Analysis Of In-Service Traffic Sign Visual Condition: An Overview

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Abstract
This paper provides an overview of various methodologies and approaches for reviewing and analyzing the visual condition of traffic signs that are in use. It analyses image processing, machine learning, and computer vision techniques for evaluating the degradation, readability, and overall visibility of traffic signs. The paper also discusses the challenges and advancements in this field, with the goal of improving the maintenance and effectiveness of traffic sign systems for safer road environments. The visual condition of traffic signs must be assessed on a regular basis to ensure their efficacy and safety. Damage, fading, obstruction, and placement are all factors that affect visibility. Road safety can be significantly improved by identifying and mitigating these issues, allowing drivers to navigate roads with greater precision and safety. The study looks at the shape, background colour, symbol colour, temperature, land use, visibility distance, and prevailing visibility conditions of traffic signs.

Keywords: Traffic Signs, Visual Conditions, Visibility, Road Users

1. Introduction

1.1 General

Traffic signs are an essential component of the traffic control ecosystem, acting as silent guardians for the safety of drivers, pedestrians, and all road users. In India, the government has launched proactive initiatives to revamp the traffic sign system, with the goal of instilling a culture of traffic rule awareness among drivers. However, the journey towards improved traffic flow and safety necessitates a more robust implementation and enforcement of traffic laws and regulations. Simplicity in visual design is essential for effective communication to a diverse audience, including those who may not be fluent in written language. Furthermore, strategically placing traffic signs in intuitive and unambiguous locations is critical to ensuring drivers can quickly interpret the conveyed message and make informed decisions. In essence, traffic signs are an important cog in the traffic control mechanism, and their strategic placement holds the key to significantly increasing road safety and reducing traffic bottlenecks. The Indian government's ongoing efforts to improve the traffic sign system and raise driver awareness are commendable, emphasizing the importance of continuing to improve the implementation and enforcement of traffic laws and regulations.

1.2 Background of Study

1.2.1 History of Traffic Sign

Traffic signs in India first appeared in the early 20th century in major cities such as Mumbai and Kolkata. However, road safety became more prominent in the 1960s, resulting in the implementation of comprehensive traffic rules and regulations. The Indian Road Congress (IRC) was founded in 1965 to develop guidelines for road design, construction, and maintenance. The IRC was critical in developing traffic signs that met international standards and gradually deploying them across the country. Since then, India has advanced road safety initiatives such as strict traffic law enforcement, the integration of automated traffic management systems, and advanced driver training programmes. India now has an extensive traffic sign system that includes regulatory, warning, and informational signs. The Motor Vehicles Act of 1988 protects road signs in India by ensuring uniformity and effective communication.

1.2.2 Classification of Traffic Signs

Regulation or Provision Signs are circular in shape and serve to communicate required or prohibited actions, such as overtaking or making a U-turn. They can also convey parking restrictions, vehicle size restrictions, and speed limits. These signs are distinguished by black text, arrows, and diagonal bars set against a white background and surrounded by a red circular ring. The diagonal red bar represents limitations on the action represented by the black symbol, whereas the red ring represents a prohibition or regulation.

Signs indicating required actions that drivers must take, on the other hand, display a round white symbol set against a blue background. Finally, the STOP sign, with its octagonal shape, indicates that the driver must come to a complete stop. Conversely, the GIVEWAY or YIELD sign, in a triangular shape, directs the driver to yield to other traffic [1].

