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over dimensions **DESIGN AND DEVELOPMENT OF AN OVER-DIMENSION ESTIMATION DEVICE USING THE YOLO ALGORITHM AND OPENCV**

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ABSTRACT
Operational violations of motor vehicles, particularly goods vehicles, have become an increasingly prevalent issue in Indonesia. Based on available data, 64.11% of violations are attributed to ODOL (Over Dimensions and Over Load), while the remaining 35.89% are related to violations of technical requirements, documentation, and loading procedures. Currently, the supervision of vehicle loads relies on Weigh in Motion (WIM) technology, which automatically weighs passing vehicles. However, the monitoring of vehicle dimensions is still conducted manually using measuring tools such as meters, which can lead to fatigue among officers and a reduction in measurement accuracy. To address this issue, this study aims to design an Over-Dimensions Estimator device using the YOLO Algorithm approach combined with OpenCV. The device is intended to estimate vehicle dimensions and identify dimensional violations based on variables such as Wheel Base (WB), Front Overhang (FOH), and Rear Overhang (ROH). The criteria for identifying dimensional violations are determined as follows: FOH_OD = FOH > (0.475 × WB) and ROH_OD = ROH > (0.625 × WB). This study is an applied research effort that produces a prototype device capable of detecting dimensional violations. With this tool, field officers will only need to conduct manual measurements when the device identifies a dimensional violation, thereby making the monitoring process more efficient. The device can be installed at Vehicle Weigh Stations (UPPKB) or other strategic locations, ensuring compliance with technical requirements, roadworthiness standards, and proper supervision of motor vehicle dimensions on the road.

Keywords: dimensions; estimator;

INTRODUCTION

Operational violations of motor vehicles, particularly goods vehicles, are becoming increasingly rampant in Indonesia. According to data from the Directorate of Road Transportation Infrastructure, Ministry of Transportation, in 2023, 27.95% of the 2,281,215 vehicles inspected across 84 Motor Vehicle Weighing Implementation Units (UPPKB) nationwide were found to have violations. This highlights the high frequency of such breaches, with January 2024 statistics showing that 24.93% of the 201,617 vehicles inspected by UPPKB officers were in violation (Directorate of Road Transportation Infrastructure, 2024). The majority of these violations, 64.11%, were caused by over-dimensional and overloading (ODOL), while the remaining 35.89% pertained to technical requirements, documentation, and loading procedures. Over-dimensional and overloading violations in freight vehicles significantly impact payload capacity, a critical factor in transportation efficiency. Previous studies have shown that the relationship between vehicle size and payload influences various aspects of vehicle performance, including energy consumption, mileage, and safe load distribution (Sagaria, 2021). Furthermore, such violations adversely affect toll road operators, increase accident risks, accelerate road damage, and contribute to air pollution through excessive exhaust emissions (BPTJ, 2022).Given these challenges, rigorous supervision of vehicle dimensions and payloads is essential to ensure safety, operational efficiency, and environmental sustainability.

The prevalence of ODOL violations reveals significant shortcomings in the current supervision process conducted by UPPKB officers. Vehicle dimension monitoring is still performed manually using simple tools like measuring tapes, which are labor-intensive and prone to human error. This manual process often leads to officer fatigue, reducing measurement accuracy and compromising surveillance effectiveness. In high-performance work environments, there is an increasing need for advanced technologies that enhance human performance and streamline operations. Modern performance management is increasingly driven by cutting-edge technologies that strengthen decision-making and improve organizational efficiency (Ryan S. O'Leary, 2020). To address these issues, this study proposes the "Design and Development of an Over-Dimension Estimation Device Using the YOLO Algorithm and OpenCV" as a tool to streamline dimension measurement processes. This research leverages advancements in computer vision technology for real-time automatic dimensional measurements. The proposed solution employs the You Only Look Once (YOLO) algorithm, renowned for its speed and accuracy in object detection within a single prediction step, unlike two-stage methods like R-CNN. OpenCV, an open-source computer vision library, is integrated into the device to support the YOLO algorithm, enabling efficient and resource-friendly object detection. OpenCV also offers compatibility with a wide range of video and camera formats, facilitating seamless adoption in hardware-based systems (Krishna, Reddy, Reddy, Madhav, & Sudham, 2021; Nazir & Wani, 2023).

