Dr. Sanjeeva Kumar B.H [1]

[1] **SLS Transport Training Institute and Consultancy**
Email for correspondence, e.g. sanjeev@tticblr.com

1 INTRODUCTION

Bengaluru is the capital and the largest city of the Indian state of Karnataka. Since 2007, Bengaluru Metropolitan Region covers an area of 8,005 km2 (3,091 sq mi), the second largest metropolitan area in India, after the Amaravati Metropolitan Region.

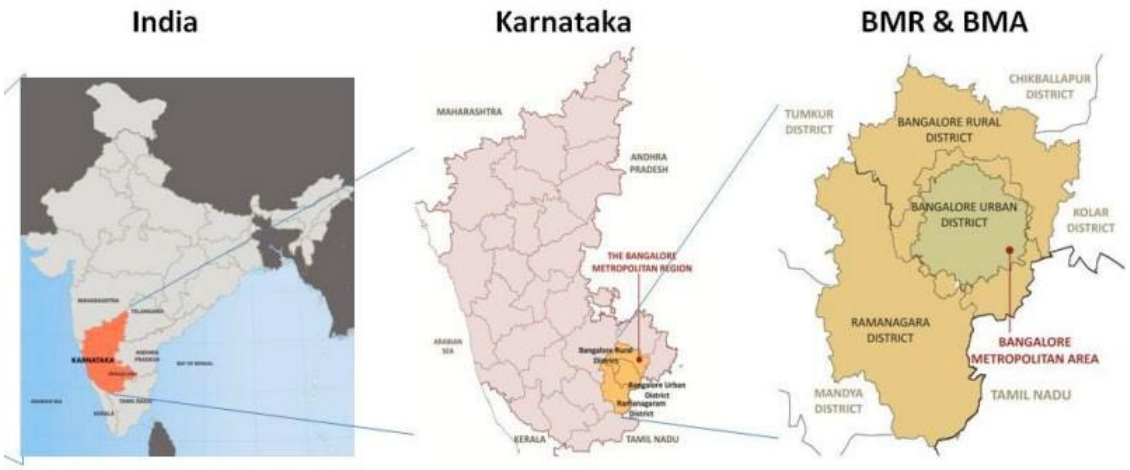


Figure 1. Location of Bengaluru Metropolitan Region, BMR and Bengaluru Metropolitan Area, BMA

It has population of more than 8 million and a metropolitan population of around 13 million, making it the third most populous city and fifth most populous urban agglomeration in India. Bangalore is widely regarded as the "Silicon Valley of India" (or "IT capital of India") because of its role as the nation's leading information technology (IT) exporter. Indian technological organizations are headquartered in the city.

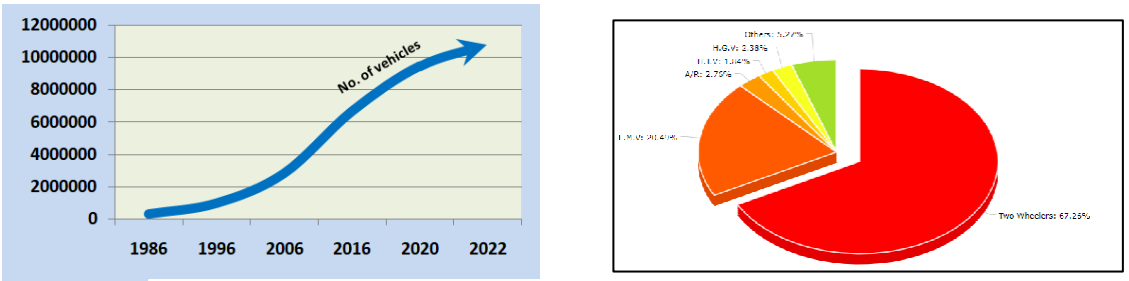


Figure 2. Growth of Vehicles and Vehicular Composition in Bengaluru City

Around the world, cities are transforming. Thanks to the employment opportunities in metros, the urbanization process is at its peak. Urbanization influences the road traffic. The city crossed a population of 12.5 million in 2022, while the number of vehicles registered as of 2022 was more than 11 million.
Bengaluru's road network (around 14,000km) consists of ring roads, major roads (arterial, sub-arterial) and residential streets. Bengaluru, has been ranked among the most traffic congested cities of the world, next only to London, with an increased travel time of nearly 29 minutes and 10 seconds to drive a distance of 10 km in the year 2022.
All these factors are causing multiple traffic issues such as congestions, accidents and fatalities. The following are the major problems faced by commuters in the central business district of Bengaluru,

- Red Light Jumping
- Stop Line Jumping
- Speeding of the vehicles without following the speed safety limits
- Poor safety habits of the drivers such as talking on phone while driving, not wearing safety belts
- Not Wearing Helmets
- Triple Riding

2 NEED AND OBJECTIVES

The supply augmentation (such as widening roads, providing flyovers, construction of bye-passes and urban expressways, introduction of mass transit facilities) will relieve congestion, but the ever-growing traffic will always need to be managed efficiently.

