The Invisible Eye - A Security Architecture to Protect Motorways

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Abstract. There have been proposals and even some successful deployments (by official bodies) of various road safety and traffic **control** systems. Emerging technologies like the Internet of Things (IoT) and Image Processing have found effective uses for developing the same. Although road security hasn't been considered a very pushing topic. Particular motorways hold severe significance when it comes to a nation; security concerns. And hence it is very crucial for these motorways to have security systems in place and sometimes even have officials deployed for checking all passing vehicles which seem vulnerable to them using barriers and other equipment. Two peculiar problems that come into the picture when considering road security are first, lack of availability of automated, intelligent and feasible systems on motorways that can detect vulnerabilities in passing automobiles and second, knowability and visibility of any security mechanism used for checking the vehicles is an easy task for anyone traveling by the road under surveillance. The prior makes it easy for malevolent individuals(one's carrying any illegal weapons, equipment, etc) to escape and the latter makes them well aware about which security-checks they will have to tackle to surpass the checking zones without being caught red-handed. Hence need for a system which eliminates these two problems becomes vital to increase the security of motorways. This chapter introduces an intelligent cop assisting system TIE (The Invisible Eye). The system senses parameters that aren't direct knowable by anyone at their first glance on the vehicle like weight, etc and make them available to the security personnel(s) deployed to check those vehicles. Also, the system would provide a vulnerability index and it can be deployed in an unnoticeable way.

Keywords. Security, Motorways, Invisible Eye, Surveillance, Intelligent Transportation System (ITS) and Traffic.

1 Introduction

Transportation is a rudimentary aspect for every nation on the planet. It empowers trade between people, which in turn is crucial for the development of civilizations. Transport plays a critical part in globalization and financial germination. Though it is heavily subsidized by governments, careful planning of transport is quintessential to make traffic flow and smooth growth of any developing country.

Scaling up all 3 modes of transportation also brings in the need of reliable tools, technologies, and mechanisms for maintaining safety and security to the people and commodity traveling through it and even to the people who live by areas from which the vehicle carrying passengers it is going to pass through. Unsafe and insecure vents in any mode of transportation directly lead to either loss of life or drastic reduction in the quality of life [1].

Among all 3 modes motorways are the majorly used one in almost all the developed nations [2] [3]. Despite this large scale use of Motorways, assurance of safety on them is still a critical issue in developing countries like India.

Both technology and legislative wise there [4] [5] are considerable efforts being taken in the direction of rectifying the bad scenario. Also, authors have seen massive campaigns in India for the same which reflect on the importance of the issue [6]. Showing the importance of tech in road safety Dr. Nishi Mittal, Head, Traffic Engineering & Safety Central Road Research Institute, New Delhi said, "…Technology is an aid to traffic policemen, not a substitute. So, technology helps in curbing traffic violations because the people who deny that they did the violation they cannot deny because it's proof." [7]. Hence building reliable Intelligent Transportation Systems (ITS) is quite an evident need.

Technologies like Facial recognition and Internet of Things (IoT) [8] have immense potential in the police force's ammunition against fighting criminality. Additionally using image processing in criminal detection has been an efficient, effective & speedy way to catch malevolent individuals and activities [9] [10].

Processing of the images in real time using analytics algorithms is making it considerably more effective [11]. Many official bodies are suffering a future of lessened funding. Compelling new technologies render a way for forces to conduct and serve their populations more efficiently.

This chapter, A Cop Assisting ITS named TIE System is put forth. It attempts to identify and solve two loopholes of most current road security mechanisms (1) High knowability and (2) Chances of human error.

The rest of the chapter is organized as: Section 2 covers the related work, Section 3 delineates the model and design of TIE system, Section 4 poses a case study of the Pulwama Attack in the context of the proposed system, Section 5 contains conclusion of the chapter and finally the chapter ends with the future directions for further extension.

2 Related Work

Amongst all of the road safety and security problems like rash driving, breaking signals, etc. few common and current problems related to vehicle overloading and lawful use of license plates render inevitable.

Large democracies like India [12] and China [13] are facing a big challenge in rectifying truck overload problems in specific. Prior addressed problem of overloading vehicles causes serious harm to the roads plus reduce their life span to a noteworthy extent. Providentially the development of sensors that can sense the gross weight of the vehicles with 96-97% [14] accuracy favors prompt development of frameworks and systems that work towards keeping the weight of vehicles in legal limits.

License plate recognition is a big help to traffic forces since they unfold a lot of details about the vehicle, its owner and related commodities. Issues like non-uniformity of the license number plate models, the low resolution of the license plates for vehicles in video frames under typical surveillance systems, etc are faced by many researchers [15].

Due to the physical placement constraints in many systems, the sole way to get more accurate results is by improving and innovating on the image processing aspect. On the other hand, if there is a possibility of changing the placement aspect of the cameras, its accuracy can be leveraged by appropriately placing the camera to face the region of interest as directly as possible.

Use of micro-controller based systems that are deployed on the motorways for various purposes and with various sensors and modules have yielded decent results in many past use cases. In supplement to producing decent results, they also make the system more ubiquitous with respect to the variety of motorways at a lower cost. And the cost of developing such systems is indeed a concern in some countries [16]. This low-cost option can sometimes render a security system useless because of their intermittent errors and high dependency. Hence to niche the system at its right position authors say such systems turn out, in case of a being a security system, to be useful “assisting systems” which leverage and fasten the security to a considerable extent on busy roads, doing which is quite important by bringing in technology [17].

3 Model & Design of TIE System

3.1 TIE System Positioning

In TIE System, positioning of the sensors and camera modules is an important issue since it has to accomplish the requirement of reducing the knowability about the presence & operation of the system.

The aim of the system is to position and deploy the sensors and camera modules such that they either seem (1) obvious to be present (e.g. presence of a CCTV Camera Module would be expected in a security checking scenario) or (2) Completely unnoticeable.

Figs 1.1, 1.2, 1.3 and 1.4 illustrate the placement of various modules in a Black Box manner:

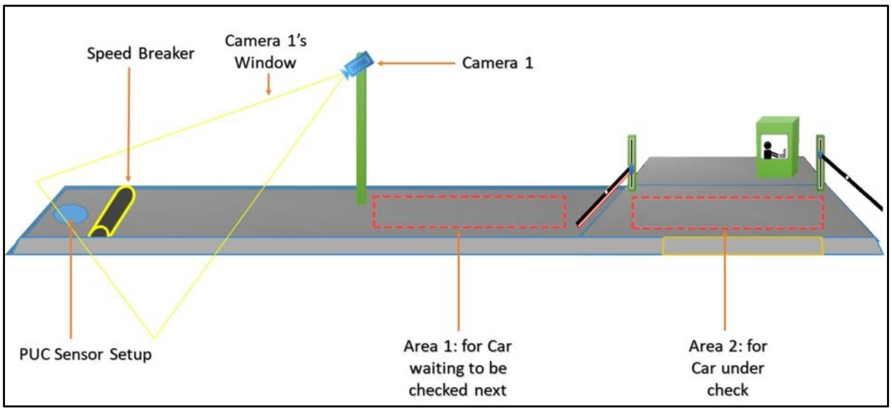


Fig. 1.1 Placements of VCP Sensor Setup, Speed Breaker and Camera 1

VCP Sensor module is made unnoticeable by placing it in a Sewer manhole like exterior. The sewer manhole will have a lattice-like cap making way for the smog to reach the VCP Sensor.

Speed breaker has been placed as shown in the fig. 1.1 due to 3 major reasons or pros that accompany this placement decision:

1. A slight tilt of the vehicle upwards i.e. towards the Camera 1 will help in capturing a proper photo of the vehicle.
2. And that same tilt also encourages silencer of the vehicle to face more towards VCP Sensor Sink than otherwise.
3. To lower the speed of the car before the checking area. Area 2 and 1 are for the current and next vehicle under check respectively.