The proposed estimation device is designed to automatically detect potential vehicle dimension violations, such as excessive length, front overhang, and rear overhang, using processed digital images. This automation minimizes the need for manual measurements, requiring officer intervention only when the device identifies a violation. By deploying this device in UPPKB units and other strategic locations, the enforcement of technical requirements, vehicle roadworthiness, and dimension supervision can be significantly improved. This technological solution is expected to enhance the effectiveness of supervision, reduce workload for field personnel, and contribute to safer and more efficient road transportation operations in Indonesia.

METHOD

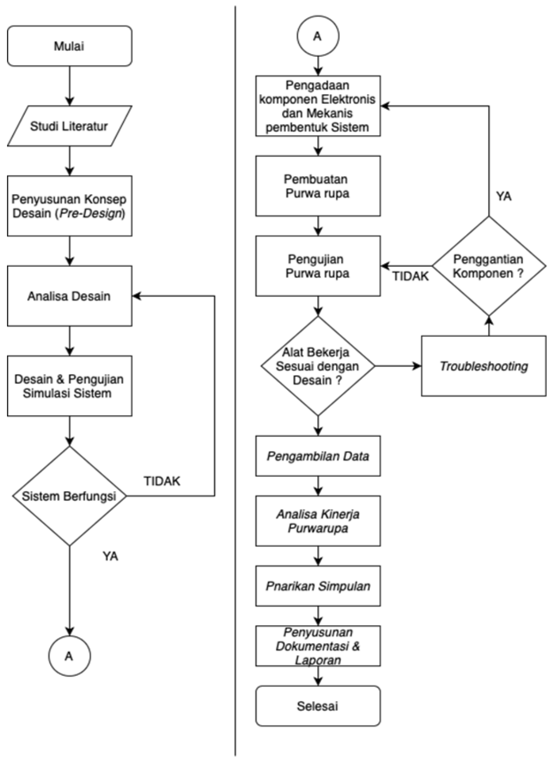

Figure 1. Research Flow Diagram

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This research is categorized as applied research, which focuses on solving problems through experimental methods in gradual and systematic stages. The research process follows the applied research steps outlined in the flowchart presented in the following figure.
In the Flow Diagram Image, this study has shown a concise sequence of research steps.
Further explanation of the details of each step will be discussed later.

Concepts and Ideas
The Overdimension Estimator tool to be developed is an instrument designed to provide information about dimension violations in vehicles, particularly freight transport, using variables such as Wheel Base (WB), Front Overhang (FOH), and Rear Overhang (ROH). The thresholds used as a reference are based on vehicle length dimensions as per the applicable regulations. A vehicle is considered overdimensioned (OD) if the FOH and ROH measurements exceed the thresholds, as indicated by the following formulas:

$$FOH_{OD} = FOH > (0{,}475.WB) \quad 1$$
$$ROH_{OD} = ROH > (0{,}625.WB) \quad 2$$

The values of these dimension-defining variables are obtained through digital image processing of live video frames captured by a surveillance camera. The image processing uses the OpenCV library to detect objects in the video frames and the YOLOv8 algorithm to identify the types of freight vehicles. The program is developed using Python scripts in Visual Studio. The image processing results are computed to determine the overdimension estimation and provide an indicator on a monitoring screen.
Software Design
The software is designed to follow an algorithm that processes digital image data captured by the surveillance camera to provide measurement indicators and display the dimension status on an LCD monitor. The program operates with Python scripts structured into a sequence of instructions (code) through a programming process using Visual Studio. The steps include:

1. Import Libraries: The system imports necessary libraries, such as OpenCV (cv2), PyTorch (torch), and YOLO (ultralytics.YOLO). The YOLO model (yolov8m.pt) is used to detect objects in video frames.
2. Variable Initialization: The system initializes program variables, including: bounding_box_info to store detected vehicle bounding box information. paused to manage whether the process is paused or not. Prev_x_center to track the previous (x) center position of the bounding box to monitor vehicle movement.
3. Object Detection: The system detects vehicles, particularly freight trucks and buses.
4. Axis Configuration Detection: Detects axle configurations for buses and trucks.
5. Object Parameter Definition: The system calculates Wheel Base (WB), Front Overhang (FOH), and Rear Overhang (ROH), draws lines for these parameters on the video frame, and labels them. Additionally, it calculates FOH and ROH percentages relative to WB, comparing them to the threshold standards to determine the overdimension status.
6. Output Visualization: The program overlays lines, text, and bounding boxes around vehicles based on detection and calculation results. It also displays FOH and ROH percentage information on the screen.

Mechanical Design
The mechanical design of the measurement tool is created using the SketchUp 2023 software. This results in a structure and dimensions as illustrated in Figure 2.

