

# Survey on Traffic Light Violation Detection Tools and Techniques using Modern Technologies

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**Abstract:-** The violation of traffic lights by motorists is a huge concern, which requires innovative technological approaches that must be implemented to ensure compliance. However, developing countries are lagging behind on the adoption of enhanced technologies. This in general has always kept productivity low and has even caused social instability. This research investigates modern technologies that have been used to develop smart techniques and tools to account for traffic light violations. A survey has been done and it reveals other techniques which can be implemented as single entities or as a combination of different technologies to achieve one goal. An example of such a goal is accounting for anomalies of red traffic light (RTL) running. The use of automated techniques and technologies can assist the traffic controlling police officers who may be sometimes unavailable to observe the flow of traffic and related anomalies. Computer vision is dominating together with other technologies like Radio Frequency Identification (RFID), Radio Detection And Ranging (RADAR), induction loops and Light Detection And Ranging (LiDAR). Collectively these components and devices can be called Internet of things (IoT) devices. In developing countries there is a need to embrace inexpensive technologies to ease the current traffic situations. Identifying inexpensive solutions opens opportunities of more funding for improved tools and technologies.

**Keywords:-** Computer Vision, Red Traffic Light, Induction loops, Internet of Things (IoT), Radio Frequency Identifiers, traffic light violations.

## I. INTRODUCTION

Motorists' safety on the roads is imperative for improved social and economic development in any developing country. However, safety on roads is not the only cause of concern that can have an impact on the development or economic growth of any country. In comparison to developing countries, developed countries have much better infrastructure and technological advancements. The latter should not stop the developing countries from catching up. Developing countries have a lag because of the unavailability of funds and resources to expand or adopt such better technologies. Implementing these technologies can be

expensive, but better options can be developed so that advanced technologies running with the available resources may be available on the ground.

Rather than having police officers at different intersections to enforce traffic laws (Franklin Mohana, 2020) or just having the ordinary closed circuit televisions (CCTVs) cameras mounted and recording images and videos whole day (Tonge *et al.*, 2020), there should be techniques backed with capabilities like those of humans of observing, recognizing, differentiating (Hussain, 2023) and accounting for any object on a certain event that takes place within the captured frames, without the human interaction. Other advanced technologies may also require proper infrastructures, which may not be available in developing countries.

Modern technological solutions exist, combined with the power of Artificial Intelligence and Machine Learning they transform the transportation industry. There are some vehicles where operational safety has improved through the implementation of technology like computer assisted control(CAC) as well as technology based traffic management systems, but traffic safety remains one of the main challenges in today's life.(Razi *et al.*, 2022).

On the roads, the possibility of violations exists even if there are many drivers obeying traffic signals. This may be due to issues like driver distractions, aggressive driving or even drivers ignoring traffic lights deliberately (Cohn *et al.*, 2020). This research has identified and noted with concern the issues which do not require any direct funding from the government or other parties to manage motorists and public safety on the roads. If one becomes aware of the monitoring systems and controls in place, caution can be exercised to some extent.

This paper provides an insight into different techniques that can be employed in the process of traffic lights violation detection. The technologies aid in deducing meaningful information that is required to deal with some complexities of how traffic moves and has always been a challenge as there can be some different drawbacks which disrupt the normal operation of the technologies.

## II. TRAFFIC RULE VIOLATION AND DETECTION

Traffic rule violation is an illegal act that is executed by a motorist and has a potential to put other road users at risk of injuries or even death. In general such violations will eventually lead to negative effects on both the environment and human lives (Dams *et al.*, 2021). The traffic rules of any countries are in the form of traffic laws and may differ from country to country. Some of the offences related to traffic rules include but not limited to exceeding speed limits, changing lanes where prohibited, red traffic light running and parking violations.

If one breaks the law and for them to be held accountable, there is a process that is implemented to identify and flag them. When a violation takes place and is identified that is when we may say that there is a violation detection. It can be attained by using different tools and technologies which include IoT devices, cameras and supporting systems. According to (Uy *et al.*, 2017) when a violation has been detected there is usually need to provide evidence or information about that certain violation.

## III. TRAFFIC LIGHT VIOLATION

Just like any other traffic rule, motorists should obey traffic lights at traffic light-controlled intersections, proceed when it is allowed. It becomes a violation when one fails to observe the light signals (Dams *et al.*, 2021). Traffic light violation is often referred to as red light running. Just like any other traffic related violations, traffic light violations may be intentional or unintentional due to factors like ignorance, weather conditions, road conditions, time of day (Fu and Liu, 2020).

