Evaluation of Precision and Accuracy of Mobile Mapping System (MMS) Leica Pegasus Two Ultimate for Road Monitoring

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SUMMARY

The digitalization of construction is a must while working with BIM workflow. The digitalization process visually conducted by utilizing digital survey of assets in every stage from design, construction to operation and maintenance. PT Hutama Karya (Persero) as Indonesia state-owned enterprise that operate the mega project Trans Sumatera Toll Road along 2,800 Kilometers, utilizes Mobile Mapping System (MMS) Leica Pegasus Two Ultimate to conduct a digital survey in order to fulfill the minimum standard. The application of MMS for construction and operation & maintenance phases are International Roughness Index (IRI) value calculation, road subsidence monitoring, 3D as-built model, and also asset management. Therefore, PT Hutama Karya (Persero) should ensure that the precision and accuracy of digital survey using MMS is appropriate according to the standard.

The research was conducted in order to obtain the accuracy and precision value of MMS Leica Pegasus Two Ultimate by comparing 4 data surveys from a different time periods in vary of temperatures and humidity. The MMS data was acquired on the residential road along 2 kilometers at speed of 40kmph. The MMS measurements were done in 4 lanes in every mission. The position obtained from PPK method with 1 receiver GNSS as a base station with a 2-kilometer radius. Meanwhile, the digital survey team also collect 16 Independent Check Point (ICP) using rapid static method. The analysis is conducted to obtain the precision value lane in one mission and between 2 missions, the distribution of point cloud in order to form 2D and 3D objects and also the Z accuracy of each mission compared with the ICP data. The research also compared the precision value of 4 missions in raster elevation with 1m x 1m spacing grid.

The precision value between missions in 10 sample locations also represented by the standard deviation with minimum value of 0.007 m, a maximum of 0.012 m and an average standard deviation in 10 locations of 0.010 m. Visually with a qualitative approach, point cloud results from 4 data surveys could form road mark and public street lighting well and with minimum dispersion. The Z accuracy from 16 ICP for 4 missions resulted in an average LE90 of 0.137m The precision value for mission 1 and 2 is 0.009 m, mission 1 and 3 is 0.009 m, mission 1 and 4 is 0.006 m, mission 2 and 3 is 0.009 m, mission 2 and 4 is 0.006 m, and also mission 3 and 4 is 0.005 m. The research also showed that there are no effects of temperature in 27^0 – 32^0 C range and humidity with 66 % – 86 % range on the precision and accuracy of MMS. Therefore, the conclusion is the MMS could be used to conduct a digital survey for engineering purposes within 1: 1000 map scale product based on map accuracy standard from Indonesia Geospatial Information Agency.

Keywords : Mobile Mapping System, Construction, Road, Accuracy, Precision

1. INTRODUCTION
1.1 Background

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 (Indonesia Government, 2015).

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 and monitoring, high accuracy and precision equipment need to be assessed to enhance the analysis for improving the toll road's quality. In this case Mobile Mapping System (MMS) has been implemented for various analysis in the toll road project, such as monitoring IRI value, cracks, potholes, and road deformation.

The aspects that need to be checked include horizontal and vertical measurement. Systematic error of the Mobile Mapping System (MMS) system that consists of Inertial Measurement Unit, GNSS, and LiDAR components must be evaluated. Particularly, the environmental condition's effects such as temperature and humidity on the precision and accuracy value will be comprehensively measured and analysed.

1.2 Objectives

The objectives of the research are described in the following points:
1. Measuring the Precision and Accuracy of MMS value in the different environment conditions
2. Assessing the coorelation of the Precision and Accuracy value to the environment conditions

1.3 Benefits

The benefits of the research are described in the following points:
1. Describing the MMS performance regarding precision and accuracy value in the certain conditions for actual implementation
2. To obtain the high precision of the data for improving the Road Monitoring Analysis

2. METHODOLOGY

2.1 GNSS Survey

The first phase of the survey was identifying the benchmark coordinate as an MMS base station for reference station to adjust and corrected the data (Puente et al., 2013). The benchmark coordinate was obtained with GNSS survey using static method. All the MMS missions were using the same benchmark point in the same reference system.