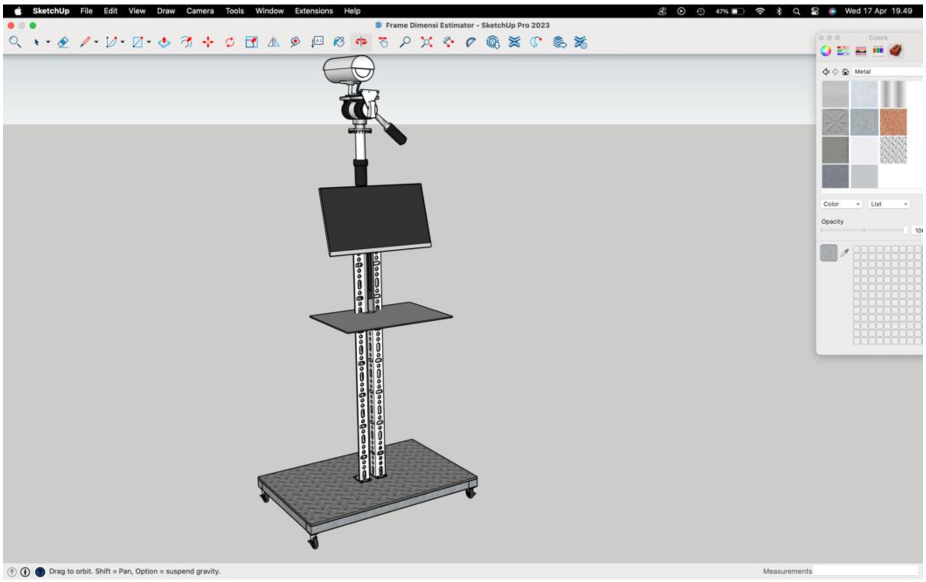

Figure 2. Mechanical Design

Electronic System Design

The electronic system is constructed by assembling the necessary components to support the system and control processes using Raspberry Pi 5, forming a block diagram as shown in Figure 3.

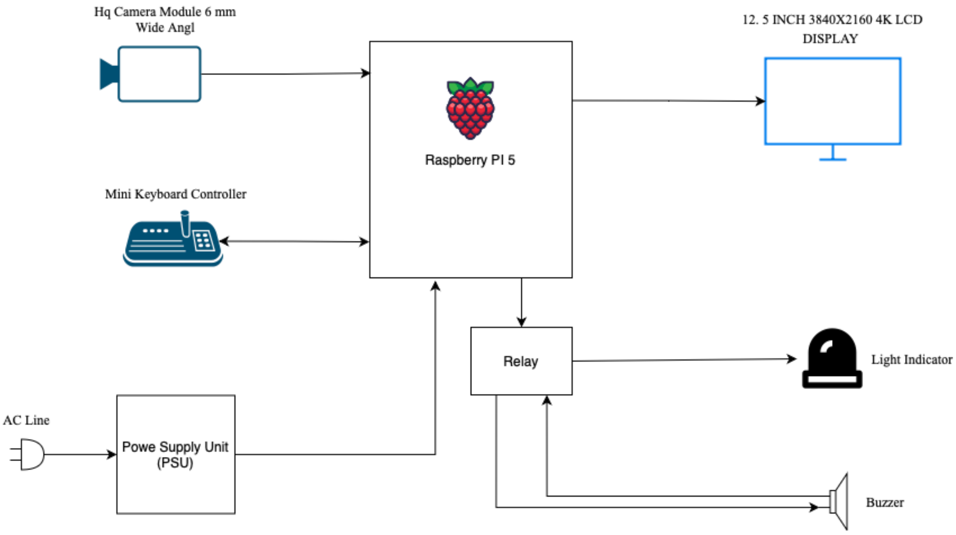

Figure 3. Block Diagram System

As illustrated in Figure 3.3, the complete monitoring tool system is composed of several sub-systems, which are described as follows:

Power Supply Unit

An external power charger charges a lithium-ion battery with a 6.5VDC output voltage and 2A charging current. A central-tap transformer (9V/1A) reduces voltage, with a full-wave rectifier diode bridge, an LM317 voltage regulator, and capacitors for voltage filtering configured as shown in the following diagram.

