Original Research Paper

Emerging Technologies for Driving Road Safety and Traffic Management for Urban Area

[1]Yogesh Golhar and [2]Manali Kshirsagar

[1]*Research Scholar, Department of Information Technology, Yeshwantrao Chavan College of Engineering,*
Nagpur, Maharashtra, - 441110, India
[2]*Department of Computer Technology, Yeshwantrao Chavan College of Engineering,*
Nagpur, Maharashtra, - 441110, India

Abstract: The on-road traffic increases due to the exponential growth of the number of vehicles on the road. That leads to undesirable road conditions and makes urban population life uncomfortable. It includes traffic congestion, traffic jams and long queues at traffic signals and toll booths. Many people violate road traffic rules and regulations rules every day. Manual human effort and supervision are not enough to resolve these issues. Still, many road traffic managements follow the traditional approach, which results increase in road accidents that makes humans seriously injured and even loss of life. To address these issues, we have proposed four strategies as (1) congestion status on square, (2) efficient toll tax collection, (3) fine collection on road for the people who violate road traffic rules, (4) shortest pathfinder for drivers. This research work mainly focuses on the various strategies and their implementation with the help of the Map-Reduce framework. We have combined video surveillance, big data analytics algorithm and proposed an innovative way to manage and handle the road traffic.

Keywords: Map Reduce, Road Traffic Management, Big Data Analytics, Hadoop Framework

Introduction

In India travel by highway is risky because of two reasons (1) due to road conditions, (2) Irresponsible behavior of drivers on road leads to accidents. India is at the top position in the world in traffic-related deaths. In other countries like U.S. people suffered from severe traffic accidents in recent times. Every person should be more attentive while walking side by road, specifically in the area of pedestrian walking zones. Every four and six-wheeler driver must use safety seat belts. Each two-wheeler driver must use the Helmets. Travel in the evening is especially dangerous. Buses, habituated by hundreds of millions of Indian people. It is observed by the traffic authority many drivers are driving fast and fearlessly in the congested areas. Results in on road accidents are quite obvious. However, robust traffic monitoring and management system is required to deal with such problems in India and other countries. Current traffic management system is manual. Human traffic controller monitors and manage the on-road traffic in India. At, many places the surveillance camera are used to monitor the traffic and capture traffic rules and regulation

scenarios. But not all the roads, are under surveillance in India. Existing on road traffic surveillance cameras-based traffic management system have different issues and challenges such as huge traffic record management, active surveillance missing on road, because in current system no automated fine collection module is not included. It is getting enhance day by day in India. Recently, Traffic control management organization in India comes with the initiative of FastTrack system on toll booth. It is used for the collection of tax on toll booth for avoiding the long queue on the road. In FastTrack system, every vehicle has their own unique QR code attached with the account.

Whenever, the vehicle comes on toll both, the camera on the toll booth mounted on the top scanned the QR code of vehicle. Then amount is automatically deducted from the account without any human involvement. But, issue with FastTrack system include, (1) vehicle and camera mounted camera calibration, position of vehicle should be appropriate to capture the QR code on vehicle. (2) Quality of camera on toll booth is poor. Sometimes it is difficult for vehicle driver to positioned the vehicle on the toll booth. We try to address these issues with our proposed strategies of traffic management using big data analytics.

In proposed work we have come with four efficient strategies to overcome the existing system drawbacks. The proposed framework utilized the Map Reduce framework to manage the traffic big data efficiently. The four strategies include (1) traffic status on the road based on the congestion degree, (2) efficient toll tax collection, (3) fine collection on road for the people who violate road traffic rules, (4) shortest path finder for drivers. The proposed approach will resolve the aforementioned issues and challenges of traffic monitoring and management system.

Literature Survey

Nowadays, ruler people are moving towards the urban cities due to better job opportunity and urban road traffic increase day by day. In the upcoming years approximately 70% of the world population expected to live in urban cities (Dobbs *et al*., 2011). The government of India Smart Cities announced the fund of 160 billion for making the 100 smart cities of country (Abbu *et al*., 2015; Nandury and Begum, 2015).

Javaid *et al*. (2018), proposed distributed and centralize approach to manage road traffic. The traffic information collected using the video surveillance camera and automated signal changes automatically. Cloud platform used as a storage to store and manage large size videos. Hence, there is a risk of single source failure. Swathi *et al*. (2016), introduced an efficient traffic routing system, less congested road path was suggested to the end user. Different infrared and image sensors are utilized to collect the road traffic. However, change in illumination, temperature variation, overcast condition and humidity affects the traffic density values which is based on the weather situation. Wiering *et al*. (2004), proposed adaptive control system to control traffic light of roads. In this system based on on-road traffic condition traffic light color changes adaptively. Due to this long queue on signal get reduce, the drivers can always take the lowest estimated waiting path for reaching destination. In this system, if all the drivers select or opts for the same route, the optimal and less time-consuming path becomes overcrowded and thus, the system may become inefficient for all.

Calvert *et al*. (2018), proposed improved traffic management system by taking into consideration of the uncertain and unpredictable behavior of traffic flow. Kim *et al*. (2018) proposed a remote location one fingertip mobile application and cloud-based traffic management system. The system uses the intelligent traffic monitoring and navigation system using formal methods and graph theory techniques. This system works efficiently when the on-road traffic is heavy, this system will be more effective as manual traffic management system does not work well in emergency situations. Further, the drivers notified with the alternative path notification.

Latif *et al*. (2018), introduced smart road transportation approach to efficiently control the heavy congestion areas on the road and managing the on-road accident. Liu *et al*. (2013), introduced the intelligent and active traffic monitoring system using a RFID sensor, it creates a custom routing map of the shortest and less time-consuming map of the city. It will help drivers and traffic authorities to get overviews of traffic of whole city.

Currently, traffic data collected using video cameras, sensors, etc. Video camera used for video analysis, in this the smart cameras with high quality image sensors, processing and communication entities. These cameras are used to monitor the traffic. Traffic information statists are computed using the scene description and video understanding. These include vehicle type, frequency, number plate detection, average speed of vehicles and lane occupancy information, etc. Liu *et al*. (2013). The on-road sensors sometimes called as Traffic detectors (Manikonda *et al*., 2011). The application includes such as network traffic measurement, traffic monitoring and control, computation of speed of vehicle, on road accident detection.