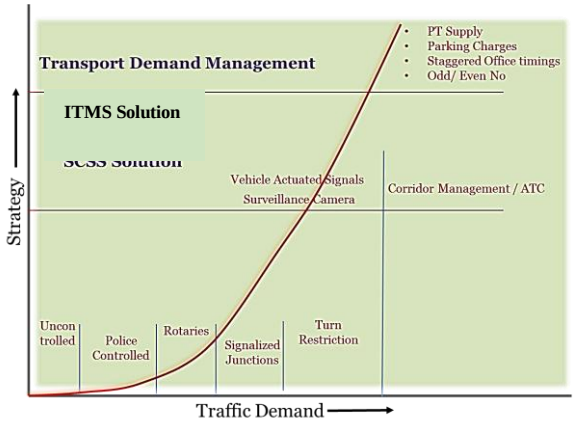


Figure 3. Graph depicting Traffic Demand vs Strategy

As any other traffic police of any city in India, Bengaluru Traffic police who are in charge of enforcement also do the planning required for traffic management and regulation. They are one of the most visible arms of Police and play an important role in the day-to day policing. The manifold increase in the number of vehicles has created tremendous pressure on the existing resources in terms of infrastructure, manpower and technology. The manual methods of law enforcement often lack proper evidences to prove violations in the court of law. There is always a question of transparency in the behaviour of the policemen. Also there is huge dependency on third party database and integration of applications is sparse.

The Bengaluru traffic police are taking several initiatives for infusing and integrating technology in police functioning to bring in transparency and evidence-based enforcement. In this regard, the Bengaluru Traffic Police has taken an initiative to deploy Integrated Traffic Enforcement Management System (ITeMS) across Bengaluru which will help the Authority reduce the number of accidents and fatalities and inculcate safety habits on the road for the motorists with the aid of advanced Artificial Intelligence based Video Analytics technology. This is a contactless automatic enforcement system of traffic violations with minimum human intervention.

The key objectives of ITeMS is to establish a collaborative framework where traffic input from different cameras from the city are assimilated and analyzed on to a centralized platform; consequently, resulting in aggregated city central traffic database. Further this aggregated traffic information yields an actionable intelligence and provide the decision support system for the Authority. Following are the tangible and intangible objectives of the ITEMS project:

- Efficient traffic management
- Enhanced safety and security
- Better management of traffic resources and quantification of services
- Reduce accidents and fatalities
- Decision Support through the Data Analytics
- Safer roads for pedestrians
- Improved Traffic Flow as a result of the reduced violations and accidents

3 FUNCTIONING OF THE SYSTEM

The ITMS system deployed for Bengaluru is an amalgamation of ITeMS application and ICMS application, which are AI based applications coupled with cameras installed at the traffic intersections, which provide a tool to detect and recognize vehicles disobeying traffic regulations and generate real-time alerts at the Central Command Center. Challans are automatically generated for traffic offenders as per law and sent electronically to the violators. Each e-challan is associated with supporting evidence data in terms of snapshots and videos. The two systems are explained in detail in the following sections.

3.1 Intelligent Traffic Enforcement Management System (ITeMS)

The ITeMS consists of traffic violation detection use cases with the help of Artificial Intelligence and Deep Learning based technology. Following are the use cases of the project:

i. Automatic Number Plate Recognition
ii. Red Light Violation Detection
iii. Speed Violation Detection
iv. No Helmet Detection with ANPR
v. Triple Ride Detection with ANPR
vi. No Seatbelt Violation Detection with ANPR
vii. Driver on Call Detection while driving with ANPR

These use cases are a part of the Intelligent Traffic Management System (ITeMS) providing

- data aggregation
- actionable intelligence
- data center and disaster recovery solution
- integration capabilities with other systems and external databases

The ITeMS has centralized as well as distributed components. The system is deployed using a decentralied architecture with Local Processing Units (LPUs) at the traffic junctions and the centralized servers to manage and aggregate the alerts generated from the LPUs.

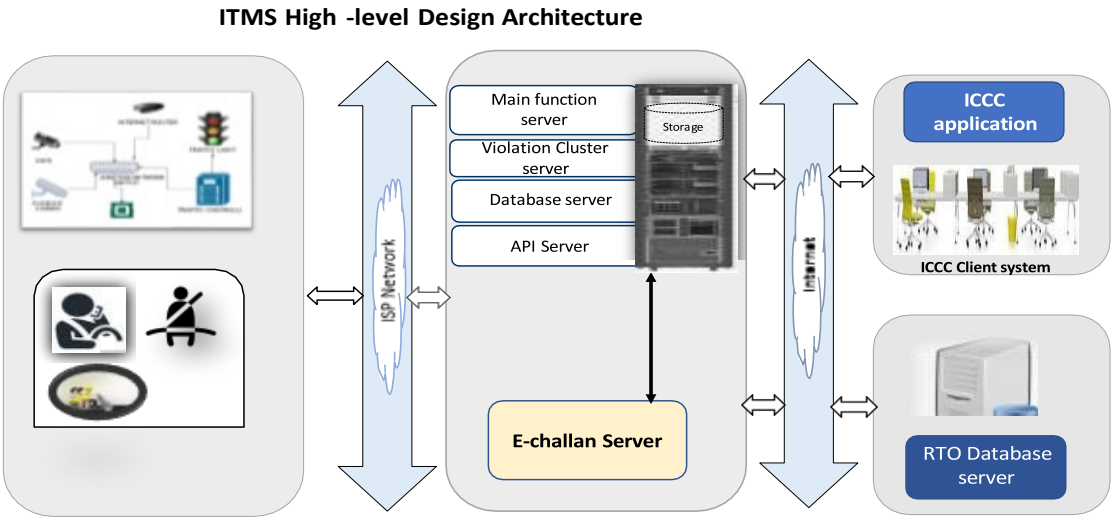


Figure 4. ITMS Design Architecture

The primary processing of all the use cases happen on the LPUs at the junction and the alerts, images and video clips (event specific and continuous recording) are transferred to the control room servers. Continuous recording at LPU level is undertaken and what is received at TMC is,

- Event
- Event snap - 5 photos of the event (violation)
- Event clip - 10 seconds of the event (violation)

Picture 1. ANPR Camera, Local Processing Unit at an Intersection

In certain places, where provision of LPUs and field infrastructure is not possible / feasible, the video feeds from the junction cameras are processed at the control room. The authority takes a decision on the type of deployment to be considered.