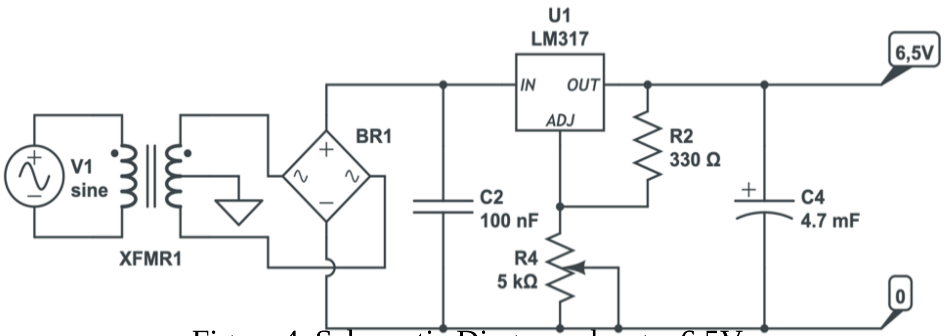

Figure 4. Schematic Diagram charger 6,5V

Raspberry Pi 5

The Raspberry Pi acts as the central processing unit for image processing and system control. The choice of Raspberry Pi 5 is based on its memory capacity and processor performance, which are adequate for executing video-based programs. Table 3.1 provides the technical specifications of Raspberry Pi 5.

Table 1.
Raspberry Pi 5 Specifications and Features

Feature	Specification
System-on-Chip	Broadcom BCM2712
Number of Cores	4 x ARM Cortex-A76
Clock Speed	2.4GHz
Memory Support	8GB LPDDR4X up to 176GB/s
Cache	64K L1 per core, 512K L2 per core, 2MB L3 shared
Graphics Processor	12-core VideoCore VII @ 800MHz

The Raspberry Pi connects to interfaces such as a keyboard, camera, monitor, relay for the buzzer, and indicator lights. The wiring diagram for Raspberry Pi 5 is shown in the following diagram.

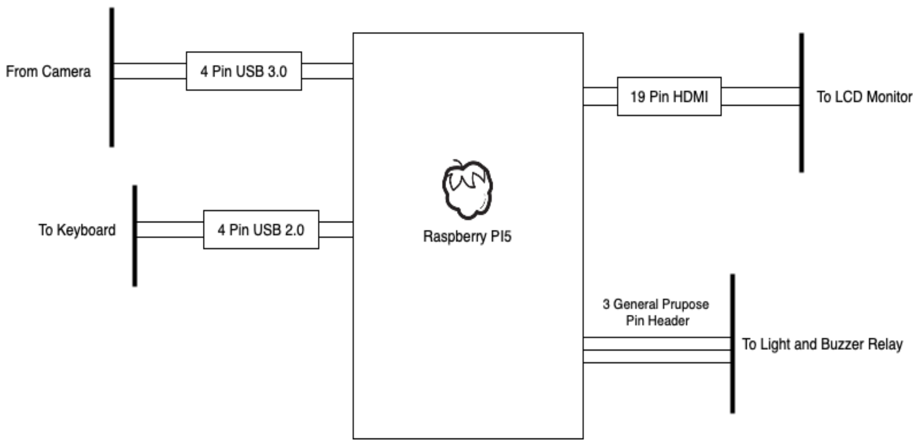

Figure 5. Wiring Diagram Configuration with Raspbberry PI 5

Camera

The camera monitors road areas and detects vehicles to estimate their dimensions. It serves as an input device for visual data, which is digitally processed by the Raspberry Pi 5. The camera selection is based on pixel density, resolution, and viewing angle. This research uses the HQ Camera Module Sony IMX477R, with specifications detailed in Table 2.

Table 2.
IMX477R Camera Specifications and Features

Feature	Specification
Sensor	Back-illuminated, 12.3 Mp, 7.9 mm diagonal, 1.55 µm × 1.55 µm pixel size
Output	RAW12/10/8, COMP8
Focus	12.5 mm–22.4 mm
Lens Standard	C-Mount, CS Mount

The HQ Camera Module Sony IMX477R connects to Raspberry Pi 5 via a 15-pin CSI ribbon cable, as illustrated in the following diagram.

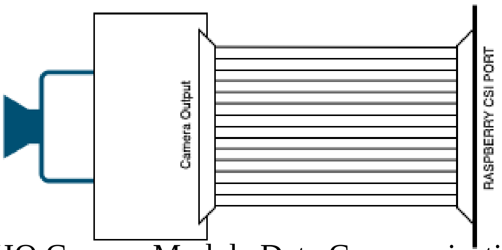

Figure 6. HQ Camera Module Data Communication Configuration

Monitor

The monitor displays detection results processed by the Raspberry Pi 5. The chosen monitor must provide high-resolution visuals and compatible data communication ports. This research uses the LM001 12.5-inch monitor, with specifications detailed in Table 3.

