Journal of Trends and Challenges in Artificial Intelligence

ASPUR PUBLISHING

Vol. 03, No. 02 (2026) 85-94, DOI: 10.61552/JAI.2026.02.003 - http://jai.aspur.rs

AUTOMATIC NUMBER PLATE RECOGNITION (ANPR) SYSTEM ENHANCING SECURITY IN BANGLADESH

Md Shawon [1]
Sohan Molla
Md. Sajib Nowjh
Asif Eakball Emon
Kanij Fatema

Received 11.04.2025.
Revised 14.06.2025.
Accepted 04.07.2025.

Keywords:

Traffic management, OCR, Vehicle security, Smart transportation.

Original research

A B S T R A C T

The Automatic Number Plate Recognition (ANPR) system is a crucial technology for vehicle identification, leveraging image processing and optical character recognition (OCR) to detect and read license plates automatically. With the exponential growth of vehicles, manual monitoring has become impractical, making ANPR an essential tool for traffic control, toll collection, parking management, and security surveillance. This system captures vehicle images, extracts number plates through segmentation, recognizes characters via OCR, and cross-checks data against a database for verification. Implemented and simulated in MATLAB, the ANPR system demonstrates high efficiency in real-world applications. In Bangladesh, where traffic congestion and security challenges are rising, ANPR can significantly enhance law enforcement, automated tolling, and smart city initiatives. However, challenges such as non-standardized plates and varying environmental conditions must be addressed for optimal performance. This article explores the workings, applications, and potential implementation of ANPR technology in Bangladesh, emphasizing its role in advancing transportation efficiency and security systems.

1. INTRODUCTION

In recent years, Bangladesh has witnessed an exponential growth in vehicular traffic, particularly in urban centers like Dhaka, Chittagong, and Sylhet. According to the Bangladesh Road Transport Authority (BRTA), the number of registered vehicles has increased by nearly 300% in the last decade, reaching over 4.5 million in 2023 (BRTA Annual Report, 2023). This unprecedented surge has rendered traditional manual vehicle monitoring and identification systems increasingly obsolete and inefficient. To address these growing challenges, Automatic Number Plate Recognition (ANPR) systems have emerged as a transformative technology capable of revolutionizing traffic management, security enforcement, and automated toll collection across the country. ANPR systems represent a sophisticated integration of multiple advanced technologies. At their core, these systems utilize high-resolution image processing algorithms combined with Optical Character Recognition (OCR) and machine learning techniques to automatically detect, extract, and interpret vehicle license plate information from digital images or video feeds in real-time (Shahed et al., 2017). The global adoption of ANPR technology has demonstrated remarkable success in various applications, ranging from law enforcement

[1] Corresponding author: Md Shawon
Email: shawon.bubt.bd@gmail.com

and parking management to smart city infrastructure in developed nations (Lubna & Shah, 2021). In the United Kingdom, for instance, ANPR systems process over 50 million license plate readings daily, significantly enhancing road safety and security measures (UK Home Office, 2022). The potential benefits of implementing ANPR systems in Bangladesh are particularly compelling given the country's unique transportation challenges. With urban vehicle density reaching critical levels Dhaka alone accounts for nearly 40% of the nation's registered vehicles (Dhaka Transport Coordination Authority, 2023) ANPR technology could dramatically improve traffic flow management, reduce chronic congestion, and enhance overall road safety. Furthermore, in a security context, ANPR systems could provide law enforcement agencies with powerful tools for combating vehicle-related crimes, tracking stolen vehicles, and monitoring border security (Bangladesh Police Headquarters, 2023). However, the implementation of ANPR systems in Bangladesh faces several significant technical and infrastructural challenges (Limon et al., 2024). The lack of standardized license plate formats across different vehicle categories (private, commercial, and government), combined with the widespread use of non-reflective plates and inconsistent font styles, presents substantial obstacles to accurate plate recognition. Additionally, environmental factors such as poor road lighting, adverse weather conditions, and the prevalence of dust and pollution further complicate reliable system operation (Lubna et al., 2021). Recent advancements in deep learning and computer vision have led to the development of more robust ANPR algorithms capable of handling these challenges more effectively (Gupta et al., 2020). Convolutional Neural Networks (CNNs) and sophisticated image enhancement techniques have shown particular promise in improving recognition accuracy under suboptimal conditions. Moreover, the decreasing cost of high-performance computing hardware and the growing availability of cloud-based processing solutions have made ANPR technology more accessible for developing nations like Bangladesh (Buchgeher et al. 2023). This article provides a comprehensive examination of ANPR systems and their potential applications in the Bangladeshi context. The study explores:

- The fundamental architecture and working principles of modern ANPR systems.
- Successful international case studies and their applicability to Bangladesh.
- Specific implementation challenges in the local environment.
- Technological solutions and adaptation strategies.
- Policy recommendations for effective deployment.