Infrared embedded sensors are divided into two categories as (1) passive detector and (2) active detectors. Passive type extracts the information from environment specifically it records the information reflected or generated from the object. It can be useful to compute the speed, length, number of vehicles and dimension of vehicle. Active type propagates the signal and received the reflected energy from the object. Ultrasonic object detectors (Manikonda *et al*., 2011) transmit the wave in omni direction and gather the information available in the environment. Hadoop Distributed File System (HDFS) is utilized for storing the big data. The master and slave architecture adopted by the HDFS. It exposes a file system namespace and allows user data to be stored in files. HDFS is used for processing the Big Data efficiently.

Recent literature survey uses different technologies and strategies for efficient traffic management framework. Cárdenas-Benítez *et al*. (2016) proposed traffic congestion detection using connected component analysis. It includes two approaches (1) traffic event detection algorithm and (2) route Monitoring Algorithm useful for road incident detection and navigation. The algorithms utilized the simulated data generated using SUMO (Simulation of Urban Mobility) traffic simulator. This approach is not suitable for real-time road traffic scenarios and situation aware routing is not possible using this model. Gupta *et al*. (2013) proposed a Detect Traffic Congestion (DTC) by Mining versatile GPS data model. It includes (1) identification of On-Road Clusters Algorithm, (2) Binary Traffic Output Algorithm. The source of data for these approaches are GPS enabled devices like mobiles, tablets and from vehicles etc. The limitation of this is misclassification of traffic jam scenarios due to in-accurate vehicle of GPS location. Ganesh and Appavu (2015) an Intelligent Video System (IVS) Framework with Big Data Management for Indian

Road. The limitation of this approach includes (1) not suitable for large scale deployment, (2) misclassification of traffic jam scenarios due to in-accurate vehicle localization. Adoni *et al*. (2017) proposed a traffic event detection using Map Reduce framework. The input traffic event logs are generated using the Apache flume. The limitation of this framework includes (1) time complexity for traffic event detection is more, (2) advanced traffic analysis algorithm can be integrated to this framework for improve the processing of traffic event logs, (3) reuse the same approach for traffic congestion detection can enhance the performance this framework. Due to existing system limitation in real time environment, it is observed that there is need of efficient traffic management system to handle the current traffic scenarios in the urban environment.

Proposed Methodology

The proposed approach is classified into three stages as (1) Road traffic information captured using video camera, (2) Extraction of traffic information from video frames, (3) Map Reduce framework for predicting traffic states. Again, proposed work further classified as, A. video processing/analysis i.e., preprocessing of video footages. B. storage of data in HDFS and analyzing it using Hadoop to find the congestion degree. Pre requisite for this project: Implementing camera for recording traffic information on various prominent location. This will detect the types of vehicles, vehicles speed, then calculating a congestion degree. Implement a complete system for Vehicle Registration system with various other modules, such vehicle registration, fine collection system, toll tax collection, shortest path.

A. Video Analysis

The vehicle in a video detected and classified using the vehicle detection and classification algorithm. It uses HAAR cascade classifier De Souza *et al*. (2017). It describes in brief as follows.

Algorithm-1: Vehicle detection and classification

Step 1: a. Video $\rightarrow$ Converted to frames (25f/s)
      b. Tot Count $\rightarrow$ 0
Step 2: By using HAAR cascade algorithm following information is extracted
$\int (x,y,w,h)$
Step 3: Moving objected represented by rectangular box defined by: (x_1, y_1), (x_2, y_2) where $x_2 = x_1 + w$, $y_2 = y_1 + h$

Step 4: Finding the centroid $C = \left(x_1 + \left(\dfrac{w}{2} \right) \right), \left(y_1 + \left(\dfrac{h}{2} \right) \right)$

Step 5: Input the training set for cascade classifier
Step 6: Frame by frame reading of video
Step 7: Detection of ROI of lane represented as spatial (x, y) coordinate location.

Step 8: if length(rectBox) $\neq$ 0 then
      Total vehicle = Total vehicle + 1
  If area of the rectangle is less than 10,000 classified it as bike {Increment bike value by 1}
  If area of the rectangle is 10,000 to 17,000 classified it as car {Increment car value by 1}
  If area of the rectangle is greater than 17,000 classified it as truck/bus {Increment bus value by 1}
Step 9: For each video frame repeat step two to step eight otherwise End.
Step 10: End
(where,
x, y = are the coordinated,
w = width,
h = height,)

The Table 1 shows the types of vehicles and classification category of vehicle utilized in the proposed algorithm:
The Table 2 shows the vehicle classification category based on the speed utilized in the proposed algorithm:
The above data and classification useful in extracting the information such as, number of vehicles on road, road speed, etc.

B. Storage of data in HDFS and Congestion degree computation using Hadoop

The extracted parameter in algorithms is used by Mapper Reducer function in HDFS for processing data in Hadoop. The congestion degree is computed to get the current status of traffic state using following algorithm.

Algorithm-2: Computation of congestion degree

Step 1: [Initialization and consideration]
      On road vehicle count $\rightarrow$ *Tvr*
      Avg. speed $\rightarrow$ *ASvr* for the five minutes.
      Stand still vehicles on the road $\rightarrow$ *Sv*.
      Road standard speed $\rightarrow$ *Rs*
      On road moving vehicles $\rightarrow$ *Rv*
      Avg. speed of road $\rightarrow$ *As*
Step 2: [Computation of average vehicle speed]
      Rv $\rightarrow$ *Tvr – Sv*
      If *Rv* equals *Sv then*
        Road is full congested.
      Else
      Go to the step 2.
      End
Step 3: [Calculating average speed of road for the movable vehicle states]
      As $\rightarrow$ *Avg. * speed (Rv)*
Step 4: Congestion degree $\rightarrow$ *(Rs- As)/ Rs*

Table 3 shows the computed congestion degree will vary from 0 to 1 as per the traffic congestion and it is divided into different category as follows:

Table 1: Classification of vehicle based on wheels

Vehicles types	Vehicles category
2 wheelers vehicle	Scooter, Bike, Scotty, etc.
3 wheelers vehicle	E-Riksha, Auto, Micro transportation vehicle, etc.
4 wheelers vehicle	LMV, Car,
More than 4 wheelers vehicle	Heavy Trucks, Bus