Table 3.
LM001 Monitor Specifications and Features

Feature	Specification
Screen Type	Capacitive Screen
Display Size	12.5 Inch
Pixel Format	(RGB) 3840x2160, UHD
Frame Rate	60Hz
Signal Interface	eDP (4 Lanes), 40 pins, CSI Connector
Input Voltage	3.3V

The LM001 monitor connects to Raspberry Pi 5 via an HDMI lane connector, as shown in the following diagram.

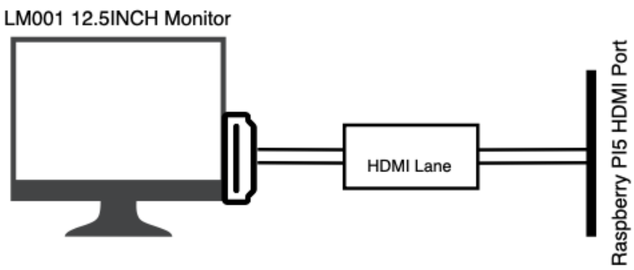

Figure 7. Monitor Communication Configuration

Relay Module

The relay module activates the buzzer and indicator lights to notify and signal when an overdimension is detected. The relay also stabilizes the output current from the Raspberry Pi 5, preventing excessive power usage by employing an external power supply. The relay module configuration is shown in the following diagram.

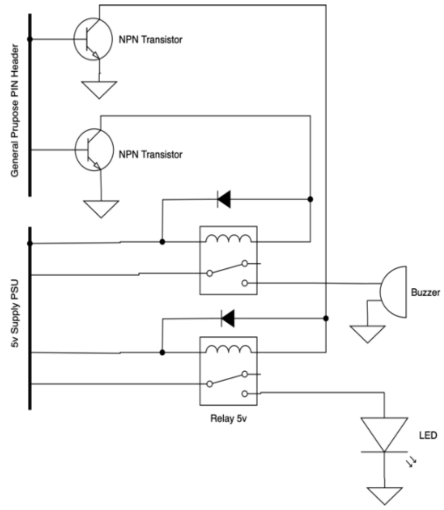

Figure 8. Relay Module

RESULT AND DISCUSSION

Electronic Systems

The components of the system outlined in the block diagram in the previous chapter, including the Raspberry Pi 4, camera, LED, buzzer, and other instrument devices, are integrated into a complete system. This integration results in the overall schematic arrangement shown in Figure 9, with the breakdown and configuration of the components detailed in the following table.

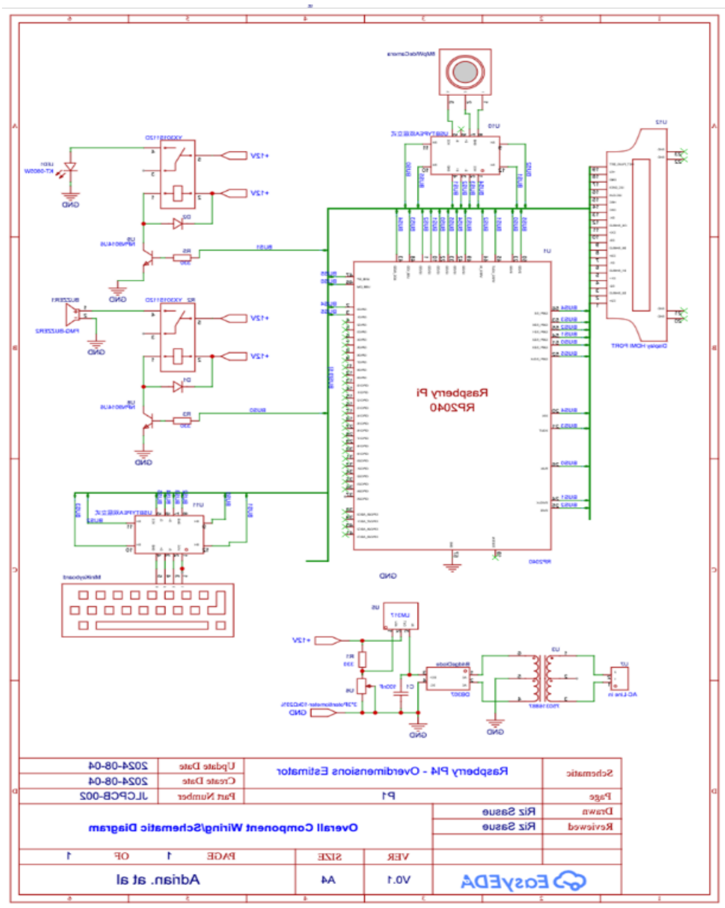

Figure 9. Overall Schematic Diagram

Software Design Results

By following the logical sequence of steps in software design, a flowchart can be created to visually represent the logical flow and the processes performed by the system in executing its functions. The preparation of the flowchart is carried out in the following steps:

