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ORIGINAL CONTRIBUTION

Development of Intelligent Transportation System and Its Applications for an Urban Corridor During COVID-19

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Abstract Transportation is a driving force behind economic development and well-being of all people around the world. An urban transport system is one of the most critical infrastructures for urban development. Impacts of a poor urban transport are manifested in terms of congestion, delays, pollution, accidents, high-energy consumption, low productivity of resources, community severances and inadequate access to the service. In urban areas, despite the construction of flyovers and roads, the roads continue to face traffic congestion, environmental pollution and lack of mass transportation facility resulting in heavy shift of commuters to intermediate and private vehicle ownership. Therefore, it is necessary to make transport system attractive and user friendly in terms of safety, reliability, travel time and comfort, which can be achieved using intelligent transportation system (ITS). This study has been intended to develop a methodology for development and operation of intelligent transportation system namely Presto ITS mobile application. The Android application, Presto ITS, developed works along with the Urban Traffic Data Management Centre to help reduce the congestion on the road networks by allowing the users to make informed decisions about route choices. This helps in reducing further inflow of vehicles in an already congested road network and thus allowing distribution of vehicles among the different routes resulting in lesser overall congestion. This system when installed on an overall city wide basis will drastically help in reducing the congestion and evenly distributed traffic.

Keywords Traffic congestion · Android · Road network · ITS · UTDMC

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Introduction

Mobile phone is a technology that is widespread in our present market scenario. Google Transit that provides web-based transit information system in India has several issues related to quality of information. It is based on historical data as well as number of cell phone users in the current vicinity which generally does not provide users with accurate information about the current traffic scenario. Application of IP (Internet Protocol)-based traffic cameras will not only remove the current dependency on users for providing the information about current traffic volume but will also help to identify the accurate scenario of the current state of traffic, incidents/accidents and roadway characteristics. Traffic cameras linked with the Android application will provide users with accurate transit information enabling them to make better transit route choice and mode of travel.

Internet provides a medium for transport agencies to share transport-related information with the users and market the same. In today's era, the Internet, as well as mobile applications, whether they are used or otherwise, has become indispensable. Presto ITS is useful for travellers at pre-trip stage for planning a trip and obtaining information about the traffic congestion and also assists with the en-route information requirements of travellers. It is expected that adequate information will make the transport system user friendly and will help in reducing congestion and its adverse effects.

Objective

This study has been intended to develop a methodology for development and operation of Intelligent Transportation System namely Presto ITS mobile application. The Android application, Presto ITS, developed works along with the Urban Traffic Data Management Centre (UTDMC) to help reduce the congestion on the road networks by allowing the users to make informed decisions about route choices. It provides an overview of various technologies that have been used in the development and also elaborates the algorithms implemented. Finally, mobile application developed in this study has been developed on Android platform to provide notifications in both audio and text format to address en-route congestion scenario. The proposed system used PhP, HTML5, CSS3 for creating the UTDMC site, MySQL for database, Android Studio and JAVA for mobile application and Google Maps to enhance the user-friendliness of the application, as expectations of users with regard to user interface are very high. PRESTO ITS will be useful for supporting the information needs of incidental users of road network and visitors to the city. Moreover, the proposed system can also be extended to other cities in India by suitably altering the back-end database.

Research Survey

An urban transport system is one of the most critical infrastructures for urban development. In last few decades, it is observed that urban transport faces several problems due to rapid urbanization and motorization [1]. Therefore, it is necessary to develop a sustainable transport system. The promotion of Intelligent Transportation System (ITS) is one of the measures to minimize inconvenience of congested roads and raising the level of service of the roads. Smart mobility, which is one of the key features of smart cities, attempt to provide innovative and sustainable transport, promote low environmental impact transport and improve mobility management through info-mobility [2]. Deployment of ITS technologies usually requires combination of sensors, communication technologies, computing infrastructure and algorithms.

Wootton and Garcia-Ortiz presented the global perspective on ITS and identified various thrust areas in each of these functional areas, while outlining the progress made in several countries, notably USA, Europe and Japan, in implementation of ITS [3]. Deakin in 2004 interviewed 51 leaders to identify issues in implementation of ITS [4]. Shah and Dal warn that the hasty adoption of ITS technology can be counterproductive and may not deliver the desired benefits. Growing demand for urban transport in recent years has however pushed developing countries in introducing ITS [5].