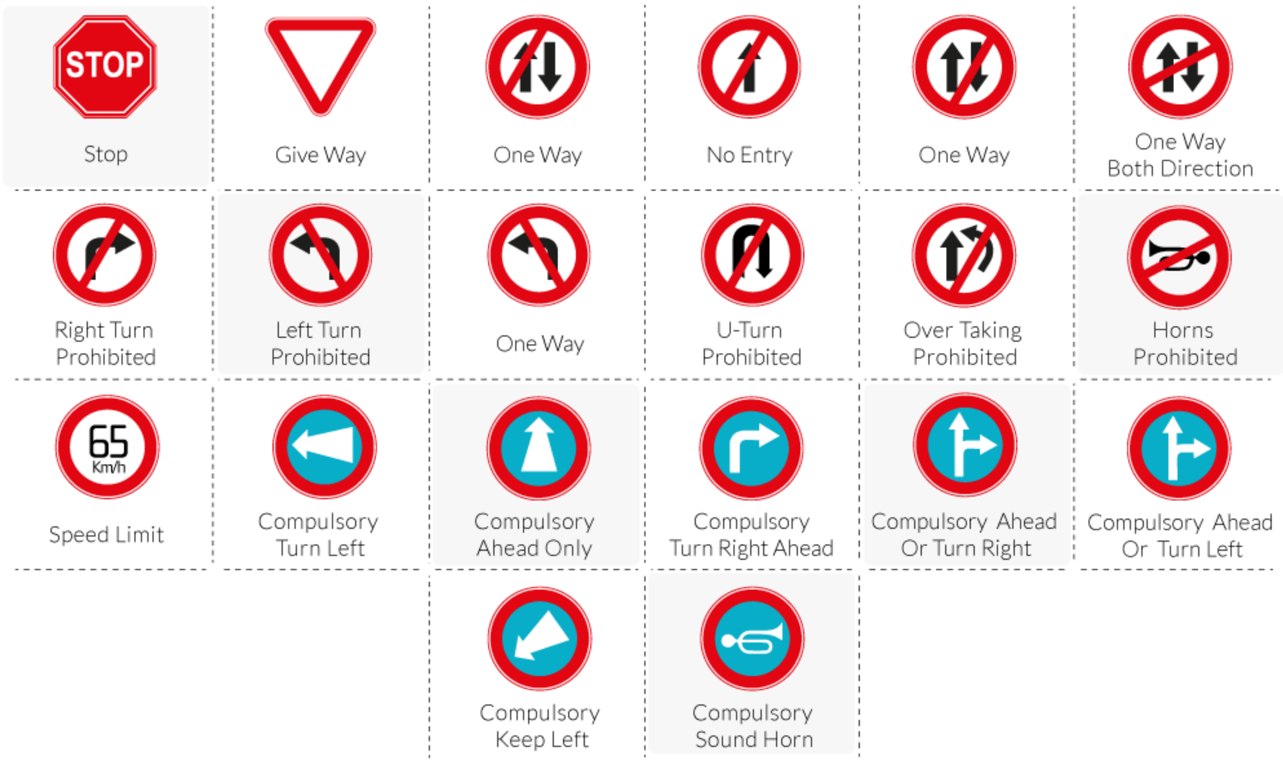

Figure 1.1 Mandatory / Regulatory Signs

1.2.3 Cautionary/Warning Signs

Warning or cautionary signs are critical for alerting drivers to impending road conditions and encouraging strict adherence to safety regulations. The primary goal of these signs is to emphasise driver safety by encouraging increased caution. These signs' distinctive colour scheme includes black inscriptions on a white background.

These warning signs provide critical information to drivers, prompting them to be extra cautious. In some cases, they may need to slow down or perform specific manoeuvres to ensure their safety. Signs such as Hairpin Bend, Narrow Bridge, Median Gap, and School Ahead are examples of such signs [2].

Figure 1.2 Cautionary / Warning Signs

1.2.4 Informatory / Guide Signs

Informative signs with facility information use a blue rectangular board with symbols representing services such as "fuel station," "dining place," or "parking." Rectangular information signs with directional arrows and distances to destinations are also common. These signs assist travellers by providing information about mileposts, services, routes, tourist attractions, cultural sites, and other pertinent traffic information.

Different designs are used for route markers that are designated for numbered roads. These markers feature black letters on a yellow background for easy visibility. Destination signs, which are used to mark significant crossroads and direct people to important destinations, have white letters on a green background. For added navigational clarity, they frequently include a kilometer marker to the right of the destination [3].

Figure 1.3 Informatory / Guide Signs

1.2.5 Standard Colors of Traffic Sign

The colour scheme used for traffic signs in India is crucial for communicating important information to drivers and pedestrians navigating the roads. While there may be minor variations in colour usage across different states or regions of India, the core principles of colour coding remain consistent across the country. This standardized approach ensures that people, regardless of where they are, can easily understand and respond to traffic signs.

