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Automatic BRT Lane Divider Shifter

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***Abstract*— The increase in urban population, high density of vehicles at a single point, the poor quality of roads and the use of aged traffic management systems have been leading to problems of heavy traffic jams in metropolitan cities. This results in traffic jams, increased travel durations, elevated fuel usage, and a drop in efficiency for city areas. Bus Rapid Transit (BRT) lanes are not continuous, as they do not function without buses operating. It significantly decreases usable road capacity and increases congestion in adjacent traffic lanes. Consequently, the BRT system is not able to provide the benefits for which it was originally designed. To tackle this problem, this study presents an Automatic BRT Lane Divider Shifter. Utilising ultrasonic detection to know when a bus is present, this intelligent motorised system will change lanes in real-time. The system uses a microcontroller to analyze traffic data and perform automatic shifting of the road divider. This enables mixed traffic access in BRT lanes when buses are not on the scene, without threatening bus priority. Prototype trials have shown the system would enhance traffic flow, reduce vehicle queues and improve existing road capacity as well as overall transportation efficiency. It is meant to be cost-effective, scalable and compatible with existing urban infrastructure with minimal disruption. This solution enhances efficiency and safety as it also lays a solid groundwork for future AI-driven traffic prediction and smart city development.**

***Keywords*— BRT lane, urban mobility, dynamic lane shifting, traffic congestion, lane divider mechanism, smart transportation, Arduino control system.**

I. Introduction

In rapidly expanding cities worldwide, traffic jams have emerged as one of the most significant challenges. In 2024-25, India introduced over 20 million new vehicles, marking an 11.6% increase Urban planners cannot resolve this issue simply by constructing more roads, as it results in traffic jams, delays, and congestion. Recent global mobility reports indicate that drivers in large Indian cities spend 100 to 150 hours annually trapped in traffic, highlighting the inefficiency of current road systems. A major factor contributing to this is that dedicated bus lanes in Bus Rapid Transit (BRT) corridors are frequently left unused. When buses are absent, the lanes remain empty while the adjacent lanes become congested with vehicles. This issue needs to be resolved.
Traditional traffic systems rely on fixed lanes that remain unchanged regardless of traffic conditions, resulting in inefficient road usage and increased waiting times. In today's time, there is no automatic system in existence that allows regular vehicles to use BRT lanes without compromising bus safety or their priority. This inefficient use of road space worsens traffic flow and complicates movement for people in cities. To address these problems, this document presents the BRT Lane Divider Shifter, an intelligent and automated system designed for dynamic lane management.

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It employs sensors to identify buses and an electromechanical system based on a microcontroller to adjust lane dividers when necessary. When no buses are arriving, the divider moves to form additional lanes for mixed traffic, allowing for more efficient use of the road. When a bus arrives, the barrier automatically moves back to its original position, allowing the bus to pass through unobstructed. This adaptable system helps decrease traffic, cut down on travel time, and enhance the efficiency of current infrastructure without requiring expensive road expansions. It also provides a scalable, efficient, and secure solution that can be integrated into modern urban traffic management systems, enhancing traffic flow, increasing commuter satisfaction, and improving the efficiency of public transportation during both peak and off-peak hours.

Furthermore, the automatic BRT Lane Divider Shifter aligns well with the increasing global emphasis on smart cities and intelligent transport systems (ITS). It employs real-time monitoring and automation to enable data-based traffic control, contributing to more sustainable urban transportation. By making better use of road space, it also minimizes unnecessary idling, fuel consumption, and vehicle emissions, thereby promoting environmental sustainability.

The system is also economical and not overly invasive, allowing it to be easily integrated into existing BRT systems with minimal modifications. This is particularly crucial in densely populated cities of developing nations, where limited resources and available space pose significant challenges.

II. Literature Review

Urban traffic congestion poses a significant problem in swiftly growing metropolitan areas because of the increasing volume of cars on the streets. Bus Rapid Transit (BRT) systems were established to enhance public transport efficiency through the designation of exclusive lanes; nonetheless, the underuse of these lanes during non-BRT times leads to ineffective utilization of road space. As a result, there has been increasing interest in utilizing dynamic lane management, intelligent transportation systems (ITS), and automated movable divider technology to enhance the efficiency of road space utilization. This literature review highlights current and past contributions to dynamic BRT lanes, lane reversal methods, connected vehicle technologies, and movable barrier technologies.

In a recent study, Luo et al. [1] proposed a dynamic moving-block lane concept for Bus Rapid Transit (BRT) using connected vehicle technology. The researchers emphasised the need for real-time communication between buses and road infrastructure so that dedicated lanes can be assigned dynamically. Their findings indicated that vehicle-to-infrastructure (V2I) communication can improve traffic movement and contribute to reducing road congestion. Nonetheless, the approach focused mainly on communication systems rather than on portable partitions.

Likewise, Lindsay [2] studied an engineering evaluation of adjustable barrier systems for managing lanes. The study was based on whether adjustable lane dividers could work effectively from a mechanical and structural perspective in busy urban environments. The findings showed that movable barriers could be helpful and effective; however, the limitation was that the study did not include features such as automation or smart sensing technologies.