Gurjar in 2016 discussed the physical architecture to develop an Advanced Traveller Information System for I-95 Corridor in the USA [6]. Ioannou et al. presented a logical framework as a part of Decision Support System (DSS) that they have developed [7]. Zavattero and Wu presented a traveller information service of Gary–Chicago–Milwaukee (GCM) Corridor, USA with a focus on the integration and interoperation of the many Intelligent Transportation Systems (ITS) within this corridor [8].

Information provided by any regional ATIS to the traveller is based on factors and issues governing planning, building, deployment, operational and maintenance (PBDOM) and stakeholder (which also includes users of systems) requirements [9]. Components of ATIS are the information and control technologies (viz. software hardware and personnel) that provide core functionality of the ATIS [10]. Relevant traveller information has potential to change travel behaviour of the travellers about available travel options (time of travel, route to follow and mode of travel) in ways that are beneficial to the efficiency of the use of the transportation infrastructure and safety and mobility of travellers [11, 12]. Thus, ATIS assist the public transport (PT) users (1) by reducing their travel related stress, (2) by providing them satisfaction with the decision to take transit and (3) by providing greater control over time and travel decisions [13]. Adler and Blue in 1998 termed evolutionary systems as next generation ATIS [14]. Majumdar et al. emphasised role of coordination and collaboration for mobility management in the USA. The study observes existence of several rules and regulations aimed at mobility management besides the national advocacy groups promoting the cause and concludes that sharing of information and communication across the stakeholders is essential for successfully ensuring transport for all [15].

Kotzinos and Prastacos developed a web GIS-based system for disseminating real-time traffic information and implemented it for Athens and Chania cities in Greece [16]. Dziekan and Vermeulen in 2006 studied the psychological effects of real-time information displays. The study concluded that perceived wait time at stops was reduced by 20%, which may lead to an increase in ridership [17].

Narayanan and Prakash proposed an in-vehicle Intelligent Transportation System for the city of Chennai. Their proposed system provides drivers with information about congestion, alternate routes and provides network analysis functionalities for most direct path between two points [18].

Kumar et al. have developed a GIS-based advanced traveller information system for Delhi Metro Railway using ArcGIS 8.1 software (ESRI Inc.). This system provides detailed information about Delhi Metro Railway from origin to destination [19]. Yoganand in 2004 further extended the Kumar et al. work and proposed a Multi-Modal Traveller Information System with new functionalities like distance-based shortest path routing from Delhi Metro Stations to different locations, nearby feature search functions, fare information about taxis and buses and information (text and image based) about places of tourist interest [20].

Applications of Developed Intelligent Transportation System

The various applications of ITS developed in the study are as the following:

- Congestion Management: ITS plays a major role in reducing congestion in the traffic network. Traffic rerouting technique achieved through Presto ITS helps mitigate congestion by providing alternate uncongested routes for the incoming traffic.
- Travel Time Reduction: Travel time reduction is one of the major reasons to develop ITS. Travel time reduction can be achieved by rerouting traffic through uncongested routes and efficient traffic network management.
- Minimizing Fuel Consumption and Reduce Environmental Adverse Effects: ITS deployment induces traffic efficiency and fluidity to grow and reduces fuel consumption, thus resulting in reductions in CO2 emission and other air-borne pollutants such as small particles.
- Safety: Improved traffic efficiency and reduced congestion using ITS also enable transportation managers to respond promptly to traffic incidents. Emergencies can be avoided by alerting users to potential hazards, which in turn further reduces congestion and pre-empts accidents.

Flow Diagram

The flow diagram shown in Fig. 1 describes the work flow path of the adopted system beginning from capturing live traffic video feed to sending notification to the users of the developed PRESTO ITS mobile application.

1. IP traffic cameras are set up at locations at a specific angle along the road network so that it can record real-time traffic videos in specific format for STA (Smart Traffic Analyzer) to analyse.
2. The video feed captured by the IP camera is sent to the UTDMC server where it is analysed by the STA software.
3. Output of the STA, which is a text file containing traffic volume counts and travel speed, is stored in server database, designed using SQL and updated regularly at fixed intervals of time.
4. Traffic data are fed to the admin panel from the data server which acts as the base of operations.
5. Admin panel analyses the data from the database and sends audio and text notification to the users of the Presto ITS mobile app, when the traffic volume crosses the threshold value.

