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Traffic density prediction using the YOLO algorithm to improve traffic management in Bandar Lampung City

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Abstract

Purpose: This study aims to develop a traffic density prediction system in Bandar Lampung City to address increasing congestion caused by the rapid growth of vehicles that exceeds road capacity. The system is intended to support real-time monitoring, improve traffic management efficiency, and facilitate data-driven decision-making for adaptive traffic light control and route diversion.

Research Methodology: The study employed an experimental approach combined with prototyping. Vehicle detection was performed using the YOLO algorithm on CCTV footage collected from congestion-prone areas. The resulting data were processed and visualized through a web-based dashboard. System performance was evaluated based on vehicle detection accuracy and real-time processing speed under various traffic conditions.

Results: The developed system successfully detected vehicles from CCTV footage in real-time and displayed traffic density information through an interactive web dashboard. The system enabled adaptive traffic management by providing authorities with accurate and timely data on congestion patterns.

Conclusions: The study demonstrates that integrating YOLO-based vehicle detection with a web-based dashboard improves traffic management efficiency in Bandar Lampung City. Real-time monitoring and data visualization enhance the ability of authorities to make informed, timely decisions, contributing to more effective traffic control.

Limitations: The study is limited by the use of CCTV footage from selected congestion-prone areas, a relatively small dataset, and potential variability in detection accuracy under extreme weather or low-light conditions.

Contribution: This research provides a practical model for real-time traffic monitoring and management using YOLO and web-based visualization. The system offers a replicable framework for other urban areas facing similar traffic congestion challenges and supports data-driven policymaking.

Keywords: *Deep Learning, Traffic Congestion, Traffic Management, Vehicle Detection, YOLO*

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1. Introduction

Traffic congestion has become a major problem in urban areas, including Bandar Lampung City. This issue continues to intensify, along with the significant annual growth in the number of motor vehicles. The rapid increase in vehicle volume is not matched by the expansion and improvement of road infrastructure, resulting in frequent congestion, particularly during peak hours (Margareth et al.Margareth, Franklin, and Warouw (2015). The impacts of traffic congestion are wide-ranging, including travel delays for road users, increased fuel consumption that leads to higher transportation costs, and increased vehicle emissions that degrade the air quality. Congestion also affects the social and economic aspects of society, such as reduced work productivity, increased driver stress, and an overall decline in quality of life. This problem has become a critical concern for both the government and the public, highlighting the need for effective solutions, including improved transportation planning, the application of intelligent technologies for traffic control, and increased public awareness of alternative transportation usage.

Traffic management efforts carried out by the Bandar Lampung City Police (Polresta Bandar Lampung) through the Traffic Unit (Satlantas) and Si-TIK system still face several significant challenges. One of the main constraints is the limited availability of human resources and technology, which affects the effectiveness of traffic monitoring and management in the city. Furthermore, the current monitoring system remains largely conventional, relying on manual supervision using closed-circuit television (CCTV) cameras (Cahyono & Budiyanto, 2020). These limitations prevent the real-time detection and handling of traffic congestion, resulting in delayed responses to such disturbances. This condition underscores the need to develop more modern and integrated traffic management strategies, including the utilization of intelligent technologies, enhancement of personnel capacity, and optimization of coordination among relevant units, to create a more efficient and responsive traffic management system.

Previous studies in traffic management and prediction have generally relied on traditional statistical methods, such as linear regression, correlation analysis, and conventional time series models. These methods tend to be rigid and less adaptive to complex traffic dynamics, particularly in urban areas that experience rapid and unpredictable traffic flow fluctuations. Along with technological advancements, several studies have adopted deep learning–based approaches to model and predict traffic patterns more accurately. Although these approaches offer better adaptability to dynamic data, their implementation poses significant challenges. The main challenges include the large-scale data processing speed, efficient use of computational resources, and limitations in urban infrastructure to support real-time intelligent system integration. Therefore, the development of methods that are not only accurate but also efficient and practically applicable in urban environments has become a key focus in recent traffic-management research.

To address these challenges, this study developed a traffic density prediction system based on the You Only Look Once (YOLO) algorithm (Ayodeji et al., 2025). The system was designed to provide real-time information on traffic flow conditions at various strategic locations in Bandar Lampung City. The information generated by the system is expected to support rapid and accurate decision-making by authorities, such as adaptive traffic signal control, vehicle route diversion to reduce congestion, and operational planning by traffic officers. By leveraging YOLO's capability to automatically detect and count vehicles from video data, the proposed system offers a more accurate and responsive data-driven approach than conventional methods. The implementation of this approach is expected to enhance the effectiveness of traffic management in Bandar Lampung and support the development of a more integrated, adaptive, and sustainable urban transportation system, serving as a model that can be replicated in other cities facing similar challenges.