Traffic signs in India become a powerful tool for promoting road safety and reducing the risk of accidents by adhering to a universally accepted color-coding system. Colour consistency provides road users with a sense of familiarity and predictability, allowing them to quickly interpret and act on the instructions or warnings conveyed by the signs. The effectiveness of this color-based communication cannot be overstated, significantly contributing to overall traffic management and improving the safety of everyone sharing the roads. As a result, ensuring compliance with standardized colour codes in traffic signs throughout India is critical for a safer and more efficient transportation system [4].

Table 1.1 Standard Colors of Traffic Signs

Red	The colour red has a distinct meaning in traffic signage, typically associated with stop signs, yield signs, and other critical directives that require immediate attention from road users. Furthermore, red is used to convey prohibition, as seen in signs such as "no entry" or "do not enter."
Yellow	Yellow is the standard colour for cautionary signs because it effectively alerts both drivers and pedestrians to potential hazards ahead. Such hazards include impending "speed limit changes" or a "slippery road," requiring increased awareness and preparation for safe navigation.
Green	The colour green is reserved for directional signs, which provide useful information about destinations, distances, and routes to effectively guide

	travellers. Green signs are also used to mark exits on highways, allowing for easier navigation and informed route choices.
Blue	Blue is assigned to signs that provide informative guidance to both drivers and pedestrians. These signs provide vital information, such as "rest area" or "hospital" indications, assisting individuals in making informed decisions while travelling.
Orange	The colour orange is reserved specifically for construction and maintenance signs, which effectively communicate work zones, detours, and road closures. These signs serve as notices of ongoing maintenance, temporary traffic restrictions, and road repairs. Drivers are reminded to be cautious, to adjust to changing speed limits, and to be aware of workers on the road.
White	The normal colour for regulatory signs, which convey important information about traffic laws and regulations, is white. Examples include speed limit signs, no parking signs, and one-way signs, which all serve as reminders to drivers to follow the rules of the road and maintain a safe and orderly flow of traffic.
Brown	In India, navigation signs directing people to parks, historical sites, or recreational areas are usually brown. This colour choice is intentional and globally recognized, assisting travellers in readily identifying and following signage going to cultural, recreational, or historical monuments.
Fluorescent Yellow-Green	For pedestrian and cycling signs, as well as school zone signs, fluorescent yellow-green is used. It is the shade used to denote the presence of cyclists or pedestrians close or on the road. It is deliberate to choose such a vivid colour since it improves visibility greatly, especially in low light, thus enhancing safety measures.
Fluorescent Pink	Although fluorescent pink is not commonly used for regular traffic signs in most countries, it is used in specialised and temporary signals connected to construction or events. It is specifically used for warning and guiding signs during incident management, which includes tasks such as crash cleanup, debris removal, and other important response operations.

1.2.6 Standard Shapes of Traffic Sign

Traffic signs come in a variety of shapes, each with its own meaning and purpose. These signs' standardized shapes serve a critical role in efficiently relaying critical information to drivers and other road users. Drivers who are familiar with these shapes and their associated meanings can interpret the messages provided by the signs more quickly and accurately, supporting safer and more efficient driving practices. Since a result, paying attention to the design of a traffic sign is critical, since it provides vital insights into the sign's meaning and advises appropriate road responses.

Table 1.2 Standard Shapes of Traffic Signs

	**Octagon**	This particular type is only used for stop signs and is immediately identified by its octagonal shape, which features a vivid red colour with white letters. Only stop signs have this distinguishing form. It is mandatory for automobiles to come to a complete stop at junctions where this sign is placed.
	**Triangle**	This particular shape is reserved for warning signs, which indicate potential risks or dangers ahead, such as steep curves, pedestrian crossings, or slick roadways. It acts as a warning sign, asking cars to cede the right of way and be more cautious.
	**Pennant**	A small flag-like sign provides temporary or specific warnings to drivers, indicating roadwork, construction zones, reduced speed limits, detours, or lane closures. These signs alert drivers to potential hazards or changes in road conditions, promoting safer driving.
	**Diamond**	This shape is meant for construction and maintenance signs, which include diversion signs, roadworks ahead signs and flagged ahead signs. It functions as a warning sign, drawing attention to specific road hazards. The content of the sign, whether words or images, elaborates on the reasons for proceeding with caution or at a slower speed, providing important alerts for safe navigation.
	**Rectangular**	Rectangular traffic signs serve two functions: regulation and information. They are frequently used for critical signs such as speed limit indicators, which fall under regulatory guidelines. Furthermore, these rectangular signs are used in warning, directional, and other regulatory signs, playing a versatile role in road communication.
	**Pentagon**	This distinct shape is reserved for school crossing signs, and its five sides make it easily identifiable. It is typically yellow with large black letters that clearly state "School Crossing." The use of these signs is critical for delineating school crossings and surrounding areas, thereby improving pedestrian and driver safety.