1. Initialization and Data Loading:
   The system begins by initializing and loading the input video along with the YOLO model, which will be used for object detection.
2. Video Frame Looping:
   The system enters a loop to process each video frame. During each iteration, the system reads the frame and checks whether it is in a paused or running state.
3. Detection and Feature Extraction:
   If the system is not paused, the YOLO model is utilized to detect objects within the frame, particularly cars, buses, and trucks. After object detection, the Region of Interest (ROI) around the vehicle's wheels is identified to detect circular patterns representing the wheels.
4. FOH and ROH Calculation:
   Based on the detected wheels, the system calculates the Front Overhang (FOH) and Rear Overhang (ROH) by comparing the positions of the leading and trailing wheels relative to the vehicle's Wheelbase (WB). The FOH, ROH, and WB values are determined by measuring the pixel lengths of each line representing the actual dimensions. These values are calculated using equations (1) and (2).
5. Result Visualization:
   The FOH and ROH calculation results are visualized on the video by drawing bounding boxes around the detected vehicles and displaying the FOH and ROH percentages relative to the WB. The box color (red or green) indicates whether the results comply with the established standards, helping to determine whether a vehicle is over-dimensioned.
6. Program Closure:
   After all frames have been processed, the system releases the resources used, such as the video and display windows, and terminates the program.

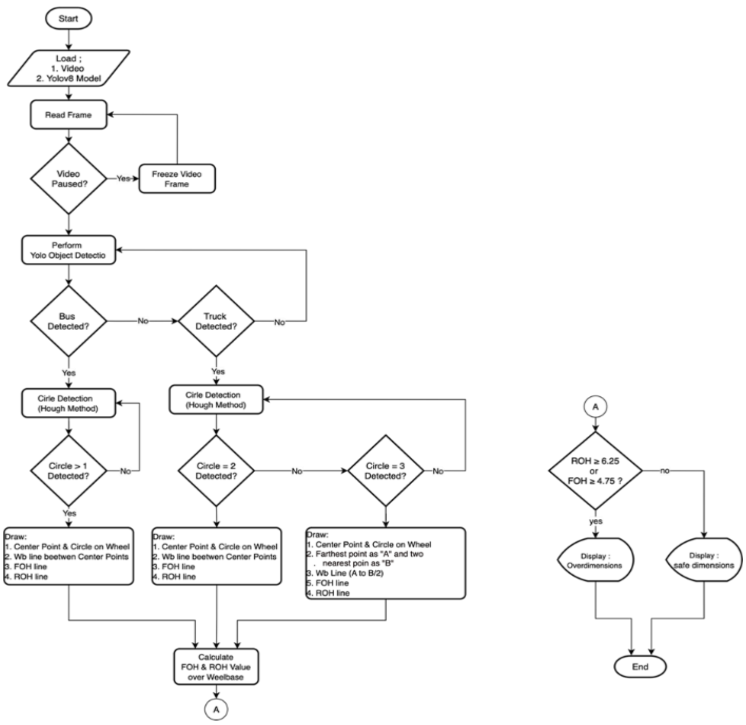

Figure 10. Program Flow Chart

After the flowchart is compiled, a logical flow is achieved and implemented in Python code using OpenCV and YOLOv8 as detection models. This includes variable initialization, object detection, and the calculation of FOH, ROH, and WB, with the program listing shown in the following figure.