2. Literature Review and Hypothesis Development

2.1. Bandar Lampung City Police (Polresta Bandar Lampung)

The Bandar Lampung City Police (Polresta Bandar Lampung) play a crucial role in maintaining traffic order and ensuring smooth traffic flow through its Traffic Unit (Satlantas). Modernization efforts have been implemented through the adoption of the Si-TIK system for digital law enforcement, as well as collaboration with the Transportation Agency in implementing the Electronic Traffic Law Enforcement (Rigel, Betlen, & Simanjuntak) system (Setiawan, Meutia, & Prihantika, 2023). However, the effectiveness of traffic management is constrained by limited real-time monitoring capabilities and difficulties in detecting dynamically changing congestion points. This highlights the need to develop technology-based intelligent strategies capable of providing accurate data and supporting adaptive decision-making, thereby enabling traffic management to become more efficient and sustainable (Tanjung, Nasir, & Bahreisy, 2025).

2.2. Traffic

Traffic conditions in Bandar Lampung City have continued to deteriorate alongside the rapid growth in the number of motor vehicles, leading to recurring congestion, increased accident rates, and inefficient traffic flows across major road segments. The expansion of vehicle ownership has not been balanced by proportional improvements in road infrastructure, resulting in a persistent mismatch between traffic demand and road capacity. Previous studies consistently identify this imbalance as the primary contributor to urban congestion. Although the Area Traffic Control System (ATCS) has been introduced to improve traffic regulation, its effectiveness remains limited due to its inability to adapt dynamically to fluctuating traffic patterns in real time. The system often relies on predefined signal timing and lacks sufficient responsiveness to sudden congestion or traffic incidents. Consequently, there is a growing need for more accurate, data-driven, and real-time technological innovations capable of detecting, monitoring, and predicting traffic density. Such intelligent systems are essential to support adaptive traffic control, improve operational efficiency, and promote sustainable urban traffic flow management.

2.3. Traffic Management

Traffic management is a strategic effort aimed at improving the efficiency of vehicle movement and ensuring road user safety through the implementation of various strategies and interventions to reduce traffic accidents. These strategies include traffic engineering, sensor-based traffic signal control, vehicle restrictions in certain areas, and parking management to reduce disruptions to traffic flow (HuizenHuizen (2024). In Bandar Lampung City, traffic management efforts have been implemented through parking area restrictions, enhanced monitoring by relevant authorities, and coordination with related institutions such as the Transportation Agency.

Nevertheless, conventional approaches that rely heavily on manual observation and static monitoring systems have proven insufficient for detecting congestion patterns in real time, resulting in delayed responses to changes in traffic flow. This underscores the urgency of adopting artificial intelligence (AI)–based technologies, particularly the You Only Look Once (YOLO) algorithm, which offers fast and automatic vehicle detection capabilities. The implementation of this technology is viewed as a potential solution to enhance monitoring accuracy, support data-driven decision-making, and ultimately improve the overall effectiveness of traffic management in Bandar Lampung City (Rizk, Arkhstan, Zaki, Kandel, & Towfek, 2023)

2.4. YOLO (You Only Look Once) Algorithm

The YOLO algorithm is a deep learning–based object detection method capable of identifying objects in real time using a single-stage detection approach. Its primary advantage over methods such as R-CNN and Faster R-CNN lies in its high detection speed, making it widely applicable in traffic surveillance systems and vehicle density prediction. Recent versions of YOLO, ranging from YOLOv5 to YOLOv8, adopt advanced backbone architectures, such as CSPDarknet53, Feature Pyramid Network (FPN), and Path Aggregation Network (PAN), as well as anchor-free detection techniques. The integration of these architectures and techniques significantly improves detection accuracy, particularly under complex and dynamic traffic conditions, positioning YOLO as a leading choice for real-time, data-driven traffic monitoring and management systems (Cahyani, Mardiana, Wintoro, & Muhammad, 2024).