## IV. WHY DETECTION TECHNIQUES?

Computer systems need a way of enhancing some processes which can be tedious tasks if carried out by humans. Detection technique is a method of identifying an occurrence or presence of a certain object in each environment. The given environment can be in the form of an image, video, or signal.

## V. DETECTION TOOLS AND TECHNIQUES

Several papers have been published on the topic of traffic light violation detection in different countries. Different techniques have been explored with regards to detection anomaly of vehicles on intersections.

Any action that is more aligned to breaking the law is regarded as an anomaly behavior. This is regarded as an anomaly as it is an action that deviates from the expected normal behavior (Zhao *et al.*, 2021). Different tools and technologies have been proposed to help in detecting such behavior automatically. Every tool has its own drawbacks and advantages as well. In some cases, the technologies could co-exist to complement each other.

(Asoba and Supekar, 2020) presents the need to have a combination of recent or latest technologies to aid in improving how roads are operating in terms of management, since the roads are regarded as a major connective mode in any country. It is difficult for authorities to account for traffic violations, so employing IoT, Radio Frequency Identification (RFID) and image processing has been proposed and as well as the possible use case for the decision of the violation. Furthermore, Global system for Mobile Communications (GSM) technology has also been used (Asoba and Supekar, 2020) to alert the penalty imposed on a prospective owner (Arnob, 2020).

For years, traffic police officers were doing tedious tasks of identifying offenders after looking at the CCTV footage of each camera that would have captured some videos. The genetic algorithm was then proposed by (Bhat *et al.*, 2021) to aid in the process of violation detection. This algorithm was being used to optimize the provided input. Genetic set of rules were then used in assisting in the certainty of an event occurrence. Generally, the input was just the CCTV videos which went through several steps until some event is detected. The main tool that was generally used was the CCTV for recording of the videos.

(Parameswaran *et al.*, 2019) explores the use of Radio Frequency (RF) signals to detect those that are supposed to be held accountable for violating traffic signals. There is an ever-increasing use of cars on the roads which eventually leads to congestion, which ends up hindering accurate recognition of the offender and they can probably get away without being caught or noticed. (Bhat *et al.*, 2021) promoted the use of RF signals citing that they can be transmitted accurately without any hindrances in line of sight. To detect an intrusion some (Light Dependent resistors) LDRs were used, and frames could be sent to the back-end server for that period. A penalty notification using SMS and Email services has been suggested as add on to alert the owner of the vehicle that might have violated the traffic light signal.

Infrared (IR) sensors which were positioned in parallel to the boundary of the zebra crossing area were used to detect any violating car or motorcycle. Research was aimed at developing an architecture which made use of the IR sensor with cameras as well for capturing number plates, and the accuracy levels were more than 70 % (Hirawan, Hadiana and Abdurakhim, 2019). Google voice API was incorporated as well so that it would give warning to the offender. Using CCTVs or law enforcement agents to monitor violations in developing countries is not efficient because the budgets set for the traffic law enforcement usually are insufficient compared to the violations that are committed every day (Suphavilai, Seetamanotch and Ekpanyapong, 2021) as noted by increase in vehicle use as well.

Total elimination of the violations may not be very feasible in any developing country but, just the reduction of violations incidents can be attained to a certain acceptable level. In the process of reducing the violations occurrences, (Dams *et al.*, 2021) introduced smart spike strip which was working in synchronous with the Traffic Light Control

System (TLCS) as a simulation. The author highlighted that the spike was activated when the traffic light turns red. Whenever a vehicle attempts to violate traffic signal during that period then the vehicle gets immediate punishment of tire puncture. Green signal provided the antagonistic mechanism to the red light as way of deactivating the spike.

It is common for developing countries to use time-based traffic control system, rather than automatic and adaptive. This condition has led to issues which include congestion and violations. (Gebregeorgis and Sarmah, 2016) supported the fact that it can be expensive and difficult to implement a solution using different sensors like RFIDs and sensors. Basically, the system could operate in two modes depending on the time of day, that is either day or night time. The base technologies used were cameras and image processing technique. The main aim was to make an adaptive traffic light rather than violation detection though it was included as an add on. Image subtraction mechanism was used to deduce the occurrence of a violation but there are some drawbacks to it which include real time performance and semantic understanding issues. It may give false positive if any object hits the area of interest which changes the threshold of image density.