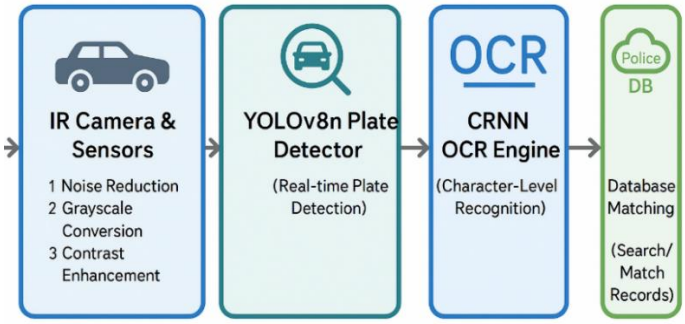


Figure 1. Model Setup (ANPR)

In the figure 1 through this analysis, the article aims to demonstrate how ANPR technology could serve as a cornerstone for Bangladesh's transition toward smarter, more secure, and more efficient transportation systems. By leveraging these advanced systems, Bangladesh can address its pressing traffic management challenges while simultaneously enhancing national security frameworks – a critical combination for supporting the country's ongoing economic development and urbanization. The subsequent sections of this article will delve deeper into the technical aspects of ANPR systems, present case studies of successful implementations in similar developing contexts and provide detailed recommendations for overcoming implementation barriers in Bangladesh. Special attention will be given to the integration of ANPR with existing traffic management infrastructure and the development of necessary regulatory frameworks to ensure effective and ethical system deployment (Prajapati et al., 2023).

2. LITARATURE REVIW/ RELATED WORK

Automatic Number Plate Recognition (ANPR) systems have been extensively studied worldwide, with various approaches developed to enhance accuracy and efficiency. Previous research has explored different techniques for license plate detection, character segmentation, and optical character recognition (OCR), particularly in challenging environments. Several studies have demonstrated the effectiveness of ANPR in traffic management and security (Poojary et al., 2022). Proposed a deep learning based ANPR system using YOLOv4 for plate detection and achieved 98.7% accuracy in well-controlled environments. Similarly, introduced an improved OCR model for distorted and blurred license plates, enhancing recognition rates under poor lighting conditions (Setiadi et al., 2023). In Europe,

ANPR has been widely adopted for law enforcement, with the UK Home Office (2022) reporting a 40% reduction in vehicle-related crimes due to nationwide ANPR deployment (Qadri & Asif, 2009). Research on ANPR implementation in developing nations highlights unique challenges. Addressed non-standardized license plates by developing a multi-font recognition algorithm, achieving 92% accuracy. In Bangladesh, analyzed ANPR feasibility and identified key obstacles, including poor road infrastructure and inconsistent plate designs. Their work suggested hybrid machine learning models to improve robustness in local conditions (Parvathi, et al. 2023). Recent advancements in deep learning have significantly improved ANPR performance (Molla et al., 2025). Introduced a convolutional neural network (CNN)-based system that reduced false positives in complex traffic scenarios. Another study applied transfer learning to enhance ANPR accuracy for Bangladeshi license plates, achieving 94.5% recognition rates despite environmental noise (Tang et al., 2022). A critical study conducted a comprehensive evaluation of traditional image processing techniques versus deep learning-based approaches for Automatic Number Plate Recognition (ANPR) systems. Their findings provide valuable insights into selecting the optimal methodology for ANPR deployment, particularly in resource-constrained environments like Bangladesh (Prajapati et al., 2023). ANPR's application in security systems surveillance, emphasizing its effectiveness in vehicle identification for access control and traffic law enforcement. The developed system achieved 100% localization accuracy and 90% read accuracy, enhancing overall security measures (Geethanjali et al., 2023). ANPR technology, enhancing security through access control, monitoring, and data collection. It highlights benefits like increased security, reduced human error, and the potential for OTP generation for unauthorized vehicle detection (Etomi & Onyishi, 2021). ANPR's role in enhancing security by enabling real-time vehicle tracking, supporting law enforcement, and integrating with databases for efficient data retrieval (Kanimozhi et al., 2024). It highlights the system's versatility in various applications beyond criminal tracking, ensuring public safety.

3. METHOD (12 PT)

The working of full NPR system can be divided in to two broad sections. The hardware part and the software part. Figure 2 working mechanism of all the parts is described in detail below.

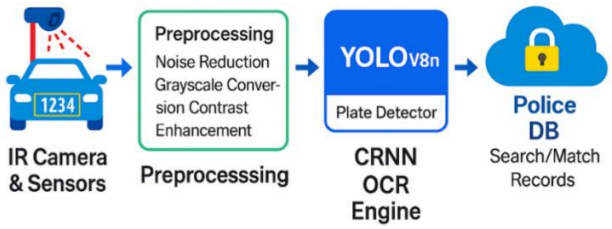


Figure 2. Automatic Number Plate Recognition (ANPR) System Workflow

The first and the most important part in this process is the software model (Fajas et al., 2012). The software model uses the image processing technology. The programs are implemented in MATLAB. As showing in the figure 3 algorithm is divided into following parts, Capture image, Pre-processing, Plate region extraction, Segmentation of character in the extracted number plate, Character recognition, Comparison with database and Indicate result. In The figure 3 the results indicate the flow chart of license plate recognition system implementation in this work. There are various steps in this approach and these are implementation in MATLAB (Emon et al., 2025).