Table 2: Classification of vehicle on the speed parameter

Vehicle Speed	Vehicles speed classification
0.0 Km/h	Vehicle stationary
0 - 25Km/h	Vehicle moving slow
26.0 - 50.0 Km/h	Vehicle moving normal
51.0 - 75.0 Km/h	Vehicle fast moving
Above 75.0 Km/h	Vehicle moving very fast

Table 3: Congestion degree distribution

Congestion degree	Traffic category
0 to 0.25	Heavy congestion or stand still
0.26 to 0.50	Congestion
.50 to 0.75	Slow moving
0.75 to 1	No congestion

For every 5 min the congestion degree is computed and also stored and processed in HDFS. Each hour having 5 traffic states and 288 traffic states for 24 h. Again, prior historical information is considered to compute the peak traffic hours as illustrated follows. Table 4 illustrate the categorization of range of congestion degree, traffic type, peak traffic time in the 24 h.

The decision tree used for the detection of congested region, time of peak traffic on the road based on the congestion degree. The Mapper Reducer function implemented on the HDFS to process the traffic log information to predict the traffic states. Next, we have detected the number plate of vehicle and obtain the vehicle unique vehicle number extracted from the number plate.

Algorithm-3: License Plate Identification (LPI) and detection

Step 1: Read input video from Database.
Step 2: Convert into frames and write each frame in the output directory.
Step 3: Convert input frame into gray scale image
Step 4: Generate binary image i.e., Black and white image from gray scale image.
Step 5: Find shape of image. [It includes resolution of image i.e., dimensions matrix]
Step 6: Generate the label image. In this step connected regions in a binary image are identified and group together.
Step 7: Initialize the matrix for number plate detection (maximum width, height and minimum width and height that a license plate).
Step 8: Find the regional properties using region props. It creates a list of properties of all the labelled regions.
Step 9: Consider the area property. If the region area is so less than it is not considered as number plate.
Step 10: Ensuring that the region identified satisfies the condition of a typical license plate initialize in the step 7.

Step 11: Add bounding box coordinate on the binary image.
Step 12: Drawing rectangle red border color box around number plate.
Step 13: End

The detected number plate used as input the character segmentation algorithm to detect the character in the number plate. Each of step is describe as follows.

Algorithm-4: Character segmentation from detected number plate.

Step 1: Detected number plate is given as input then; Invert was done so as to convert the black pixel to white pixel and vice versa
Step 2: Plot the bounding box on the gray scale image to show the box on the gray scale image.
Step 3: Initialize the character dimension bounding box width and height. It is needed to identify the characters in the number plate independently. [The next two lines is based on the assumptions that the width of a license plate should be between 5 and 15% of the license plate and height should be between 35 and 60% this will eliminate some].
Step 4: The character and digit in a number plate is represented in a box with a dimension 20×20
Step 5: Draw Red border rectangle around the digits
Step 6: Resize the characters to 20×20 and then append each character into the characters list.
Step 7: Plot the bounding boxes around each character
Step 8: Initialized the model which is pre-trained using multiple character combination define in the train directory
Step 9: Pass each identified character to the train model to identify each character uniquely from the number plate
Step 10: The identified characters are generated from the trained model after testing.
Step 11: End

The extracted traffic information from the input source it is process in HDFS. Figure 1 shows the MapReduce framework of the proposed approach. First, the input data is uploaded in the HDFS in the forms of clusters, later the data is divided into key value pair at different nodes using Mapper function. Then it is shuffle in next stage before reducer process the input data. At the end, the Reducer function group together the homogeneous data into different categories with respective to the key value pair. The consolidate result obtain at the end without any ambiguity.

The proposed system uses the Hadoop environment to processed the input data. The processed output result in traffic jam or no traffic jam as shown in Fig. 2. The input source information include speed, vehicle category, congestion degree, road average speed, congestion status, geo location of vehicle, etc. the Mapper Reducer function design in such way that it will process all of these parameters at once in Hadoop distributed environment. Figure 3 shows the Mapper Reducer function utilized for the different traffic log information.

Table 4: On traffic type based on the video footage of 24 h

Range of Congestion Degree	Traffic type	Time slot in 24 h format
0.0 - 0.25	No congestion on road	Slot: 0 to 8 and 14 to 16 and 23 to 24
0.26 - 0.50	Slow moving traffic	Slot: 9,12,17,22
0.50 - 0.75	Congestion state	Slot: 10,13,21
0.75 – 1.0	Heavy congestion on road	Slot: 11,18 to 20

Mapper function.

Step 1: Initialization:

  Input:

Geo_location (G),

Speed_of_vehicle (S)

    Vehicle_Type (Vt),

    Location(Loc)

    Time_Stamp(Ts)

Step 2: Mapped Each data to specific Mapper.

    $MRg \leftarrow GeoLocationMapper(G)$

    $MRs \leftarrow SpeedofVehicleMapper(S)$

    $MRvt \leftarrow VehicleTypeMapper(Vt)$

    $MRl \leftarrow LocationMapper(Loc)$

    $MRts \leftarrow TimeStampMapper(Ts)$

Step 3: Store the details of traffic details based on speed and type in HDFS for road ID.

    $CongesDegree \leftarrow ComputeCongestionDegree(S,RD)$

Reducer function.

Step 1: Initialization:

  Input: Mapped Input

    $MRg \leftarrow GeoLocationMapper(G)$

    $MRs \leftarrow SpeedofVehicleMapper(S)$

    $MRvt \leftarrow VehicleTypeMapper(Vt)$

    $MRl \leftarrow LocationMapper(Loc)$

    $MRts \leftarrow TimeStampMapper(Ts)$

Step 2: Each reducer will generate the output.

    $Rg \leftarrow ReducerGeoLocation(MRg)$

    $Rs \leftarrow Reducer\ Speed\ of\ Vehicle(MRS)$

    $Rvt \leftarrow ReducerVehicleType(MRvt)$

    $Rl \leftarrow ReducerLocation(MRl)$

    $Rts \leftarrow ReducerTimeStamp(MRts)$

Step 3: Store the details of reducer output in HDFS for road ID.