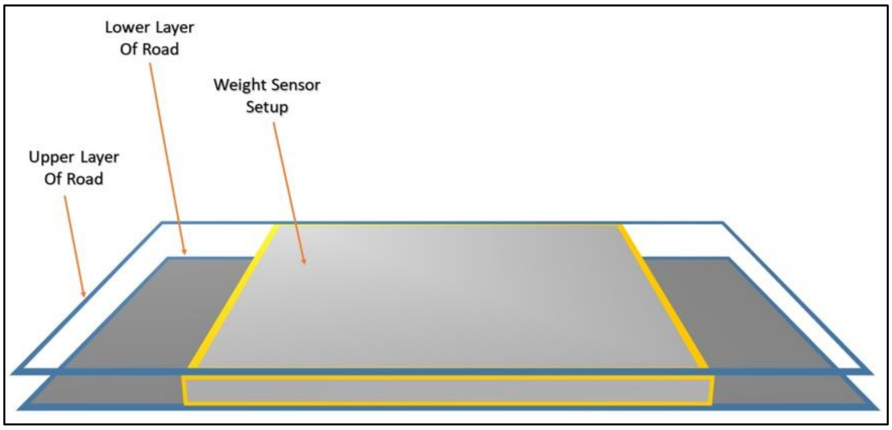


Fig. 1.2 Positioning of the weight sensor module beneath a slice of land surface

The weight sensor setup is sandwiched between two layers on the road i.e. the lower layer of road and the upper layer of the road. Both the layers get created when digging work is done for deploying the weight sensor setup. The lower layer is the earth surface whereas the upper layer acts alike sheath for the weight sensor setup.

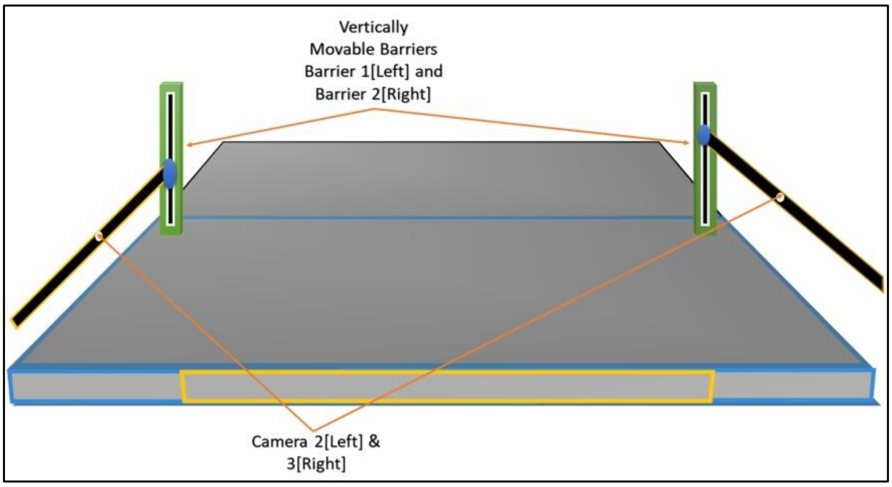


Fig. 1.3 Positioning of the Barrier 1, Barrier 2, Camera 2 and Camera 3

Barrier 1 and 2 are both vertically movable and they hold the two cameras i.e. on the movable rod of the barrier.

In the Fig 1.3 Camera 2 and 3 aim to capture backside license plate and driver image respectively.

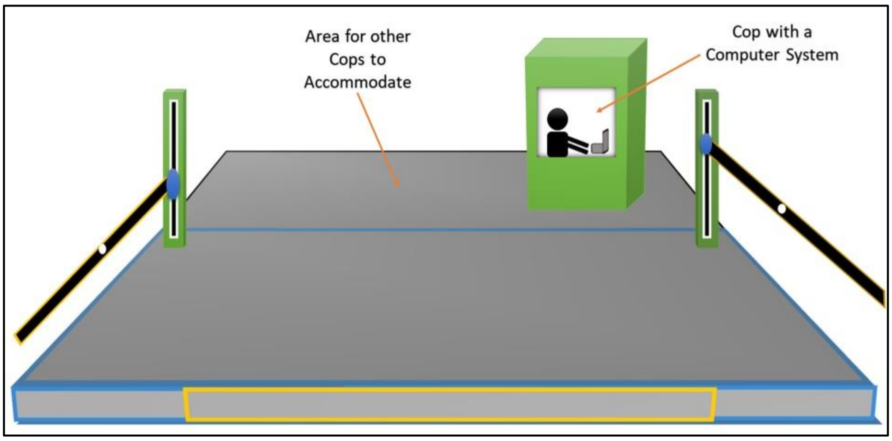


Fig. 1.4 Area where the Cops would accommodate for manually checking

The cop sitting with a computer system in the Fig. 1.4 will review the output of the Reporting Stage and then accordingly either let the car pass or take judicious action.

3.2 TIE System Stages

The TIE System is divided into 4 main stages based on the similar category of operations that it performs. Following subsections describe various stages.

3.2.1 Image Processing Stage or IP Stage

This stage carries out all the tasks related to capturing an image, sending to the server and applying image processing algorithms to extract specify objects. Hence the cameras employed to capture the input image have built-in networking module. This module is used to send the image to an HPC (High-Performance Computing Server) via the internet. The result of the requested operation is returned to the microcontroller.

The IP Stage executes its functions in two instances of a full vehicle check cycle (1) Before Area 1 and (2) In Area 2.

3.2.1.1 Before Area 1

When the Vehicle Detector Module intersects with the front area of any vehicle it gets activated. This activation is as an indication that a vehicle has arrived and will very soon enter the Area 1 and 2. The activation signal from the Vehicle Detector will trigger the Camera 1. Additionally Vehicle Detector will also trigger the VCP Sensor.

Image captured by Camera 1 is sent to the HPC server via the internet for identifying the following things:

- Car Model Name
- Expected Driver Height(from ground level)
- Backside License Plate Positioned Height(from ground level)
- Expected Silencer Sound

As the Vehicle Detector senses that a vehicle has left its detection area it is deactivated. The HPC Server returns that result to the microcontroller managing all the sensors.

Microcontroller writes the value of (1) Driver Height into the circular buffer residing inside Barrier 2’s controller and (2) Backside License Plate

Positional Height into that of Barrier 1's. Hence as a result of that when the current vehicle will get into checking area both the Barriers will automatically adjust their heights based on the dimensions of that particular vehicle. Once the current vehicle passes, the next values from the circular buffers are referred and the Barriers are position themselves accordingly.

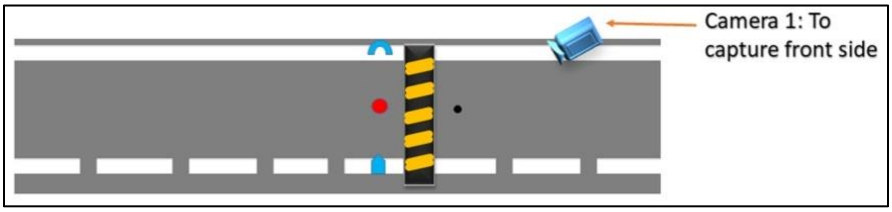


Fig. 1.5 Camera 1's Position as a part of IP Stage in Top View

3.2.1.2 In Area 2

In this part of the IP Stage, the barriers are positioned appropriately to capture the driver's face and backside license plate. In case, if the driver has learner's license the image of the person beside him/her is also captured and send for detection.

After the vehicle under check places itself appropriately in the checking area and the barriers take their vehicle-specific vertical positions, is when the cameras hidden amidst the barriers capture an image of their respective windows and send them to the HPC Server for the Image Processing Tasks.

Then after the HPC Server extracts the License Plate string from the image captured by Barrier 1 and the driver details from the image captured by Barrier 2. These extracted parameters go through a set of checks and eventually produce a Vulnerability Index (VI).

3.2.2 Sensing Stage

A vehicle's health is determined by many factors such as how frequently it is used, how it is driven i.e. how is the driver using the mechanisms e.g. in a harsh way, how regularly is it serviced etc. Its good health is not only important for the lives of people who travel inside the car but also for the roads and areas they are traveling through. At this stage, the sensors are used to inspect various safety and security-related aspects of vehicles.

The sensors are positioned in an almost unnoticeable way. It is also tried and made sure at a logical level that even if their functioning needs physical movement there is hiding from the knowledge of the existence of the sensing procedure and the sensors. Following subsections limn the sensor modules, their working and setup plan.