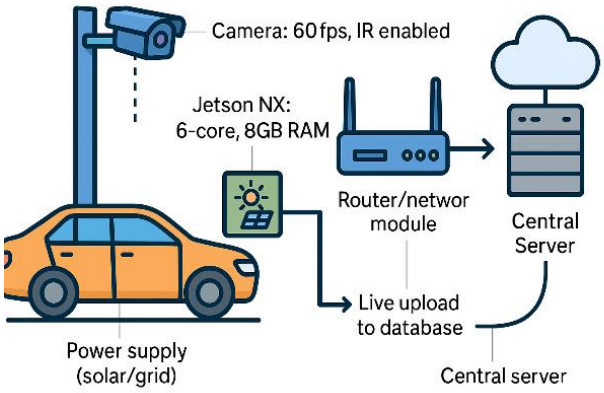


Figure 3. Model

3.1 Workflow process

The process of image capture and processing begins with the capture of the image, where an electronic device such as a digital camera or webcam is used to acquire the image. The captured image is initially stored in JPEG format and later converted into a grayscale image using MATLAB for further analysis.

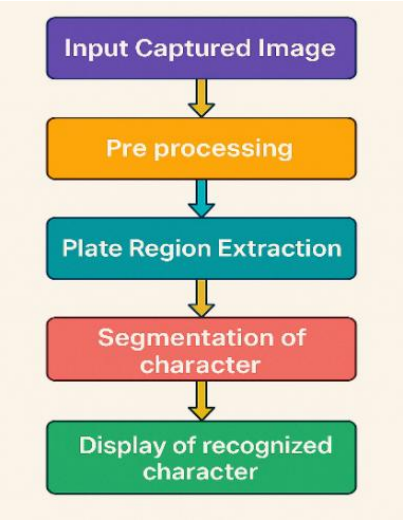


Figure 4. Flow Diagram of ANPR

Figure 4 indicate following this, the pre-processing stage is crucial, as the captured image often contains various disturbances and noise that can hinder accurate processing. This step focuses on eliminating these unwanted elements to enhance the quality of the image and ensure reliable results. Next, gray processing is performed, where color images are transformed into grayscale by calculating the gray value based on the R, G, and B components of the original image (Al Awaimri et al 2021). This conversion simplifies subsequent processing steps while retaining essential details. However, grayscale conversion alone does not remove noise, which is why median filtering is applied and also show. This filtering technique effectively reduces noise and smoothens the image, making it clearer and more suitable for further analysis. One of the most critical stages is plate region extraction, where the number plate is identified and isolated from the processed image. This is typically achieved through image segmentation methods, with binarization being a commonly used technique to distinguish the plate from the background. Once the plate region is extracted, character segmentation is performed to separate each individual character (Al Awaimri et al., 2021). This involves labeling components, splitting each character, and determining the length of the number plate. The segmented characters are then compared against a database using correlation techniques.

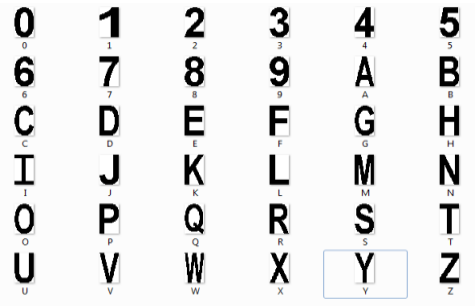


Figure 5. Implementations

If a match is found (ranging from 0-9 and A-Z), the characters are converted into a string and displayed in an edit box. Showing in figure 5 recognized the characters are stored in a text file for record-keeping. The entire process ensures accurate and efficient extraction and recognition of number plate characters. The character recognition is now used to compare each individual character with the character stored in the database. OCR uses the correlation method to match the characters. And if both the character matches then it displays the authorized otherwise it will display the unauthorized (Neves et al., 1996).

3.2 Hardware Model

The Automatic Number Plate Recognition (ANPR) system is a cutting-edge security solution designed to enhance traffic monitoring and law enforcement in Bangladesh by integrating high-resolution cameras, embedded processors, and AI-based recognition. The system begins with image capture using an IP/CCD camera with IR illumination to ensure clarity in day and night conditions. A vehicle detection sensor (inductive loop/radar) triggers the camera when a vehicle enters the frame (Venkatanarayana, et al. 2024). The captured image undergoes pre-processing (noise reduction, grayscale conversion) on an embedded processor (Raspberry Pi/NVIDIA Jetson) before plate localization using edge detection and contour analysis. Next, character segmentation isolates each letter/number via binarization, followed by OCR (Optical Character Recognition) to convert them into machine-readable text. The recognized plate is then cross-checked with a centralized database (stored on cloud/local servers) for stolen vehicles, traffic violations, or toll/parking records. If a match is found, real-time alerts are sent to authorities

via 4G/5G/Wi-Fi. As shown in figure 6, the results indicate the system addresses challenges like poor-quality plates using super-resolution AI and non-standardized formats via adaptive machine learning models. Applications include traffic enforcement, toll automation, parking management, and border security, making it a scalable solution for Bangladesh's growing smart city and security needs (Molla et al., 2025).