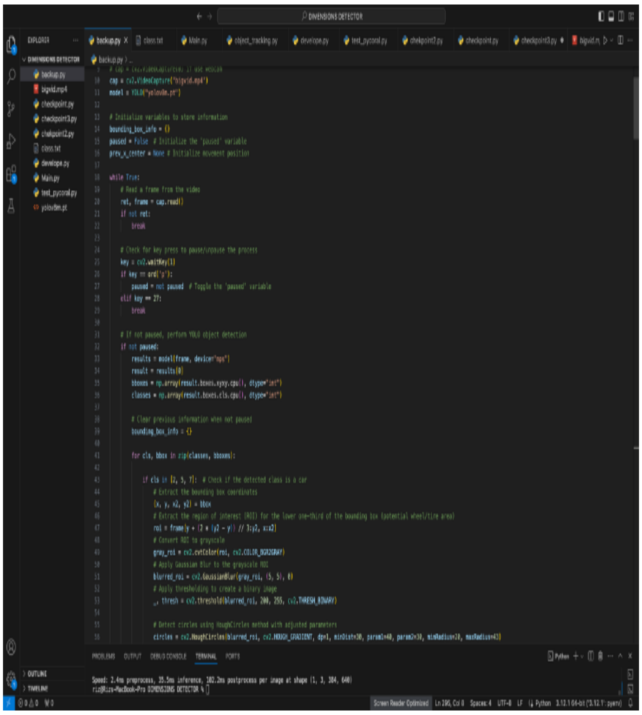

Figure 11. Python Code Programming With OpenCV

The design of the software and hardware above serves as a guide during the installation phase of electronic components, ensuring that the installation of hardware components results in the setup shown below

Figure 12. Prototype Design Results

Tool Detection Results

The prototype of the tool that has been prepared is then tested for performance by ensuring that all installed components are functioning correctly in detecting vehicles, as shown in Figure 6. The tool has been programmed with a calibration feature directly integrated into the system. In the vehicle detection process, calibration plays a crucial role as it directly impacts the accuracy and precision of the data produced. The following features are designed within the tool system to perform calibration:

1. Detection: This menu allows the user to adjust the confidence level for detecting objects. A higher confidence value results in fewer objects being detected.
2. Wheel Setting: This menu is used to set the minimum and maximum wheel sizes for detection.
3. Parameters: This menu allows the user to set the detection sensitivity of the wheels (Parameter 1) and configure the minimum distance between detected wheels (Parameter 2).
4. Direction Setting: This menu is used to set the sensitivity for detecting the direction of left/right wheel movement (threshold) and to define the maximum number of frames that will be considered as a change in direction (frames).

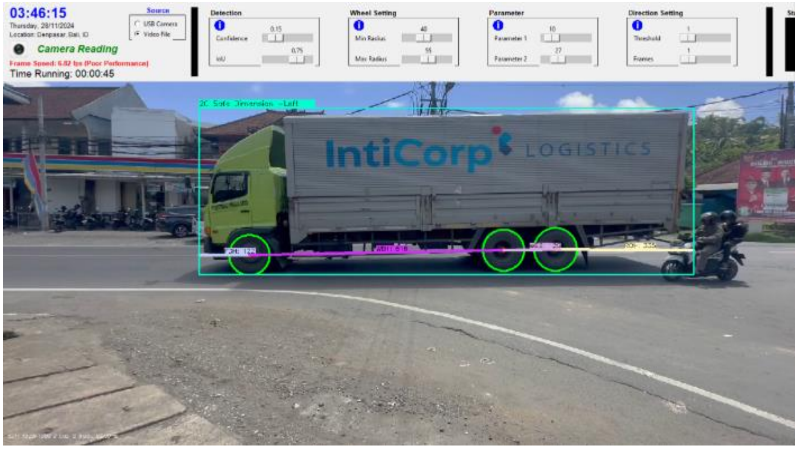

Figure 13. Tool Detection Results

From the results above, it can be concluded that the designed tool is capable of detecting vehicles and providing an over-dimensional estimate in line with the objectives of the research. The programmed menus on the tool have functioned as intended. In the next step, the tool's performance will be tested to ensure both accuracy and precision in estimating over-dimensional measurements

Tool Performance Testing

Tool performance testing is an essential part of the evaluation process to assess how well a tool or device functions according to specified specifications and requirements. The testing of the designed tool is conducted to determine its accuracy and precision in detecting the potential for over-dimensional vehicles, specifically by measuring objects such as FOH, ROH, and Wheelbase. The test includes 15 vehicles that will be detected using the Over Dimensions Estimator tool. The trial is conducted according to the following procedures:

1. Position the prototype of the tool on a flat surface at the vehicle location to ensure that the video capture area is clearly visible.
2. Calibrate the tool prototype by adjusting the confidence, wheel setting, parameter, and direction setting menus.
3. Record and display videos of passing vehicles to detect the potential for over-dimensionality.
4. Measure, calculate, and compare the vehicle measurements with the readings provided by the tool system.

The results of the prototype experiment are presented in the table below.

Table 4.