	**Cross buck**	The unusual crossbuck shape is used exclusively for railway crossing signs, resembling an X with the initials "RR" in the center. These signs are a clear indication of the presence of the railway at every railway crossing. Furthermore, a numerical representation on the crossbucks indicates the number of railroad tracks that must be crossed at that specific crossing location.
	**Circle**	The circular traffic sign with a red border and a white center, which frequently displays a number value or a speed limit in black, is an important indicator of speed regulations. It is a standard representation used to indicate the defined speed limits that cars in the given region must follow. The red circular border emphasizes the importance of adhering to the speed limit, promoting road safety and responsible driving.

2. Literature Review

When it comes to traffic signs, storefront signs act as their sole point of reference for drivers navigating the complex system of streets and highways, effectively directing them to commercial destinations. A notable study conducted by *Abdulilah Z. Zineddin et al. (2005)*, which focused on premise signage, sought to refute the widely held belief that larger parallel signs would be more noticeable than their smaller perpendicular counterparts. The study meticulously observed 120 people from various age groups in both diurnal and nocturnal settings, using real-world scenarios and an open-field research methodology. This study focused on a critical comparison between parallel signs that ran parallel to the road and perpendicular signs that were placed in strategic alignment with the direction of approaching traffic. Contrary signs stood out significantly, proving to be more discernible and legible when compared to their larger parallel counterparts, challenging the conventional wisdom in the field of traffic signage visibility, contrary to conventional belief, which was uncovered by the research [5].

A fundamental study was carried out by *X.W. Gao et al. (2005)* into the inherent qualities of traffic signs, paying particular attention to the crucial facets of colour and shape. These characteristics are crucial for the development of artificial traffic sign recognition systems as well as human sign interpretation. Notably, these fundamental sign attributes have not been fully and robustly incorporated by existing recognition systems, especially in situations where viewing conditions are less than ideal. In order to fill this gap, Gao's study improved the preexisting behavior model of vision and used a colour appearance model based on human vision. This strategy was used in the study to represent the vital colour and shape information present in traffic signs in an accurate and efficient manner. In order to segment and categorize traffic signs, colour information is extracted using the colour appearance model CIECAM97. The study also develops the FOSTS model by extending the behavior model of vision, which enables the extraction of shape features. Surprisingly, even under artificial transformations simulating potential real-world sign distortions, such as up to 50% noise level, 50 meters distance variations to signs, and 5° perspective disturbances in still images, the recognition rate still remains remarkably high. The recognition rate specifically for British traffic signs (n = 98) observed under various viewing conditions reaches an impressive 95% [6].

LIU Bohua et al. (2011) conducted a dynamic visual cognition experiment using a driving simulation barn and an eye tracker system to capture crucial eye movement parameters of drivers while interpreting traffic signs with varying information loads at different speeds. Fixation number and duration were among the eye movement parameters under consideration. Dynamic clustering was used to divide the driver's visual field into three sections. The eye movement parameters within these delineated areas were subjected to a thorough analysis. The study's findings revealed a significant relationship between fixation distribution and both driving speed and information quantity. In particular, as driving speed and information quantity increased, there was an increase in the number and duration of fixations within the traffic sign area, accompanied by a decrease in visual focus on the front lane. Furthermore, when guide signs contained more than five pieces of information, there was a noticeable abrupt change in the number and duration of drivers' fixations, significantly reducing the efficacy of visual cognition. Based on these insights, it was recommended that the volume of information on highway traffic guide signs should not surpass five. Additionally, under similar conditions, drivers required more fixations when interpreting non-guide signs, indicating a more intricate visual cognition process [6].