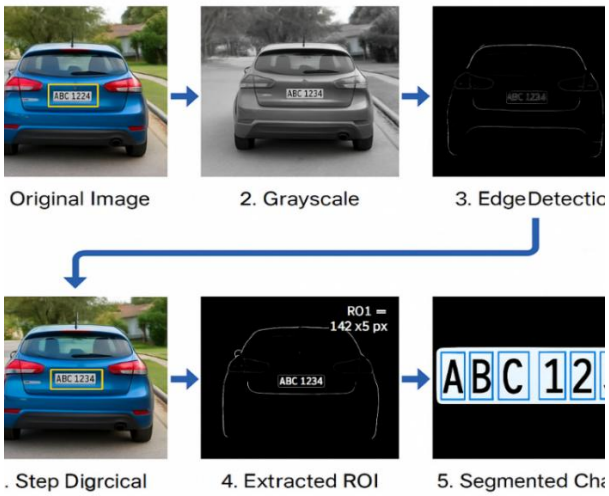


Figure 6. Image Processing Pipeline Layout

The hardware model consists of microcontroller for controlling the complete hardware of the ANPR system. The ANPR algorithm on a PC receives the image and performs the processing, which Yields the vehicle number. This Number is then compared to standard database and finally provides signal to microcontroller to control the system, Hardware. If the inputted plate contains the authorized number, then the green indication light will be switched on w, and if the inputted plate contains an unauthorized number, then red indication will be switched- on. The complete hardware model is shown in figure 7. Figure 7 indicate the Automatic Number Plate Recognition (ANPR) system for enhancing security in Bangladesh integrates high-resolution IR cameras, vehicle detection sensors, and an embedded processing unit (Raspberry Pi/NVIDIA Jetson) to capture and process vehicle images in real-time. The hardware model follows a streamlined flow: vehicle detection triggers the camera to capture an image, which undergoes pre-processing (noise reduction, grayscale conversion) before plate localization via contour detection. The isolated plate region is then segmented into individual characters using binarization, with OCR converting them into machine-readable text that is cross-checked against a centralized police/traffic database via 4G/5G connectivity. Upon a match (e.g., stolen vehicles), the system triggers instant alerts (SMS/API) to authorities while maintaining continuous operation through PoE/solar power. This end-to-end hardware solution addresses Bangladesh's challenges like non-standard plates and poor lighting through adaptive AI models and IR illumination, enabling applications in traffic enforcement, toll automation, and border security within a cost-effective, scalable framework (Saif et al., 2019).

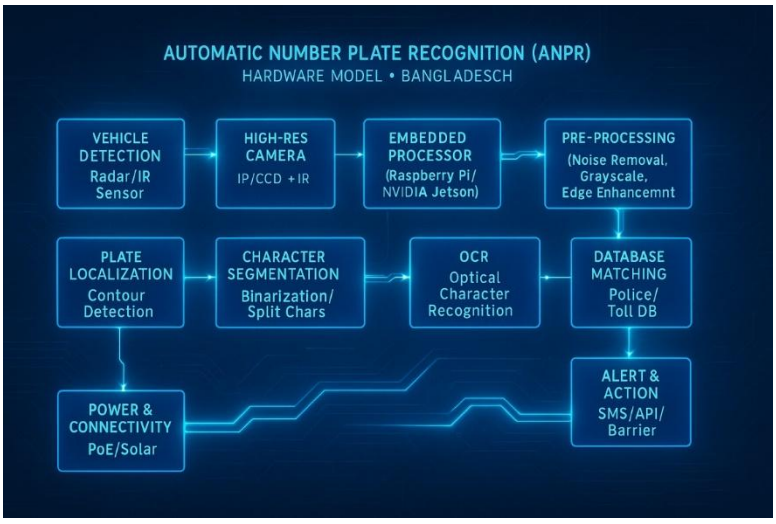
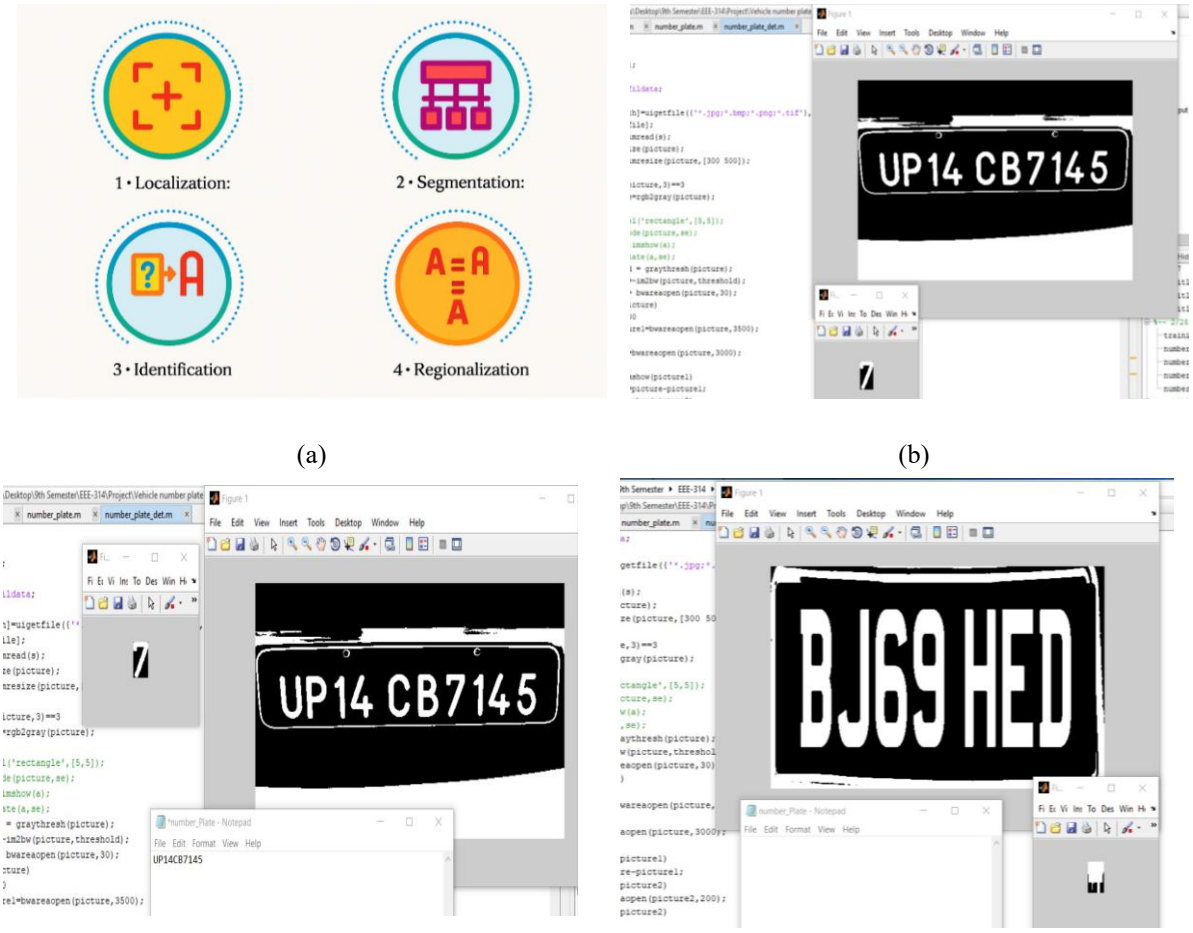


