Characterization and Accuracy Evaluation of the PBS-03JN LiDAR Sensor on an Automated Guided Vehicle System Against Various Types of Objects

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Batam, 23 Januari 2026

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Sarjana Terapan Teknik (S.Tr.T)
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Politeknik Negeri Batam

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Dengan judul:
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Abstract **Automated Guided Vehicles (AGVs) require a reliable obstacle detection system to ensure operational safety in industrial environments. This study evaluates the performance of the PBS-03JN LiDAR sensor using measurement error analysis and detection accuracy against variations in distance and object attributes such as color, material, and surface properties. Quantitative testing was conducted indoors under static AGV conditions. This was done by comparing the sensor reading distance with the actual distance. The results showed that the PBS-03JN LiDAR sensor detected light-colored non-reflective objects, especially cardboard, well, with low error values and nearly 100% accuracy. Conversely, reflective and transparent objects, such as clear acrylic plastic, glass, and mirrors, had high measurement error values and low accuracy due to the optical characteristics of the material to near-infrared light. The PBS-03JN LiDAR sensor meets the datasheet specifications under the best conditions, but has limitations on certain objects that need to be considered when implementing AGV safety systems in industrial work environments.**

Keywords: Automated Guided Vehicle, LiDAR PBS-03JN, obstacle detection, measurement error, detection accuracy.

I. INTRODUCTION

In modern manufacturing and logistics environments, Automated Guided Vehicles (AGVs) are widely used to automatically transport and move goods from one location to another. AGVs are designed to operate independently according to user requirements, thereby increasing efficiency in material handling processes and reducing dependence on human labor [3]. However, to ensure that AGVs can operate safely in dynamic industrial environments where they often share space with humans and other objects, safety systems are a very important factor [23]. One of the main components of an AGV safety system is a reliable obstacle detection system that is capable of recognizing various types of objects before a collision occurs. AGV safety standards state that the detection system must be able to recognize various types of obstacles with different surface characteristics at a certain distance in order to prevent workplace accidents [10], [23].

With the advancement of technology today, AGVs are equipped with a variety of sophisticated sensors, one of which is Light Detection and Ranging (LiDAR). LiDAR is a laser-based sensor that operates on the principle of time-of-flight (ToF), which measures the duration of a laser light pulse emitted to an object and reflected back to the sensor to determine the distance of the object [11]. The ToF principle is widely used in the fields of robotics and industrial automation because it can provide accurate distance measurements, has good angular resolution, and has a relatively fast and stable response time, making it suitable for AGV applications in industrial environments [2], [3], [9]. Therefore, LiDAR is a commonly used sensor on AGVs to detect the surrounding environment and function as a safety sensor during operation [10].

Although LiDAR is known for its high accuracy in distance measurement, its performance in real-world conditions is greatly influenced by the characteristics of the detected objects. Several researchers have shown that the surface color, material type, reflectivity, and surface texture of objects have a direct impact on the reflected signal received by the LiDAR sensor [1], [4], [5]. Highly reflective surfaces such as metal and glass tend to produce specular reflections, so that most of the laser energy does not return to the sensor, while dark or rough surfaces can absorb laser light energy and reduce detection quality [2], [4], [16]. In addition, infrared interference and variations in ambient lighting, such as exposure to artificial light or sunlight, can also cause errors in distance measurements or even object detection failures by LiDAR sensors [8], [17].

The PBS-03JN LiDAR is one of the safety sensors widely used in industrial AGV applications. This sensor has a scanning angle of 180°, a detection range of 0.2 to 3 meters, and a response time of approximately 180 ms, as stated in the LiDAR datasheet [7]. However, these specifications were obtained from tests using standard objects with high reflectivity, generally in the form of white surfaces of a certain size [7], [16]. These conditions do not fully reflect the operational environment of AGVs in the field, where obstacles encountered vary in color, material, and surface characteristics [1], [6], [15].

In addition to object characteristics, material properties at near-infrared (NIR) wavelengths also affect LiDAR detection capabilities. Research on the application of LiDAR in automotive shows that materials with low reflectivity in the NIR spectrum can cause errors in distance measurements or even detection failures, especially at longer distances [1], [4], [6]. Therefore, the smaller the error or difference between the distance measured by LiDAR and the actual distance, the better the accuracy and performance of this LiDAR sensor in supporting the safety of the AGV system [15], [16], [17].

Based on this, this study was conducted to assess the performance of the PBS-03JN LiDAR sensor against the datasheet specifications through direct testing on the pbscfg - Shortcut and AGVStudio applications. This evaluation focused on analyzing distance measurement errors and detection accuracy for various object colors and materials. The objective is to verify whether the sensor's detection features meet the specifications listed in the manufacturer's datasheet [7]. The results of this study are expected to provide a more realistic picture of the capabilities and limitations of the PBS-03JN LiDAR sensor, as well as serve as a technical reference in designing a safer and more accurate obstacle detection system for AGVs.

II. METHOD

This study was designed to assess the performance of the PBS-03JN LiDAR sensor installed on the Automated Guided Vehicle (AGV) system. The assessment focused on distance measurement errors and object detection accuracy for various object surface characteristics. This method is designed to provide an honest assessment of the capabilities of this LiDAR sensor when tested directly to see if it matches the specification data listed in the manufacturer's datasheet [7], [16], [17].

A. Research Design of Automated Guided Vehicle (AGV)

This study utilised a quantitative experimental method, whereby the output data was obtained through direct measurement by the PBS-03JN LiDAR sensor on the prepared test object. This research model was chosen because it allows for honest analysis of sensor performance through comparison between actual distance (ground truth) and distance from sensor readings, as used in LiDAR sensor evaluation research in automation and robotics applications [1], [16].

The research was conducted in two stages that were most relevant to the objectives of this study:

1) Basic characterisation of the PBS-03JN LiDAR sensor
This stage aimed to validate the basic performance of the sensor, including its effective detection range, distance reading stability, and sensor response uniformity to objects. The results of this stage were used as an initial reference to assess the suitability of the sensor to the manufacturer's datasheet specifications [7], [17].
2) Testing the accuracy of detection against object variations. This stage aims to test the influence of object properties, such as material, colour, and surface texture, on sensor failure and accuracy rates. This approach is in line with research revealing that the reflectivity and optical properties of materials greatly affect the performance of time-of-flight-based LiDAR sensors [1], [4], [5], [15].