(Ibadov *et al.*, 2017) proposed an algorithm for automatic traffic rule violation detection using multi step proceedings. The paper was basing on computer vision approaches of vehicle detection. There was detection of crosswalk area using alpha channel method, detection of vehicle using faster Region-based Convolutional Neural Networks (R-CNN) and then pedestrian detection using Motion-Based Multiple Object Tracking method. The main aim was to reveal vehicles that would have violated traffic

regulations in cases where a vehicle approaches the crosswalk at the same time as the pedestrians (Ibadov *et al.*, 2017).

In the case of (Amiruzzaman, 2019), the technology was not implemented to combat, detect or deter but to predict the likelihood of a violation using data mining. The main aim was to come up with findings which may be used to increase awareness as well as reducing the violations occurrence. Author used different Machine Learning algorithms to analyse data of previous incidents. Just like any other statistical information, it had a set of attributes which were being used in the processing the data. This means that Machine Learning as a technology can be adopted in cases to do with traffic rules violation issues.

In Thailand, (Suphavitai, Seetamanotch and Ekpanyapong, 2021) acknowledges the existence of road safety regulations and traffic laws violations. It pointed out as a challenge mainly for low- and middle-income countries. The paper presented an architectural design of a violation enforcement system that can optimize cost of deployment and resource utilization, since it is still costly for such types of systems in the mentioned economies. As a comparison then the paper gives a conclusion on making use of computer vision techniques using cameras installed on the roadway infrastructure to deliver the proposed main objective.

**VI. SUMMARY OF TOOLS**

Table 1 summarises the different tools and technologies that have been discussed in the literature, giving the advantages and disadvantages of these tools and general comments from authors’ perspective.

Table 1: Advantages and Disadvantages of detection tools and technologies

<b>Tools/technology</b>	<b>Advantages</b>	<b>Disadvantages</b>	<b>Comment</b>
RFIDs	<p>Accurate and reliable especially in high traffic areas.</p> <p>Scalable to accommodate growing traffic demands.</p> <p>Capable of integrating with existing systems.</p>	<p>Infrastructure costs are encountered to implement the RFIDs based light detections.</p> <p>Tag can be missed if not properly placed and readability may be affected by interference from other electronic devices.</p> <p>Can collect limited data as it primarily focuses on vehicle presence, leaving out other parameters like speed or vehicle type.</p>	<p>Can be costly to equip every vehicle with the components and also upgrading the roadside infrastructure.</p>
GSM technology	<p>Realtime notifications to provide immediate notification to offender (Asoba and Supekar, 2020).</p> <p>Cost effective as infrastructure is already established.</p> <p>Traceability of offenders using their mobile numbers.</p>	<p>If change of ownership has not been done when a vehicle was sold, the first owner may end up being held accountable.</p> <p>Privacy issues, since there is collection and storing of personal information and coordination between MNO and traffic authorities.</p>	<p>It is convenient as one will become aware of their charges, but there may be inconveniences in cases where there are false positives.</p> <p>It aids as a communication protocol that notifies the one who may have violated, rather</p>