The above Mapper Reducer function is used for the traffic state detection at the end. Later all of the processed data visualized on the Map using geolocation. The toll tax collection and fine collection mechanism is implemented on cloud platform, in which detected number plate and other driver related information store in database and all the status of collected fine or toll tax visualize on the map using geo location. The shortest path routing navigation feature also embedded in the framework for finding the shortest routing path between different location. In the next section we have describe the all the experimented conducted.

Experimental Results

The road traffic information gathers from various region of Nagpur city. The Fig. 4 illustrate the camera setup on the bridge to record the video of different road lane at different angles 5º, 20º and 25º from the ground position. The camera place 25m away from the road specifically on the bridge. The position camera allows to record the on-road vehicle information in both direction as show in the Fig. 4. The blue and read dash lines shows the cameras range.

The daily road traffic capture using DSLR camera shown in Fig. 5. The left side image shows the raw video frame recorded by the camera placed at the top of the bridge. Right side image consists of ROI marked with white color in rectangle box shape to represent the region from which vehicle information is calculated. The different information extracted from the video such as vehicle speed, vehicle type, number of vehicles in the lane. The two vertical solid lines on the frame shows the road specific region.

Next, the traffic information such as speed of vehicle identified from Region of Interest (ROI). The traffic information proposed using HDFS using Mapper Reducer batch processing unit. On road traffic information useful for computing the congestion degree to predict the traffic state of road. The processed result in HDFS shown in Fig. 6. (a) Directory structure of HDFS where physically computation of files is performed. (b) Job processed output in HDFS using double Map Reduce framework. (c) Computation of type of vehicle using vehicle processing algorithm and (d) Computation of Speed of vehicle using vehicle speed computation algorithm. (e) Congestion degree computation for traffic data.

The license plate Identification system is developed in the Phyton. The hardware configuration used for the implementation of the algorithm is Intel Core i3 CPU@ 3.00 GHz, 16.00 GB RAM, 64-bit operating system. The Video camera used for capturing the video frames is DLSR camera with progressive scan and CMOS sensor. 1280X1024, 25/30fps, H.264/MJPEG/MPEG4, Triple stream, 30 m IR. The camera is manually recording the incoming and outgoing vehicles on the various location of the road. The output of license plate identification system Fig. 7.

The four strategies user interaction shown in Fig. 8. Figure 8(a) shows the congestion status using congestion degree geolocation wise shown on the map. Figure 8(b) shows the toll tax status and collected amount on screen. The map implemented are dynamic in which if end user clicks on the desired toll tac location point. The alert will show the toll tax collection status on screen. Similarly for the fine collection. At last shortest pathfinder for drivers allows end user to select the source and destination location and suggest the shortest path between the selected location.

The database consists of all the traffic log and event details. Table 5 shows the extracted information from input video. It also divided into different location on road, other data traffic scenarios, size of information with its duration and attribute extracted from the algorithms after processing of source raw data.

The proposed approach compares with the existing approach based on the time complexity. It is observed

that the proposed approach requires less time compare to the approach of (Cárdenas-Benítez *et al*., 2016; Gupta *et al*., 2013; Ganesh and Appavu, 2015; Adoni *et al*., 2017). The four strategies are useful for efficient traffic management. The result comparison of proposed system with the existing approaches are shown in Table 6.
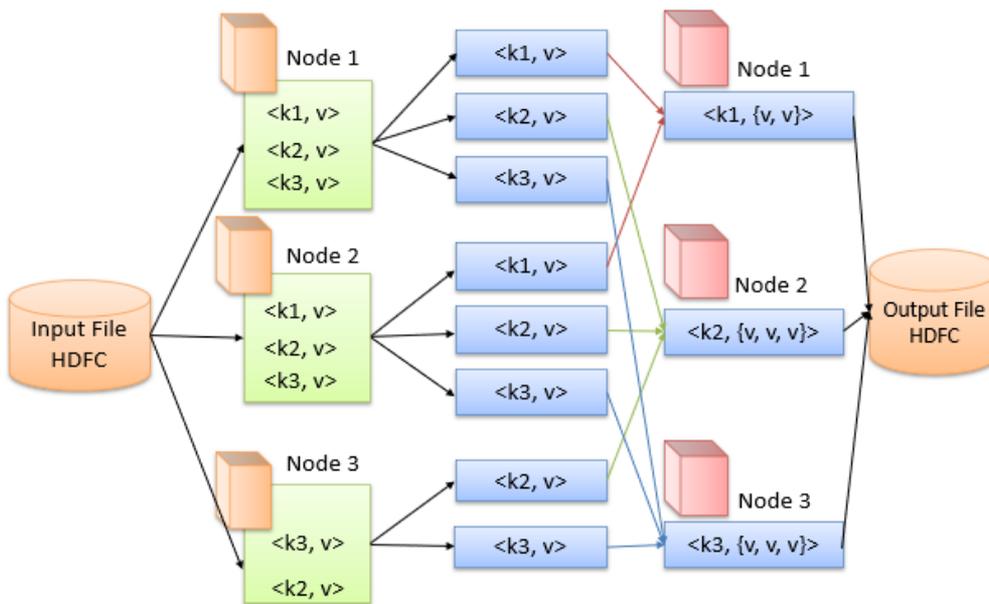
Fig. 1: Map Reduce framework of proposed system
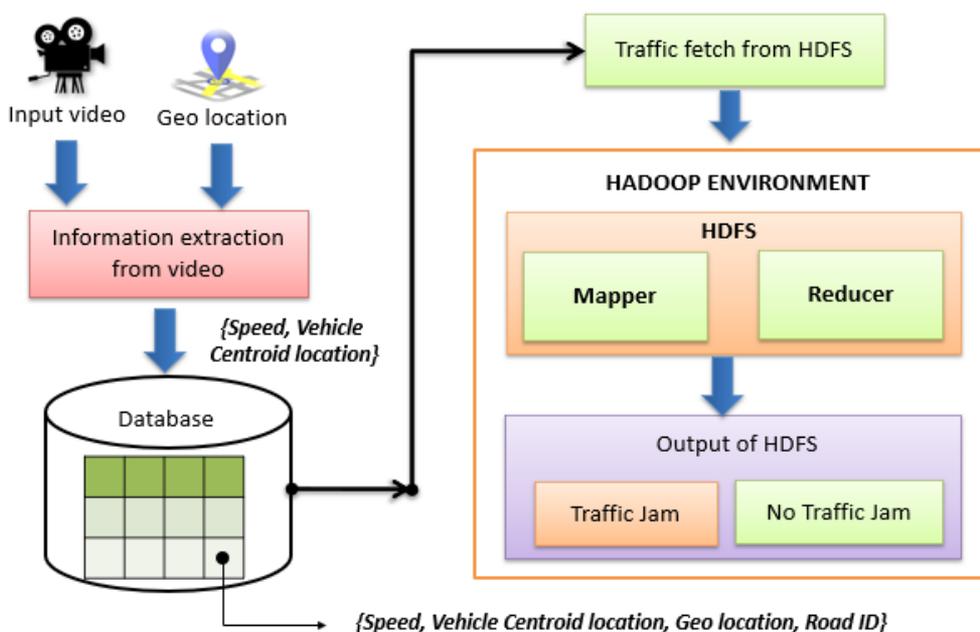
Fig. 2: Proposed system architecture