All testing was conducted while the AGV was stationary in order to eliminate the impact of vehicle dynamics and ensure that the results obtained represented the characteristics of the sensor itself, as recommended in LiDAR benchmarking studies [16], [17].

B. Use of LiDAR Sensors

Figure 1 Hokuyo PBS-03JN LiDAR Sensor

In this study, the PBS-03JN two-dimensional safety laser scanner LiDAR sensor manufactured by Hokuyo is shown in Figure 1. This sensor works based on the time-of-flight (ToF) principle. It works by emitting an infrared laser pulse that is sent to an object, then measuring how long it takes for the light to be reflected back to the sensor so that the distance can be determined [11]. PBS Configurator software is used to operate the sensor, which functions to display scanning data in real time, record distance data readings, and set the sensor's detection area.

The PBS-03JN LiDAR sensor was selected because it is specifically designed for AGV safety and is widely used in industrial material transport systems [10], [23]. However, further research is needed to determine how the sensor functions on surfaces [1], [16]. These specifications were obtained through standard testing with highly reflective objects. The main specifications in Table 1, specifications of the PBS-03JN, are as follows according to the manufacturer's official datasheet [7].

Tabel 1 Specification of PBS-03JN

Model	Specification
Detection range	0,2m – 3m
Scanning angle	180°
Data communication	RS-232
Voltage	24 V DC
Maximum response time	180 ms

C. AGV System and Sensor Integration

Figure 2 Installation of LiDAR sensors on AGVs

To detect obstacles in the path of the Automated Guided Vehicle (AGV), the PBS-03JN LiDAR sensor is installed on the front of the AGV as shown in Figure 2, parallel to the floor surface so that the detection scanning field on the sensor is at the optimal height for detecting obstacles in the AGV path.

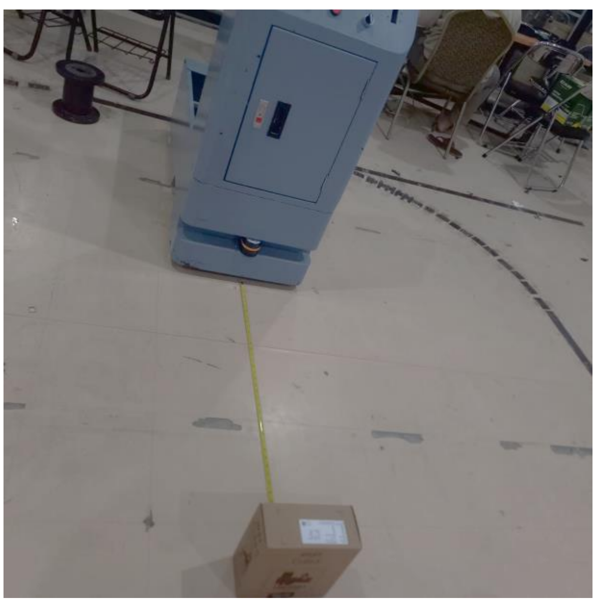

Figure 3 Front View of AGV During Testing

In Figure 3 of this study, AGVs are used as sensor mounts rather than in moving conditions. The aim is to distinguish the effect of sensor performance from vehicle navigation and control factors, as was done in studies evaluating AGV perception systems and autonomous vehicles [3], [22]. The sensor integration process is carried out through:

1) DC power supply used by the AGV system.
2) Communication interface with the computer running the PBS Configurator programme, which monitors and records data.

D. Test Objects and Variations

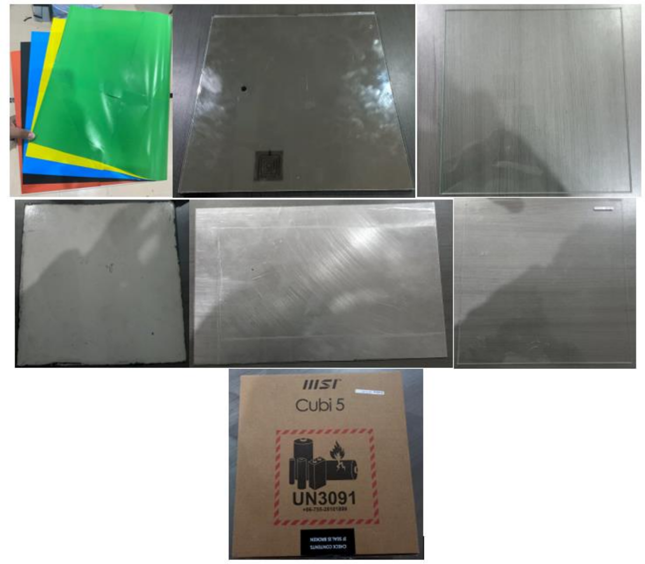

Figure 4 Variations in Test Objects

In Figure 4, the test objects are intended to demonstrate obstacles commonly encountered in indoor AGV operating environments. Factors known to influence the intensity of LiDAR signal reflection in the near-infrared (NIR) spectrum include differences in material, colour, and surface characteristics of objects [1], [2], [5]. Test variations include:

1) Material: aluminium plate, acrylic plastic plate, coloured paper, glass, acrylic and mirror.
2) Surface colours: white, black, red, green, blue, yellow and brown.
3) Testing distance: 0.3m, 0.5m, 1m, 1.5m, 2m, 2.5m, 3m.

Figure 5 Position of Test Objects Relative to Sensors at Specific Distances, such as 1 m and 2 m

The variation in object selection is a reason that shows that dark-coloured objects and certain materials can significantly absorb NIR light, increasing errors or even causing detection failures [4], [5], [15].