The research conducted by *Yichang (James) Tsai et al. (2009)* in on a wide range of traffic sign types, each with its own shape and colour, presents a challenge for the development of a universal traffic sign detection method. As a result, agencies performing sign inventory tasks frequently find themselves manually reviewing a massive number of roadway video log images. This paper introduces a novel image-processing model designed to automate traffic sign detection, thereby significantly reducing the workload associated with sign inventory. The proposed model was rigorously tested using 37,640 images supplied by the Louisiana Department of Transportation and Development, resulting in an impressive 86% reduction in manual review efforts. The method consists of four major components: (1) a comprehensive traffic sign model that encompasses the entire class of traffic signs, (2) an innovative statistical traffic sign colour model, (3) a robust traffic sign region of interest detection system based on polygon approximation, and (4) traffic sign candidate decision rules based on shape and colour distributions [8].

In *Štefan Toth's (2012)* research paper, challenges related to traffic sign recognition (TSR) are thoroughly investigated. TSR, an integral component of image processing and computer vision, involves capturing an image of a real-time traffic scene through an in-vehicle camera. The captured image undergoes processing to detect and recognize traffic signs. This recognition technology serves multiple purposes, primarily enhancing road safety and assisting companies in furnishing maps containing speed limit data. Moreover, local authorities can leverage TSR to maintain an updated record of traffic sign statuses on the roads, highlighting its diverse range of applications [9].

In a study by *Rubén Laguna et al. (2014)*, a software application for traffic sign recognition (TSR) is presented, operating through four different stages. Regions of interest (ROIs) are first detected during the image pre-processing stage by converting the image to gray scale and applying edge detection using the Laplacian of Gaussian (LOG) filter. Next, by comparing the ROIs with different shape patterns, potential traffic signs are found. Then, using a large database, a recognition stage uses a cross-correlation algorithm to categorize potential traffic signs that have been verified. Finally, a specially created graphical user interface is used to effectively manage and control these stages. When taking into account the acceptable conditions related to the size and contrast of the input image, the application displayed impressive performance results [10].

Majid Khalilikhah et al. (2016) conducted research on transportation asset management, focusing on optimizing construction, operation, and maintenance of transportation systems. Many states Department of Transportations (DOTs) have established effective asset management systems for high-cost, low-quantity assets like bridges and tunnels. However, due to the large number of traffic signs deployed by DOTs, comprehensive statewide sign inventory and condition information are lacking. Currently, handheld devices are the preferred method for sign measurement by agencies. To address safety challenges and reduce data collection costs, a novel stationary image-based method has been proposed. The paper comprehensively discusses the advantages and disadvantages of this image-based method compared to handheld devices, considering factors such as accuracy, data consistency and possibility, speed, safety, maintenance, and cost. The study concludes by providing valuable suggestions to overcome challenges associated with the image-based method [11].

Majid Khalilikhah et al. (2016) carried out research on the effects of dirt buildup on traffic sign faces on readability. In contrast to other damages, dirt on traffic signs can be removed rather than needing to be replaced. The purpose of the study was to identify the main elements causing dirt to build up on traffic signs. To do this, measurements were made of a sizable number of traffic signs in Utah using a car with mobile LiDAR imaging and digital photolog technologies. Digital images captured during the day were checked for dirt. ArcGIS was also used to compile location and climate data from official sources.

The factors causing traffic sign dirt were identified using the chi-square test, and the Random Forests statistical model was used to rank these factors according to their significance in sign dirt accumulation. The findings showed that air pollution, sign mount height and ground elevation were the main contributors to dirty traffic signs. These findings help transportation authorities identify traffic signs that are more likely to collect dirt. In order to ensure improved visibility and readability, agencies can give these signs a priority and plan routine cleaning [12].

Majid Khalilikhah et al. (2016), provide a comprehensive review on the role of traffic signs in conveying information to drivers, particularly focusing on compliance with minimum retro-reflectivity standards. The review highlights the importance of visibility during nighttime or low light conditions, necessitating adherence to these standards. The review uses various assessment methods and management methods, including expected life, blanket replacement, and control signs, to maintain compliance. It challenges the focus on sign age and examines the impact of various forms of damage on retro-reflectivity. The findings provide valuable insights for transportation agencies, aiding in the development of effective sign management plans and informed scheduling of sign replacement [13].