ITeMS also consists of Intelligent eChallan Management System (ICMS) which integrates with the Intelligent Traffic Management Platform to generate eChallans in an automated fashion for the traffic violations detected through the violation detection use cases mentioned above. It also allows to generate eChallan through a manual mode as well as through the hand-held devices based eChallan app.

3.2 Intelligent eChallan Management System (ICMS)

The Intelligent eChallan Management System provides the ability to generate eChallans for the vehicles violating the traffic rules detected through the video analytics use cases. It also allows the Authority to generate challans using manual mode in the control room and also through the handheld device based apps on the streets. The Intelligent e-Challan Management Software (IeCMS) operates in multiple modes as mentioned in this section. The same software is capable of challan generation on the spot using hand-held devices by the field officers using a versatile android based e-Challan app installed in the hand-held device.

The Intelligent e-Challan Management Software (IeCMS) is a unified framework to effectively generate, receive, process, store and manage challans against traffic violations for efficient traffic management in cities. The unified architecture can take input from field handheld devices, Intelligent Traffic Management Systems, as well as manual input from other surveillance systems to generate and manage challans. The system has below mentioned modes of operation:

- Central Automated Mode: to manage violations through a central command room (CCR). This Intelligent e-Challan Management Software (IeCMS) has in built video management and manual violation capture module to generate and manage challans for the violations (such as RLVD, Stop Line Violation, and others) detected & captured by analyzing video feeds from field cameras.
- Central Manual Mode: Operator in central control room detects violations visually and manually takes snap of the violation using existing surveillance system. The operator enters the license plate number, violation type and select the relevant snap manually through the user interface of the IeCMS to generate a challan.
- Field Spot Mode: to manage violations on spot through smartphone app, or a handheld device carried by traffic personnel on the road,

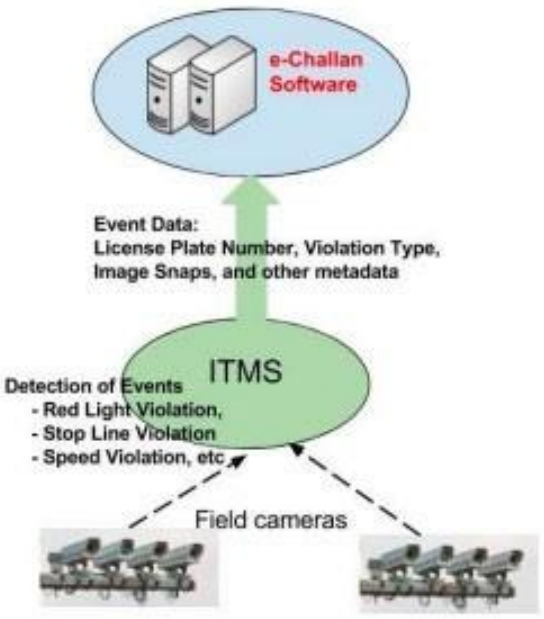


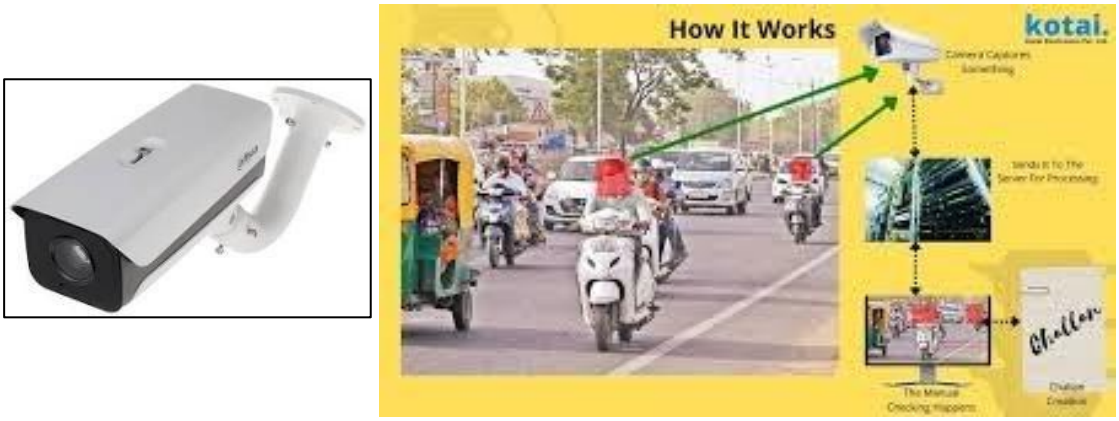
Figure 5. Central automated mode of operation of IeCMS

IeCMS works seamlessly with Intelligent Traffic Management System (ITMS). The ITMS takes video from field IP cameras to automatically detect traffic violation events like ―Red Light Violation, Stop Line Violation, Speed Violation etc. The event data is sent to the IeCMS for automatic challan generation and management. Authorized traffic personnel to validate the generated challans against violations detected by the ITMS automatically. Once detected, the ITMS system sends license plate information, violation type, and other information along with images as evidence of the offence as event data to the IeCMS. The information is validated by authorized personnel to generate an official challan against the offender. Once the challan is generated the IeCMS to take care of the life cycle of the generated challan.