3.2.2.1 Vehicle Detector Module

Using image processing to detect an arriving car has two major drawbacks in TIE Systems setup (1) a lot of processing power will be used upon in a long run and (2) the time delay introduced between capturing of images infinitely, then detecting presence of arriving car and then triggering appropriate modules leads to considerable lagging in many other modules. Hence authors choose a hardware-based approach instead.

In this module, Light Dependent Resistors (LDR) and Infrared Radiation (IR) Sensors are coupled. They work alternately in the day and night time to detect the presence of any arriving vehicle.

IR sensors work on the principle of infrared light. And hence IR sensors are ineffective mostly during day time i.e. under direct sunlight. On the other hand, LDRs react on the basis of the intensity of light falling on it. Hence they render ineffective at night time as there will be no light surrounding it.

Therefore at day time LDR will be active and used for detecting vehicles presence. So when the car will arrive and its shadow will fall on the LDR the intensity of light will change. On the other hand at night time IR will be active. As the vehicle arrives it will block the lights fired by the transmitter and receiver placed at opposite ends of the road will not receive any light.

Using the above mentioned method TIE system can detect vehicles during both day and night times.

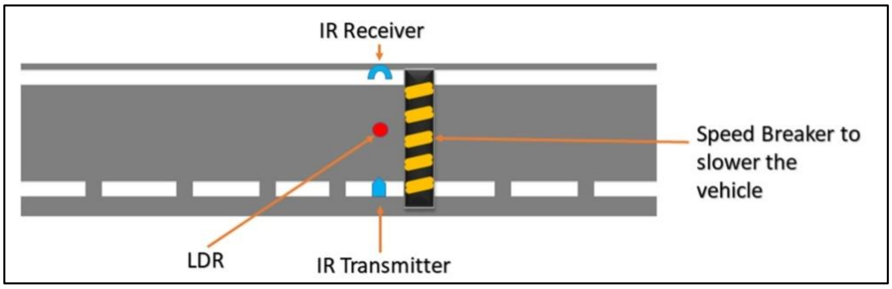


Fig. 1.6 Placement of the Vehicle Detector Module from Top View

3.2.2.2 Weight Sensor Module

This sensor module is used to find the gross weight of a vehicle. Knowing the same also assists cops in sensing some weirdness in the weight of a vehicle. It is also used to detect the overweighting of vehicles.

Weight Sensor Module is composed of an array of weighing pads. To calculate the weight on each pad (i.e. each axle) the proposed system internally needs to find the sum of following 4 weight cells placed at 4 for corners of a weighing pad.

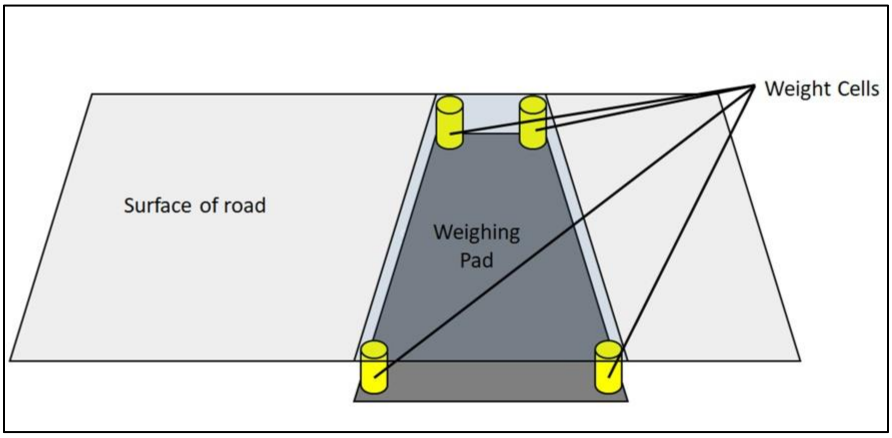


Fig. 1.7 Internal view of each weight pad

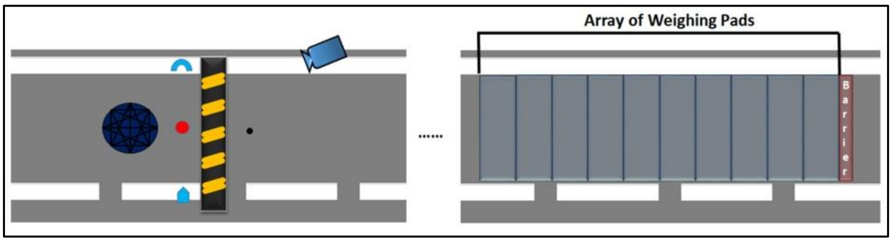


Fig. 1.8 Top view of placement of weighing pads

Automobiles, especially trucks that are carrying excess weight can constitute a serious hazard for the driver and other drivers, which have led to the authorities cracking down on the issue and penalties in place.

Since all vehicles are not the same especially in case of trucks, the length and number of axles differ considerably; hence a straight-forward way of weighing multiple different types of vehicles has to be calculating the weight of all such vehicles on each axle. Therefore the authors came across a solution to create a set of weighing pads of a fixed length and breadth which can be placed one after other in an array-like fashion. The array can be extended linearly along the road lane to a point where it can accommodate the longest vehicle (horizontally) that is expected to pass by that road. This approach helps to find the weight of any type of vehicle from two-wheeler to multi axels truck. Once the weight of each axle is found then the total weight of the vehicle can be found out by adding all those weights.

Also, the benefit is every axle is designed to handle some maximum amount of weight. As a result, if the weight exceeds the system will come to know and alert the security personnel.

3.2.2.2.1 Mutli-Lane Deployment

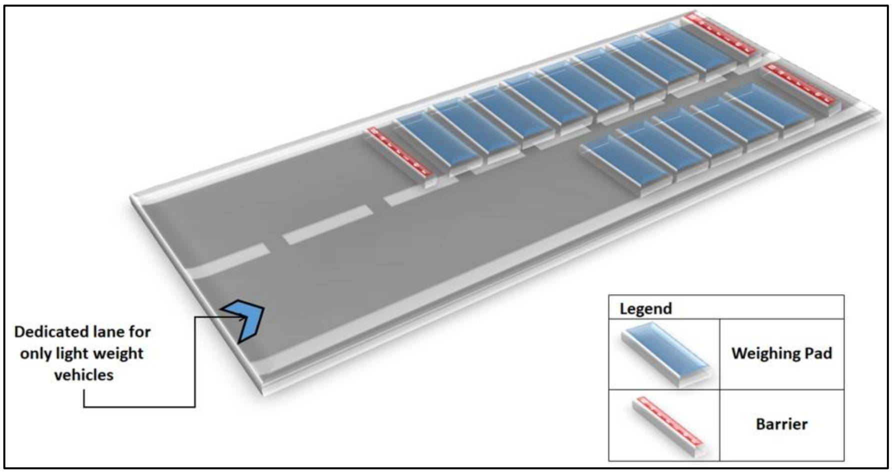


Fig. 1.9 Weight sensor setup using Multi-lane deployment concept

The weighing system is placed to weight almost all size of vehicles from 2-wheeler bikes to 5-Axle Trucks and this system is not restricted to the number of lanes.

Typically at toll roads, there is a dedicated lane for heavy vehicles such as trucks, buses and light vehicles like personal cars. In such a scenario where it is certain that a heavy vehicle is not allowed to pass from light vehicle lane in any circumstances, the total number of weighing pads can be adjusted to reduce cost. In case where such segregation is not possible the array of weighing pads can be increased or decreased based on lengths of the expected vehicles.

This concept for Multi-lane deployment of the system to reduce cost is a niche use and not a compulsion.

3.2.2.3 Vehicle Created Pollution or VCP Sensor Module:

This sensor module will be placed under the road near the vehicle exhaust area; the position will be 1 to 3 feet before the vehicle detector's LDR is placed.