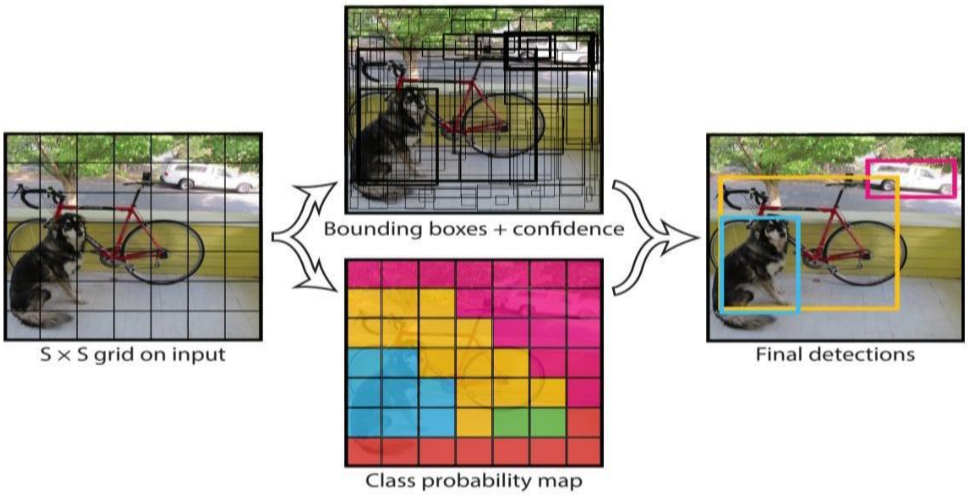

Figure 1. Illustration of the YOLO Working Mechanism

2.5. *Object Detection*

Object detection is a fundamental component in developing modern traffic monitoring systems. This technology enables the identification of various moving and static elements on roadways, including vehicles, pedestrians, and traffic signals. With this capability, the system can generate real-time data that are highly useful for accurately monitoring traffic flow conditions Dewi, Chen, Jiang, and Yu (2022). The collected data not only support traffic density analysis at various strategic locations but also assist in decision-making for adaptive traffic signal control. Consequently, object detection technology plays a vital role in creating more responsive, efficient, and data-driven traffic management systems, while also providing a foundation for the development of intelligent and sustainable urban transportation systems.

2.6. *Deep Learning*

Deep learning plays a critical role in traffic detection systems using convolutional neural networks (CNNs), which can extract image features with high precision. The integration of CNNs into the YOLO algorithm enables fast and efficient vehicle detection, supporting real-time monitoring and traffic density analysis in urban environments (Sunarso, Chairani, Triloka, & Kurniawan, 2025).

2.7. *Google Colaboratory*

Google Colaboratory was used as the primary platform for training the YOLO model because it provides free access to cloud-based graphics processing units (GPUs). This platform allows researchers to conduct deep learning model training at high speeds without relying on expensive or large-scale hardware. By leveraging the cloud infrastructure of Google Colab, model training can be performed efficiently, flexibly, and cost-effectively, while also supporting experiments with large and complex datasets. In addition, the use of this platform facilitates collaboration among researchers and enables easier replication and validation of experiments, thereby strengthening the reliability and effectiveness of YOLO-based vehicle detection systems for urban traffic management.

2.8. *Roboflow*

Roboflow is utilized for dataset processing in this study by providing features for annotation, augmentation, and integration with deep learning models. This platform improves the quality of vehicle training data, enabling the YOLO model to detect objects with higher accuracy and stability.

2.9. *MongoDB*

MongoDB, a leading NoSQL database management system, was employed in this study to store the object detection results generated by the YOLO model in JSON format. The main advantage of MongoDB lies in its ability to efficiently handle unstructured or semi-structured data, allowing for fast and flexible data storage and retrieval. These characteristics make it particularly suitable for supporting real-time traffic monitoring systems, where large and diverse volumes of data are continuously generated by vehicle detection processes. Using MongoDB, the system not only stores data efficiently but also enables dynamic data processing, querying, and analysis, allowing information on traffic density and vehicle movement to be accessed and utilized directly for faster and more accurate operational decision-making (Putra et al.Putra, Rahmadi, and Armin (2025). The application of MongoDB in this context supports the development of more responsive and data-driven traffic management systems, in line with the needs of modern cities facing dense and dynamic traffic flows.

2.10. Website

A PHP-based website is developed in this study as a data visualization interface for the traffic monitoring system Sinlae, Irwanda, Maulana, and Syahputra (2024) This platform is designed to allow relevant stakeholders, such as the Transportation Agency and the Police, to access real-time traffic density information directly. Through this website, vehicle detection data and traffic flow analysis are presented in an easily understandable format via interactive dashboards, complete with graphs, maps, and other visual indicators (Husnul, Nurhatisyah, and Friadi Husnul, Nurhatisyah, and Friadi (2023). The primary function of this website is to support rapid decision-making in traffic management, including adaptive traffic signal planning, vehicle route diversion, and monitoring critical congestion points. The implementation of this web-based visualization interface not only enhances data accessibility and transparency but also supports the sustainable integration of the monitoring system, enabling traffic management in Bandar Lampung City to be more responsive, efficient, and data driven.