Sharma and Rao [3] introduced a bollard system that can move back on its own. This system uses cameras and sensors to control the barrier. The study said that monitoring traffic in a timely manner is very important for managing traffic efficiently. The system was mainly made to control which individuals can enter, not to manage lanes all the time. Their system is an example of using cameras and sensors for access control.

Moreover, a study by Patil et al. [4] demonstrates a lane barrier that can be adjusted. Their system uses sensors and actuators and is controlled by a microcontroller. The system helps to manage lane changes based on traffic conditions. This design is economical and practical. It mainly focused on making prototypes. However, the study did not do an analysis of traffic on a large scale.

Recently, Li et al. [5] came up with a way to manage traffic in cities. They made a system that changes the direction of lanes when there are a lot of vehicles on the road. This system helps to reduce traffic jams. The system works by changing the lane directions when it gets busy. They also found out that this system really helps to reduce traffic congestion. However, they used computer models to figure out how the traffic was moving, of actually changing the lanes.

Similarly, Choi et al. [6] added to the idea by proposing a Connected and Automated Bus Rapid Transit (CA-BRT) system that employs deep reinforcement learning. The authors' study showed intelligent decision-making for BRT priority allocation applying AI-based optimisation methods. Although highly effective in simulations, adapting to current infrastructure remains a challenge.

In an earlier study, Viegas and Lu [7] introduced the idea of intermittent bus lane priority, where bus lanes are temporarily activated when required. This groundbreaking research laid the theoretical groundwork for flexible bus lane operations. The design mainly emphasized policy-based implementation rather than automated physical infrastructure.
The U.S. Federal Transit Administration [8] also talked concerning automated enforcement for bus lanes and intelligent transportation systems, underlining technologies related to surveillance, monitoring, and control. The document featured the use of ITS technologies to improve the efficiency of bus management. However, it failed to consider dynamic physical lane reconfiguration.
In addition, Liu et al. [9] examined real-time dynamic lane management methods for controlling urban traffic. The authors concentrated on optimization models and control approaches for adaptive traffic systems. Although useful in simulation scenarios, the details regarding the mechanical implementation were not examined.
In the end, Daganzo [10] developed the Cell Transmission Model (CTM), a dynamic traffic flow model based on hydrodynamic principles. This significant study established the mathematical foundation for contemporary traffic management techniques and strategies for dynamically assigning lanes. Although the study was primarily theoretical, it has had a significant impact on subsequent research in the area of intelligent transportation systems.
Earlier studies indicate significant advancements in areas like dynamic lane management, intelligent transportation systems, and the prioritization of Bus Rapid Transit (BRT) services. However, a gap remains in integrating real-time sensing, intelligent decision-making, and physically adjustable lane divider systems into one unified setup. One of the most important gaps is that these existing systems do not involve human supervision. The suggested project seeks to fill this gap by integrating automation, sensing technology, and adaptive BRT lane management into a single adaptable infrastructure system.

III. METHODOLOGY

This system uses cheap and widely available components. This system simply uses servo motors for the movement of the BRT lane. The sensors are used for safety concerns, and they send a signal to the Arduino Uno Microcontroller. These continuously monitor the status of the lane and act readily when needed.

A. Hardware Components

- Ultrasonic Sensors (HC-SR04): It continuously monitors the distance of the bus, which enables dynamic lane control.
- Arduino Microcontroller: The microprocessor receives the signals from the safety sensors and controls the servo motors.
- High-Torque Servo Motor: They are used to shift the divider up or down. They have angles 0°, 90°, 120°.
- Mechanical Lifting Mechanism: A strong scale-like structure is attached to the servo motor, which acts like a divider.
- Motor Driver: Helps to drive both the servo motors.
- Safety Sensors: For the safety concerns, IR sensors are used.

B. System Operation

- The system is under manual control by an authorized supervisor located at the BRT bus stop.
- The supervisor is given a push button to control the shifting of the divider.
- The supervisor presses the push button when he or she realizes that there is no approaching BRT bus.
- The sensors send a signal to the microcontroller and it moves the BRT accordingly.
- Upon the expected arrival of a BRT bus, the supervisor is expected to press the push button again, prompting the microcontroller to activate the servo motor and shift the lane divider to the closed position, thereby restoring the dedicated BRT lane.
- Safety sensors, such as ultrasonic or infrared sensors, continuously monitor the zone of movement of the divider to detect the presence of vehicles, pedestrians, or any other obstructions.
- If any obstructions are detected during movement, the Arduino microcontroller instantly stops or prevents the movement of the divider for safe operation, even when human error is involved.

C. Software Deployed:

Arduino IDE: Used to develop, compile, and upload the code to the Arduino microcontroller.

- Embedded C: Used Embedded C programming for the development of a system program in the Arduino IDE.