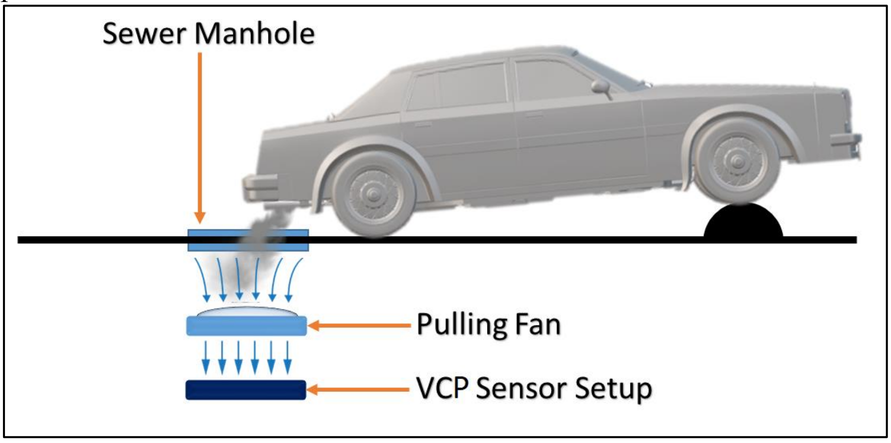


Fig. 1.10 Side view of VCP Sensor Module Setup

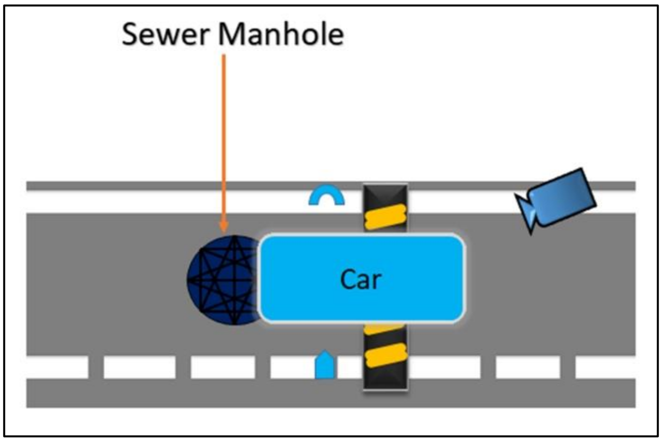


Fig. 1.11 Top view of VCP Sensor Module Setup

To make the sensing process effective following arrangement are made:

- There will be a fan pulling the exhausted air of vehicle which is placed below the sewer manhole.
- This metal net will be parallel to the road and will be placed on the surface of the road.
- The air pulled by the fan will directly be thrown on the VCP Check Sensor which then finds the purity of air throw by any vehicle.

3.2.2.4 Silencer Sound Module:

Every vehicle is assigned some maximum limit on the silencer sound it can produce [18] [19]. If the sound is beyond that limit, it is illegal to drive that vehicle. To adapt to the standard method of me measuring the vehicle sound, some calibration mechanism will have to be used to calculate the equivalent value of the sound produced from 50 feet away of the vehicle's centre.

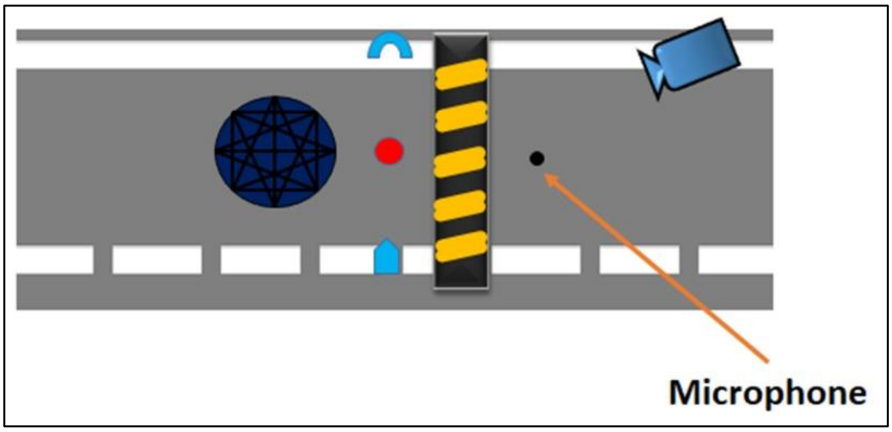


Fig. 1.12 Top view of placement of microphone

To check the overall sound of the vehicle TIE system uses a microphone. The microphone then calculates the sound intensity rating in decibel. The microphone input is then compared with maximum allowed decibel.

Since the prior mentioned maximum limit is vehicle specific it is fetched from the vehicle details database after the model is extracted in the Image Processing Stage. And as a result of this, the comparison of the input intensity and the legal limit are compared and presented to the security personnel in the Reporting Stage.

This microphone is placed on the surface of the road, right after the speed breaker ends. Favourably, this is also the area where the vehicle is expected to get accelerated. Acceleration helps sense the intensity of sound more effectively.

3.2.3 VI Calculation Stage or Vulnerability Check Engine (VCE)

This is a software engine residing on the HPC Server. The goal of this engine is to consider all the sensor outputs and to inspect whether sensed parameters are within the legal boundaries or not.
Vulnerability Index or VI: It is a percentage value between 0 to 100%. The intended interpretation of the Vulnerability Index is as an indicator of how vulnerable the vehicle is in the context of the checks TIE System is performing in the VCE Stage.

The magnitude of VI is raised by a certain percentage when it satisfies the conditions mentioned in the VCE Subsystems. One peculiarity about the VI is that it doesn't indicate how safe a car is. That validation is completely left on the security personnel protocols and judgment which to a certain extent may be dependent on the TIE system's report.

The engine also uses the result of the IP Stage to check whether the vehicle and its driver are both legally sound.

Inputs to this stage are:

1. License Plate Number
2. Driver Name & Licence Number
3. Past Output for the Same Combination

Appropriate weight is assigned to each inspected parameters based on their law based importance [20]. The weights have been calibrated based on the penalties and punishments associated with the performed check. In this way, if the intensity of the check being performed is legislatively weighed more than others, TIE System will assign it more weight. Assigning weights to VCE subsystem checks in this manner will help rudimentarily assess the vulnerability in a legislative manner and will render VI more impactful and legally sound.
Table 1.1 tabularizes the details about the various sections used from the Motor Vehicle Act (issued by the Indian government in 1988) that TIE System referred for probing the penalties imposed for particular unlawful activities.

Table 1.1 Details of sections used from Motor Vehicle Act for assigning weightage to VI calculation parameters

Violation Scenario	**Section**	**Penalty and/or Punishment**		
		1st time fine (Rupees)	**Fine change after 1st time fined (Rupees)**	**Imprisonment (Years)**
License Invalid	177	100	300	-
Person with learner's license driving without any instructor besides	177	450	500	-
Improper License Plate	177	100	300	-
PUC not done	177	100	300	-
Driving without license	180	1,000	-	Up to 3
Silencer sound is more than legal limit	190	500	-	-
Permit of the vehicle invalid	192	10,000	-	Up to 3
Overloaded vehicle	194	2,000 + 1,000 per extra ton of		-

load

3.2.3.1 Driving License Checks

This particular subsystem is responsible for conducting a series of checks related to the vehicle's license plate. Following cases are considered to be addressed:

1. Not Found: It means that no license plate was found after processing the image captured by camera 2.
2. Expired License: The driving license is renewed, yet the driver is driving the vehicle.
3. Past Criminal: The driver has past criminal cases associated with him/her.
4. Current Criminal: The driver has ongoing criminal cases associated with him/her. This also means he/she is on bail or has to be caught.
5. Wrong Use: This case is named as a consistency check in the fig 1.14. Consistency check here means to check whether the vehicle type detected from the captured image in the IP stage and category of vehicle(s) the license is assigned to, are same or not. If they differ it will be a case of "Wrong Use".
6. Unlawful Learner: This means that the driver has a learner's license yet he doesn't have a fully licensed driver seated beside him/her.