Results of the Tool Performance Test

	Hasil Baca Sistem (pixel)								Hasil Pengukuran (mm)							
No.	**FOH**	**ROH**	**WB**	**FOH/WB**	**ROH/WB**	**FOH> (0,475x WB)**	**ROH> (0,625x WB)**	**Ket**	**FOH**	**ROH**	**WB**	**FOH/WB**	**ROH/WB**	**FOH> (0,475x WB)**	**ROH> (0,625x WB)**	**Ket**
1	96	426	630	0,152	0,676	✓	✗	OD	1000	4400	6200	0,161	0,710	✓	✗	OD
2	134	345	614	0,218	0,562	✓	✓	SD	1250	3550	6100	0,205	0,582	✓	✓	SD
3	60	344	576	0,104	0,597	✓	✓	SD	620	3450	5760	0,108	0,599	✓	✓	SD
4	78	339	569	0,137	0,596	✓	✓	SD	800	3400	5750	0,139	0,591	✓	✓	SD
5	92	295	528	0,174	0,559	✓	✓	SD	900	2750	5150	0,175	0,534	✓	✓	SD
6	90	265	593	0,152	0,447	✓	✓	SD	950	2750	5350	0,178	0,514	✓	✓	SD
7	104	298	513	0,203	0,581	✓	✓	SD	1000	3100	5500	0,182	0,564	✓	✓	SD
8	110	313	544	0,202	0,575	✓	✓	SD	1100	3150	5450	0,202	0,578	✓	✓	SD
9	74	294	524	0,141	0,561	✓	✓	SD	800	2850	5350	0,150	0,533	✓	✓	SD
10	82	360	631	0,130	0,571	✓	✓	SD	900	3650	6100	0,148	0,598	✓	✓	SD
11	72	302	352	0,205	0,858	✓	✗	OD	700	3100	3550	0,197	0,873	✓	✗	OD
12	76	320	518	0,147	0,618	✓	✓	SD	750	3250	5250	0,143	0,619	✓	✓	SD
13	92	290	486	0,189	0,597	✓	✓	SD	900	2950	4850	0,186	0,608	✓	✓	SD
14	96	295	510	0,188	0,578	✓	✓	SD	900	3000	5150	0,175	0,583	✓	✓	SD
15	115	344	626	0,184	0,550	✓	✓	SD	1100	3500	6250	0,176	0,560	✓	✓	SD

Information:
OD : Over Dimensions
SF : Safe Dimensions

Referring to the results of the tool's performance test above, it can be observed that the prototype of the designed tool is capable of detecting vehicles and making accurate decisions regarding whether there is a potential for over-dimensioning. In the table above, the tool detects 13 vehicles that are safe from potential over-dimensioning based on the maximum threshold. Additionally, 2 vehicles are detected with over-dimensioning in the ROH part, exceeding the maximum threshold. The detection results from the tool can be seen in the image below $FOH_{OD} = FOH > (0,475.WB) \frac{and}{or} ROH_{OD} = ROH > (0,625.WB)$

Figure 14. Tool System Reading

Furthermore, validation is performed on the tool's detection by directly measuring and calculating the dimensions of the vehicles that pass through, as shown in the figure below.

Figure 15. Dimension Measurement

Based on the measurements and calculations performed, the results obtained from the tool system readings match the measurement results, indicating consistency. Specifically, 13 vehicles were detected as safe from potential over-dimensioning, while 2 vehicles were detected with potential over-dimensioning. The vehicles identified with over-dimensioning also showed an issue in the Rear Overhang (ROH) section, which aligns exactly with the detection made by the tool system. Given these results, all the data can be considered valid, as evidenced by the comparison between the tool prototype system readings and the direct measurement results, demonstrating that the detection accuracy is reliable.

CONCLUSION

This research focuses on the design of an over-dimensions estimator utilizing the YOLO algorithm with OpenCV. The goal is to create an instrument capable of providing information on dimension violations in vehicles, particularly freight transportation, based on three key variables: Wheel Base (WB), Front Overhang (FOH), and Rear Overhang (ROH). The system aims to detect potential over-dimensions and determine whether a vehicle violates predefined dimension thresholds. The research methodology follows a systematic process, beginning with theoretical assessment, concept development, design, troubleshooting, and analysis, leading to the drawing of conclusions. Through this research, it was found that the prototype of the designed tool is capable of detecting vehicles and making accurate decisions on whether there is potential for over-dimensioning. All the collected data is valid, as demonstrated by the comparison between the readings of the tool prototype system and the measurement results, confirming the accuracy of the detection. The over-dimension detection for FOH and ROH is based on the following criteria:FOH (OD): FOH > (0.475 × WB) and/or ROH (OD): ROH > (0.625 × WB).

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