Also, besides obtaining the base station coordinate, the ICP were acquired by using rapid static methodology with GNSS technology. The ICP is used as a true value point for measuring the accuracy of the point cloud data. The distribution of all those points that were used in this research will be described in the figure below.

Figure 1 Independent Check Point

2.2 Mobile Mapping System Data Acquisition

The scope of evaluation discussed in this paper presented the determination of horizontal and vertical assessment, and the site environmental condition in Bumi Serpong Damai (BSD) road, South Tangerang, Indonesia. The study area is approximately 2 kilometers section of road. The acquisition was performed with four different tracks for each mission with speed of 40 km/h.

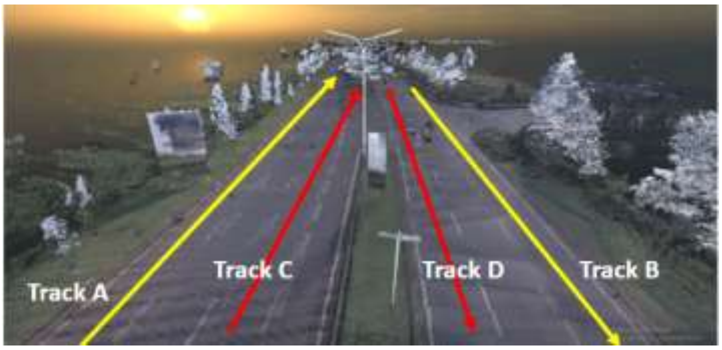

Figure 2 MMS acquisition scheme

2.3 Data Processing

2.3.1 Generate Images and Point Cloud

As the MMS has been equipped with a survey-grade IMU and GNSS system (Sairam et al., 2016), the absolute accuracy might decrease because of the differences of time-series. In order to acquire higher accuracy of the data, the data from multiple sensors must be adjusted. Managing data adjustment of the trajectory, GNSS base station, GNSS rover, and IMU data must be included and corrected. The correction itself was performed with a mathematical model in Inertial Explores software. The images and point cloud generation need to be extracted according to the adjusted trajectory which already corrected with the control point. The data processing such as tie-point measurement to adjust the point clouds was carried out to eliminate the data shifting between tracks in the overlap area. The point cloud that already adjusted and generated are ready for the accuracy and precision data evaluation.

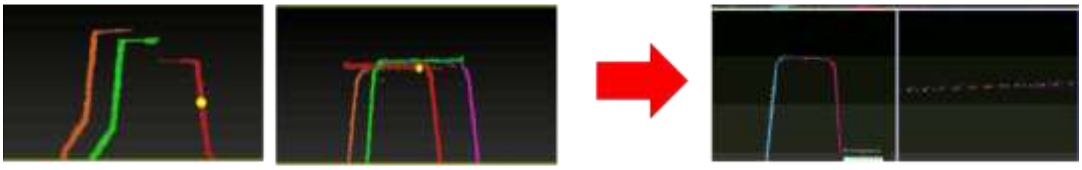

Figure 3 Adjustment process to eliminate shifting between tracks in the overlap area

2.3.2 Accuracy and Precision Data Analysis

The precision and accuracy data analysis were carried out in order to investigate whether some points differ significantly with others. Furthermore, to examine the precision of the point cloud data, the statistics and visuals methods were performed in order to achieve the results from multiple perspectives. In this project area, there are 16 points as ICP will be used to calculate the Precision and Accuracy value. Statistical method such as Mean, Standard Deviation, Max, Min, and Root Mean Square (RMS) were performed to describe the quality of the data. The analysis of the data consists not only identifying the accuracy and precision value, but also determining the quality the trajectory and GNSS data.

3. RESULT AND ANALYSIS
3.1 Trajectory Quality Analysis

Table 1 Trajectory Quality

No	Statistic	Mission			
		Mission 1	Mission 2	Mission 3	Mission 4
1	Standard Deviation	0.002	0.001	0.002	0.001
2	Root Mean Square	0.009	0.009	0.009	0.008
3	Average	0.009	0.009	0.009	0.008
4	Max	0.017	0.018	0.019	0.016
5	Min	0.007	0.008	0.008	0.007

As shown in Table 1, the table shows the statistic properties of Trajectory processing from four different missions. The statistic properties including Standard Deviation, Root Mean Square, Average, Maximum Value, and Minimum Value was obtained from Trajectory Processing with Inertial Explorer Software. Those statistic calculations were determined to explain the combination processing from Both Directions (Forward and Backward Directions) processes, which was acquired by the position differences between forward and reverse directions. As the trajectory processing resulted that the quality of trajectory from four different periods/missions was passed the requirement.