Traffic signs play a crucial role in providing drivers with important information, greatly enhancing road efficiency and safety. However, there has been little research done to date to fully understand sign degradation. *M. Khalilikhah et al. (2018)*, fill this research gap in the study, by exploring the many variables that affect a sign's visual quality. The study uses the Random Forests model and Odds ratio to analyze mobile light detection and ranging (LiDAR) and digital photo log data by carefully combining a large traffic sign dataset with location and climate data.

The findings highlight the impact of snow frequency and vandalism and highlight the elevated risk of sign failure for signs mounted at a height of 2 meters or less. The deterioration of signs is also known to be significantly influenced by air pollutants. The study suggests a thorough schedule for sign inspections and provides transportation agencies with useful information. Furthermore, by laying a solid foundation for asset tracking systems, risk analysis plans, performance evaluation of transportation systems, and well-informed decision-making, this research will help to increase the effectiveness of surface transportation systems [14].

This research paper by *Rajesh Kannan Megalingam et al. (2022)*, presents an autonomous system based on deep learning for recognizing traffic signs in India. The system uses a Convolution Neural Network (CNN) combined with Refined Mask R-CNN (RM R-CNN) for an end-to-end learning approach. The dataset used for training and testing was an extensive collection of 6480 images, encompassing 7056 instances of Indian traffic signs classified into 87 categories. The Mask R-CNN model underwent several enhancements to improve its performance. The study focused on challenging Indian traffic sign categories that had not been adequately explored in previous research. The dataset was captured using real-time images on Indian roads, providing a comprehensive representation of diverse traffic scenarios. The evaluation results showed an error rate of less than 3%. A comparative analysis was conducted, comparing the performance of RM R-CNN against conventional deep neural network architectures such as Fast R-CNN and Mask R-CNN. The proposed model demonstrated superior precision, achieving an impressive rate of 97.08%, surpassing the precision achieved by Mask R-CNN and Faster R-CNN models [15].

In their recent study, *Iman Ilkhani et al. (2023)*, focused on understanding how drivers perceive and respond to Variable Message Signs (VMSs) in intelligent transportation systems. They conducted a stated preference survey to investigate driver attitudes and reactions regarding VMS information. The study revealed that visual health and providing expected delay information significantly influenced driver decisions to change routes based on VMS messages related to accidents or traffic congestion. Additionally, personality traits like Agreeableness, neuroticism, extraversion, and openness played a notable role in driver route choices in response to VMS indications of traffic congestion or adverse weather conditions. This research offers valuable insights for optimizing the effectiveness of VMS and refining traffic management strategies [16].

The rapid growth of Artificial Intelligence (AI) applications, particularly in Intelligent Transport Systems (ITS), has profoundly influenced the field. One crucial research area within this domain is Traffic Sign Recognition (TSR), a pivotal component in ensuring safe driving and a key feature of Advanced Driver Assistance Systems (ADAS). This study focuses on robustly and efficiently recognizing traffic signs, especially in challenging environmental conditions. A novel 30-layered deep Convolutional Neural Network (CNN) model is proposed, with each convolutional layer extracting salient and highly discriminative features from various datasets for classification purposes. Remarkably, this approach achieves exceptional results without relying on a Graphics Processing Unit (GPU). After training the model, competitive classifiers like Tree, SVM, KNN, and discriminant analysis are employed for data classification. The Linear Discriminant Analysis (LDA) classifier stands out, achieving a commendable 97.4% accuracy with a training time of only 5.12 seconds on the CURE-TSR dataset. Extensive testing on benchmark datasets, including GTSRB and BTSRB, demonstrates the proposed approach's effectiveness, yielding accuracies of 99.12% and 98.16% respectively. These results underscore the applicability and advantages of the proposed approach across diverse datasets by *Aish Batool et al. (2023)* [17].