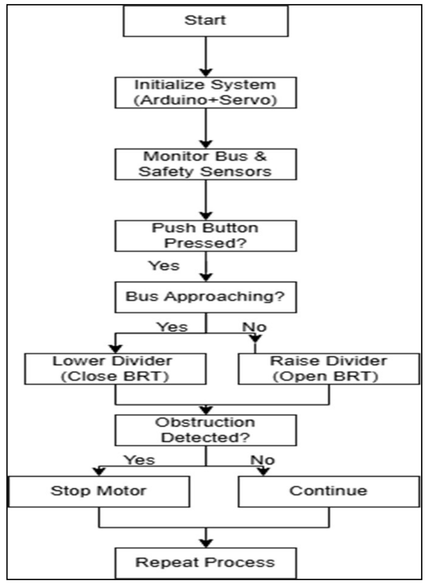

Fig 1. System Architecture of the BRT Lane Divider Control System

IV. Result and Discussions

A. Results

The Automatic BRT Lane Divider Shifter was tested multiple times to check the effectiveness of the safety sensors in some conditions. The readiness of the system was checked through these experiments.

TABLE I: SAFETY SENSOR–BASED LANE DIVIDER MOVEMENT RESPONSE

Situation	Obstacle Detected	Divider Movement
No obstacle	No	Allowed
Vehicle present	Yes	Stopped
Pedestrian detected	Yes	Stopped

While the divider's motion area became freed from limitations, the protection sensors recognized an unobstructed direction. This enabled the Arduino controller to interact with the servo motor and adjust the divider as needed. The system's movement was steady, indicating that the interplay among the supervisor's input, the microcontroller, and the motors was functioning efficaciously and dependably.

While an obstacle entered the divider's movement region, the safety sensors, without delay, identified the obstruction and transmitted a signal to the controller to stop the operation. As a result, the divider either failed to start or halted instantly if it had already started moving. This reaction became cited consistently across diverse check sessions. Those findings suggest that the safety system using sensors operates reliably and consistently. This system guarantees safety over human commands and guarantees the device's smooth operation of the system.

TABLE II: TIME ANALYSIS OF LANE DIVIDER OPERATIONS AND EMERGENCY RESPONSE

Divider Operation	Average Time (sec)	Minimum Time (sec)	Maximum Time (sec)
Lowering	2.3	2.2	2.5
Raising	2.4	2.2	2.6
Emergency Stop	0.3	0.2	0.4

From the experimental readings above, it is clear that the system responds notably to the instructions. The coordination of automated sensors with human supervision improves system performance. The Lowering and Rising times of the divider are very low. The safety sensors stop the dividers' movement within very little time, when an obstacle is detected. This capability helps avoid hazardous actions and greatly minimises the risk of incidents arising from human error, delayed decisions, or sudden movements by road users.

B. Discussion

While the tested system was practical and efficient, it also exhibited certain constraints. The system currently relies on human supervision to operate the divider, which can cause delays under certain conditions, especially during rush hours. Environmental conditions such as heavy rain, dust, or fog also affect sensor performance and may lead to incorrect detections or obstacle recognition errors. Eventually, components such as the split mechanism and servo motor can wear out, degrading performance and increasing maintenance requirements.

A further constraint of this is that at present, the system is not completely adapted to major smart city implementation due to the incomplete arrival bus auto detection. Despite these disadvantages, the system remains a cheaper and safer means of implementing adaptive BRT lanes. With enhanced sensor communication, water resistance, and some automation, the system can be more efficient, reliable, and adapted to real-world city traffic conditions.

V. Future Scope

By integrating IoT-based monitoring and cloud connectivity, the Automatic BRT Lane Divider Shifter can contribute to a more intelligent and interconnected traffic control system. The improvements will enable real-time data collection, remote monitoring, and consolidated management of multiple BRT corridors in the city. Integrating general data analysis and machine learning methods into the system to analyse historical and real-time traffic patterns can improve prediction-based traffic control and enable more accurate lane control and reduced congestion, without the need for continuous human intervention. Furthermore, the system could be enhanced by incorporating prioritisation for emergency vehicles (e.g., ambulances), thereby enabling rapid lane clearing in critical situations. Enhanced sensor precision, actuation speed and the overall mechanical endurance of the system will enable adaptation to dense urban environments and high traffic loads. The proposed technological innovations will markedly advance smart city initiatives, road safety, the effectiveness of public transport, and sustainable intelligent urban mobility.

VI. Conclusion

This invention improves urban traffic flow by leveraging the presence of a bus to reallocate traffic lanes. The system optimises road use, reduces traffic by permitting temporary use of bus lanes, and guarantees immediate and safe reversion to dedicated bus use when necessary. The connection of sensors, actuators, and a microcontroller enables safe and efficient control of the divider's movement, maintaining the operational continuity of the BRT system. Another major advantage of this system is improved safety and reliability. The system reduces the occurrence of human errors in road management while allowing human checks when needed. The equilibrium between automated and manual processes renders the system operational in real-world scenarios such as emergencies or peak-traffic periods. Eventually, the system could be extended to include IoT connections and traffic forecasting, enabling more accurate predictions of urban traffic dynamics and more efficient traffic monitoring.

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