E. Data Collection Methods

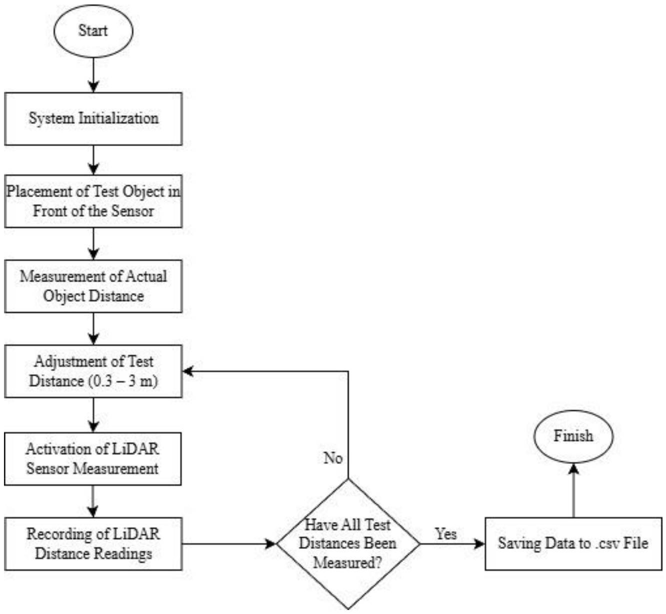

Figure 6 Data Collection Flowchart

Data collection was carried out using PBS Configurator software, which is provided directly by the LiDAR sensor itself. This program provides facilities to monitor LiDAR scanning directly, as well as recording the distance values of objects that were successfully detected, as shown in Figure 6 [7].

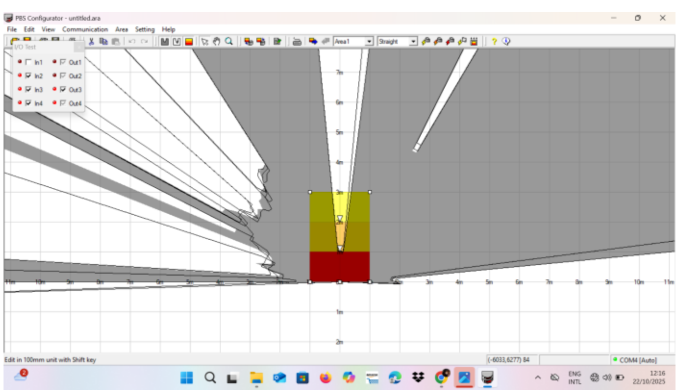

Figure 7 PBS Configurator Display When Detecting Objects

The data collection process was carried out in the following order:

1) Place the object at a predetermined distance.
2) Turn on the sensor and ensure that the scanning process runs smoothly.
3) Record the distance readings obtained from the sensor.
4) Repeat the test for each difference in object and distance.

This method is in line with the data collection approach applied in research evaluating the performance of LiDAR sensors and obstacle detection systems in autonomous vehicles, as shown in Figure 7, which is a display of the PBS Configurator when detecting objects [9], [16], [17].

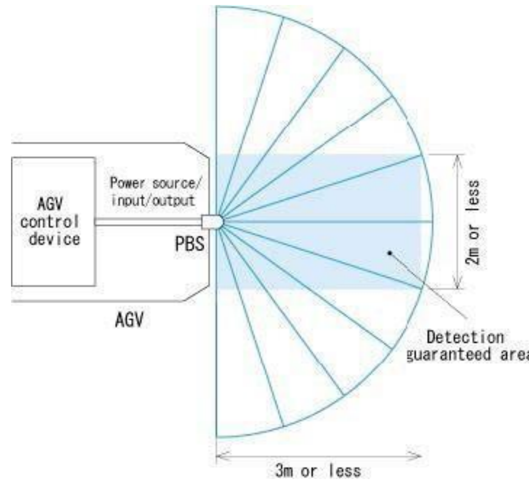

Figure 8 Sensor Detection Area

Figure 8 illustrates the detection system of the PBS-03JN sensor. The detection system consists of an AGV control that functions as the brain, as well as a photoelectric sensor (PBS) that emits light to detect objects in its vicinity. When the light beam is blocked by an object, the PBS sends a signal to the AGV control unit. The control unit then processes the signal and instructs the AGV to take action, such as stopping or changing direction. The guaranteed detection area is detected by a sector-shaped sensor, with a detection width of 2 metres and a maximum detection length of 3 metres, covering an area of 180 degrees.

F. Data Analysis Methods

To assess the performance of the PBS-03JN LiDAR sensor, data analysis was performed based on measurement error and detection accuracy parameters. The data collected is shown in Table 2 below. The distance readings from the LiDAR sensor were obtained using PBS Configurator software or serial data communication, then compared with the actual distance measured manually using a meter as a reference value. The testing was conducted at several object distance variations, namely 0.3m, 0.5m, 1m, 1.5m, 2m, 2.5m, and 3m. To facilitate the data processing, all actual distance data and sensor readings were stored in .csv file format.

The following table shows the actual distance and LiDAR detection distance data for cardboard objects.

Table 2 Actual Distance and LiDAR Detection Distance Data for Cardboard Objects

Jarak Real (cm)	Jarak baca ukur PBS_cfg Sentimeter (cm)		
	area 1	area 2	area 3
300	300	301	299.9
250	247.5	250	250
200	199.5	200.4	200
150	150	150.8	150.1
100	100	99.3	99.3
50	49.9	50	49.9
30	30	30	30

The following equation is used to calculate the measurement error value for each distance variation:

$$\text{Error (\%)} = \frac{|D_{\text{sebenarnya}} - D_{\text{LiDAR}}|}{D_{\text{sebenarnya}}} \times 100\% \qquad (1)$$

Explanation of the measurement error formula in equation (1):

1) $D_{\text{sebenarnya}}$ is the actual distance value measured using a manual tape measure in centimetres (cm) or millimetres (mm).
2) D_{LiDAR} is the distance value read by the LiDAR sensor through PBS Configurator software in centimetres (cm) or millimetres (mm).
3) $|D_{\text{sebenarnya}} - D_{\text{LiDAR}}|$ is the absolute value of the difference between the actual distance and the distance read by the sensor.
4) $\times$ 100% is the multiplier factor to convert the division result into a percentage.

These error calculations are used to determine the relative difference between the LiDAR sensor readings and the actual distance. The sensor's ability to measure the distance of objects increases in line with the error value produced.