Development of UTDMC and Presto ITS

The Android app Presto ITS was designed using Android Studio and JAVA 8. The target for this app was Oreo (SDK VERSION 26) and will support till Ice Cream Sandwich (SDK VERSION 14).

UTDMC is deployed on Apache server version 2.4.18. The UTDMC was developed using HTML5, CSS 3, jQuery 3.3.1 and Bootstrap 3.3.7 on the front end and Php 7.0 on the server side. It further requires deployment of database for storing the traffic data which was developed using MYSQL 5.7.22. Also, STA (Smart Traffic Analyzer) version 15.0.0 needs to be running on a server to work on a real-time basis. These applications are also deployed on the same server, though they can be deployed on separate servers to distribute computing load across multiple servers. The website was tested in Microsoft Internet Explorer 11, Google Chrome (Version 69.0) and Mozilla Firefox (Version 4.42). It may however be noted that the UTDMC requires a client browser of Internet Explorer 7.0 or higher, Mozilla Firefox 2.0 or higher, or Safari version 3.0 or higher. The website also worked satisfactorily on screens of different sizes and resolutions. UTDMC enables the admin of Traffic Management Centres to analyse the data and set appropriate values for better determining the level of congestion on the road.

STA or Smart Traffic Analyzer is a professional project that is used for the management of Traffic. This software facilitates incident detection, data collection and planning with the help of artificial vision, i.e. artificial intelligence and video processing. STA has been tested on various different circumstances that allow the software a large