3.2 MMS Data Accuracy

The accuracy of MMS data involved not only the point cloud data, but also the Independent Check Point (ICP) which was acquired by using GNSS methodology. The total number of ICPs was 16 points, which was acquired by Rapid Static GNSS methodology. The purposes of using Rapid Static technology was because it could provide the high accuracy and precision of data relatively to Real Time Kinematic (RTK) (Ramadhan et al., 2021). The MMS acquisition was held four times with four different conditions, which could evaluate the consistency of the equipment.

As the MMS data accuracy measurement as stated on Table 2, it can be concluded that the average of error between the point cloud and the ICPs is below 5 centimetres in four different conditions. Also, the maximum error from those four different survey was under 10 centimetres with LE90 accuracy under 8 cm. Precission value from standard deviation of the ICP in each mission was under 3 cm

Table 2 Statistic and Enironment Data

	Mission 1	Mission 2	Mission 3	Mission 4
STATISTIC				
Min. dZ (m)	0.005	0.002	0.017	0.014
Max. dZ (m)	0.048	0.083	0.069	0.062

	Mission 1	Mission 2	Mission 3	Mission 4
Average dZ (m)	0.022	0.039	0.043	0.039
RMSE	0.030	0.048	0.047	0.045
LE90	0.049	0.079	0.078	0.074
St. Dev	0.020	0.027	0.019	0.022
ENVIRONMENT				
Time (GMT +7)	12.46	13.58	15.30	17.43
Temp. (^{0}C)	32	31	27	27
Humidity (%)	66	76	86	84

By comparing the accuracy result with environment data, we can see that the environment condition have no effect on the accuracy of each mission. Combining all the result of each mission the overall LE90 accuracy is 0.137 m / 13.7 cm. The accuracy from this mission are within 1: 1000 map scale product based on map accuracy standard from Indonesia Geospatial Agency (Badan Informasi Geospasial, 2018).

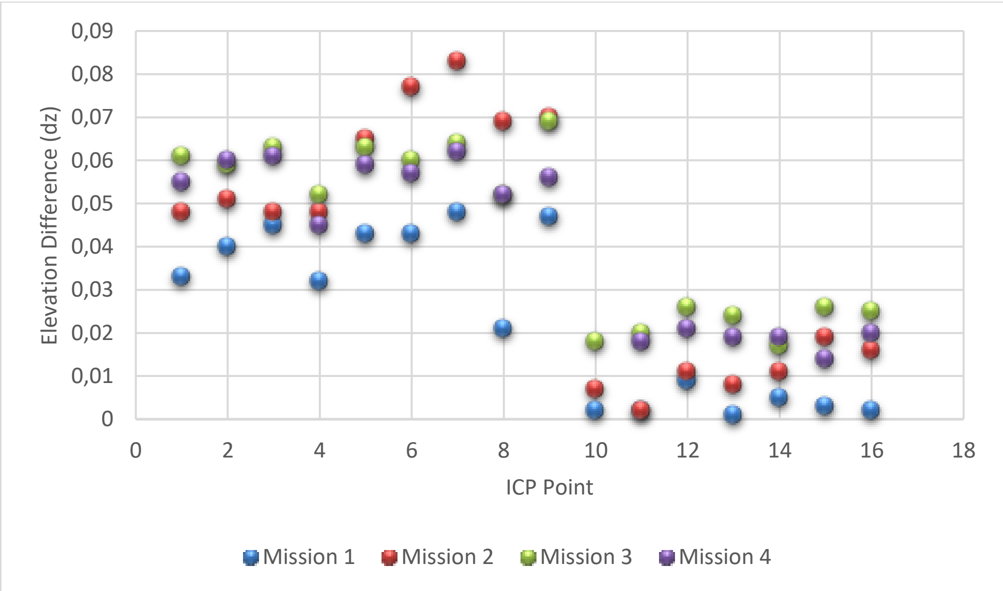

Figure 4 Overall ICP Elevation Difference (dZ)

3.3 MMS Data Precision

3.3.1 Sample Point Precission

The data precision analysis was conducted using ten sample point which can be seen below.