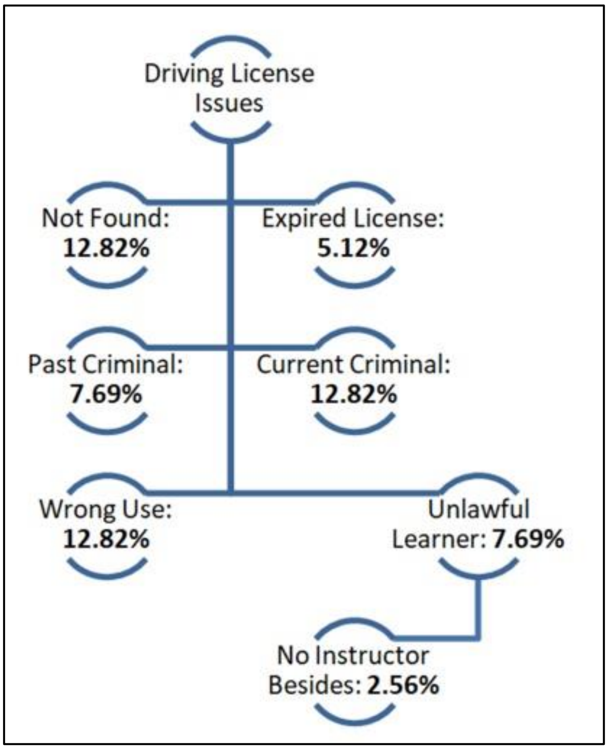


Fig. 1.13 Assigned weightage to Driving License Related Checking

Fig. 1.14 Sequence of steps executed by Driving License Checks Subsystem

3.2.3.2 License Plate Related Checks

This particular subsystem is responsible for conducting a series of checks related to the vehicle's license plate. This subsystem takes as input the string value of the license plate number which got extracted in the image processing stage after processing the image captured by Camera 2 / Camera in the back barrier.

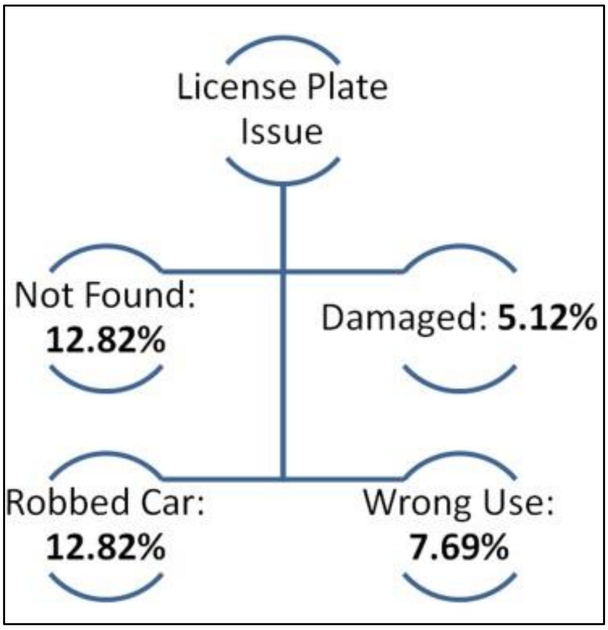


Fig. 1.15 Assigned weightage to License Plate Related Checks

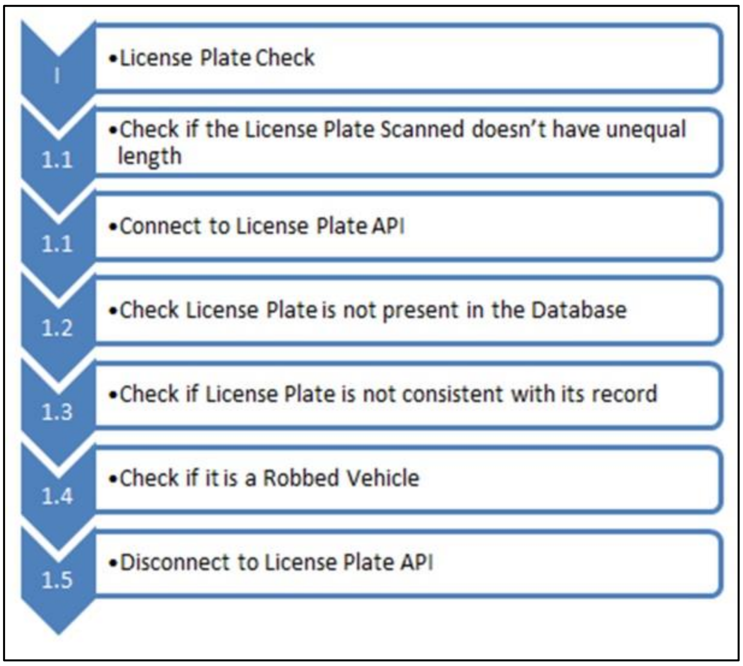


Fig. 1.16 Sequence of steps executed by License Plate Checks Subsystem

Following cases are considered to be addressed:

1. Not Found: The license plate string was NULL i.e. No license plate was found.
2. Damaged: The string that was extracted from the image did not have proper length and/or had illegal characters on it.
3. Robbed Car: The license plate is of a car which has been reported robbed by the owner.
4. Wrong Use: The license plate is not used on the vehicle type it is assigned to.

3.2.4 Reporting Stage

This stage is the last stage of the TIE System Life Cycle. It is meant to consolidate the results of all the sensed parameter and image processing based criminal association or history finder. It provides a comprehensive yet clear cut idea that out of the Parameter. A web-based report is prepared since that would allow the ability to share the report with the remote officials also who are doing surveillance tasks.

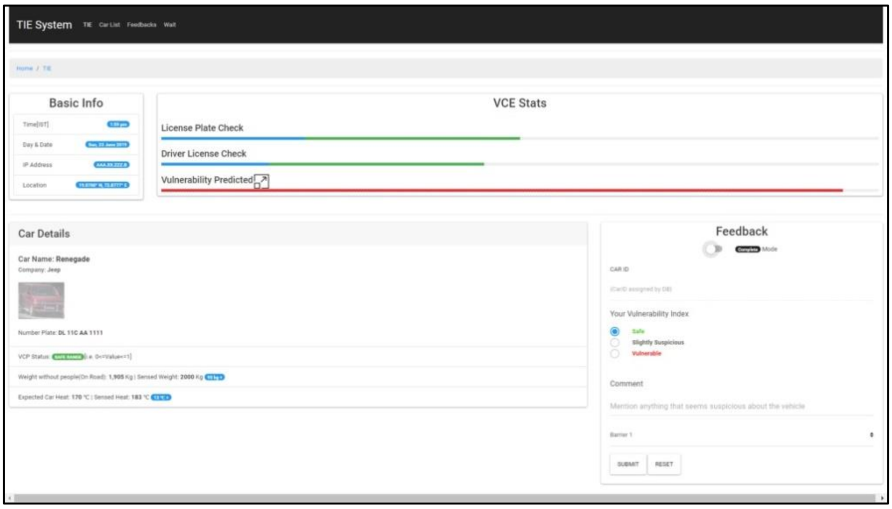


Fig. 1.17 Sample Report produced by Reporting Stage

Above displayed fig 1.17 is a sample report that shows the basic look and feel of the output of the Reporting Stage. There are 4 sections in the generated report as shown in the fig 1.17:

1. Basic Info(Information) Section

2. VCE Stat(Statistics) Section
3. Vehicle Details Section
4. Feedback Section

3.2.4.1 Basic Info Section

Fig. 1.18 Basic Info Section of Sample Report

The fig 1.18 shows the values that are automatically filled in the Basic Info Section. Time zone specific time, Current day and date, The Internet Protocol Address assigned to the Computer System being used, and Location of the deployment of the TIE System. All these parameters although rudimentary have a risk of being leaked and hence should not be stored. Due to this requirement, these values are all generated using only the browser-based libraries or frontend functions. These parameters, therefore, do not get communicated which lower the chances of leakage.