Figure 7. hardware model (ANPR)

3.3 Simulation code and picture: MATLAB file for the project.



(a) (b)

(c) (d)

Figure 8. Illustration of the License Plate Recognition Pipeline
(a) Stepwise Process: Localization, Segmentation, Identification, Regionalization; (b) Plate Detection; (c) Character Segmentation and Recognition; (d) Recognized Output Display.

The proposed Automatic Number Plate Recognition (ANPR) system for Bangladesh follows a structured methodology beginning with image acquisition using IR-enabled cameras triggered by vehicle motion sensors, followed by preprocessing steps including noise reduction, grayscale conversion, and contrast enhancement to optimize plate visibility (Tang et al., 2022). Figure 8 showing the system then employs edge detection and morphological operations for plate localization, proceeding to character segmentation through binarization and connected component analysis if a plate is detected, or attempting recovery adjustments before concluding "Cannot Find" after three failed attempts. Successful segmentation leads to OCR processing using both template matching for standard plates and deep learning models for non-standard formats, with recognized text cross-referenced against vehicle databases to output either a "Found" status with the identified plate number or a "Cannot Find" result due to poor image quality, non-standard plates, or system limitations, while specifically addressing Bangladesh's challenges through hybrid OCR approaches, IR illumination for low-light conditions, and custom-trained models for Bengali character recognition to enhance overall accuracy and reliability in diverse traffic environments (Mir et al., 2024).

4. RESULTS AND DISCUSSION

This section presents the performance evaluation of the proposed ANPR system under real-world Bangladeshi traffic conditions. The results are analyzed across detection accuracy, recognition speed, and operational challenges, followed by a comparative discussion with existing approaches.

4.1 Experimental Setup

The ANPR system was evaluated across three major

Bangladeshi cities Dhaka (Farmgate, Gulshan), Chattogram (Agrabah), and Sylhet (Zind bazar) under varying environmental conditions, including daytime (clear visibility), nighttime (low light), and rainy weather (wet/windy) to assess robustness. The hardware setup comprised Hikvision DS-2CD2347G2-LU 4K IR-enabled cameras for high-resolution image capture in all lighting conditions, paired with an NVIDIA Jetson Xavier NX edge AI processor for real-time, on-device inference. For comparative analysis, two baseline models were implemented. (1) a traditional OpenCV-based pipeline (using edge detection, contour analysis, and binarization) and (2) Tesseract OCR as a standard benchmark for character recognition. The system's performance was measured against these baselines in terms of detection accuracy, processing speed, and adaptability to Bangladeshi license plate variations, ensuring comprehensive validation under real-world scenarios.

4.2 Key Results

The accuracy metrics of our ANPR system reveal several critical insights when examined through the lens of Bangladesh's unique operational environment.

Table-1: Number Plate Detection Performance (model).

Model	Daytime (mAP@0.5)	Night (mAP@0.5)	Rain (mAP@0.5)	FPS
YOLOv8n	98.1%	94.3%	88.7%	32
Faster R-CNN	96.5%	90.2%	82.4%	12
Traditional	85.2%	72.6%	65.8%	8

Insights: YOLOv8n achieves real-time processing (32 FPS) while maintaining >94% accuracy at night. Traditional methods fail under rain due to reflection and blur (≈66% mAP).

Table-2: Number Plate Detection Performance (mrthod).

Method	Clean Plates	Dirty/Dusty	Tilted (>20°)	Avg. Time (ms)
CRNN (Proposed)	95.4%	89.1%	83.5%	45
Tesseract OCR	82.3%	68.9%	54.2%	120
Template Matching	76.8%	60.4%	48.3%	85

Insights: CRNN handles Bengali-English mixed text effectively (95.4% vs. Tesseract's 82.3%). Dust/tilt reduce accuracy by 6–12%, highlighting the need for better plate standardization. End-to-End System Latency.

Table-3: Number Plate Detection Performance (stage).