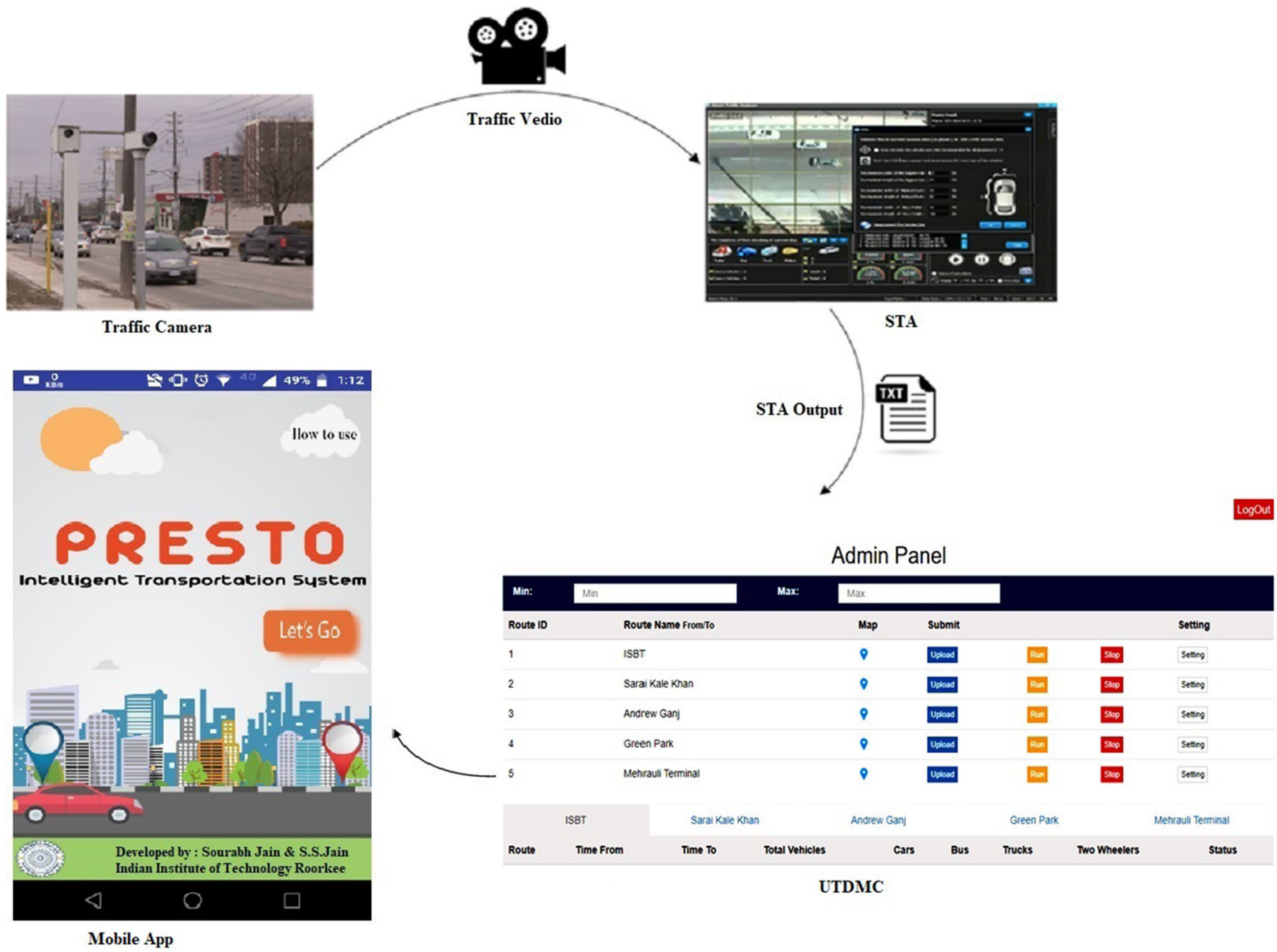


Fig. 1 Intelligent transporation system flow diagram

degree of flexibility as well as accuracy. STA can be used to analyse both real-time as well as pre-recorded videos.

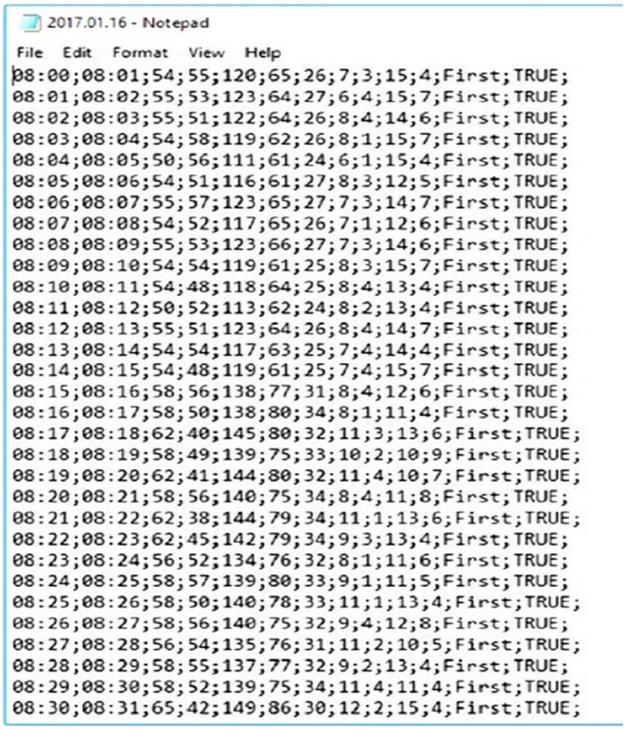
In this study, the software is run on a local server to analyse the real-time feed from an IP camera set at the study section, recording and transmitting the video feed of the study section. The sample output is from STA is shown in Fig. 2.

Application of UTDMC

UTDMC or Urban Traffic Data Management Centre is the Control Operation Hub that helps in management of traffic. In this study, the UTDMC is created as an information dissemination system that helps in reduction of congestion along the urban traffic corridor by providing the travellers information about present traffic scenario discouraging further influx of vehicles in already saturated roadway networks. UTDMC analyses the traffic data imported and stored in the database based on roadway characteristics to determine the level of congestion in roadway network and transmits the necessary information to the concerned users and indirectly reducing congestion.

The user interface of the UTDMC is a website as shown in Fig. 3 that allows easier management and analysis of the data. After successfully logging onto the UTDMC, the Admin panel which is the control centre of the UTDMC operation is loaded. The Admin panel is shown in Fig. 4.