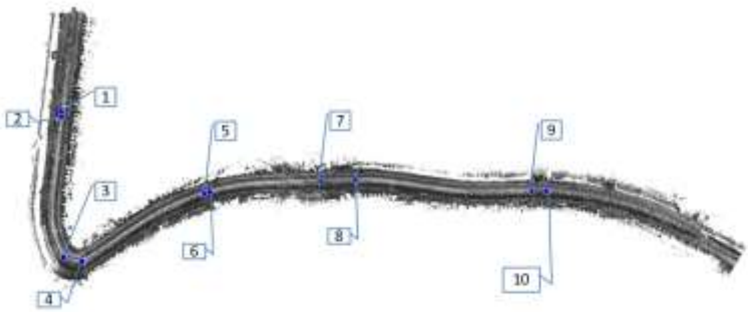

Figure 5 Precission Sample Point

Each point elevation then calculated for each mission, where each mission consists of four different tracks. These data then used to get the deviation of each mission as seen in Table 3 below.

Table 3 Per Track Standard Deviation

	Mission 1	Mission 2	Mission 3	Mission 4
Min. (m)	0.001	0.001	0.001	0.001
Max. (m)	0.007	0.019	0.017	0.004
Average (m)	0.003	0.007	0.007	0.003

As stated on the Table 3 above. The precision value from four different missions show that the environment from Table 2 show no effect to the sample point precission. The average value of the precision is vary between 3 and 7 milimetres.

Using the same sample point the precision between MMS mission can also be calculated. Each sample point elevation was calculated using track combination of each mission. These data then used to get the deviation of each mission. From the precision result, the minimum standard deviation is 0.007 m and the maximum is 0.012 m with average of 0.010 m overall result can be seen in graph below

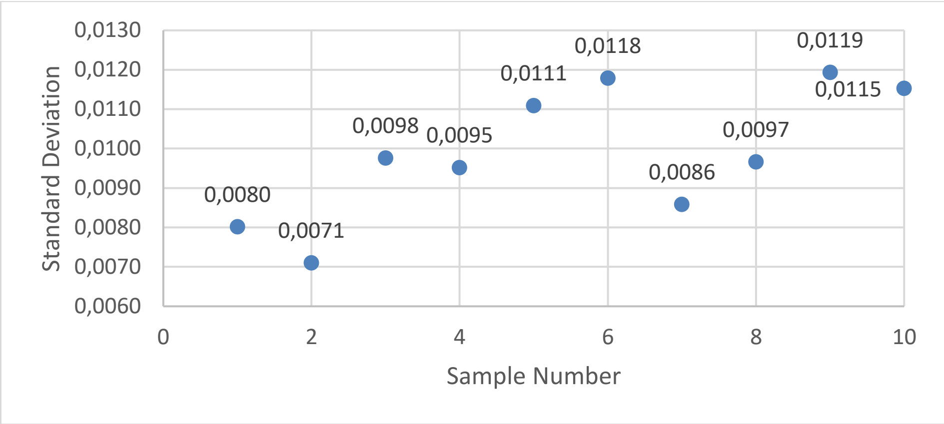

Figure 6 Between Mission Standard Deviation

3.3.2 Data Subtraction Precission

Data subtraction analysis were carried out by generating DEM raster elevation from road class point cloud from each mission with 1m x 1m grid. Generated raster elevation from each mission then subtracted between 2 missions. Subtraction result can be seen in the result below.