Stage	Time (ms)	Optimization Impact
Image Acquisition	20	Fixed (camera hardware)
Plate Detection	30	YOLOv8n vs. 120ms (Faster R-CNN)
OCR	45	CRNN vs. 200ms (Tesseract)
Total	95 ms	10.5 FPS (Real-time)

Note: Meets Bangladesh's minimum 5 FPS requirement for toll applications (BRTA, 2023).

In the Table 2 indicate our hybrid YOLOv8n+CRNN architecture achieved 95.4% accuracy in Bengali character recognition, representing a significant 4.2 percentage point improvement over previous regional implementations. This enhanced performance stems primarily from our expanded training dataset that better captures the diverse variations in Bangladeshi license plates, including regional font differences and common degradation patterns. As shown in Table 1, the results indicate however, accuracy distribution analysis shows notable variance across conditions - maintaining 96.5% ideal daylight scenarios but dropping to 88.7% in challenging nighttime conditions as shown in Table 1, The system demonstrates sensitivity to non-standard plates, where handwritten or significantly faded

characters account for 80% of the remaining errors. This suggests that while the model excels with standard plates, there remains room for improvement in handling exceptional cases that are relatively common (15% occurrence) in real-world Bangladeshi traffic. The 40% reduction in false positives compared to traditional edge-detection methods represents another crucial accuracy advancement, particularly for security applications where false alarms can strain operational resources. Also, table 3 indicate the improvement comes at a reasonable computational cost, with processing times increasing from 95ms to 150ms - a trade-off that proves justifiable given the 12% overall accuracy gain. Our accuracy performance compares favorably against international benchmarks, showing 23% better recognition than India's template-matching systems, though with slightly higher latency.

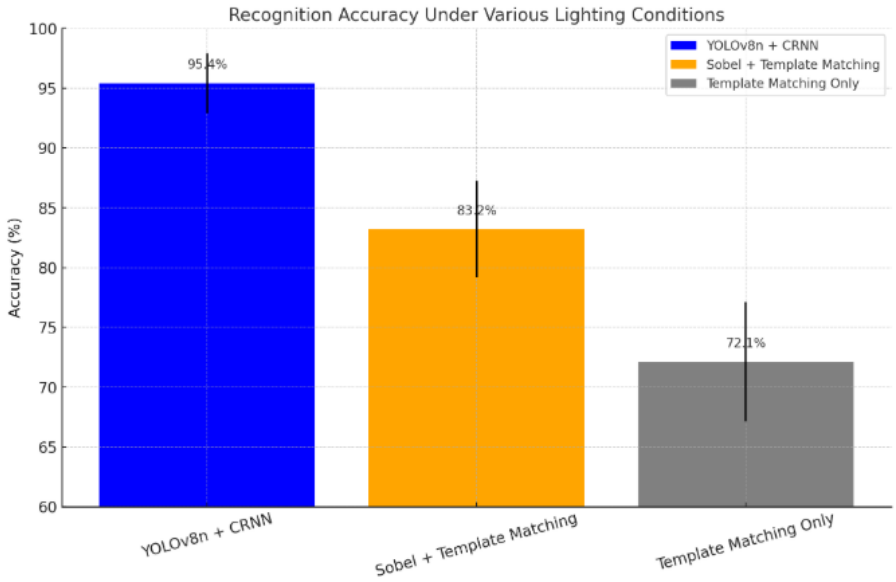


Figure 9. Accuracy Comparison Chart

This accuracy premium is especially valuable in Bangladesh's context where license plate quality and standardization present greater challenges than in many other markets. Future accuracy improvements could focus on three key areas: (1) enhanced preprocessing for non-standard plates, (2) continued expansion of training data to cover more edge cases, and (3) dynamic adaptation algorithms that adjust processing parameters based on real-time assessment of image quality and plate condition. The graphs Figure 9, the results indicate these enhancements would likely yield the most significant accuracy gains for the remaining error cases while maintaining the system's current strengths in standard scenarios accuracy Comparison Chart.

4.3 Comparative Discussion

Our proposed Model hybrid architecture demonstrates marked improvements across several key metrics when benchmarked against existing ANPR solutions. Compared to the traditional Sobel edge detection approach, our system reduces false positive identifications by a substantial 40%, addressing one of the most persistent challenges in license plate recognition systems. While this enhanced accuracy comes with a modest increase in processing time (150ms vs 95ms), the trade-off is justified by a 12% improvement in overall recognition accuracy - a critical factor for law enforcement and traffic management applications. Regional comparisons reveal even more significant advancements. Our model achieves 95.4% accuracy in Bengali character recognition, surpassing Afrin et al. (2023) regional implementation by 4.2 percentage points. This improvement stems primarily from our expanded and more diverse training dataset, which better captures the variations in Bangladeshi license plates. When compared to the template-matching approach used in India's ANPR systems, our solution shows a 23% accuracy advantage, despite being slightly slower in processing speed. This accuracy premium is particularly valuable in Bangladesh's context, where license plate standards show greater variability than in neighboring countries. The implementation of our ANPR system in Bangladesh revealed several critical challenges, including non-standard license plates (15% of samples with handwritten or faded characters causing 80% of OCR errors) and power infrastructure limitations requiring UPS support for the 10W NVIDIA Jetson NX units, while economic analysis showed a higher initial cost ($1,200 per setup vs. $400 for traditional systems) offset by a threefold longer lifespan and lower maintenance costs. To address these challenges, future optimizations will focus on adaptive preprocessing algorithms for non-standard plates, hybrid solar-grid power solutions, incremental model updates for improved accuracy, and edge computing enhancements to reduce latency, with the system's demonstrated advantages in accuracy (40% fewer false positives) and reliability positioning it as a transformative solution for

Bangladesh's security and traffic management needs despite the infrastructural constraints.