Next, this equation is used to calculate the accuracy level of the sensor based on the measurement error value.

$$\text{Akurasi (\%)} = \left(1 - \left|\frac{D_{\text{sebenarnya}} - D_{\text{LiDAR}}}{D_{\text{sebenarnya}}}\right|\right) \times 100\% \qquad (2)$$

Explanation of the measurement error formula in equation (2):

5) $D_{\text{sebenarnya}}$, D_{LiDAR}, $|D_{\text{sebenarnya}} - D_{\text{LiDAR}}|$, as the same definition as equation (1).
6) $1 -$ is the measurement factor that converts the error value into an accuracy value. Because the value 1 represents perfect accuracy (100%), subtracting the error ratio will produce the actual accuracy value.
7) $\times$ 100% is the multiplication factor to convert the result into a percentage.

From this formula, a value of one hundred percent accuracy indicates better LiDAR sensor performance, and this value also shows how close the LiDAR sensor readings are to the actual distance values.

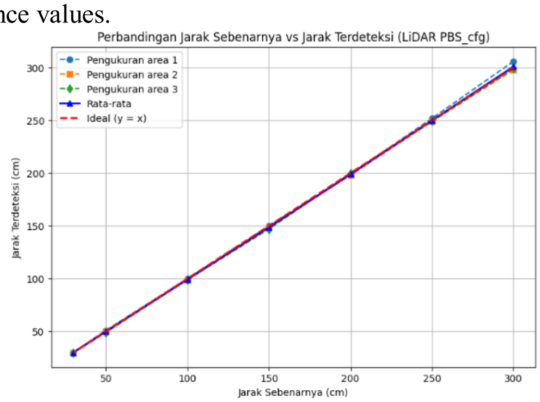

Figure 9 Graph of Actual Distance VS LiDAR Detected Distance on Kaedus Object

Figure 9 shows the overall test results, which is a graph showing the relationship between the actual distance and the distance observed by the LiDAR sensor. This graph is used to evaluate the linearity and consistency of the sensor readings. The measurement results, which are close to a straight line, indicate that the PBS 03-JN LiDAR sensor has stable characteristics and meets the technical specifications listed in the manufacturer's datasheet.

III. RESULT

This chapter presents the test results and discussion on the ability of the PBS-03JN LiDAR sensor to detect obstacles in an Automated Guided Vehicle (AGV) system. The focus of the evaluation is to assess various types of objects with different material characteristics, colours, and surface properties to evaluate distance measurement errors and detection accuracy. Using PBS Configurator software to read the sensor, the test data is compared with the actual distance measured manually.

A. *Test Results on Cardboard Objects*

Initial testing was conducted using a 21 × 22 cm cardboard object representing a non-reflective object with a matte surface and neutral color. This object was used as an initial reference because it has sufficient reflectivity stability against LiDAR laser beams. The following is a table of test results for the cardboard object.

Table 3 Cardboard Objects

Real Distance (cm)	Average reading distance PBS_cfg	Detection Error (100%)	Detection Accuracy (≥95%)
300	300.30	-0.1	99.97
250	249.17	0.3	99.87
200	199.97	0.0	99.99
150	150.30	0.2	99.87
100	99.53	0.5	99.53
50	49.93	0.1	99.73
30	30.00	0.0	100.00

The PBS-03JN LiDAR sensor demonstrated excellent performance in detecting cardboard objects at all test distances, as shown in the test results in Table 3. At each test distance, the sensor read the average distance very close to the actual distance with a relatively small detection error of less than 1%. At a distance of 30 cm, the sensor detected the actual distance, resulting in 100% accuracy. At distances of 100 cm and 200 cm, the sensor was also very stable with accuracies of 99.53% and 99.99%, respectively, demonstrating consistency.

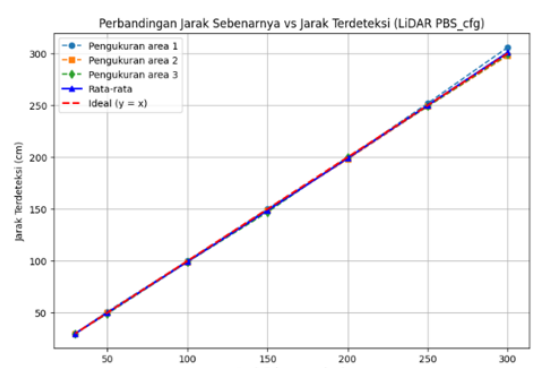

Figure 10 Cardboard Data Chart

Figure 10 shows that the PBS-03JN LiDAR sensor works very well on objects with diffuse and non-reflective surfaces. This characteristic aligns with the operating principle of time-of-flight-based LiDAR sensors, where laser beams reflected from matte surfaces tend to return stably and reliably to the receiver. Cardboard provides consistent laser signal reflections with minimal distortion, making it the optimal choice for distance testing, as demonstrated in this table.

B. Test Results on Aluminium Plate Objects

Further testing was conducted on a 30 × 21 cm aluminium plate, which generally represents metal materials with high reflectivity. Aluminium materials tend to produce specular haze, which can cause distance reading deviations.

Table 4 Aluminium Plate Objects

Real Distance (cm)	Average reading distance PBS_cfg	Detection Error (100%)	Detection Accuracy (≥95%)
300	300.40	-0.13	99.96
250	248.17	0.73	99.71
200	200.27	-0.13	99.93
150	151.53	-1.02	99.32
100	100.67	-0.67	99.33
50	50.07	-0.13	99.73
30	30.07	-0.22	99.26

Test results show that the PBS-03JN LiDAR sensor can detect aluminum plate objects with high accuracy across all test distances, as shown in Table 4. Based on the average distance readings, the sensor shows good proximity to the actual distance, with detection errors typically below 1%. The sensor detects the closest distance at 200 cm with an accuracy of 99.93%, and detects distances of 100 cm and 50 cm with accuracies of 99.33% and 99.73%, respectively. However, aluminum objects tend to produce greater errors than cardboard.