In this study, five nodes where the cameras were set up are considered and the UTDMC is built for these locations, which are shown in the Admin panel. The page has various options to control the operations that are going to be hosted by the UTDMC. The option that is included in the UTDMC is like setting up the minimum and maximum traffic in 1 min on the network. It also has the option to set up the threshold value which is used to determine the lower-limit of total number of vehicles for a congested roadway. This value changes for different roads depending on roadway characteristics and requirements. For the UTDMC to work as intended, it needs data to be fed into the database. These data are the one that is acquired from the STA software after analysing the traffic.



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2017.01.16 - Notepad
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08:01;08:02;55;53;123;64;27;6;4;15;7;First;TRUE;
08:02;08:03;55;51;122;64;26;8;4;14;6;First;TRUE;
08:03;08:04;54;58;119;62;26;8;1;15;7;First;TRUE;
08:04;08:05;50;56;111;61;24;6;1;15;4;First;TRUE;
08:05;08:06;54;51;116;61;27;8;3;12;5;First;TRUE;
08:06;08:07;55;57;123;65;27;7;3;14;7;First;TRUE;
08:07;08:08;54;52;117;65;26;7;1;12;6;First;TRUE;
08:08;08:09;55;53;123;66;27;7;3;14;6;First;TRUE;
08:09;08:10;54;54;119;61;25;8;3;15;7;First;TRUE;
08:10;08:11;54;48;118;64;25;8;4;13;4;First;TRUE;
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08:21;08:22;62;38;144;79;34;11;1;13;6;First;TRUE;
08:22;08:23;62;45;142;79;34;9;3;13;4;First;TRUE;
08:23;08:24;56;52;134;76;32;8;1;11;6;First;TRUE;
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08:26;08:27;58;56;140;75;32;9;4;12;8;First;TRUE;
08:27;08:28;56;54;135;76;31;11;2;10;5;First;TRUE;
08:28;08:29;58;55;137;77;32;9;2;13;4;First;TRUE;
08:29;08:30;58;52;139;75;34;11;4;11;4;First;TRUE;
08:30;08:31;65;42;149;86;30;12;2;15;4;First;TRUE;
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Fig. 2 Output of STA

There are two ways for working with the data, i.e. real-time data analysis or historic data analysis. Real-time data analysis can be achieved by using a script to upload the .txt file generated at regular intervals for continuous operation if on a local server, or if the STA is running on a live server, the data can be directly sent to the UTDMC from the software itself. Running on a live server should be the preferred option as it allows the time difference or ping to be negligible, but in this study, we deal with local server which provides a bit higher ping and response time. UTDMC can also work with historic data in case of technical difficulties of various services going offline like losing connection to the camera due to damage or unavailability of Internet services.

In this scenario, the historic data from the STA can be uploaded to the UTDMC to continue operations until the services are fixed. This feature is only to enable continuous operation of the UTDMC and is to be used only as a contingency plan as the errors produced will be relatively high.

After setting up the values for minimum and maximum values for traffic, threshold values and providing the database with the live traffic data, the operation can be started. To start the operation, the “Run” button is clicked to kick start the operation. The output view on ongoing analysis is shown in Fig. 5.

For the full utilization of the UTDMC, the analysis can be done for all of the five nodes simultaneously. In future, the more nodes can also be added to the server to promote further expansion and utilization of the resources provided by the UTDMC. The results of the various ongoing operations can be checked by clicking on the tabs of the corresponding nodes. When the total volume of traffic goes above the threshold value, the node is considered to be congested for that particular time.

For this test, “Sarai Kale Khan” is chosen to be the test node which means the test is performed with the camera being set up at “Sarai Kale Khan”. The minimum and maximum value for traffic in 1 min have been set to 0 and 200, respectively. The threshold value is set to “110” corresponding to the “Sarai Kale Khan” field. The threshold value is determined after intricate analysis of the roadway features and characteristics. After the uploading of the traffic data to the “Sarai Kale Khan” field, the “Run” button is clicked to start the operation of UTDMC. The operation is started at “15:00”. When the total vehicles exceed “110”, it shows the road network as