3.2.4.2 VCE Stat Section

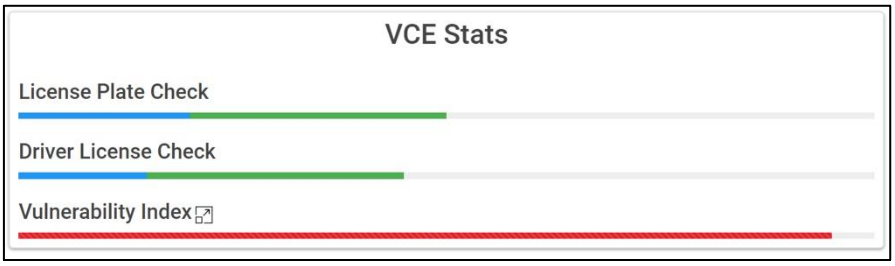


Fig. 1.19 VCE Stats Section of Sample Report

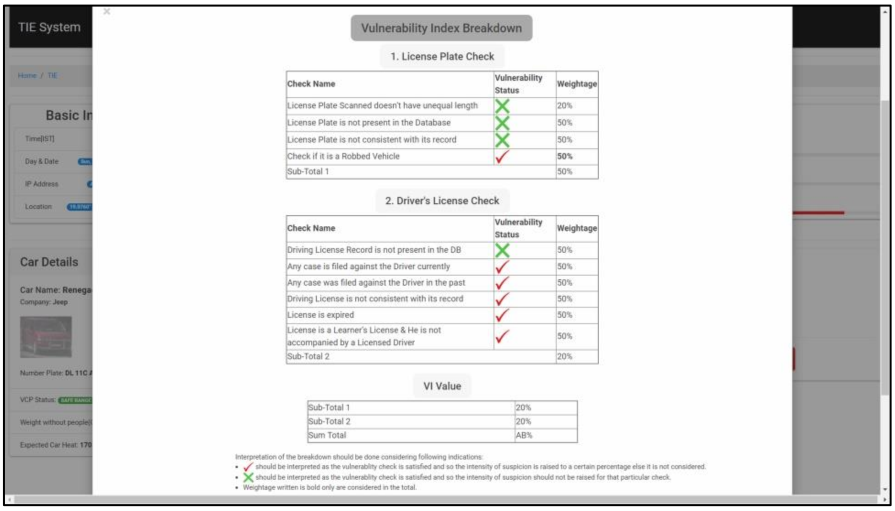


Fig. 1.20 Vulnerability Breakdown pop-up

VCE Stats Section displays the outputs of the VCE Stage to the security personnel. Distinct colors in the progress bar below “License Plate Check” and “Driver License Check” indicate the weights of different checks that got satisfied in the respective subsystems. The Vulnerability Index’s progress bar shows the sum total of both the subsystem's individual totals. The expansion icon beside the Vulnerability Index can be clicked to see the Vulnerability Index’s breakdown. This breakdown is expected to help the cops find the exact vulnerable area of the vehicle under check. The fig 1.20 shows the pop-up window and the breakdown that appears when the expansion icon is clicked. The breakdown appeared should be interpreted using the following rules:

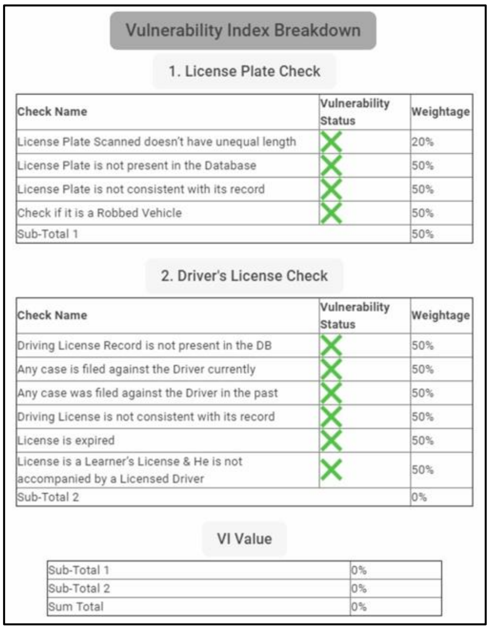
1. Red tick mark in the “Vulnerability Status” column should be interpret-

ed as “the vulnerability check is satisfied” and so the intensity of suspicion was raised to a certain percentage (i.e. the weight assigned to that individual check).

2. Green tick mark in the “Vulnerability Status” column should be interpreted as the vulnerability check is not satisfied and so the intensity of suspicion was not raised by the weight of that particular check.

3. Weights displayed is bold only are considered in the total.

4. The value written as the “Sum total” is the final value of the VI.



Vulnerability Index Breakdown

1. License Plate Check

Check Name	Vulnerability Status	Weightage
License Plate Scanned doesn't have unequal length	✗	20%
License Plate is not present in the Database	✗	50%
License Plate is not consistent with its record	✗	50%
Check if it is a Robbed Vehicle	✗	50%
Sub-Total 1		50%

2. Driver's License Check

Check Name	Vulnerability Status	Weightage
Driving License Record is not present in the DB	✗	50%
Any case is filed against the Driver currently	✗	50%
Any case was filed against the Driver in the past	✗	50%
Driving License is not consistent with its record	✗	50%
License is expired	✗	50%
License is a Learner's License & He is not accompanied by a Licensed Driver	✗	50%
Sub-Total 2		0%

VI Value

Sub-Total 1	0%
Sub-Total 2	0%
Sum Total	0%

Fig. 1.21 Example 1 of breakdown of VI

Vulnerability Index Breakdown

1. License Plate Check

Check Name	Vulnerability Status	Weightage
License Plate Scanned doesn't have unequal length	✗	20%
License Plate is not present in the Database	✗	50%
License Plate is not consistent with its record	✗	50%
Check if it is a Robbed Vehicle	✗	50%
Sub-Total 1		50%

2. Driver's License Check

Check Name	Vulnerability Status	Weightage
Driving License Record is not present in the DB	✗	50%
Any case is filed against the Driver currently	✗	50%
Any case was filed against the Driver in the past	✗	50%
Driving License is not consistent with its record	✗	50%
License is expired	✓	**50%**
License is a Learner's License & He is not accompanied by a Licensed Driver	✗	50%
Sub-Total 2		50%

VI Value

Sub-Total 1	0%
Sub-Total 2	50%
Sum Total	50%

Fig. 1.22 Example 1 of breakdown of VI

For e.g. breakdown like the one shown in fig 1.21 should be interpreted as there is "No vulnerability detected with respect to the checks performed." whereas the one alike fig 1.22 should be interpreted as "The driver's license not renewed and hence he/she is unlawfully driving the vehicle."

3.2.4.3 Vehicle Details Section

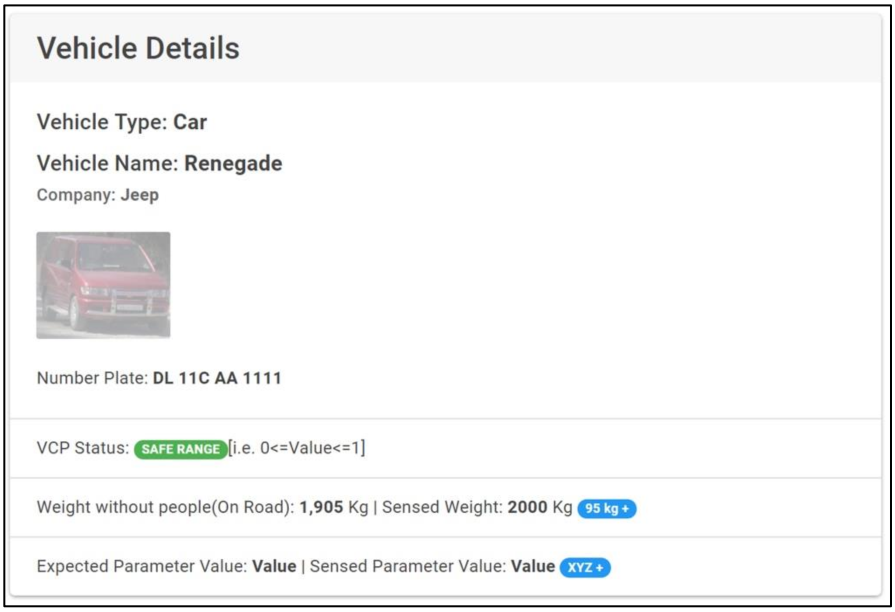


Fig. 1.23 Car Details Section of Sample Report

The car details section contains the subsections as shown in the above figure 1.23. Values of Vehicle name, company name, model name, license plate number, VCP Status, the weight of the vehicle are all encompassed in this section. Also, the difference between the corresponding values is displayed. A hover on the photo of the vehicle would enlarge it for viewing if needed.

3.2.4.4 Feedback Section

Feedback Section is used to take asses the system’s IP Stage and VCE Stage results. There are two modes that can be used to the give feedback mainly based on the level of traffic on that road but there can be other factors which lead to choosing one of them too.