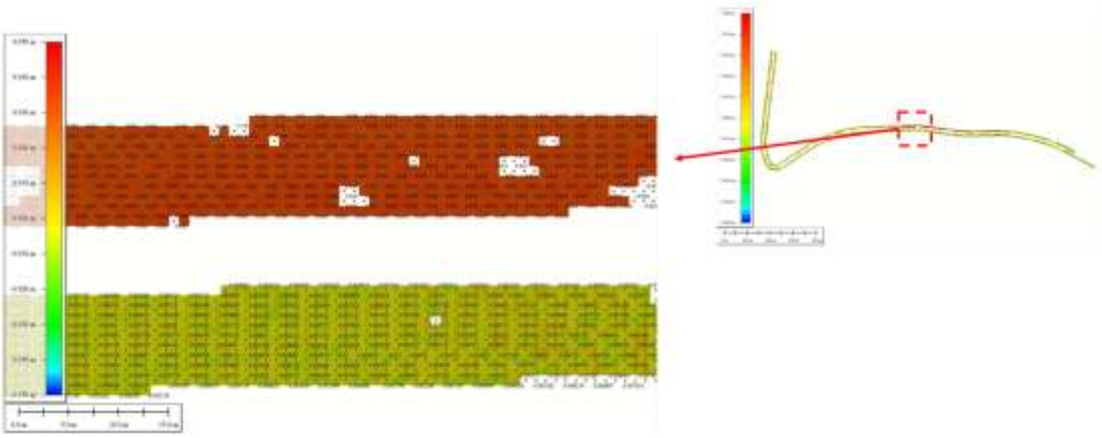

Figure 7 Subtraction of Mission 3 with Mission 4

Table 4 Subtration statistics

	Mission					
	1-2	1-3	1-4	2-3	2-4	3-4
Average (m)	0.022	0.023	0.022	0.015	0.010	0.009
Std (m)	0.011	0.014	0.008	0.008	0.006	0.008
Max (m)	0.05	0.05	0.043	0.047	0.048	0.046
Min (m)	0	0	0	0	0	0
Total Data	29,196	29,422	28,440	33,733	33,218	33,331

From subtraction result some area have higher differences value from their surroundings. Further trajectory analysis shows when MMS record the data in that area it record PDOP spike. PDOP graph can be seen below.