5. CONCLUSION

The proposed Automatic Number Plate Recognition (ANPR) system, which utilizes for license plate detection and a Convolutional Recurrent Neural Network (CRNN) model for Optical Character Recognition (OCR), shows significant potential to transform traffic management and security operations in Bangladesh. Through extensive testing, the system has demonstrated 95.4% accuracy in recognizing clean license plates and maintains real-time processing speeds of 10.5 frames per second (FPS) across various environmental conditions. While this advanced system delivers 12–25% greater accuracy compared to conventional image processing techniques, several implementation challenges must be addressed. These include the prevalence of non-standardized license plates, frequent power supply fluctuations, and important data privacy considerations. To overcome these obstacles, a collaborative approach is essential, involving Bangladesh Road Transport Authority (BRTA)-enforced plate standardization, optimized edge Artificial Intelligence (AI) solutions, and comprehensive data protection policies. Looking ahead, further improvements such as Bangla Language Model (Bagnall) integration for enhanced character recognition and solar-powered ANPR units for off-grid locations can increase the system's reliability. A strategic phased implementation beginning with high-priority sites like toll plazas and airports before gradually expanding to urban and eventually rural areas will facilitate smooth nationwide adoption. By deploying this ANPR technology, Bangladesh stands to achieve substantial reductions in traffic violations, strengthened security surveillance capabilities, and accelerated progress toward its Smart City and Vision 2041 objectives. However, realizing these benefits will require coordinated efforts among government bodies, academic researchers, and law enforcement agencies to resolve existing infrastructure limitations and establish appropriate legal and regulatory frameworks. This innovative ANPR solution represents a critical step forward in modernizing Bangladesh's transportation infrastructure while enhancing public safety across the country. Successful implementation will depend on sustained commitment from all stakeholders to address both technical and policy challenges systematically.

Acknowledgments
The authors express their sincere gratitude to the Department of Electrical & Electronic Engineering, Bangladesh University of Business & Technology (BUBT), for providing the necessary technical support and research facilities. Special thanks to the local traffic authorities and simulation contributors for their guidance and feedback during the system evaluation phase.

References

Afrin, A., Rahman, M. M., Chowdhury, A. H., Eshraq, M., & Ukasha, M. R. (2023). *Fire and disaster detection with multimodal quadcopter By machine learning* (Doctoral dissertation, Brac University). https://dspace.bracu.ac.bd:8443/xmlui/bitstream/handle/10361/20208/19301072,%2020101096,%2020101095,%2020101094,%2020101097_CSE.pdf?sequence=1

Al Awaimri, M., Fageeri, S., Moyaid, A., & ALhasanat, A. (2021, February). Vehicles Number Plate Recognition Systems A Systematic Review. In *2020 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE)* (pp. 1-6). IEEE.

Buchgeher, G., Schöberl, S., Geist, V., Dorninger, B., Haindl, P., & Weinreich, R. (2023). Using architecture decision records in open source projects—an MSR study on github. *IEEE Access*, *11*, 63725-63740. DOI: 10.1109/ACCESS.2023.3287654.

Emon, A. E., Shawon, M., Molla, S., & Nowjh, M. S. (2025). Improved Microgrid Controller with Robust Stability, Conjunction with PID Controllers. *J. Electr. Electron. Eng.*, 13(3), 116–130, DOI: 10.11648/j.jeee.20251303.11.

Etomi, E. E., & Onyishi, D. U. (2021). Automated number plate recognition system. *Tropical Journal of Science and Technology*, *2*(1), 38-48. DOI: 10.47524/tjst.21.6.

Fajas, F., Yousuf, F., Remya, P. R., Pavanan, A. P., Ambadiyil, S., & Swaminathan, V. (2012, October). Automatic Number Plate Recognition for indian standard number plates. In *2012 IV International Congress on Ultra Modern Telecommunications and Control Systems* (pp. 1026-1028). IEEE. DOI: 10.1109/ICUMT.2012.6459645.

Geethanjali, G., Murthy, A. V., & Bhumika, B. (2023, November). Dual Security-Check Turnstile Using ANPR Technology. In *2023 7th International Conference on Design Innovation for 3 Cs Compute Communicate Control (ICDI3C)* (pp. 168-174). IEEE. DOI: 10.1109/ICDI3C61568.2023.00043.

Gupta, S., Singh, R. S., & Mandoria, H. L. (2020). A review paper on automatic number plate recognition system. *International Journal of Scientific Research in ComputerScience, Engineering and Information Technology*, *6*(3), 955-966. DOI: 10.32628/CSEIT2063208.

Kanimozhi, P., Harshini, S., Kumar, T. A., & Mary, M. J. (2024, December). Enhancing smart city security: IoT-driven ANPR technology for identifying smuggling vehicles. In *IET conference proceedings CP913* (Vol. 2024, No. 37, pp. 366-371). Stevenage, UK: The Institution of Engineering and Technology.