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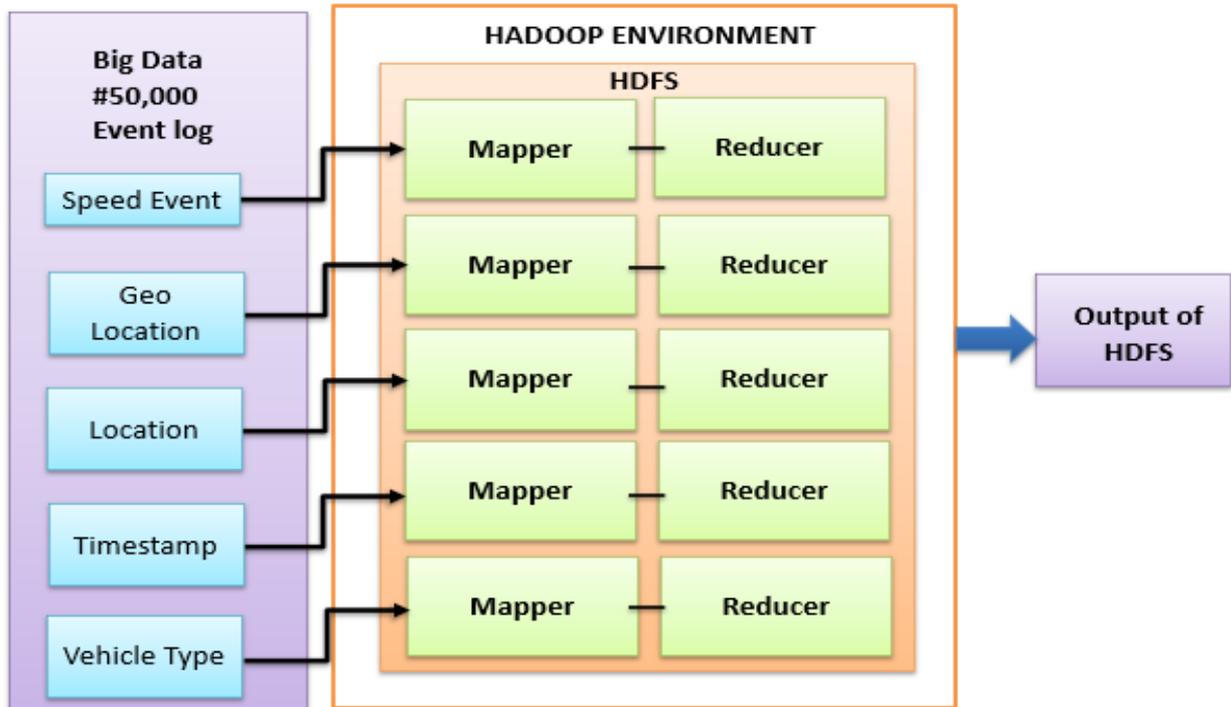
**Fig. 3:** HDFS input data process using Map Reduce framework
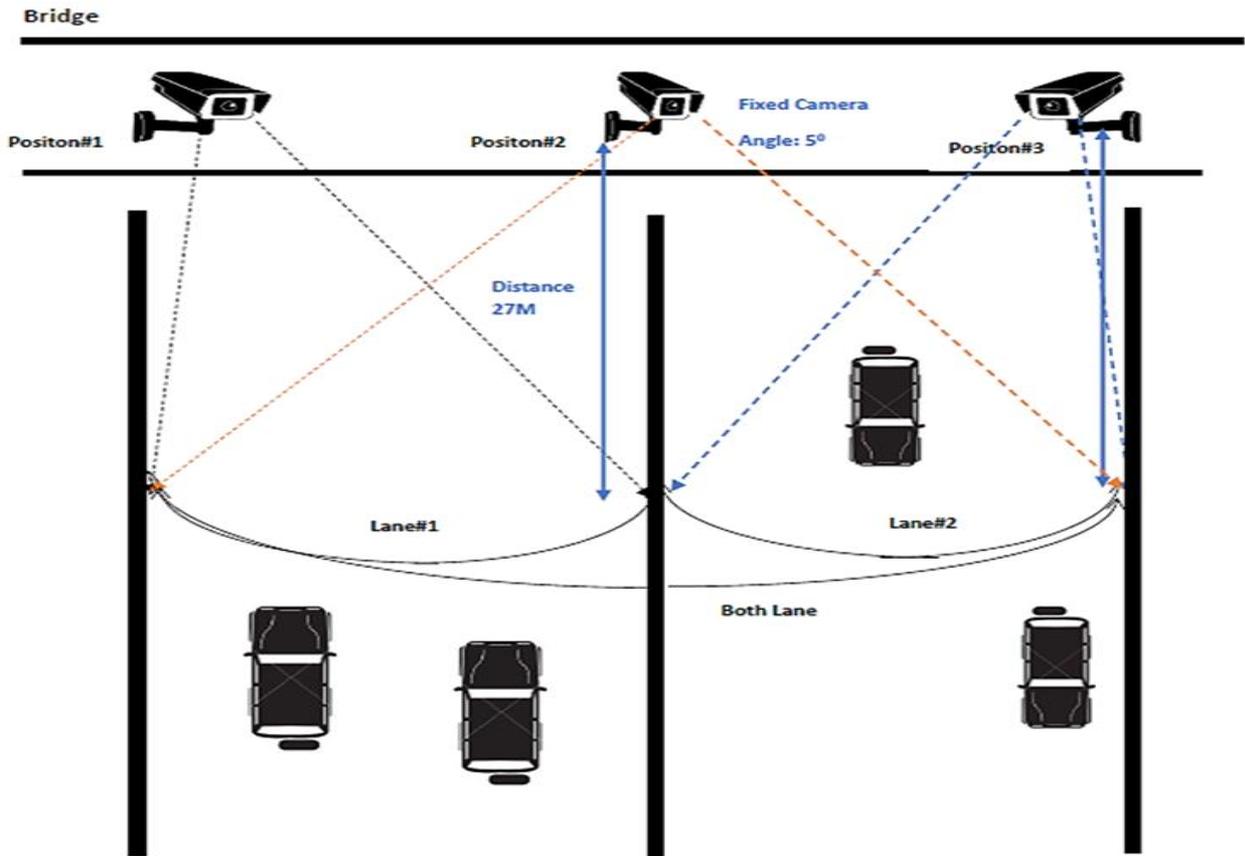
**Fig. 4:** Experimental setup to record on road highway traffic from bridge
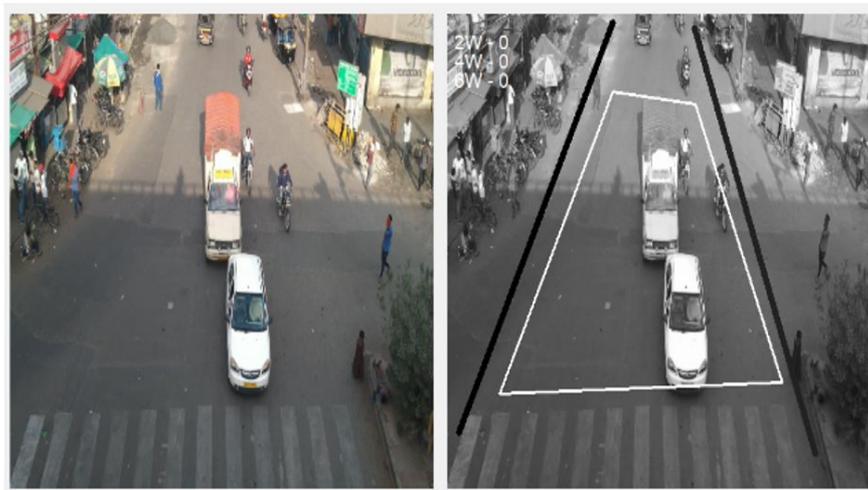
Fig. 5: On road traffic video footage. (a) Top view of road (frame of video) (b) Camera cali-brated video frame
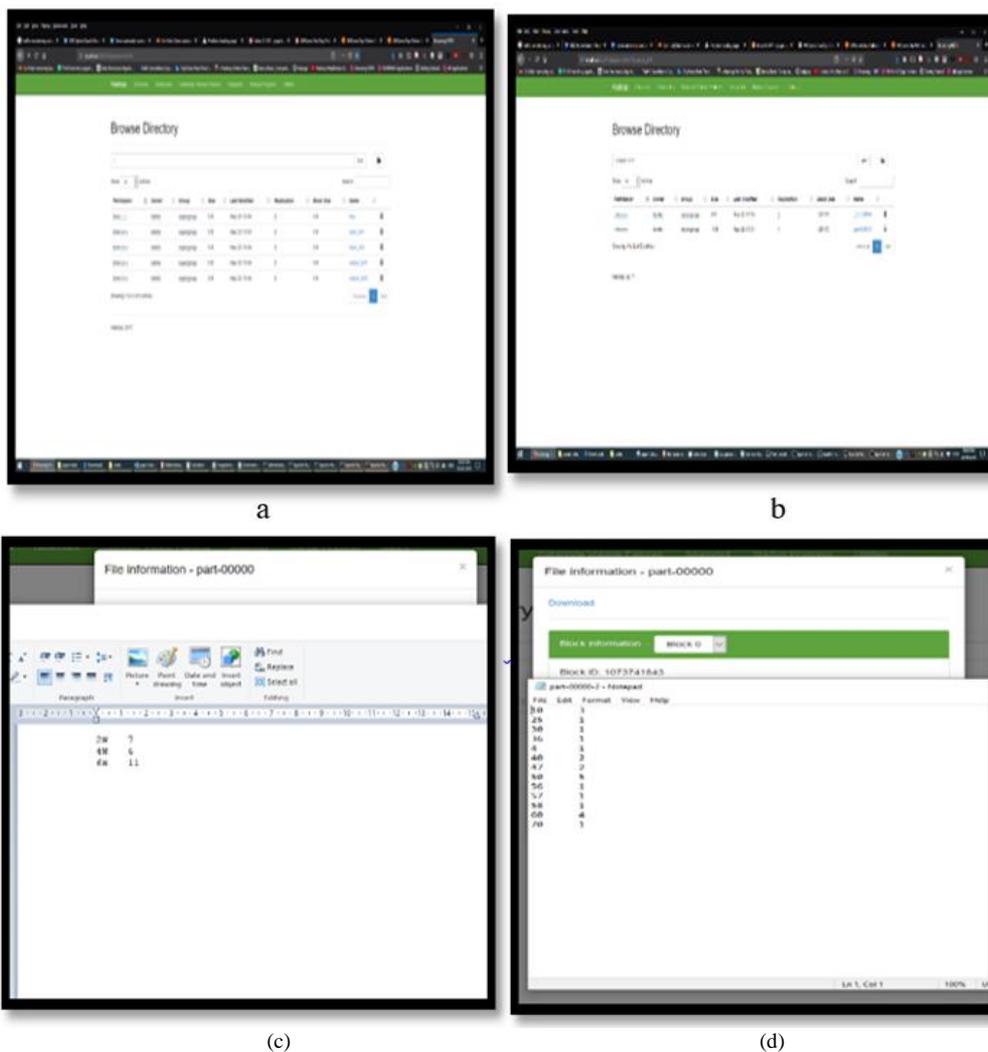