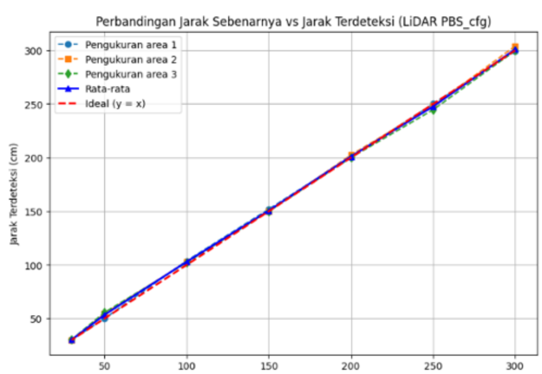

Figure 11 Aluminium Plate Data Graph

In Figure 11, this graph shows that the sensor is still considered to be functioning properly because the measurement accuracy value is still above the minimum feasibility limit, which is greater than ≥95%. This occurs because the laser beam reflection does not fully return to the receiver due to the reflectivity of the aluminium surface. As stated in the table above, there is an increase in error compared to cardboard, but the sensor is still considered feasible for detecting objects such as non-transparent metals.

C. Test Results on Iron/Metal Objects

A 30 x 30 cm iron or metal object is used to observe how different metals have different surface textures from aluminium. Iron surfaces are usually rougher, so laser reflections are more scattered.

Table 5 Iron/Metal Objects

Real Distance (cm)	Average reading distance PBS_cfg	Detection Error (100%)	Detection Accuracy (≥95%)
300	298.87	0.38	99.87
250	249.67	0.13	99.95
200	199.77	0.12	99.94
150	150.13	-0.09	99.94
100	99.97	0.03	99.97
50	50.23	-0.47	99.07
30	30.07	-0.22	99.26

The PBS-03JN LiDAR sensor shows stable and reliable detection performance for iron or metal objects at all test distances, as shown in Table 5. In general, iron objects produce greater errors than aluminum objects. At a test distance of 250 cm, the sensor detects most accurately with an accuracy of 99.95%, and at distances of 200 cm and 150 cm, the sensor detects very well with an accuracy of 99.94% respectively. The average sensor reading distance is very close to the actual distance, with a relatively small measurement error of less than 1%.

Figure 12 Iron/Metal Data Chart

In Figure 12, this graph shows that a rougher iron surface texture increases laser light reflection diffusion, resulting in a more consistent signal from the sensor. Although both are made of metal, iron and aluminium show better detection performance.

D. Test Results on Clear Acrylic Plastic Objects

Tests conducted on clear acrylic plastic measuring 30 x 30 cm showed very different results from the previous example. This is because clear plastic becomes transparent to laser light at certain wavelengths, so that the laser beam tends to penetrate and does not reflect back off the object well.

Table 6 Clear Acrylic Plastic Objects

Real Distance (cm)	Average reading distance PBS_cfg	Detection Error (100%)	Detection Accuracy (≥95%)
300	353.10	-17.70	94.10
250	439.03	-75.61	69.75
200	290.37	-45.18	77.41
150	513.20	-242.13	-61.42
100	172.63	-72.63	27.37
50	101.27	-102.53	-105.07
30	70.67	-135.56	-351.85

The PBS-03JN LiDAR sensor showed poor detection performance for clear acrylic plastic objects at all test distances, as shown in Table 6. At almost all test distances, the sensor read distances that were much greater than the actual distances, with errors far exceeding the tolerance limit. At distances such as 150 cm, 50 cm, and 30 cm, the sensor reads distances that are much greater than the actual distance, resulting in very low accuracy values and even exceeding 100%, which indicates detection failure. The results show that clear acrylic plastic cannot be reliably detected by the PBS-03JN LiDAR sensor, so it cannot be used as a safety obstacle object in AGV systems without additional sensors. This is due to the fact that clear acrylic plastic is highly transparent and non-reflective to LiDAR laser beams.

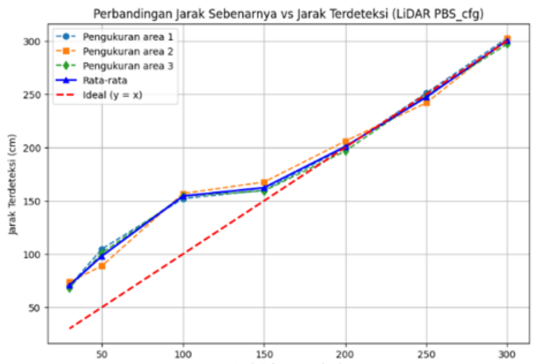

Figure 13 Graph of Clear Plastic Data

Figure 13 shows that the PBS-03JN LiDAR sensor cannot detect transparent objects, such as clear plastic. This is because the physical properties of LiDAR depend on the reflection of laser beams from the surface of objects. The table shows the sensor's failure to detect transparent objects correctly.

E. Test Results on Glass Objects

The glass was tested to observe the simultaneous effects of its reflective and transparent properties.

Table 7 Glass Objects

Real Distance (cm)	Average reading distance PBS_cfg	Detection Error (100%)	Detection Accuracy (≥95%)
300	437.20	-45.73	84.76
250	428.03	-71.21	71.51
200	439.17	-119.58	40.21
150	217.70	-45.13	69.91
100	149.27	-49.27	50.73
50	117.17	-134.33	-168.67
30	73.70	-145.67	-385.56

The PBS-03JN LiDAR sensor showed very unstable glass object detection performance across all test distances, as shown in Table 7. The sensor read close distances, such as 200 cm, 100 cm, 50 cm, and 30 cm, and showed negative accuracy values at certain distances. The average reading distance at each test distance shows a significant deviation from the actual distance, with high detection errors and accuracy values well below the threshold of acceptability (at least 95%). The results show that the PBS-03JN LiDAR sensor cannot detect glass objects correctly, and that when used as the only obstacle detection sensor in an AGV system, the LiDAR laser beam can be transmitted or reflected specularly and not return to the sensor. This condition is caused by the reflective and transparent nature of the surface.

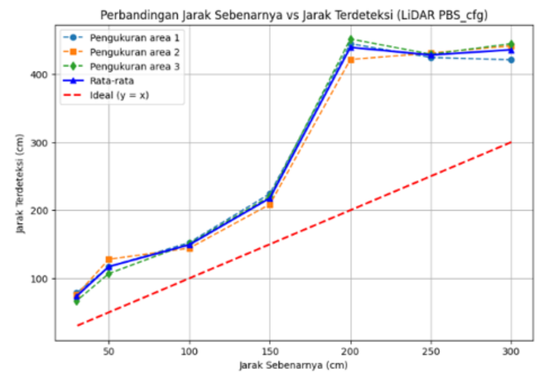

Figure 14 Glass Data Chart

Figure 14 shows that glass is a major problem for the PBS-03JN LiDAR detection system due to the combination of specular reflection and laser light transmission through glass. As a result, the reflected signal does not always return to the sensor.