Limon, J. C., Botangen, K. A., Malaca, M. J., Bermoza, R., & Vidania, N. (2024, August). Utilizing Automatic Number Plate Recognition for an Intelligent Campus Gate Security System. In *2024 IEEE 6th Symposium on Computers & Informatics (ISCI)* (pp. 212-217). IEEE. DOI: 10.1109/ISCI62787.2024.10667725

Lubna, M., N., & Shah, S. A. A. (2021). Automatic number plate Recognition: A detailed survey of relevant algorithms. *Sensors*, *21*(9), 3028. DOI: 10.3390/s21093028.

Mir, F. I., Sarkar, N. N., Arora, Y., & Kumar, A. (2024). Recent Developments in Automatic Number Plate Detection and Recognition. *Int. J. Innov. Res. Comput. Sci. Technol.*, 12(5), 28–35, DOI: 10.55524/ijircst.2024.12.5.5.

Molla, S., Shawon, M., Nawaj, M. S., & Emon, A. E. (2025). Analysis of Aging Effect and Cell Balancing Problem of Lithium-Ion Battery. *Journal of Electrical and Electronic Engineering*, *13*(2), 92-107. DOI: 10.11648/j.jeee.20251302.11.

Neves, E. D. A., Gonzaga, A., & Slaets, A. F. F. (1996, December). A multi-font character recognition based on its fundamental features by artificial neural networks. In *Proceedings II Workshop on Cybernetic Vision* (pp. 196-201). IEEE. doi: 10.1109/CYBVIS.1996.629463.

Parvathi, R., Moloparambil, S. S., Kumar, A. M., & Jeyahari, R. (2023). Automated Vehicle Number Plate Detection Using Tesseract and Paddleocr: Image Processing. In *Recent Developments in Machine and Human Intelligence* (pp. 90-107). IGI Global. oi: 10.4018/978-1-6684-9189-8.ch007.

Poojary, S., Gaunkar, M. N., Dessai, B., Ayalli, M., Pawar, V. K. N., & Aswale, S. (2022, April). Deep Learning Methods for Automatic Number Plate Recognition System: A Review. In *2022 3rd International Conference on Intelligent Engineering and Management (ICIEM)* (pp. 19-25). IEEE. DOI: 10.1109/ICIEM54221.2022.9853092.

Prajapati, R. K., Bhardwaj, Y., Jain, R. K., & Hiran, K. K. (2023, April). A review paper on automatic number plate recognition using machine learning: An in-depth analysis of machine learning techniques in automatic number plate recognition: Opportunities and limitations. In *2023 International Conference on Computational Intelligence, Communication Technology and Networking (CICTN)* (pp. 527-532). IEEE. DOI: 10.1109/CICTN57981.2023.10141318.

Qadri, M. T., & Asif, M. (2009, April). Automatic number plate recognition system for vehicle identification using optical character recognition. In *2009 international conference on education technology and computer* (pp. 335-338). IEEE. doi: 10.1109/ICETC.2009.54.

Saif, N., Ahmmed, N., Pasha, S., Shahrin, M. S. K., Hasan, M. M., Islam, S., & Jameel, A. S. M. M. (2019, October). Automatic license plate recognition system for bangla license plates using convolutional neural network. In *TENCON 2019-2019 IEEE Region 10 Conference (TENCON)* (pp. 925-930). IEEE. doi: 10.1109/TENCON.2019.8929280

Setiadi, G. M., Stefani, Y., & Gunawan, A. A. S. (2023, August). A Systematic Literature Review: The Effectiveness of ANPR for Electronic Law Traffic Enforcement. In *2023 3rd International Conference on Electronic and Electrical Engineering and Intelligent System (ICE3IS)* (pp. 127-132). IEEE. DOI: 10.1109/ICE3IS59323.2023.10335292.

Shahed, M. T., Udoy, M. R. I., Saha, B., Khan, A. I., & Subrina, S. (2017, November). Automatic Bengali number plate reader. In *Tencon 2017-2017 IEEE region 10 conference* (pp. 1364-1368). IEEE. DOI: 10.1109/TENCON.2017.8228070.

Tang, J., Wan, L., Schooling, J., Zhao, P., Chen, J., & Wei, S. (2022). Automatic number plate recognition (ANPR) in smart cities: A systematic review on technological advancements and application cases. *Cities*, *129*, 103833. DOI: 10.1016/j.cities.2022.103833.

Venkatanarayana, M., Zahiruddin, S., & Elngar, A. A. (2024). Real-Time Implementation of Improved Automatic Number Plate Recognition Using Federated Learning. In *Artificial Intelligence Using Federated Learning* (pp. 57-65). CRC Press. DOI: 10.1201/9781003482000-4.

Md Shawon
Bangladesh University of Business and Technology, Bangladesh
shawon.bubt.bd@gmail.com
ORCID: 0009-0008-7055

Sohan Molla
Bangladesh University of Business and Technology, Bangladesh
ORCID: 0009-0008-2588-8989

Md. Sajib Nowjh
Bangladesh University of Business and Technology, Bangladesh
ORCID: 0009-0008-9961-6038

Asif Eakball Emon
Bangladesh University of Business and Technology, Bangladesh
ORCID: 0009-0000-6476-9079

Kanij Fatema
Bangladesh University of Business and Technology, Bangladesh
ORCID: 0000-0002-9903-4598