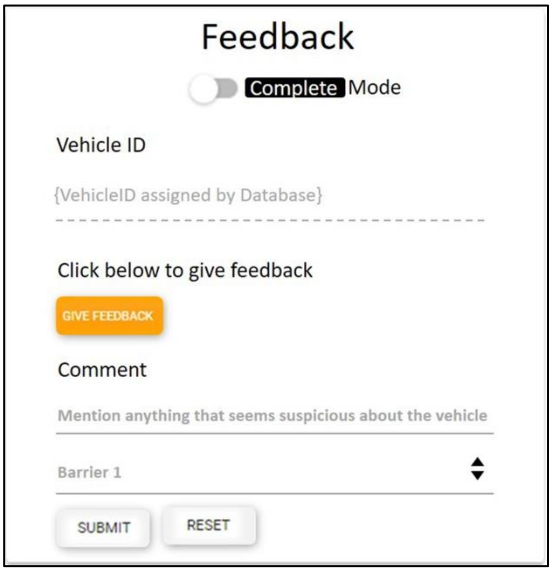


Fig. 1.24 Feedback Section of the Sample Report configured in Complete Mode

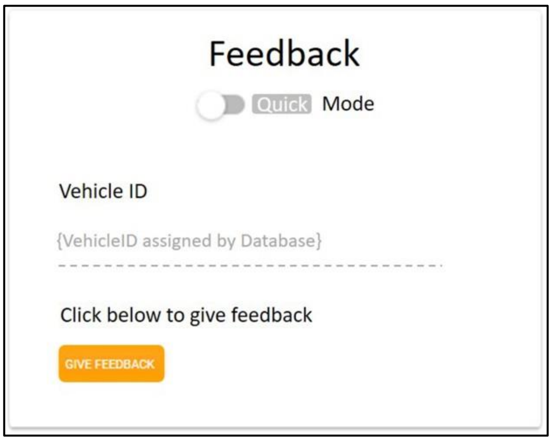
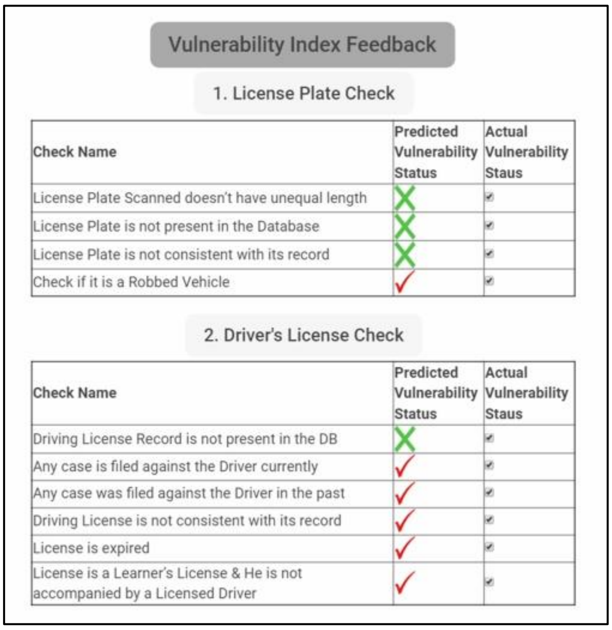


Fig. 1.25 Feedback Section of the Sample Report configured in Complete Mode

3.2.4.4.1 Complete Mode



Vulnerability Index Feedback

1. License Plate Check

Check Name	Predicted Vulnerability Status	Actual Vulnerability Staus
License Plate Scanned doesn't have unequal length	✗	☑
License Plate is not present in the Database	✗	☑
License Plate is not consistent with its record	✗	☑
Check if it is a Robbed Vehicle	✓	☑

2. Driver's License Check

Check Name	Predicted Vulnerability Status	Actual Vulnerability Staus
Driving License Record is not present in the DB	✗	☑
Any case is filed against the Driver currently	✓	☑
Any case was filed against the Driver in the past	✓	☑
Driving License is not consistent with its record	✓	☑
License is expired	✓	☑
License is a Learner's License & He is not accompanied by a Licensed Driver	✓	☑

Fig. 1.26 Structure of Feedback Form

This mode of the feedback section is used when there handleable traffic on the road. This section will take the following inputs from the security personnel viewing the report:

1. Vehicle ID or Vehicle Identifier: This is the unique identifier assigned to the vehicle under check. The webpage itself will dynamically fill this value into the textbox from the Vehicle ID that it receives from the microcontroller.
2. Barrier Number: This parameter is used only in case of a security check arrangement with multiple barriers. It will indicate the barrier number where the TIE System is deployed.
3. Comment: It is used to record what appeared as suspicious about the vehicle. It is expected to largely record those parameters or aspects related to vehicle and road security that is not examined by the TIE System. The comments can timely be then checked and analyzed to enhance TIE System and identify various patterns.
4. Actual VI: This is the most crucial part in the feedback section. This part has all the parameters shown in the Vulnerability Index Breakdown window excluding the (1) "totals" related rows in the "License Plate Check" and "Driver's License Check" and (2) the whole table showing "Sum total" in the last row. Actual VI

has high importance because the value of this parameter will train the IP Stage and VCE Stage to improve their processing. And as a result of which the system will perform better in subsequent detections. This training cycling will continue infinite runs of the system.

This input of this part is given in the form that gets popped up after clicking the “Give Feedback” button. The report viewer will have to just uncheck the parameter that was wrongly identified and then submit the feedback form.

3.2.4.4.1 Quick Mode

This mode is used to give feedback of the system’s IP Stage and VCE Stage when there is more traffic or due to any issue, the vehicle passing speed via the checking zone has to be increased. And the most crucial part i.e. the Actual VI. All parameters inside the Actual VI will be the same in both modes.

For ease of giving the feedback all the checkboxes in the Actual VI for are already checked and hence only the wrongly detected parameter should be found and unchecked. This subtle strategy would save the time of the cops viewing the report since they are now freed from the job of going through the whole form every time they give their feedback.