4 FUNCTIONS OF EACH USE CASE

4.1 Automatic Number Plate Recognition Software (ANPR)

The System automatically detects a vehicle in the camera view using video detection and activate license plate recognition and detects the license plate in the captured video feed in real-time performing Optical Character Recognition (OCR) of the license plate characters.



Picture 2. Functioning of ANPR Camera

Category of the vehicle such as cars, Heavy Commercial Vehicles/HTV, Three Wheelers and Two Wheelers, speed of the vehicle are recognized and information is stored along with the license plate information for each transaction in the database in the form of JPEG image of the vehicles, colour of the vehicles along with information regarding whether the vehicle features in hot list (wanted, suspicious, stolen). The system also recognizes heavy vehicles violating the entry

prohibitions during certain time of the day for selected traffic junctions and sends an alert and generates eChallan automatically.

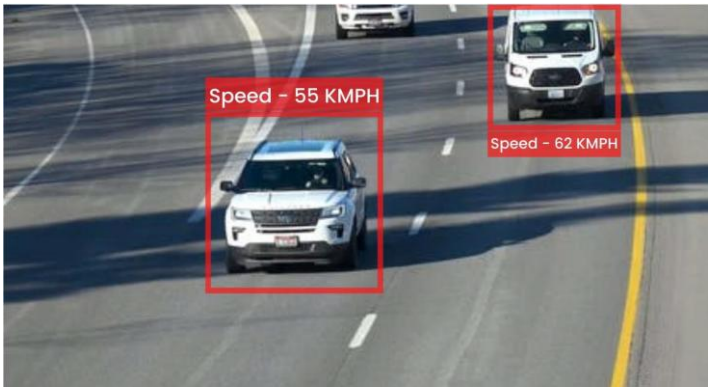
4.2 Red Light Violation Detection (RLVD)

The system captures the License Plate of the vehicles violating the red light or stop line when the signal is Red by either detecting red light status by taking the signal feed from the traffic signal controller or by video analytics method using an evidence camera. The evidence camera records the evidence snap showing the violating vehicle and the traffic signal status and store the record in database with license plate image, image of the vehicle, and at least five snaps showing clearly that the vehicle is crossing the red light / stop line while the signal is RED. This event is corroborated with the video clip archived in the VMS system at the control room. It intimates the incidence in real time through SMS to the designated mobile phone. The system generates alert when the signal light doesn‘t change for the pre- configured duration and detects pedestrians not crossing the junction through the area marked under zebra crossing.

Picture 3. Red Light Violation Detection at a Signalised Intersection

4.3 Speed Violation Detection (SVD)

The system is video based speed violation detection system and speeds from 40 KMPH to 150KMPH with variation of less than 2% at various speed thresholds such as 40 KMPH, 50 KMPH, 60 KMPH, 80 KMPH, 100 KPMH and 150 KMPH speeds are recorded. Different speed limits for different categories of vehicles can be set.



Picture 4. Speed Violation Detection on a road stretch

4.4 No Helmet Detection

The system collectively identifies and detects the two-wheeler, the rider and the pillion (if applicable), helmet for the rider and the pillion and the number plate. The system differentiates between a helmet and various other conditions such as the bald head, person covering the head with a cap or dupatta or pagree, or any other headgear. The system also differentiates a person sitting on two-wheeler and a pedestrian in the close proximity and also detects the speed of the vehicle.

Picture 5. No Helmet Detection at a Signalised Intersection

The system integrates with challan generation software and RTO database to generate challans for No-Helmet violation event with details like violation image, time stamp, date, vehicle number and seamlessly integrates with traffic management systems like ANPR, RLVD, Speed Detection and has unified user interface.

4.5 Triple Riding Detection

The system has the capability to detect the persons riding triple seat on the two-wheeler and captures the number plate of the vehicle with ANPR and generate an alert with the evidence images and video. The system also detects the No Helmet violation for persons riding in triple ride as well.

Picture 6. Triple Riding Detection at a Signalised Intersection

4.6 No Seatbelt Violation Detection with ANPR

The system captures the driver and co-passenger not wearing a seatbelt while driving, license plate of the vehicle with auto-localisation and OCR conversion and generates a violation in the system using the cameras which capture the vehicle from the front side. The system detects two traffic lanes from the single camera.

Picture 7. No Seat Belt Violation Detection at a Signalised Intersection

4.7 Driver on Call Detection while driving with ANPR

The system captures the driver talking on mobile phone while driving, license plate of the vehicle with auto-localisation and OCR conversion and generates a violation in the system using the cameras which capture the vehicle from the front side. The system detects two traffic lanes from the single camera.