3. Research Methodology

This study applied an experimental approach using the prototyping method to design and develop a traffic density prediction system based on the YOLO algorithm.

3.1. Location and Data

The research data were obtained from traffic CCTV recordings owned by the Bandar Lampung City Police (Polresta Bandar Lampung), installed at several congestion-prone locations, including Z.A. Pagar Alam Street and Teuku Umar Street. From these video recordings, a dataset consisting of vehicle images was systematically extracted and used as training data in the development of a YOLO-based traffic density prediction model (Karim & Aâ, 2019).

3.2. Data Processing

The vehicle dataset was processed using the Roboflow platform to conduct systematic image annotation and data augmentation. This process produced a dataset that was more diverse and representative than the original data by introducing variations in lighting conditions, object scale, orientation, and background complexity. The enhancement of dataset quality aimed to reduce bias, improve model generalization, and strengthen the robustness of the YOLO model, thereby enabling higher vehicle detection accuracy and more reliable performance in real-time traffic monitoring scenarios.

3.3. Model Development

The model was trained using YOLOv8 on the Google Colaboratory platform with GPU support. YOLO was selected because of its superior performance in real-time object detection.

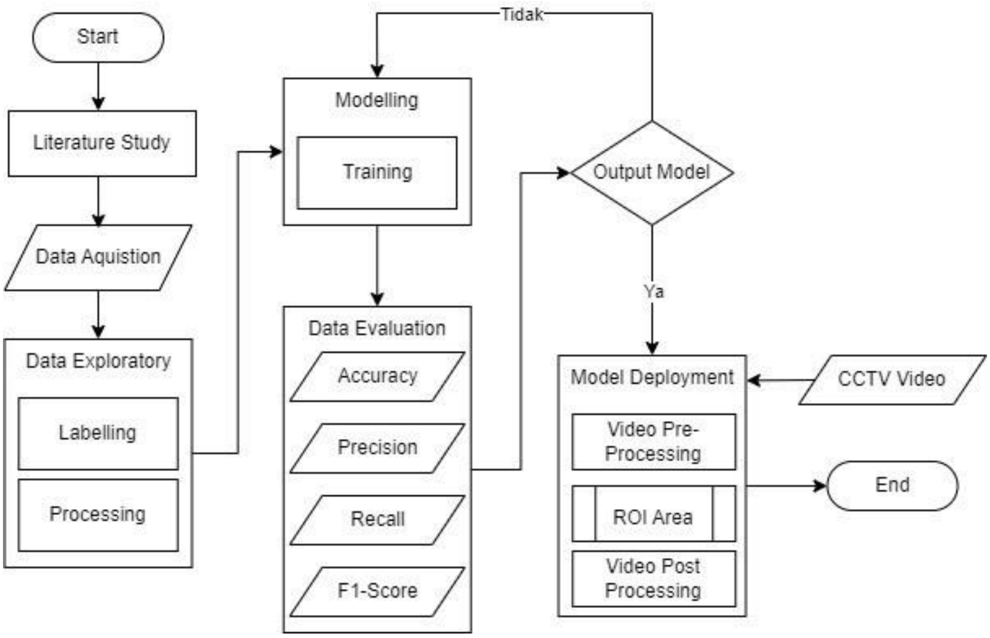

Figure 2. Stages of System Development Using YOLO

3.4. System Implementation

The vehicle detection results generated by the YOLO model were stored in a MongoDB database, which enabled efficient and flexible data management in the JSON format. These data were then integrated and displayed through a PHP-based website that functioned as a real-time interactive dashboard. The website is designed to allow both the police and the Transportation Agency to directly access traffic density information, monitor vehicle flow conditions, and make responsive decisions. Through this visualization interface, the system not only presents data in an easily understandable format but also supports more effective data-driven traffic monitoring, analysis, and control. The implementation of this web-based system aims to improve the efficiency of urban traffic management, enable rapid responses to congestion, and support strategic decision-making for maintaining traffic flow and safety.

