero))
HK Tower, Jl. Letjen M.T Haryono Kav 8, Cawang
East Jakarta
Indonesia
Tel. +62818718864
Email: idwan.suhendra@hutamakarya.com

Ragil Wahyu Tasyrifin Karim
PT. Hutama Karya (Persero))
HK Tower, Jl. Letjen M.T Haryono Kav 8, Cawang
East Jakarta
Indonesia
Tel. +6285788800066
Email: ragil.wahyu@hutamakarya.com

Billy Silaen
PT. Hutama Karya (Persero))
HK Tower, Jl. Letjen M.T Haryono Kav 8, Cawang
East Jakarta
Indonesia
Tel. +6285760889007
Email: billy.silaen@hutamakarya.com

Darmawan Eka Wicaksono
PT. Hutama Karya (Persero))
HK Tower, Jl. Letjen M.T Haryono Kav 8, Cawang
East Jakarta
Indonesia
Tel. +6281291200452
Email: darmawan.eka@hutamakarya.com