F. Test Results on Mirror Objects

To assess the sensor's response to highly reflective surfaces, testing was carried out on mirrors. Mirrors reflect laser beams at very large angles.

Table 8 Mirror Objects

Real Distance (cm)	Average reading distance PBS_cfg	Detection Error (100%)	Detection Accuracy (≥95%)
300	458.73	-52.91	82.36
250	273.37	-9.35	96.26
200	237.00	-18.50	90.75
150	197.53	-31.69	78.87
100	110.00	-10.00	90.00
50	65.20	-30.40	39.20
30	40.53	-35.11	-17.04

The PBS-03JN LiDAR sensor shows unreliable detection performance for mirrored objects at almost all test distances, as shown in Table 8. In general, the sensor tends to indicate distances that are significantly greater than the actual distances, with relatively large detection errors and accuracy that is generally below the threshold of acceptability (at least 95%). However, at closer distances, such as 150 cm, 100 cm, 50 cm, and 30 cm, the sensor's accuracy decreases significantly, even reaching negative accuracy levels. This occurs because mirror surfaces are highly reflective and reflect laser beams specularly. As a result, the reflected signal does not return to the sensor or originate from other objects in the vicinity. Overall, these test results indicate that the PBS-03JN LiDAR sensor has difficulty consistently detecting mirrored objects. Furthermore, if this sensor is not combined with additional sensors in the AGV system, it may cause detection errors.

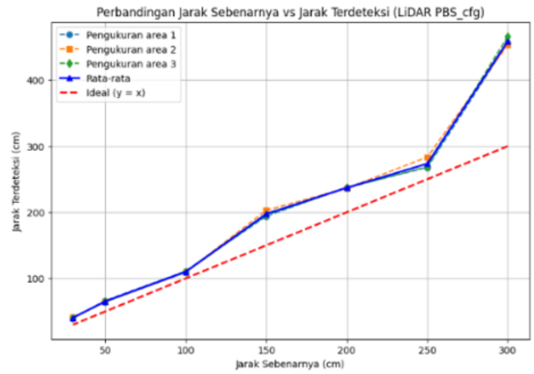

Figure 15 Mirror Data Graph

Figure 15 shows that the PBS-03JN LiDAR sensor cannot detect mirrors accurately and consistently. This is because mirrors reflect laser beams away from the receiver, making them the worst objects in LiDAR testing.

G. Test Results on Coloured Paper Objects (White, Blue, Red, Yellow, Green, and Black)

The final test was conducted to evaluate the effect of colour on sensor performance using a 30 x 30 cm coloured glossy paper object.

Table 9 Coloured Paper Objects

Real Distance (cm)	Average reading distance PBS_cfg					
	White	Blue	Red	Yellow	Green	Black
300	299.17	299.83	298.30	300.23	299.87	304.50
250	249.60	249.13	249.20	249.67	248.30	249.40
200	200.13	200.03	199.73	199.73	200.07	200.57
150	150.20	151.43	150.23	150.47	150.27	177.03
100	101.43	101.00	100.93	99.97	100.23	108.93
50	50.67	50.87	51.33	50.43	50.13	57.17
30	30.03	30.97	30.43	30.23	30.10	166.53

The test results in Table 9 show that all white, yellow, green, red, and blue papers demonstrate exceptional detection capabilities. At almost all distances, there is a low error rate and accuracy above 99%.

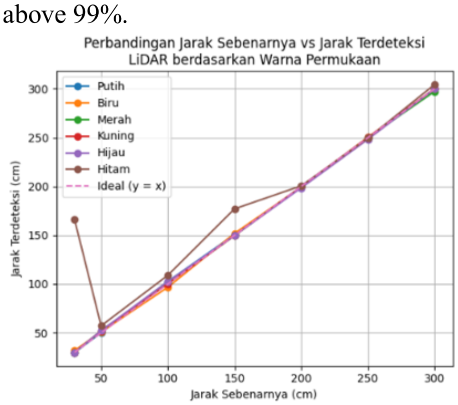

Figure 16 Colour Paper Data Chart

Because black absorbs near-infrared laser light, which reduces the intensity of reflections, black paper shows greater error, especially at medium and long distances. The colour of objects greatly affects LiDAR performance, with light colours giving the best results and black giving the worst.

IV. CONCLUSION

The results of the study show that the PBS-03JN LiDAR sensor on the Automated Guided Vehicle (AGV) system can detect objects according to the datasheet specifications, with the best performance on cardboard objects with non-reflective surfaces and light colors in the range of 0.3 to 3 meters. The test results show that the measurement error and detection accuracy values are below 1%. Metal objects also have fairly good detection results, although slightly different. Conversely, reflective and transparent objects, such as clear acrylic plastic, glass, mirrors, and dark-colored objects, have large measurement errors and low detection accuracy due to the optical characteristics of the material to near-infrared light. Thus, the PBS-03JN LiDAR sensor has reliable detection characteristics on non-reflective objects. However, it has limitations on objects with certain optical properties. Therefore, when used as an AGV safety system, the aspects of material and color variations of objects must be considered.

REFERENCES

[1] S. Muckenhuber, H. Holzer, and Z. Bockaj, "Automotive LiDAR modelling approach based on material properties and LiDAR capabilities," *Sensors*, vol. 20, no. 11, Art. no. 3309, Jun. 2020, doi: 10.3390/s20113309.

[2] X. Zhao, D. Chemodanov, J. Kim, and S. Schwertfeger, "Detection and utilization of reflections in LiDAR scans through plane optimization and plane SLAM," *Sensors*, vol. 24, no. 15, Art. no. 4794, Jul. 2024, doi: 10.3390/s24154794.

[3] Z. Liu, H. Wang, Y. Wang, and Z. Yu, "Obstacle avoidance for automated guided vehicles in real-world workshops using the grid method and deep learning," *Electronics*, vol. 12, no. 20, Art. no. 4296, Oct. 2023, doi: 10.3390/electronics12204296.