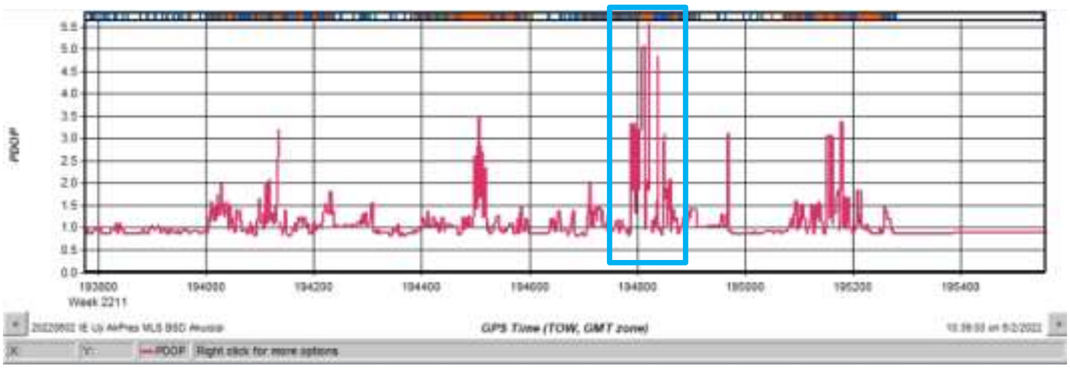

Figure 8 Mission 1 PDOP Graph

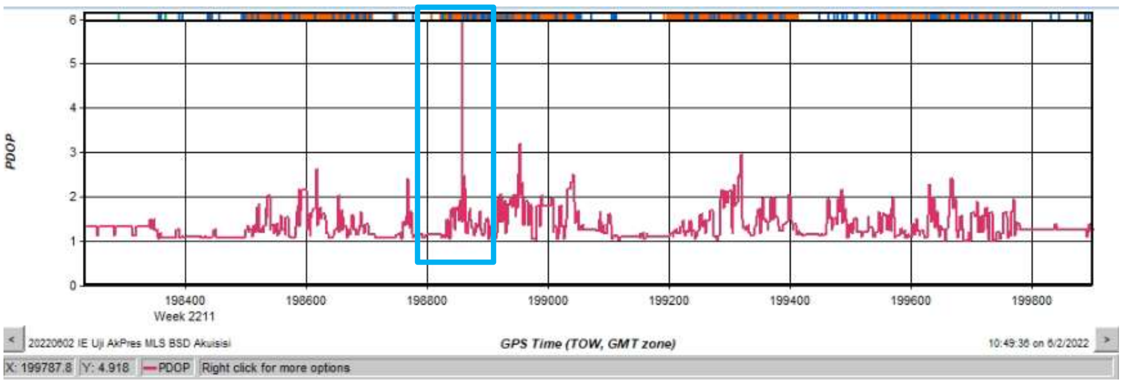

Figure 9 Mission 2 PDOP Graph

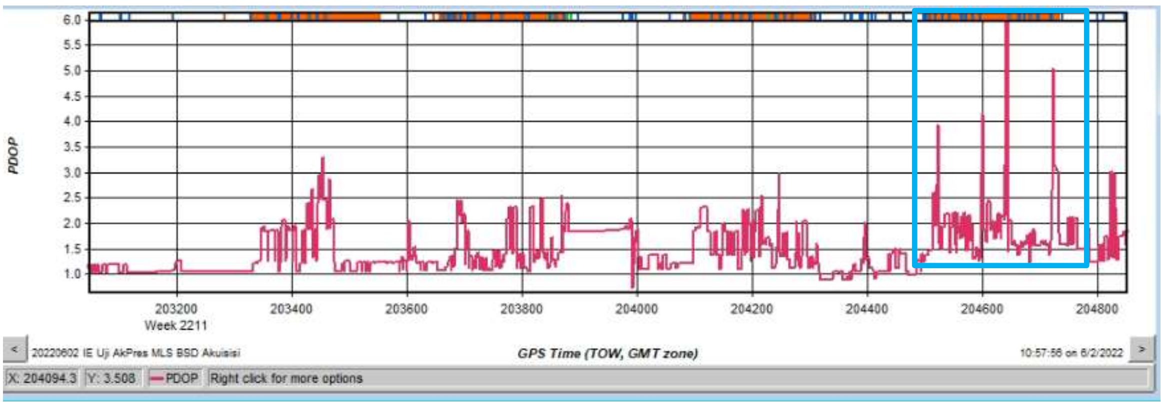

Figure 10 Mission 3 PDOP Graph

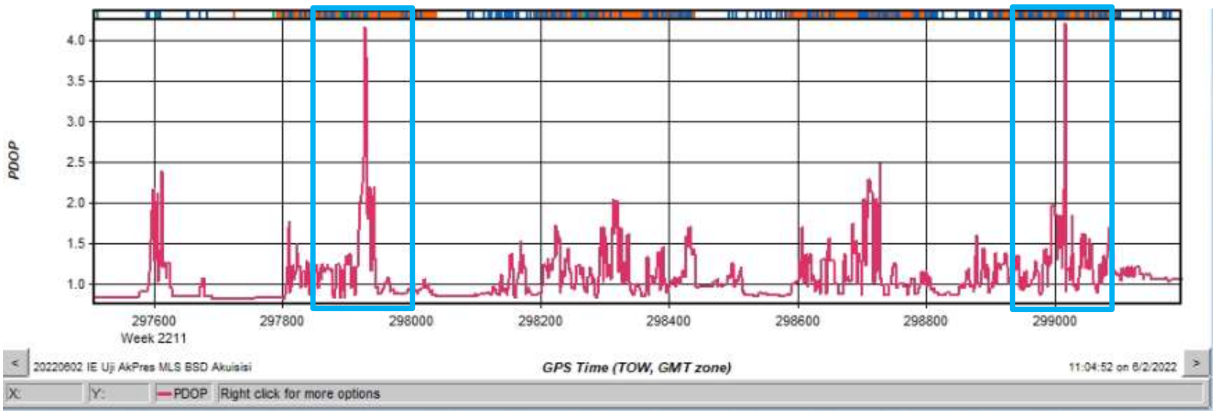

Figure 11 Mission 4 PDOP Graph

Because of spike in the PDOP this area have worst result than its surroundings (Zuo et al., 2019). Classifying this area as Bad Quality and eliminating the area from subtraction process we get result as follows:

Table 5 Subtraction Result

	Mission					
	1-2	1-3	1-4	2-3	2-4	3-4
Average	0.021	0.019	0.019	0.012	0.008	0.007
Stdev	0.009	0.009	0.006	0.009	0.006	0.005
Max	0.045	0.043	0.04	0.047	0.048	0.046
Min	0	0	0	0	0	0

By comparing the subtract result with environment data from Table 2, we can see that the environment condition have no effect on the subtraction precission of each mission.