			than being a violation detection technology or tool.
CCTV cameras	<p>Capable of providing evidence of violation because the incident can be recorded and incident can be re assessed to be certain on the violation.</p> <p>If well positions the area in site of view can be comprehensive to cover a wide region, which ease the task of violation detection.</p> <p>Enables remote monitoring of a certain intersection or an area.</p> <p>Can act as a deterrent component rather than it being a detection tool, since one can be cautious knowing that they are being recorded.</p>	<p>Privacy concerns as the cameras will be recording images and videos of public areas.</p> <p>If not properly positioned, quality of video may be compromised which end up hindering accurate detection of violations during processing of the video frames (Liu <i>et al.</i>, 2022).</p> <p>They require regular maintenance and calibration since they are always exposed to different weather conditions.</p> <p>If special video processing tools are not used it will require human resource to analysed and pick on violation detections.</p>	<p>CCTV on its own is a great tool to collect data in the form of videos and images which may then require further processing to pick on anomalies from the video frames.</p> <p>Unless the camera is equipped with some software to process images it requires extra tools and software to assess the videos in real time without delays.</p>
LiDAR	<p>A remote sensing technology that uses laser light which is good at giving high accurate distance measurements.</p> <p>Not easily effected by different weather conditions.</p> <p>Can be used where real time detection or processing is required.</p> <p>Are capable of identifying and classifying objects into different classes and has been used in autonomous vehicles to detect and avoid objects (Mehendale and Neoge, 2020).</p>	<p>Cost of implementing and maintenance can be high.</p> <p>Since it works with line of site LiDAR measurement can be affected if there is an obstructing object</p>	<p>Using LiDAR is a better option over RFIDs as its capable of classifying object and also does not make of a reader for the tools to work.</p> <p>In the context of violation, LiDAR was used to pick the distance of the vehicle and if the vehicle has passed a certain distance threshold, then it becomes subject to red light violation if the traffic light was red.</p>
LDR	<p>Inexpensive IOT components compared to most of the technologies mentioned.</p> <p>Can be easily integrated to other systems circuits.</p>	<p>Has got limited accuracy in situations where there are complex traffic setups.</p> <p>LDR can be affected by different environmental factors especially where there are ambient light conditions.</p> <p>Reliant on line of sight so obstruction has a serious impact on the readings.</p>	<p>LDRs are not usually used as standalone components to detect violation, but they were mostly used to identify change in traffic lights colour to trigger the actual components which do the frames recording or detections.</p>
IR	<p>Just like LiDAR, IR is good at measuring distances.</p> <p>And it can operate effectively in low light environment or at night.</p>	<p>Can be affected by adverse weather conditions.</p> <p>Has a limited field of view</p>	<p>Not commonly used for traffic violation tasks because there are better tools like LiDAR or cameras which outperforms IR.</p>
Induction loops	<p>Provides more details information about the passing vehicle including speed direction and position.</p> <p>They are good in areas with multiple</p>	<p>Installation of loops requires more work of cutting grooves in the road surface and can be a disruptive process which can inconvenience the road users.</p>	<p>They need another supporting technology to detect traffic light violation.</p> <p>Induction loops aid in</p>

	lanes to detect violations across various lanes.  They are known to be reliable and durable and are known to perform for longer periods without affecting performance.	They have a limited detection area, meaning that there is need to use multiple extended loops for a larger coverage.  It can be a challenging process to execute maintenance tasks on the induction loops.	accurately detecting a vehicle object, but identification or segmentation of the vehicle committing the violation may need technology like cameras.
Smart spike	When a violator commits the crime, the punishment is served instantly.  No network overheads can be encountered since there is no information that is required to be sent to the server for processing.	Ethically, it is unacceptable to use spikes especially in cases where the system malfunctions or when it gives false positives.  Requires thorough testing before deployment to avoid conflicts with motorists since it ends up becoming a burden on motorists to buy new tires.  Can be dangerous for fast moving vehicles and those driving at night, as there will be no access to tyre services.	Unless the system is 100% accurate, such punishment should be avoided.  Using spikes implies that the motorists will not pay for any fine, which can be seen as loss to the enforcing agent or government since motorists would have been entitled to pay the fines after violation.
Computer vision / image processing	There is presence of visual evidence when a violation takes place.  Can be applied for multiple uses or scenarios like detections or traffic light violations or switching lane violation or even detecting riders without helmet from the same source.  Can accurately analyse and detect objects within the images or videos, and that can be well enhanced with the improvements in image processing techniques applied.	For better results there is need to have quality images and videos.  Higher quality means more need for computational resources.  Can be affected by bad weather conditions which can have an impact on the performance of the computer vision system.  There is likelihood of false positives, so there is need to use optimal threshold levels.	Can be used with other technologies to reinforce accuracy and performance, though computer vision can work well with improved algorithms on images or videos.  The most common drawback is the scarcity of computing power for the most accurate results.

**VII. CONCLUSION**

Many researchers are trying to fuse several technologies for improved efficiency. They include tools like RFIDs, RADAR, LiDAR, induction loops, microcomputer systems and other IoT components. This was necessary so that other components can complement the drawbacks of others. However, having multiple combined components is good but the overall cost of operational, implementation and maintenance may increase, which can be a drawback to the developing countries. Picking a technology which has the capability to expand by optimizations can be a good option to consider. For instance, computer vision is regarded as the technological state of the art, that is adopted and found to be helpful in monitoring, and assessing vehicle traffic conditions, and the roads as well. Computer vision implementation can also assist in the detection of vehicle traffic anomalies.

As an outcome of enhanced technologies implementation, the risk of accidents (Saxena, Malik and Bhardwaj, 2019), injuries and deaths can greatly be reduced. This is possible because with the aid of these technologies’ motorists may not repudiate their actions, especially reckless driving.

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