Car manufacturers all over the world are racing to develop self-driving vehicles, expanding the concept beyond automobiles to include wheelchairs, golf carts, and tourism vehicles. These vehicles must be able to navigate streets safely, stay within lanes, detect moving objects, detect obstacles, and interpret both permanent and temporary traffic signs. This necessitates a fully integrated system that includes the Internet of Things (IoT), GPS, Machine Learning (ML)/Deep Learning (DL), and Smart Technologies. While there has been significant progress in traffic sign recognition, particularly in the English language, the same cannot be said for Arabic traffic sign recognition. The techniques used for traffic sign recognition can also be used for indoor signage, smart cities, supermarket labels, and other applications. The Arabic Traffic Signs (ArTS) dataset is used to train two optimized Residual Network (ResNet) models (ResNet V1 and ResNet V2) for automatic Arabic traffic sign recognition.

Ghazanfar Latif et al. (2023), one of the authors/researchers, also curated a new dataset specifically for Arabic Traffic Sign recognition, which includes 2,718 images captured from various locations in Saudi Arabia's Eastern province. While carefully addressing over fitting and under fitting concerns, the optimized ResNet V1 model achieved outstanding training and validation accuracies of 99.18% and 96.14%, respectively. Notably, the proposed models outperform similar methods found in the existing literature for the same or comparable size datasets [18].

Traffic signs are crucial in the traffic control ecosystem, serving as guardians for the safety of drivers, pedestrians, and road users. In Colombia, the government has initiated initiatives to revamp the traffic sign system to promote traffic rule awareness among drivers. Significant visibility and legibility of traffic signs are essential for warning vulnerable road users, such as cyclists, about potential hazards. Understanding the current state of cyclist-specific signs is crucial for effective road infrastructure planning, especially in cities like Bogotá, which face increasing mobility challenges for cyclists. *Shyrle Berrio's et al. (2023)* paper examines the condition of cyclist-specific signs in Bogotá and assesses their compliance with current guidelines. A reliable method was developed to evaluate existing signs, considering both physical and functional aspects. The study examined eighty traffic signs in ten high-risk areas for cyclists in Bogotá, revealing alarming statistics. 55% of the signs were in poor condition, frequently damaged, and 18% were out of place. Additionally, 38% did not adhere to the proper board size. The "Get off your bike" sign had the highest rate of violation, emphasizing the need for immediate attention and improvements to improve cyclist safety and adherence to traffic regulations [19].

The study, led by *Jiangbi Hu et al. (2022)*, delves into the decline in driving visual ability during foggy nights, a critical aspect of driving safety. The focus is on understanding how light source characteristics influence visual distance in open traffic conditions. A comprehensive visual recognition test was conducted with 12 car drivers, analyzing their recognition distances for standard gray small targets under various light and visibility conditions. The findings underscored the significant impact of meteorological visibility, illuminance, and correlated color temperature on visual recognition in low visibility at night. Notably, light sources with higher correlated color temperature were observed to enhance visual distance. The research outcomes and methodologies prepared by *Jiangbi Hu et al. (2022)* provide valuable insights for enhancing traffic visibility at night, thereby contributing to improved road construction and traffic control strategies in foggy areas [20].

The study by *Siwei Ma et al. (2021)* examines the effectiveness of upgraded traffic signs and pavement markings (PSM) at grade crossings, where flashing lights are common. The research uses driving simulation and eye tracking systems to assess the effectiveness of these changes. The study found that drivers showed improved perception and fixation on flashing-light signals with the upgraded PSM, especially in scenarios with earlier FLTTs. The improvements also led to higher stop compliance rates. However, drivers faced dilemmas when deciding whether to stop or proceed during flashing red lights, especially when FLTT was less than 4 seconds [21].

The study by *Qing Cai et al. (2022)* explores how drivers' visual environment affects speeding crashes using machine-learning techniques. It uses Google Street View images and deep neural networks to extract clustering and depth information. The data is then transformed into visual measures, and three tree-based ensemble models are used to estimate speeding crash numbers. The study found that the proportion of trees in drivers' view and road length with trees could reduce speeding crashes. The complexity level of drivers' visual environment also linked to increased crash occurrence. The study provides valuable insights for traffic safety analysis and offers actionable suggestions for road planners and engineers [22].