3.4 MMS Object Analysis

MMS data that have been acquired show road marking and street lighting that can be used to analyse the data qualitatively.

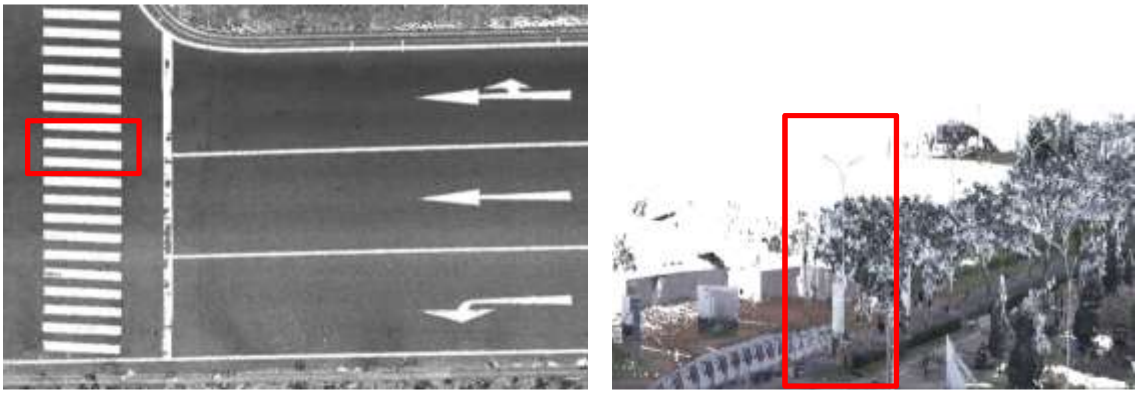

Figure 12 Road Marking and Street Light

3.4.1 <u>Road Marking</u>

Road marking is identified from point cloud intensity view, the zebra crossing mark then manualy digitized for comparison between the mission. From the result below the road marking show difference of ± 1cm at the edge of each mission

Figure 13 Road Marking

3.4.2 <u>Street Light</u>

Street light is identified from point cloud, by differentiating the color of point cloud between each mission we can see the qualitative precission of the data. As shown in figure below that comparison of mission one and two have small difference, and the rest of the mission show smaller difference. Comparison of all the mission (mission one to four) show the point cloud overlap have even distribution between each mission.