3.5. System Evaluation

The system performance was evaluated by measuring vehicle detection accuracy under various traffic conditions, including congested and uncongested situations, as well as daytime and nighttime scenarios Sonnleitner, Barth, Palmanshofer, and Kurz (2020) his evaluation aimed to assess the extent to which the YOLO model can accurately recognize and detect vehicles in dynamic urban environments. In addition, the real-time data processing speed was thoroughly analyzed, focusing on the system’s ability to deliver instant information and support rapid decision-making by the police and the Transportation Agency. Performance testing included an analysis of the system response time, frame-per-second processing capability, and detection consistency across complex traffic conditions. Thus, the evaluation emphasized not only accuracy but also ensured that the system operated effectively and reliably in supporting real-time urban traffic management.

4. Results and Discussion

This study produced a YOLO-based traffic density prediction system that was integrated with a web-based dashboard. The system is capable of detecting vehicles from CCTV recordings installed at congestion-prone locations in Bandar Lampung City and presents the results through interactive statistical visualizations. The developed dashboard is equipped with a main menu that allows users to access the vehicle detection results, traffic density data, and user feedback features. With this design, the system not only provides real-time information but also supports data-driven decision-making for the police and the Transportation Agency, enabling traffic flow management to be conducted more efficiently, responsively, and evidence-based (Pasaribu, Awangga evidence (Pasaribu, Awangga, Batubara, & Herlingga, 2024).

Surya and Wahyuni (2025) State The implementation process began with the collection of CCTV recordings, followed by video-to-image conversion, object annotation, and YOLOv8 model training. The dataset was divided into training, validation, and testing sets, with vehicle categories including cars, motorcycles, buses and trucks. The evaluation results indicate that the proposed system achieved an average detection accuracy of 87.9%. Car detection achieved the highest accuracy (100%), whereas motorcycle and truck detection accuracies were relatively lower owing to limited data and dynamic traffic conditions.

The application of a confusion matrix and the calculation of precision, recall, and F1-score demonstrated that the model was sufficiently reliable for real-time traffic monitoring Sathyanarayanan and Tantri (2024) The main weakness lies in detecting small vehicles or vehicles partially occluded by others, which results in false negatives. Nevertheless, overall, the system is capable of providing accurate traffic density information and supporting decision-making, such as adaptive traffic signal control and traffic flow diversion. By integrating the model into a MongoDB database and web-based interface, the system can be directly utilized by traffic authorities to monitor road conditions. These findings confirm that YOLO can serve as an effective solution for enhancing data-driven traffic management efficiency in urban settings.

5. Conclusions

5.1. Conclusion

In this study, a YOLO-based traffic density prediction system integrated with an interactive web dashboard was developed. The system is capable of detecting vehicles in real time from CCTV recordings with an average accuracy of 87.9%, where cars are detected with the highest accuracy, whereas motorcycles and trucks still face challenges owing to data variation and dynamic traffic conditions. The results indicate that this approach is effective in providing fast and accurate traffic density information, thereby supporting data-driven decision-making by traffic management authorities. Integration with a database and web-based visualization makes the system practical for adaptive traffic management in urban environments.

5.1. Implications

This study has several important implications for both theory and practice in the field of intelligent traffic management. From a theoretical perspective, the findings strengthen the empirical evidence that deep learning based object detection, particularly the YOLO algorithm, is effective for real-time traffic density prediction in complex urban environments. The integration of YOLO with a web-based visualization system demonstrates how artificial intelligence can bridge the gap between traffic data acquisition and actionable decision-making, contributing to the growing body of research on data-driven urban transportation systems

From a practical standpoint, the proposed system provides traffic authorities with accurate and timely information that can support adaptive traffic signal control, congestion mitigation strategies, and rapid operational responses. The implementation of real-time dashboards enhances situational awareness for the police and transportation agencies, enabling more efficient coordination and evidence-based policy decisions. Moreover, the use of scalable technologies such as MongoDB and web-based interfaces implies that the system can be replicated and adapted in other cities facing similar congestion challenges, supporting sustainable and intelligent urban traffic management.

5.2. Suggestions

Based on the findings and limitations of this study, several recommendations are proposed for future research and system development. First, future studies should expand the dataset by incorporating CCTV footage from a wider range of locations and traffic conditions to improve detection accuracy, particularly for motorcycles and partially occluded vehicles. Second, further research is recommended to integrate additional sensors or data sources, such as GPS data, traffic signals, or weather information, to enhance prediction robustness under extreme environmental conditions. In addition, future system development should consider integrating the model directly with adaptive traffic control systems to enable automatic traffic signal adjustments in real time. Performance optimization techniques, such as model pruning or edge computing, are also suggested to improve processing speed and system scalability. Finally, policymakers and local governments are encouraged to adopt and evaluate AI-based traffic monitoring systems as part of smart city initiatives to support long-term, sustainable traffic management strategies.

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