Fig. 6: (a) Directory structure of HDFS. (b) Job processed output in HDFS. (c) Computation of type of vehicle and (d) Computation of Speed of vehicle
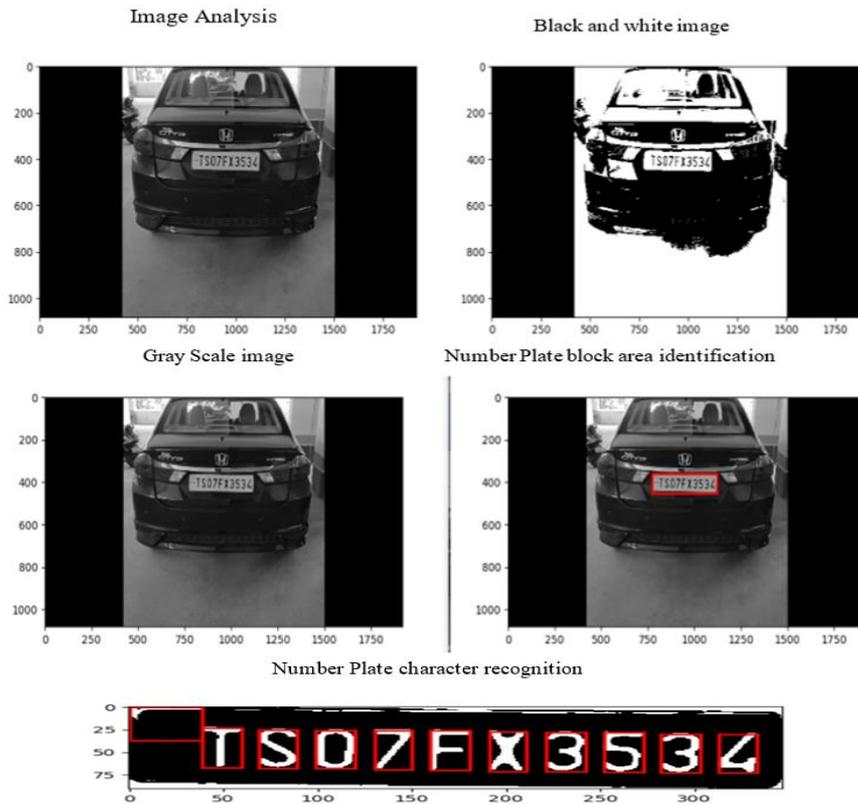
Fig. 7: Number plate detection and character classification