Picture 8. Driver on Call Detection at a Signalised Intersection

5 SYSTEM ARCHITECTURE

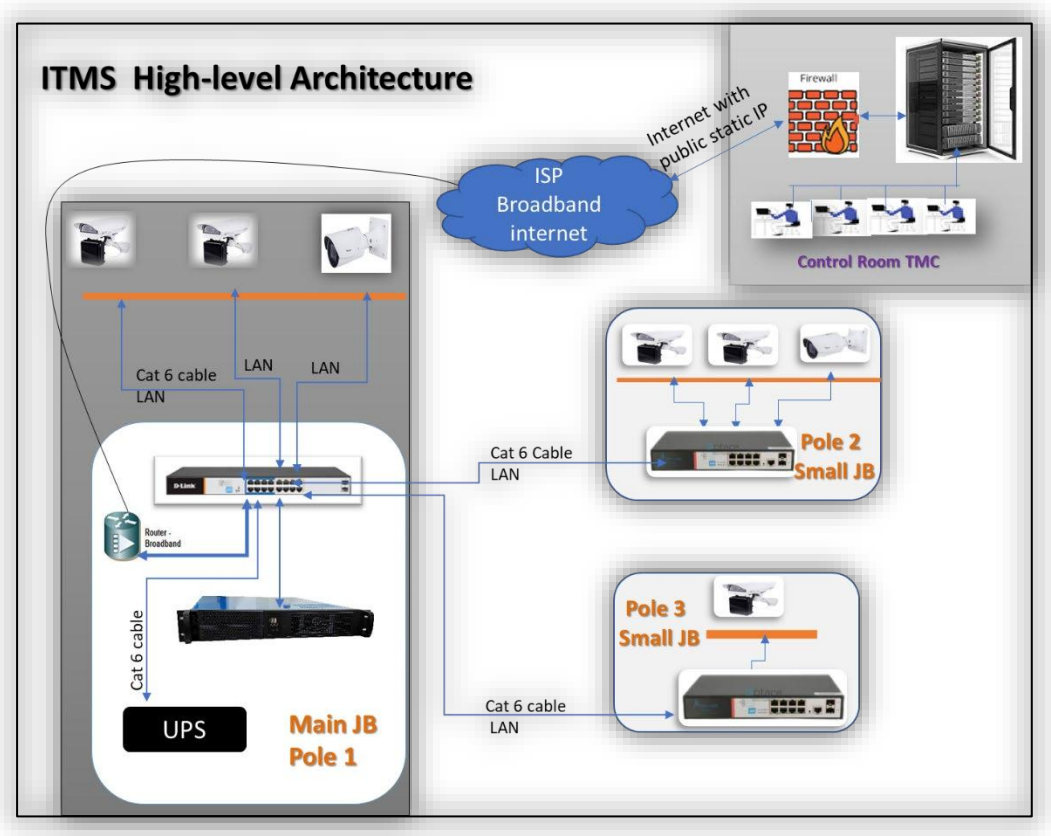


Figure 6. Diagram showing ITMS High-level Architecture

The system involves Local Processing Units at the junction for detecting various violations. The ANPR and Evidence cameras are connected with the LPUs at each junction. The LPUs provide the real time processing of the video feeds to detect and capture the violations. Each violation has multiple user selectable features such as images (single or multiple)

and video clips (with configurable duration of the pre and post video). Violation related data such as camera name, junction name, date and time stamp, etc. are captured along with the violation. The LPUs connect with the ITMS servers in the control room where the system management, records aggregation servers and storage systems are hosted.

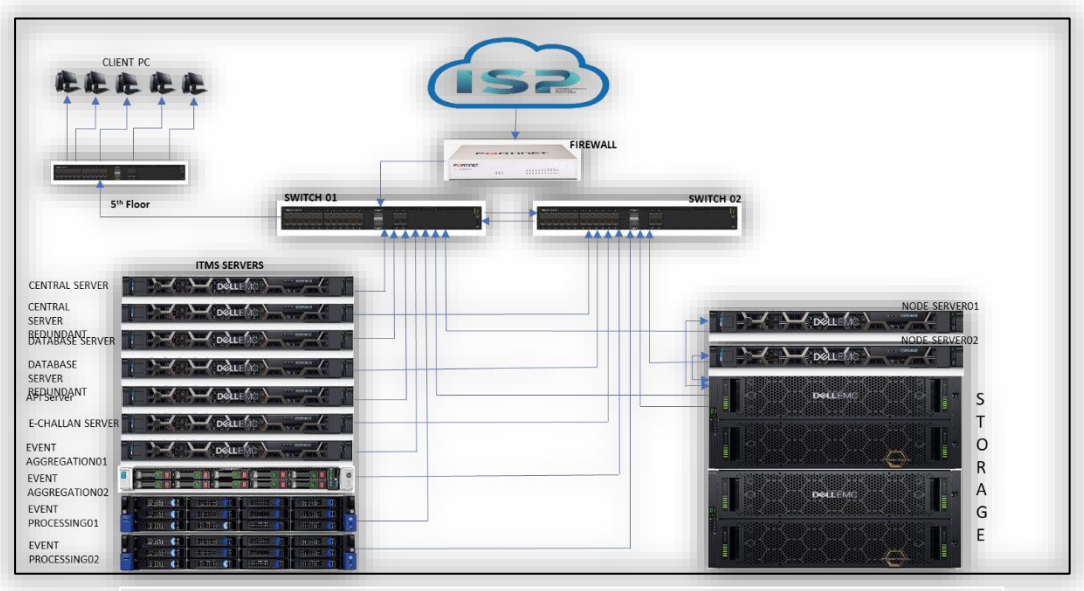


Figure 7. Diagram showing architecture of ITMS Data Center Server/ Network

In certain places, where provision of LPUs and field infrastructure is not possible / feasible or susceptible to damage or theft, the video feeds from such junction cameras are processed at the control room.
The system allows connecting the LPUs with the end to end connectivity (From location to TMC). The traffic control room serves as the primary hosting of all the required compute and storage infrastructure. The LPUs send the events data to the Control Room ITMS servers.