Arshad Jamal et al. (2022), study focuses on improving traffic sign visibility and road safety, particularly at night. Traditional statistical regression models are compared to three neural network architectures: Feed-Forward Neural Network (FFNN), Cascade Forward Neural Network (CFNN), and Elman Neural Network (ELMNN) in the study. Data from 539 in-service signs in Pakistan were collected to predict sign retro reflectivity, which is an important factor in determining sign visibility. The findings show that neural network models outperform traditional regression methods, providing useful insights for improving sign management and policies, ultimately improving road safety [23].

The Driver Alerting System relies on automated recognition of traffic signs and potholes, but most current approaches focus on either pothole detection or traffic sign recognition. Deep learning techniques such as Convolutional Neural Networks and Long Short-Term Memory are commonly used in research. These studies, however, frequently focus on foreign roads, which differ significantly from Indian roads. This study presents a unified model for detecting traffic signs as well as potholes on Indian roads. The Hybrid Features from Accelerated Segment Test and Random Sample Consensus algorithms are used to extract and match key road traffic sign features. An improved Canny Edge detector and a bio-inspired Contour detection method are used for pothole detection. The Support Vector Machine classifier is then used to classify the data. In terms of accuracy, sensitivity, specificity, Matthews correlation coefficient, and F1-Score values, the experimental results show that this unified model surpasses existing models. *Satish Kumar Satti et al. (2021)* conducted the research [24].

Autonomous vehicles must detect and recognise traffic signs in a variety of challenging environments. Accurately identifying small traffic signs in real-time, in particular, poses significant challenges. This study presents an improved YOLOv4-based deep learning model built on CSPDarknet53, with data preprocessing and image enhancement techniques used to improve model generalisation. To illuminate night images, a nighttime image enhancement method is used. Anchor boxes are calculated using the K-Means clustering algorithm with Generalised Intersection over Union (GIoU) as the distance metric prior to using the YOLOv4 model. To detect smaller traffic signs, the modified architecture employs an improved PANet with grouped convolutional layers in the detection neck and an additional feature scale. The model is tested on a variety of datasets, including the Mapillary Traffic Sign Dataset (MTSD), the Tsinghua-Tencent 100K dataset (TT-100K), and a traffic sign dataset from India. Comparative analysis with cutting-edge models reveals superior performance, with high accuracies on a variety of datasets. *Swastik Saxena et al. (2024)* is one of the study's authors [25].

3. Conclusion

Traffic signs are a fundamental component of traffic control, aiding in the organization and safety of road networks. Their visual condition, readability, and overall visibility are crucial aspects in ensuring effective communication with drivers and pedestrians. This paper presented an extensive review of methodologies and approaches utilized in evaluating traffic sign conditions, employing image processing, machine learning, and computer vision techniques. By analyzing existing literature, the paper explored challenges and advancements in this domain, with a goal of enhancing maintenance and effectiveness of traffic sign systems for safer road environments.

Understanding the history and classification of traffic signs in India laid the foundation for comprehending the importance of their standardized colors and shapes. The standardized color-coding system proved pivotal in effectively conveying crucial information to road users. Moreover, the standard shapes of traffic signs were revealed to significantly influence interpretation and response, contributing to efficient driving practices.

The literature review encompassed various studies analyzing distinct aspects of traffic sign visibility and recognition. Research on traffic sign detection methods demonstrated the potential of automation in sign inventory tasks, reducing manual efforts considerably. Notably, studies analyzing factors influencing the accumulation of dirt on traffic signs provided valuable insights, aiding authorities in scheduling routine cleaning and ensuring optimal visibility.

In recent years, advancements in deep learning have propelled the development of autonomous systems for traffic sign recognition. in recent study showcased the potential of Convolutional Neural Networks (CNN) and Refined Mask R-CNN in accurately recognizing Indian traffic signs, emphasizing the need for innovation in real-world applications.

In conclusion, this paper highlights the criticality of ensuring the visual condition and effectiveness of traffic signs through a comprehensive analysis of various contributing factors. Utilizing advanced technologies such as deep learning can significantly enhance traffic sign recognition systems, ultimately promoting safer road environments and improving overall traffic management. Continued research and innovation in this domain are essential to keep pace with evolving technology and to maximize the potential benefits for road users and transportation agencies.

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