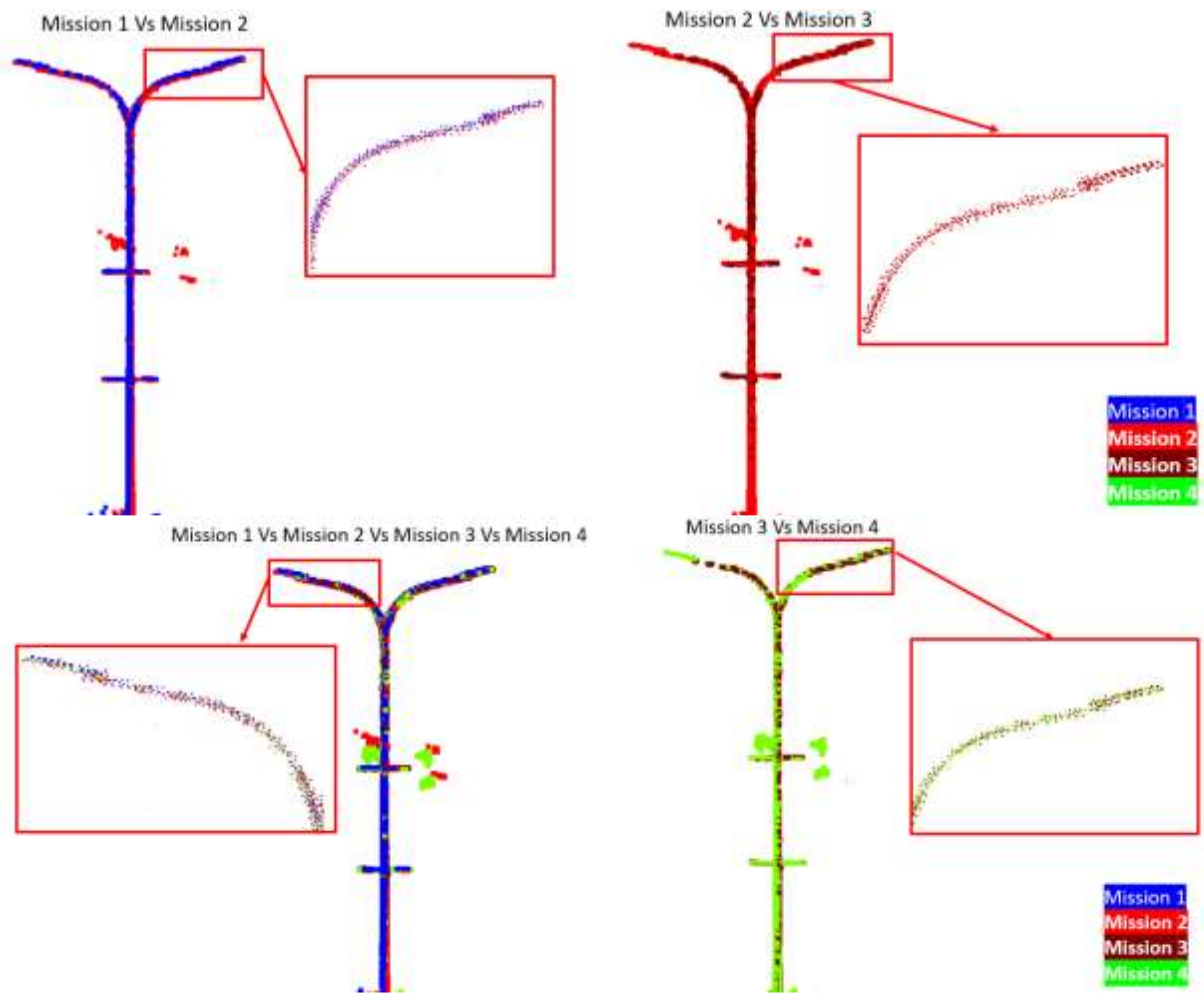

Figure 14 Street Light

4. CONCLUSION AND RECOMMENDATION

The conclusion can be concluded from this paper are :

1. The environmental conditions that we have record consists of temperature range from 27-32 C and humidity from 66% to 86% show no effect on the accuracy and precission from independent check point, sample check point and substraction of MMS data
2. The accuracy of MMS data can provide could be used to conduct a digital survey for engineering purposes within 1: 1000 map scale product based on map accuracy standard from Indonesia Geospatial Agency
3. Regarding MMS Object Analysis, the density also the precission of the pointcloud qualitatively which obtained with MMS within 40 km/h speed is quite good for 3D modelling purpose.

Recommendation for future research are :

1. It is necessary to acquire more MMS data and with more diverse environmental conditions with a greater range of temperature and humidity than the current research so that the effect of the environmental condition can be better analyzed.
2. To support a more detailed evaluation of precision and accuracy, ICPs need to be determined and distributed evenly, especially in areas of overlap between lanes and overlap between missions, as well as in locations with and without obstacles.
3. It is necessary to conduct statistical tests to validate the relationship between accuracy and humidity and temperature so that it is statistically proven that the two enviromental condition are one of the factor of accuracy and precission.
4. Qualitative analysis based on objects can be improved to quantitative analysis by comparing objects in 3 dimensions for each mission.

5. ACKNOWLEDGEMENTS

This paper and study is a part of the work practice of Toll Road Planning Division PT Hutama Karya (Persero) for Toll Road monitoring. Thank you very much to Iwan Hermawan as Executive Vice President of Toll Road Planning Division, Dhono Nugroho Vice President of Planning and Engineering at Toll Road Planning Division, and all of our coworkers for the advices during the job process.

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