(a)

(b)
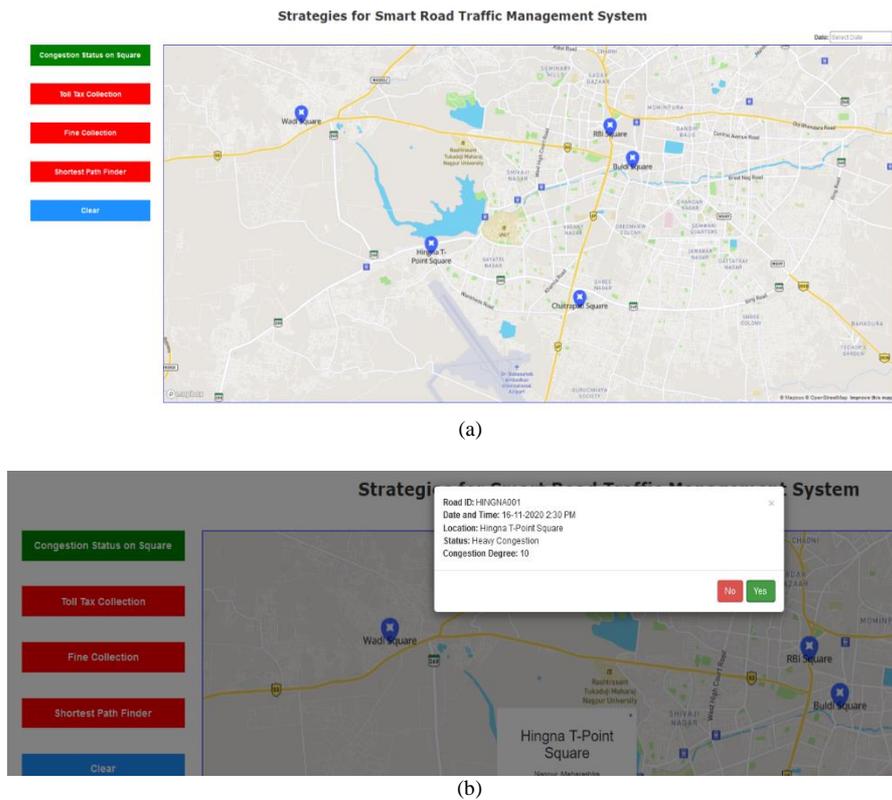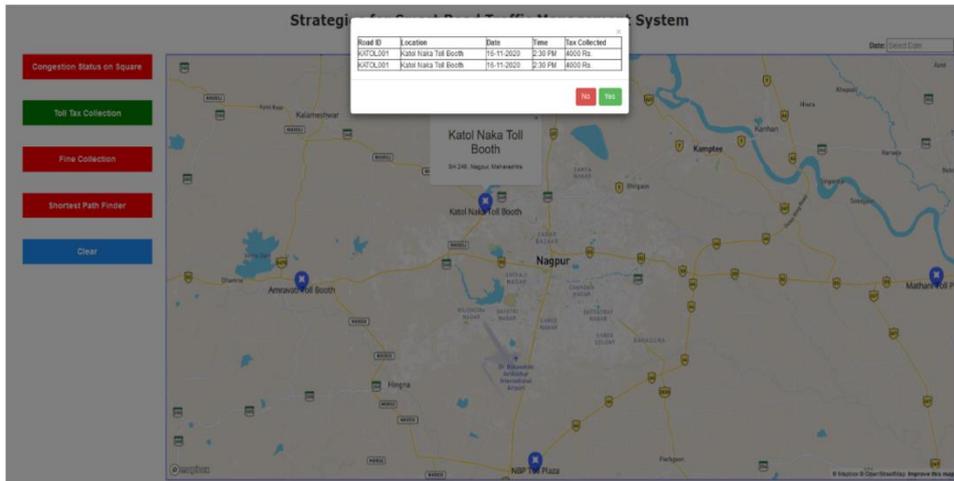
(c)
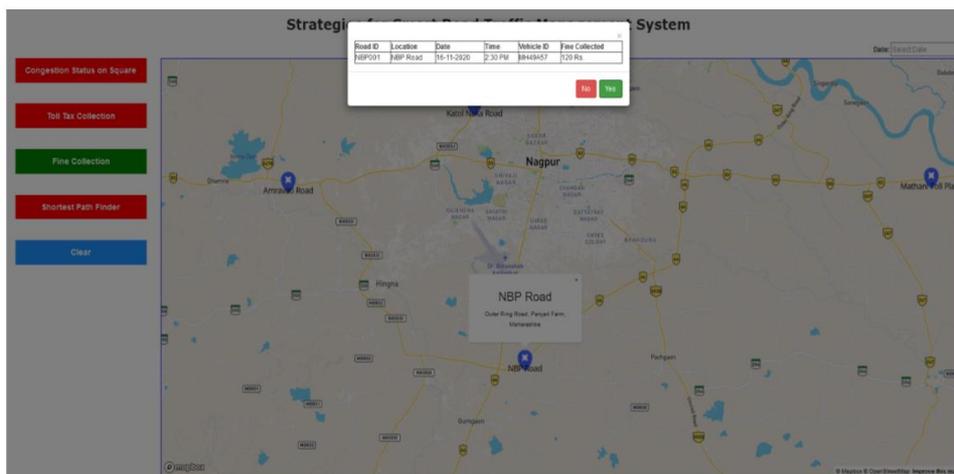
(d)
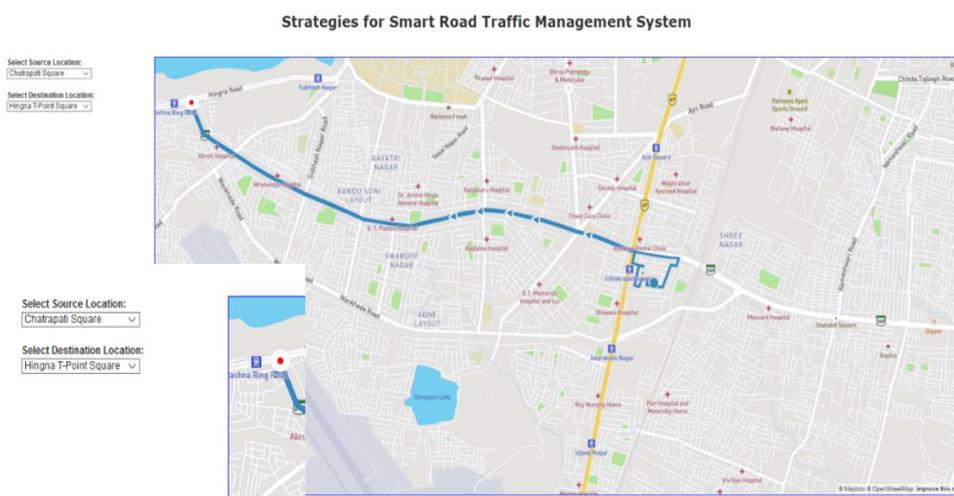
(e)