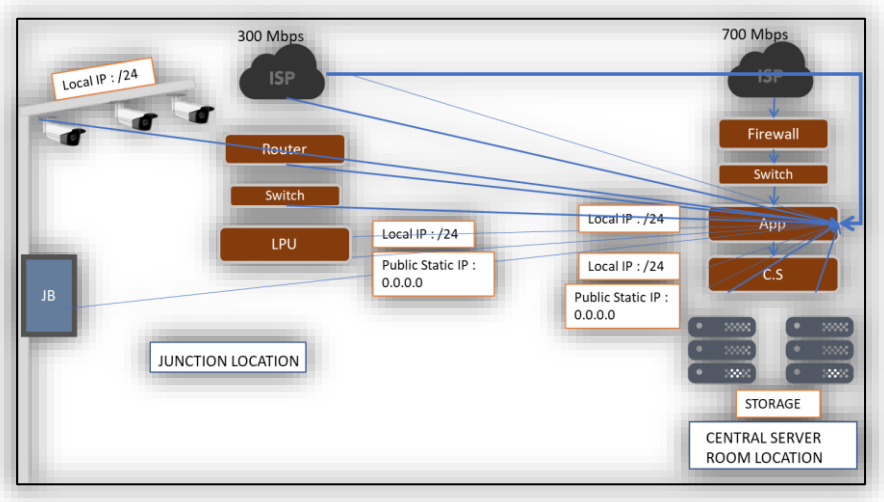


Figure 8. Field Network Connectivity Diagram

6 IMPLEMENTATION

The ITeMS and ICMS system were envisaged in the month of April 2022 and the project was tendered out to an implementing agency. The project was implemented at 50 junctions across Bengaluru city during the month of October in the year 2022.

Project Implementation Methodology consisted of the following phases,

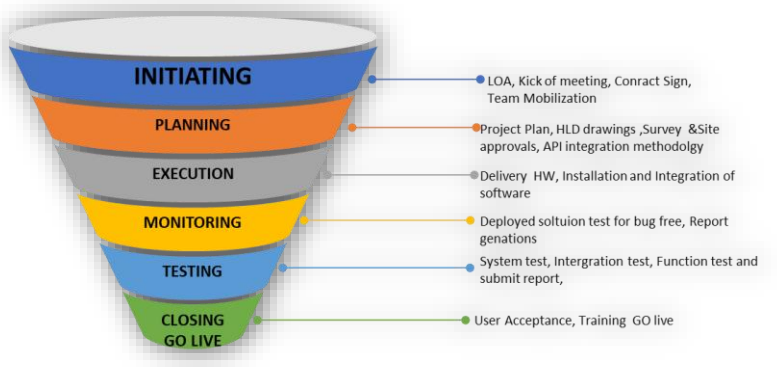


Figure 9. Diagram showing Project Implementation Methodology

The detailed task list right from preparation of Detailed Project report to laying of foundation for poles, pipes and cable laying, installation and configuration of cameras to installation and commissioning at Traffic Management Centre's Control Room is given in the following table,

S/NO	Work Description
1	Receipt of LOI from client
2	Kick off Meeting
3	Survey of sites
4	Preparation of Detailed Report
5	Approval of Site Maps From BTP Depart
6	Clarifications For Under ground Drainge, Cables, Pipe Lines
7	Permissions From BBMP /other department For Road Digging
8	Supply of all materials to respective Authority
9	Pole Foundation Work & Earthing Rod Installation
10	Pole Installations
11	Juntction Box Installtion
12	Road Cutting For Laying HDPE Pipe
13	HDPE Pipe & Power ,cat6 cable Laying
14	Power Meter connections apply and Installing meter
15	Cable Laying from Camera to JB and Btween Jn Cameras to Main JB
16	Box Equipment Installation like UPS, Switch, Etc.
17	Installation Of Cameras
18	Configuration Of Cameas
19	Network & Last Mile Connectivity
20	**Installation & Commissioning at TMC Control Room**
21	Feasiblity Survey of Control room
22	Submitting as build drwaing and getting approval from authority
23	UPS Installation and Configuration
24	Aanalys is on existing API and finding the gaps in API integration with external database
25	Connectivity establishment Between TMC and location
26	Operator workstation and configuration
27	Servers Installation at Control Room Level
28	Monitor Installation at Control Room Level
29	Network switch Installation at Control Room Level
30	Database Server installation and configuration
31	ITMS Software Installation at Control Room Level
32	API server Installation and configuration
33	VA Server Installation and Configuration
34	Firewall Installation and Configuration
35	API Integrating with RTO and other database
36	Challan server Installation and configuration
37	Control room Internet Installation and configuration
38	Functional testing of ITeMS application
39	Customer Accpetance test report
40	Training at Control Room level
41	Go-live

Table 1. Project Implementation – Detailed Task List

The list of 50 junctions where the system is implemented along with their locations is given below,