[4] G. Otgonbayar *et al.*, "Designing LiDAR-detectable dark-tone materials with high near-infrared reflectivity for autonomous driving: A comprehensive review," *Advanced Functional Materials*, Oct. 2024, doi: 10.1002/adfm.202414876.

[5] G. Otgonbayar *et al.*, "From carbon black to vibrant colors: LiDAR-detectable dark-tone materials for autonomous vehicle safety," *Advanced Functional Materials*, Nov. 2024, doi: 10.1002/adfm.202570002.

[6] Y. Sun *et al.*, "A dual-mode fusion positioning method based on 2D LiDAR and color camera," *Remote Sensing*, vol. 14, no. 15, Art. no. 3824, Aug. 2022, doi: 10.3390/rs14153824.

[7] Hokuyo Automatic Co., Ltd., *PBS-03JN Obstacle Detection Sensor: Technical Datasheet*. Osaka, Japan, 2023.

[8] K. Wang, S. Thampy, M. Sharma, and C. Chandra, "Investigation of automotive LiDAR vision in rain from material and optical perspectives," *Sensors*, vol. 24, no. 10, Art. no. 2997, May 2024, doi: 10.3390/s24102997.

[9] P. Xing *et al.*, "LiDAR-based negative obstacle detection for unmanned ground vehicles in orchards," *Sensors*, vol. 24, no. 24, Art. no. 7929, Dec. 2024, doi: 10.3390/s24247929.

[10] J. Ma, R. Duan, and J. Liu, "Ultrasonic obstacle avoidance and full-speed-range hybrid control for intelligent garages," *Sensors*, vol. 24, no. 17, Art. no. 5694, Sep. 2024, doi: 10.3390/s24175694.

[11] M. A. Kocabas, *Modeling LiDAR Signal Return for Autonomous Navigation*, M.S. thesis, Naval Postgraduate School, Monterey, CA, USA, 2021.

[12] Z. Zheng *et al*., “A lightweight lane detection network for autonomous driving,” *IEEE Robotics and Automation Letters*, vol. 9, no. 8, pp. 6778–6785, Aug. 2024, doi: 10.1109/LRA.2024.3414256.

[13] A. Javaid *et al*., “Semantic-fusion-based LiDAR place recognition with transformer architecture,” *IEEE Access*, vol. 12, pp. 169023–169038, 2024, doi: 10.1109/ACCESS.2024.3493238.

[14] M. Liu *et al*., “High-resolution automotive radar based on orthogonal multi-beam scanning,” in *Proc. IEEE Radar Conf. (RadarConf 2025)*, Arlington, VA, USA, 2025, doi: 10.1109/RADAR52380.2025.11031625.

[15] X. Song *et al*., “Semantic segmentation of urban building surface materials using multi-scale contextual attention network,” *Sensors*, vol. 22, no. 19, Art. no. 7556, Oct. 2022, doi: 10.3390/s22197556.

[16] A. Gadd, J. Newman, L. De Silva, and A. Krishnan, “Benchmarking of various LiDAR sensors for use in self-driving vehicles in real-world environments,” *Sensors*, vol. 22, no. 19, Art. no. 7146, Sep. 2022, doi: 10.3390/s22197146.

[17] [17] J. Park *et al*., “An automotive LiDAR performance test method in dynamic driving conditions,” *Sensors*, vol. 23, no. 8, Art. no. 3892, Apr. 2023, doi: 10.3390/s23083892.

[18] S. Zhao *et al*., “TraCon: A realistic traffic sign contamination dataset for autonomous driving,” *arXiv preprint* arXiv:2412.17885, Dec. 2024, doi: 10.48550/arXiv.2412.17885.

[19] L. Qin *et al*., “SafeTest: An automatic safety testing framework for autonomous driving with large language models,” *arXiv preprint* arXiv:2401.15865, Jan. 2024, doi: 10.48550/arXiv.2401.15865.

[20] B. Yang, X. Zang, Z. Dong, and P. Liang, “An automated method to register airborne and terrestrial laser scanning point clouds,” *Remote Sensing*, vol. 15, no. 2, Art. no. 442, Jan. 2023, doi: 10.3390/rs15020442.

[21] Y. Liu, “Obstacle detection and avoidance for an automated guided vehicle,” in *Automated Guided Vehicle Systems*, World Scientific, 2021, doi: 10.1142/9789814623353_0057.

[22] R. Bostelman, T. Hong, and R. Madhavan, “Performance measurement of obstacle detection systems for automated guided vehicles,” in *Proc. IEEE Int. Conf. on Technologies for Practical Robot Applications (TePRA)*, Woburn, MA, USA, 2015, doi: 10.1109/TePRA.2015.7219684.

[23] National Institute of Standards and Technology, *Review of Research for Docking Automatic Guided Vehicles*, NIST IR 8140, Gaithersburg, MD, USA, 2016, doi: 10.6028/NIST.IR.8140.

[24] M. R. Putra, A. R. Baskara, and S. Wibowo, “Analisis performa sensor LiDAR pada sistem navigasi robot mobile,” *Jurnal Nasional Teknik Elektro dan Teknologi Informasi (JNTETI)*, vol. 11, no. 3, pp. 256–264, 2022, doi: 10.22146/jnteti.v11i3.3814.

Logbook Project RE-026 Minggu ke 1

tgl. 30-09-2025 s/d tgl 01-10-2025

Identitas Mahasiswa

Nama Mahasiswa : Laura Putri Rahayu N

NIM : 4222201013

Identitas PBL dan Pembimbing

Kode PBL : PBL-RE-026

Nama PBL : Automated Guided Vehicle (AGV)

Pembimbing : Hendawan Soebhakti, ST. MT

Rincian Kegiatan Pelaksanaan Projek

(Sertakan link drive untuk bukti pengerjaan)

Progres:
=> AGV bisa mendeteksi rintangan menggunakan LiDAR
Hasil Data yang dikumpulkan
=> Eror pengukuran jarak (selisih pembacaan sensor dan jarak sebenarnya)
=> Akurasi deteksi rintangan terhadap variasi jenis material (misalnya logam, palastik, kertas, warna).
=> Waktu respon AGV ketika menerima sinyal rintangan dari LiDAR.
dimana dari progres ini yang bakal di jadikan topik untuk Tugas Akhir.