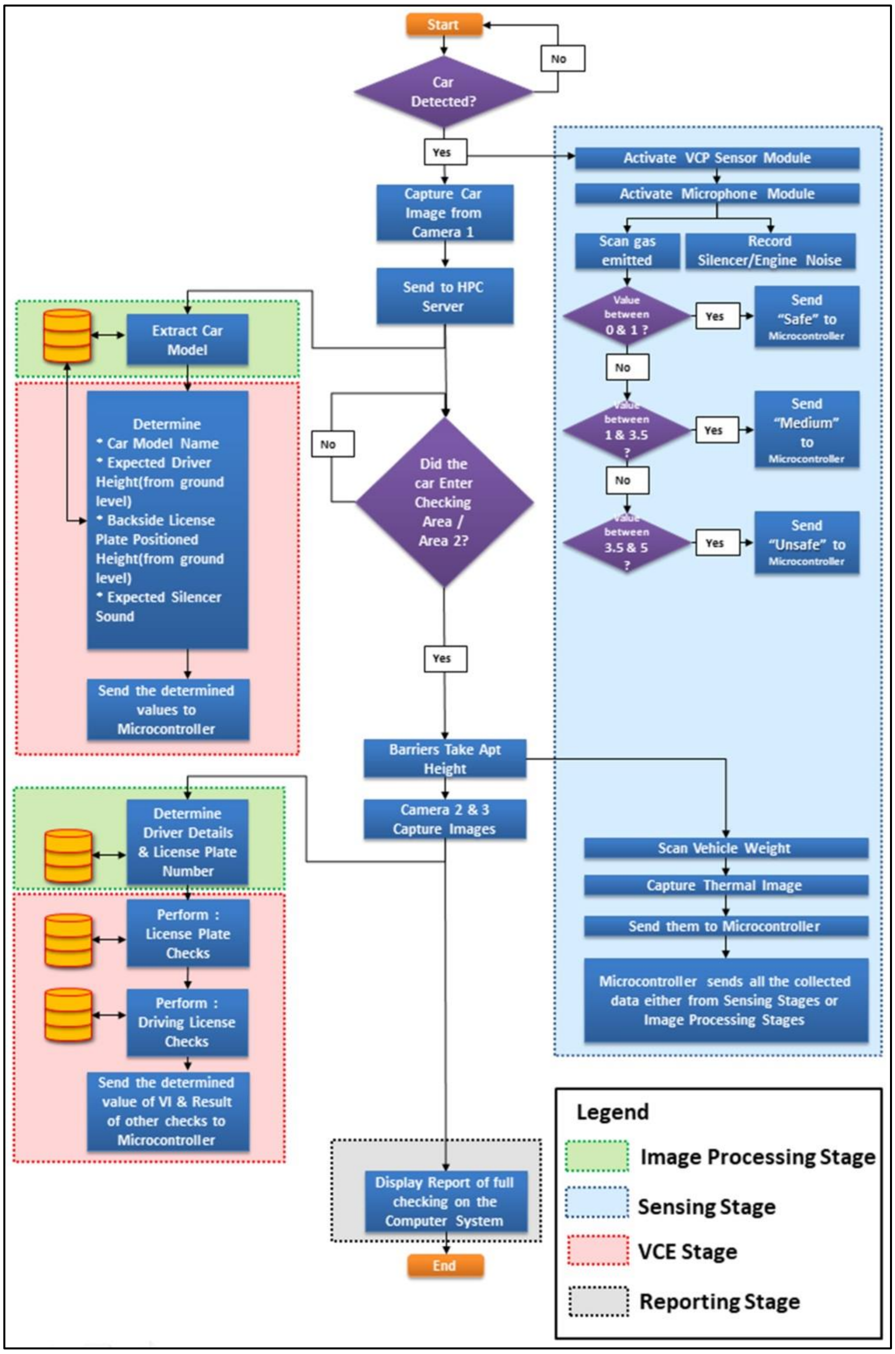


Fig. 1.27 Comprehensive diagram of operations performed by all 4 stages

Fig. 1.27 presents a collective look at the all the TIE System Stages and their sequences.

3.3 TIE System Sensors

The authors make use of a set of criteria for selecting sensors that can be used to extend or scale up the system. These sensors are a subset of traditional sensors that satisfy the following conditions:

1. The sensor has proper datasheet available which also means it's officially produced and is tested & reliable.
2. It can stably operate in the temperature range tuned for the system based on the region of its deployment.
3. It should be possible to cover it in a way it becomes unnoticeable by any person other than the ones who have deployed it. Any sensor which satisfies the following condition is considered a TIE Sensor.

3.3 Major Challenges

3.3.1 Synchronizing All Stages

Timing the processes like Image Capturing, Processing and the sensors sensing appropriately so as to synchronize them in the time domain. In the proposed model the time delay of the IP Stage will take more time compared to the Sensing Stage and hence some tasks of this stage are executed first and a queue gets updated in the local memory of the controllers placed inside barrier 1 and 2 corresponding to the order of checking the cars.

3.3.1 Dynamic Barrier

The license plate detection algorithm is mainly divided into 2 parts (1) Finding the license plate from the image and (2) Apply Optical Character Recognition or OCR on the license plate part of the image. But in reality, these algorithms usually face a considerable amount of issues in the prior step. There are quite a few reasons for the same as the shadows, lights, reflections appearing on the chassis of the vehicle due to sun light, etc.

Hence to counter the issue introduced in the prior part of the license plate detection algorithm that is creating uncertainty is eliminated by implementing the concept of dynamic barriers.

Dynamic barriers are characterized mainly by a vertically movable barrier rod, a controller module, and a circular buffer.

These barriers maintain a circular buffer locally in their controller module (which will control the vertical height of the barrier). These circular buffers store the values of the vertical height at which they have to rise or fall for the vehicle under check and the next two in the waiting queue. The barrier 1 and 2 receive the heights of the vehicle's back number plate and expected drivers face from the ground level respectively.

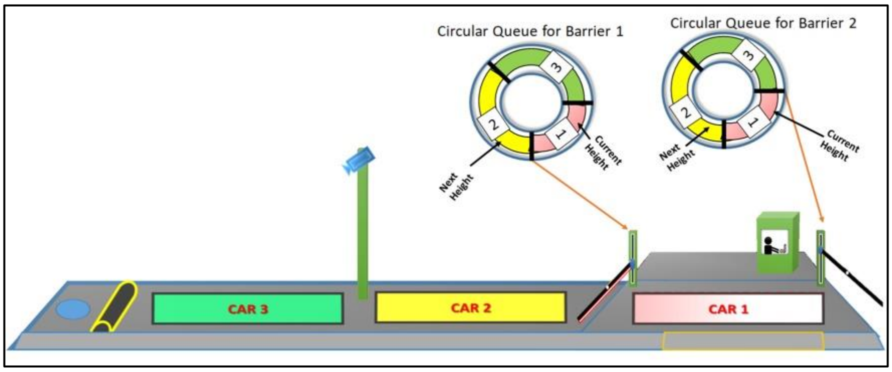


Fig. 1.28 Illustration of the Circular Queue working

Deceiving the people inside the vehicles from these dynamic barriers is done in a quite orchestrated way. The front side barrier or barrier responsible to capture the image of the driver's face is not very clearly visible to the next vehicle that will go under check. On the other hand, the back barrier or barrier that will capture the image of the rear side license plate will become completely unnoticeable to the vehicle under check. This deceiving will reduce the chances of suspicion on the process of "Driving License Check" and "License Plate Check".

4 Case Study

Authors saw a huge loss of human lives in the terrorist attack that took place on 14th Feb 2019 in Pulwama District of India [21]. Pointing out one of the reasons for the attack to be the removal of 3 barriers from the road where the incident happened Prof. Amita Singh(Professor of Law, Governance and Disaster Studies at Jawaharlal Nehru University) said, "The RDX filled vehicle could not be checked as the 3 check barriers were removed by Mehbooba Mufti..."[22][23]. The potential correctness of the statement by Prof. Singh and other parameters e.g. inclinations of certain roads, traffic bottlenecks, etc. that directly or indirectly contribute to the vulnerability of the roads like the one where the discussed incident happened. Hence a system that assists the security personnel(s) in tracking the parameters unusual to the vehicles at the same time being unnoticeable by the malevolent and criminal minded individual/groups and is feasible to be implemented can be useful. Such a system would not only leverage the intensity with which certain parameters of the vehicle under check are examined but also aid in checking those parameters not directly known to the security personnel(s) or for that matter any individual at their first glance on the vehicle.

A vehicle-borne improvised explosive device (VBIED), also known as a truck bomb or car bomb, is an improvised explosive device installed inside a car or other automobile and then exploded. This very type of bomb was used in the attack mentioned above and many others [24].

Shielding against a car bomb requires keeping automobiles at a distance from exposed targets by using metal barriers, checkpoints, roadblocks and others alike them[25].

The TIE system would assist the security personnel positioned near the barriers to check either all or just the suspicious vehicles passing by the barriers. The system would capture the photo of the vehicle and sense the parameters simultaneously. TIE System will execute all its 4 stages and would send its report to the computer system of same or other security personnel. Particularly, the VCE Stage would find the unusualness in those parameters, assign a vulnerability index to the vehicle & show the results to the security personnel. This would also help when population of cars passing by the barriers is large enough the system will help in finding the ones that need to be thoroughly checked by the security personnel with respect VCE subsystem checks. It would help them to know the magnitude of parameters which one cannot find manually & feasibly in all circumstances.

5 Conclusion

Road security checks currently face 2 major problems (1) high knowability and (2) unautomated checking. Therefore it becomes crucial to make the checks in an unnoticeable way so as to deceive the malevolent individuals or groups to believe there are no clear obstacles that they have to overcome. The system is made almost unnoticeable by placing the sensors at unexpected positions on the site. Even if they are constrained to be operated in a moving manner, the placements are done in a way that ensures they are deployed and operated in an inconspicuous location and unexpected way respectively. The authors have consolidated a system that uses image processing; embedded system; IoT and web technology jointly to counter the prior mentioned loopholes in common security checks done currently.

6 Future direction for further extension

A set of concepts and extensions can still be applied to make the system better in the aspects like reusability of sensors, turnaround time of checking(s), etc. Mentioned below are some of the specific ideas that can be worked upon to further extend the system:

1. The System can directly cut monetary penalties from the bank account of the person for the set of checks it satisfies.
2. TIE System Array can be developed which deploys TIE System clones that can reuse various sensors at the same time check multiple cars at a time.
3. To add more checks to the Learner's license checks like an "L" sticker present.
4. To use Piezoelectricity, solar energy and similar sciences and technologies to make TIE System as self-sufficient as possible with respect to power requirements.
5. To integrate mechanisms [26] that balance the tradeoff between security and efficiency involved in the communication between the various sensor modules employed.

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