SN	ITMS JUNCTION NAME	SN	ITMS JUNCTION NAME
1	80 Feet Old Madras Road	26	Kormangala80ftRD
2	AdugodiJN	27	LeelapalaceJn
3	Aishwarya-JN	28	Mariyappacircle
4	AXASignal	29	Modi hospital
5	BashayamCircleRajajinagar	30	Navaranga circle
6	BattarahalliRd	31	PromenadeWheelresroad Jn
7	BazaarStreetJN	32	RajakumarRoadManiComplex
8	BhashyamCircle	33	RajKumarStatueDomlur
9	BRVJn	34	SampigeRoad
10	CAL Cross	35	SangamCircle
11	ChikkapetTPS-Jn	36	Shaktitemple
12	ChandirkaHotel	37	ShivanandacircleJn
13	CMHHospitalJn	38	SrinivagiluJN
14	DickensonRoadMG	39	SwamiVivekananda
15	DoddaBanaswadi	40	Taralubalu junction
16	Dosusa Circle	41	TavarekereMain JN
17	GPO CIRCLE	42	TCPalaya JN
18	HALIndiranagar	43	Vanivilas JN
19	Indiranagar KFC JN	44	Watertank JN
20	Jayanaga4thblockbusstop	45	WiproJN
21	Jayanagar-4thMain	46	HAL-ASC JN
22	JPnagar-15thcrossJN	47	Sadashivanagar JN
23	JPnagar-8thmain-9thcross	48	Ramaiah Hospital
24	Kalasipalya Main Rd	49	Teachercollege JN
25	Kathriguppa Circle	50	Siddiahroad JN

Table 2. List of 50 Junctions where ITMS is implemented

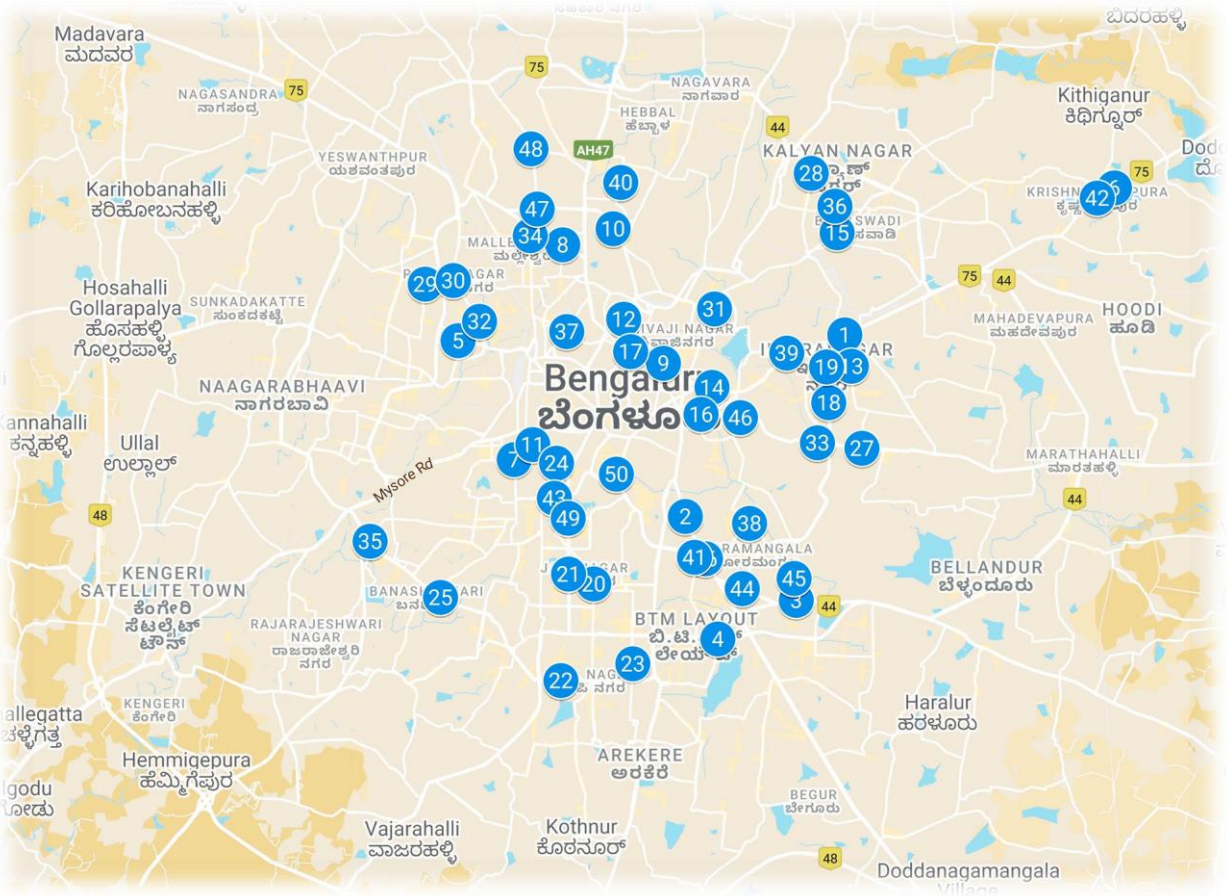


Figure 10. ITMS implemented junctions located on Bengaluru Map

Sample of the details regarding LPUs, Poles and Cameras installed at each location is given below,

Sl No	DIVISION NAME	POLICE STATION NAME	LOCATION NAME	LAT	LONG	LPU	LPU IP	TOTAL CAMERAS	POLE DETAILS	CAMERA TYPE	RLVD	ANPR	NO SEAT BELT	NO HELMET	DRIVER ON CALL	TRIPLE RIDE	SPEED
1	SE	ADUGODI	Hosur Main Road Koramangala 80 Feet Rd junction	2.93438	77.612	1	92.168.2	8	POLE-1	RLVD	1						
									POLE-1	ANPR		1		1		1	1
									POLE-1	ANPR		1		1		1	1
									POLE-2	RLVD	1						
									POLE-2	ANPR		1					
									POLE-2	ANPR		1					
									POLE-2	ANPR		1	1		1		
									POLE-3	ANPR		1	1		1		
2	SE	ADUGODI	Adugodi Main Rd Adugodi junction	2.94402	77.608	1	92.168.2	7	POLE-1	RLVD	1						
									POLE-1	ANPR		1					
									POLE-1	ANPR		1					
									POLE-2	RLVD	1						
									POLE-2	ANPR		1		1		1	1
									POLE-2	ANPR		1		1		1	1
									POLE-3	ANPR		1	1		1		