Batam, 01 oktober 2025

Pembimbing

(Hendawan Soebhakti. ST. MT)

Logbook Project RE-101 Minggu ke 2

tgl. 02-10-2025 s/d tgl 09-10-2025

Identitas Mahasiswa

Nama Mahasiswa : Laura Putri Rahayu .N

NIM : 4222201013

Identitas PBL dan Pembimbing

Kode PBL : PBL-RE-026

Nama PBL : Automated Guided Vehicle (AGV)

Pembimbing : Hendawan Soebhakti, ST. MT

Rincian Kegiatan Pelaksanaan Projek

(Sertakan link drive untuk bukti pengerjaan)

Progres pekerjaan:

=> Pengambilan data deteksi pada LIDAR menggunakan pbscfg (software) pada objek (alumunium plat, alumunium profil, akrilik, besi/metal, karton/kardus, dan kertas warna).

=> Untuk pembahasan paper diminta membuat draf nya dan diusahakan tidak menggunakan chat gpt untuk pembuatan papernya.

Batam, 09-Oktober-2025

Pembimbing

Hendawan Soebhakti. ST. MT
(............................)

Logbook Project RE-701 Minggu ke 3

tgl. ________ s/d tgl 30-10-2025

Identitas Mahasiswa

Nama Mahasiswa : Laura Putri Rahayu N

NIM : 4222201013

Identitas PBL dan Pembimbing

Kode PBL : PBL-RE-026

Nama PBL : Automated Guided Vehicle (AGV)

Pembimbing : Hendawan Soebhakti, ST. MT

Rincian Kegiatan Pelaksanaan Projek

(Sertakan link drive untuk bukti pengerjaan)

Membahas mengenai pengambilan data pada sensor lidar dengan objek kardus.

Batam, 29-Oktober-2025

Pembimbing

(Hendawan Soebhakti, ST. MT

Logbook Project RE-701 Minggu ke 4

tgl. 30-10-2025 s/d tgl 18-11-2025

Identitas Mahasiswa

Nama Mahasiswa : Laura Putri Rahayu . N

NIM : 4222201013

Identitas PBL dan Pembimbing

Kode PBL : PBL - RE - 026

Nama PBL : Automated Guided Vehicle (AGV)

Pembimbing : Hendawan Soebhakti . ST . MT

Rincian Kegiatan Pelaksanaan Projek

(Sertakan link drive untuk bukti pengerjaan)

- Menyampaikan hasil pengambilan data pada sensor LIDAR dengan objek kardus ditengah lingkaran
- Tugas selanjutnya mengambil data dengan 3 modul area pada sensor lidar.

Batam, 18 November 2025

Pembimbing

Hendawan Soebhakti, ST. MT

(................................)

Logbook Project RE-101 Minggu ke 5

tgl. 18-11-2025 s/d tgl 27-11-2025

Identitas Mahasiswa

Nama Mahasiswa	: Laura Putri Rahayu . N
NIM	: 4222201013

Identitas PBL dan Pembimbing

Kode PBL	: PBL - RE - 026
Nama PBL	: Automated Guided Vehicle (AGV)
Pembimbing	: Hendawan Soebhakti . ST. MT

Rincian Kegiatan Pelaksanaan Projek

(Sertakan link drive untuk bukti pengerjaan)

> Pengambilan data 3 Area pada LDAR dengan objeknya kardus yang menyerupai area-area deteksinya.

Batam, 11 Desember 2025

Pembimbing

Hendawan Soebhakti, ST. MT

(............................)

Logbook Project RE-101 Minggu ke 6

tgl. 27-11-2025 s/d tgl 11-12-2025

Identitas Mahasiswa

Nama Mahasiswa : Laura Putri Rahayu. N

NIM : 4222201013

Identitas PBL dan Pembimbing

Kode PBL : PBL-RE-026

Nama PBL : Automated Guided Vehicle (AGV)

Pembimbing : Hendawan Soebhakti. ST, MT

Rincian Kegiatan Pelaksanaan Projek

(Sertakan link drive untuk bukti pengerjaan)

> Membuatkan data-data yang di ambil dari deteksi object kardus, Alumunium plat, Besi, plat akrilik, orang, serta kertas warna yang lolos / Lain, untuk melihat error deteksi dan akurasi deteksi Lidar terhadap obejek-object tersebut.

Batam, 11-Desember-2025

Pembimbing

Hendawan Soebhakti. ST. MT

Logbook Project RE-701 Minggu ke 7

tgl. 11-12-2025 s/d tgl 30-12-2025

Identitas Mahasiswa

Nama Mahasiswa : Laura Putri Rahayu. N

NIM : 4222201013

Identitas PBL dan Pembimbing

Kode PBL : PBL - RE - 026

Nama PBL : Automated Guided Vehicle (AGV)

Pembimbing : Hendawan Soebhakti. ST. MT

Rincian Kegiatan Pelaksanaan Projek

(Sertakan link drive untuk bukti pengerjaan)

- Menyampaikan kan pengambilan data objek kaca dan cermin
- penulisan paper baru masuk metodologi
- mengulang pengambilan data kaca dan cermin untuk jobdesk selanjutnya dengan foto objek diambil dari belakang agv agar nampak apa yang di deteksi oleh kaca dan cermin.

Batam, 30 Desember 2025

Pembimbing

(Hendawan Soebhakti ST. MT)

Logbook Project RE-701 Minggu ke 8

tgl. 30-12-2025 s/d tgl 2-01-2026

Identitas Mahasiswa

Nama Mahasiswa	: Laura Putri Rahayu. N
NIM	: 4222201013

Identitas PBL dan Pembimbing

Kode PBL	: PBL-RE-026
Nama PBL	: Automated Guided Vehicle (AGV)
Pembimbing	: Hendawan Soebhakti, ST. MT

Rincian Kegiatan Pelaksanaan Projek

(Sertakan link drive untuk bukti pengerjaan)

- Telah menyelesaikan pengambilan data kaca dan cermin y sudah di sampaikan progres tersebut keman pro
- Lanjut mengerjakan penulisan paper.

Batam, 2-01-2026

Pembimbing

(Hendawan Soebhakti. ST. MT)