Fig. 8: (a) Dashboard of Traffic Management System. (b) Congestion status using congestion degree. (c) Toll booth toll tax collection status. (d) Fine collection system on square and (e) Shortest path navigator for drivers

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Table 5: Database information of proposed architecture

Sr. No.	Location	Traffic Scenario	#Samples	#Duration	#Attributes
1	Buldi Square, Nagpur	On Road	10k videos (30 f/s)	6 hr	Traffic information extracted from videos is as follows:
1.			Vehicle Speed,		
2.			Vehicle category,		
3.			Congestion status,		
4.			Congestion type,		
5.			Traffic state for each frame		
6.			Geospatial location, time stamp log.		
		Other data	10k traffic event logs		
2	RBI Square, Nagpur	On Road	10k videos (30 f/s)	6 hr	
		Other data	10k traffic event logs		
3	Mihan Square, Nagpur	On Road	10k videos (30 f/s)	6 hr	
		Other data	10k traffic event logs		
4	Chatrapati Square, Nagpur	On Road	10k videos (30 f/s)	6 hr	
		Other data	10k traffic event logs		
5	Hingna T-point, Nagpur	On Road	10k videos (30 f/s)	6 hr	
		Other data	10k traffic event logs		
6	Wadi Square, Nagpur	On Road	10k videos (30 f/s)	6 hr	
		Other data	10k traffic event logs		

Table 6: Comparative analysis of proposed traffic management system with the state-of-the art approaches.

Sr. No.	Name of author	Algorithms/Methodology	Dataset	Time complexity
1	Cárdenas-Benítez et al. (2016)	1. Traffic event detection algorithm,	SUMO event logs	20 sec
2	Gupta et al. (2013)	2. Route monitoring algorithm. 1. Identification of on-road clusters algorithm 2. Binary traffic output algorithm	GPS enabled devices data	19 sec
3	Ganesh and Appavu (2015)	Intelligent Video Systems (IVS) in big data	Video data	15 sec
4	Adoni et al. 2017	Traffic event detection using map reduce	Apache flume	25 sec
5	Proposed approach	Traffic event detection algorithm	Video data real time data	10 sec

Conclusions and Future Work

In this study we proposed the framework traffic event detection system for Indian traffic control system. We have proposed four different strategies as (1) congestion status on square, (2) efficient toll tax collection, (3) fine collection on road for the people who violate road traffic rules, (4) shortest pathfinder for drivers. This research work mainly focuses on the various strategies and their implementation with the help of the Map-Reduce framework for efficient traffic management in urban cities of India. The proposed system used Hadoop distributed platform and the Mapper Reducer function for the implementation. It will help in managing big data efficiently. Experiment results shows that the time required is less compare to the existing system and the proposed strategies are needed for the current state-o-the art traffic management system. In future, it be extended by adding other strategies such as adaptive traffic signal management, mobile computing platform for ease of user and traffic management authority.

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Author's Contributions

Mr. Yogesh Golhar: Contributed to define the research problem, formulation of methods, implementation and writing the paper.

Manali Kshirsagar: Assisted in the implementation of methods and conduct of the experiment. Also Contributed on the workflow design of the manuscript.

Ethics

This article is original and contains unpublished material. Both the corresponding author and the co-author confirm that

they have read and approved the manuscript and that no ethical issues are involved. The authors declare that they have no competing interests.

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