Table 3. Sample excel sheet of ITMS details at each Junction

Sl No	Junction name	Unit	ANPR	RLVD	LPU
2	K H road , Siddiah road junction (Wilsongarden Traffic Police Station)	Nos.	6	2	1

Picture 9. On-site picture of an ITMS Junction showing Camera and LPU

The various Servers commissioned at the Control Room and the Central Hardware are as follows

- ITMS Master Server
- ITMS Master Server Redundancy
- ITMS Database Server
- ITMS Database Server Redundant
- ITMS Events Aggregation Server
- e-Challan Server
- ITMS API Server

Picture 10. ITMS Servers commissioned at the Command Control Center

On an average 20,000 challans are being generated daily from the ITMS project. Out of these challans, 50% are automatically pushed for processing, while the remaining undergo manual validation.

Picture 11. eChallan Printing Work in Progress

ITMS EVENTS CAPTURED COUNT MONTH WISE									
MONTH	STOP LINE	SEAT BELT	JUMPING TRAFFIC SIGNALS	TRIPLE RIDING	NO HELMET	OVER SPEED	DRIVER ON CALL	TOTAL	
Dec-22	108600	62393	27377	5578	191814	2967	666	399395	
Jan-23	136446	103129	171278	8673	267050	3734	1263	691573	
Feb-23	71897	101346	126858	6663	218791	2522	1630	529707	
Mar-23	82149	93886	147387	6500	269403	3220	1403	603948	
Apr-23	145434	136696	205146	20827	430481	24095	4672	967351	
May-23	122241	147070	198786	23930	497469	14848	5143	1009487	
Jun-23	132565	138026	236676	23400	450331	8884	4893	994775	
Jul-23	129985	240214	250251	16635	310668	7662	3869	959284	Till 27th jul

Table 4. ITMS Events capture month-wise

From Dec-2022, the ITMS project has collected an amount of Rs. 36.2 lakh till 27th July 2023, challan amount collection details are presented below,

ITMS CHALLAN GENERATION COUNT MONTH WISE									
MONTH	STOP LINE	SEAT BELT	JUMPING TRAFFIC SIGNALS	TRIPLE RIDING	NO HELMET	OVER SPEED	DRIVER ON CALL	TOTAL	
Dec-22	64948	32163	16478	4551	135975	0	270	254390	
Jan-23	95983	74623	109548	8712	254876	0	414	544156	
Feb-23	41986	69019	56114	3456	173974	0	590	345139	
Mar-23	47596	78268	70707	2983	239163	4	494	439215	
Apr-23	62666	64668	94788	2533	281942	86	521	507204	
May-23	50134	82603	85806	4965	335818	321	272	559919	
Jun-23	51823	64746	97885	2626	281063	256	427	498826	
Jul-23	48757	42122	101356	9383	267541	158	788	470105	Till 27th July

Table 5. ITMS Challan Generation Count Month-wise

7 CONCLUSION

Thanks to the ITMS project, the people of Bengaluru are now well aware of traffic rules and safety precautions, such as wearing helmets and seatbelts. The cameras record violations 24x7x365 and the entire system is completely automated. Thereby, this system saves a lot of time and traffic manpower, which can be redeployed for traffic management and regulation and provide a better service to the public. The system provides transparency in the functioning of the Police as it is contact-less enforcement. Now the public cannot blame the Police for stopping of vehicle riders, harassment, corruption and neither the Police can blame the vehicle riders for non-compliance of traffic rules and regulations.

With the implementation of the ITMS project, the police can now trace vehicles using ANPR technology, which greatly aids in solving various cases. The data being generated through the ITMS system is being used for the benefit of the Authority as a decision support system, with the following functions being available,

i. The system generates an alert for the operator when the average speed of any junction drops by the configured threshold (e.g. 20%) as compared to the regular average of last one or two weeks
ii. The system generates an alert when an average volume of vehicles of any category increases suddenly by the configured threshold (e.g. 20%) as compared to the regular average of last one or two weeks
iii. The system detects commercial vehicles having age more than the configured age in years (e.g. 13)
iv. The system plots average count of vehicles or violations on the map such as GIS / Google Map
v. The system shows a comparative result for traffic flow and traffic rule violations across various regions in the city
vi. The system has published APIs to interface with external systems such as Command and Control Application, Incident Management System, etc.
vii. The system has the capability to integrate with the VAHAN / SARATHI system to fetch vehicle related details as required and as made available by the VAHAN / SARATHI system
viii. The operator has the facility to quickly query the RTO database to find out the name/address of the owner of the selected vehicle
ix. The system provides a query service to the other districts within the state to query a particular vehicle if it was seen in the city OR a provision to issue a lookout notice to Bangalore police which can be fed in the database and any detection of the lookout vehicle generates an alert

To summarise, the implementation of ITeMS has significantly contributed to smoother traffic movement in the city of Bengaluru. This project stands as a model for other city departments to improve their traffic enforcement methods and road safety initiatives with the use of AI based technology.

8 REFERENCE

[1] https://btp.gov.in/