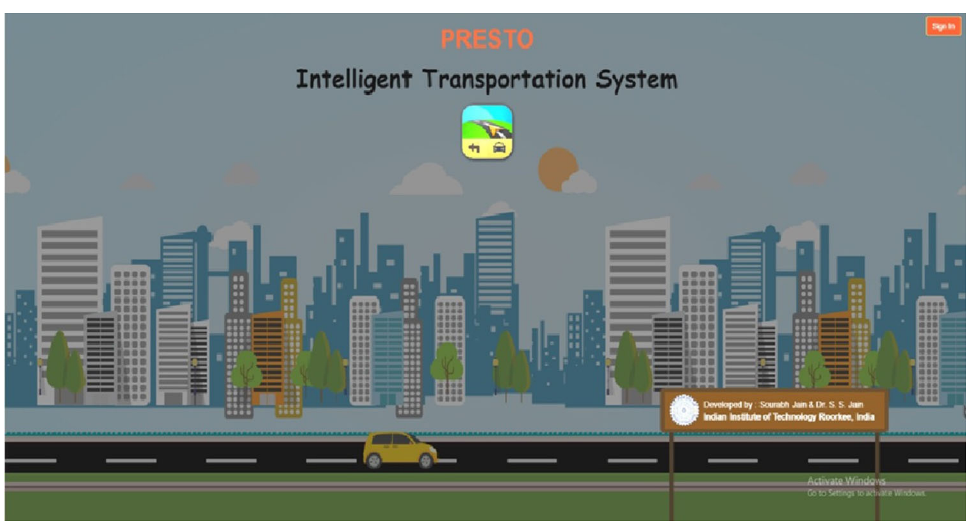

Fig. 3 Welcome page of UTDMC

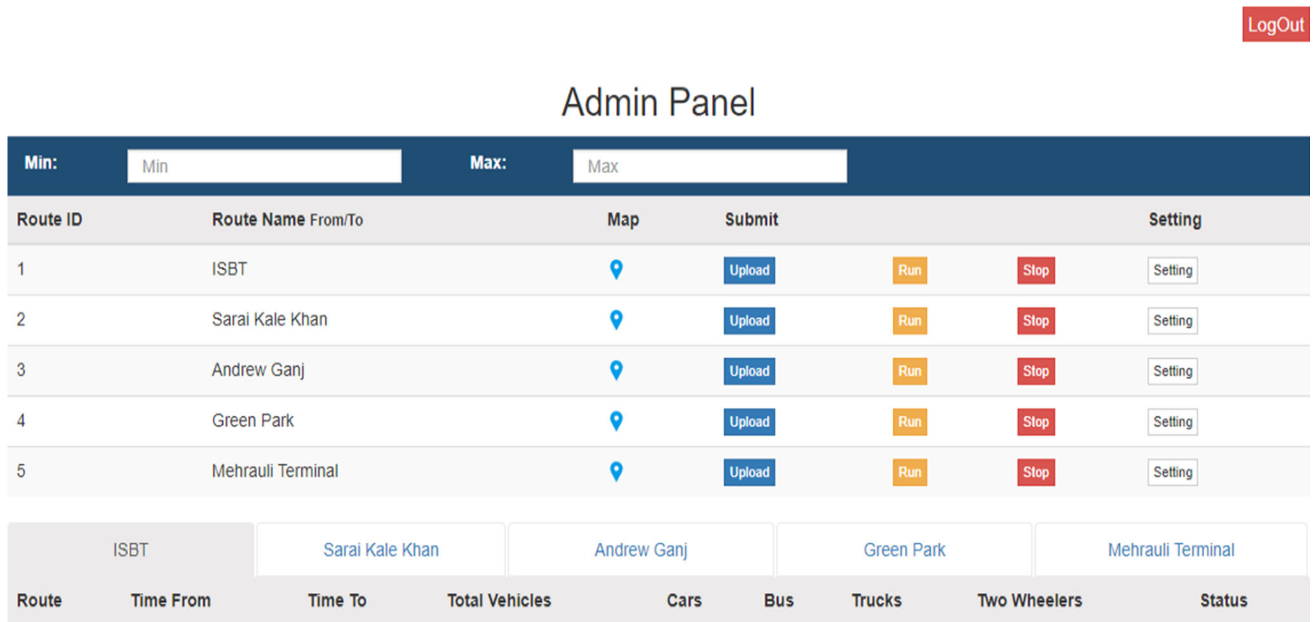

Fig. 4 Admin panel of UTDMC

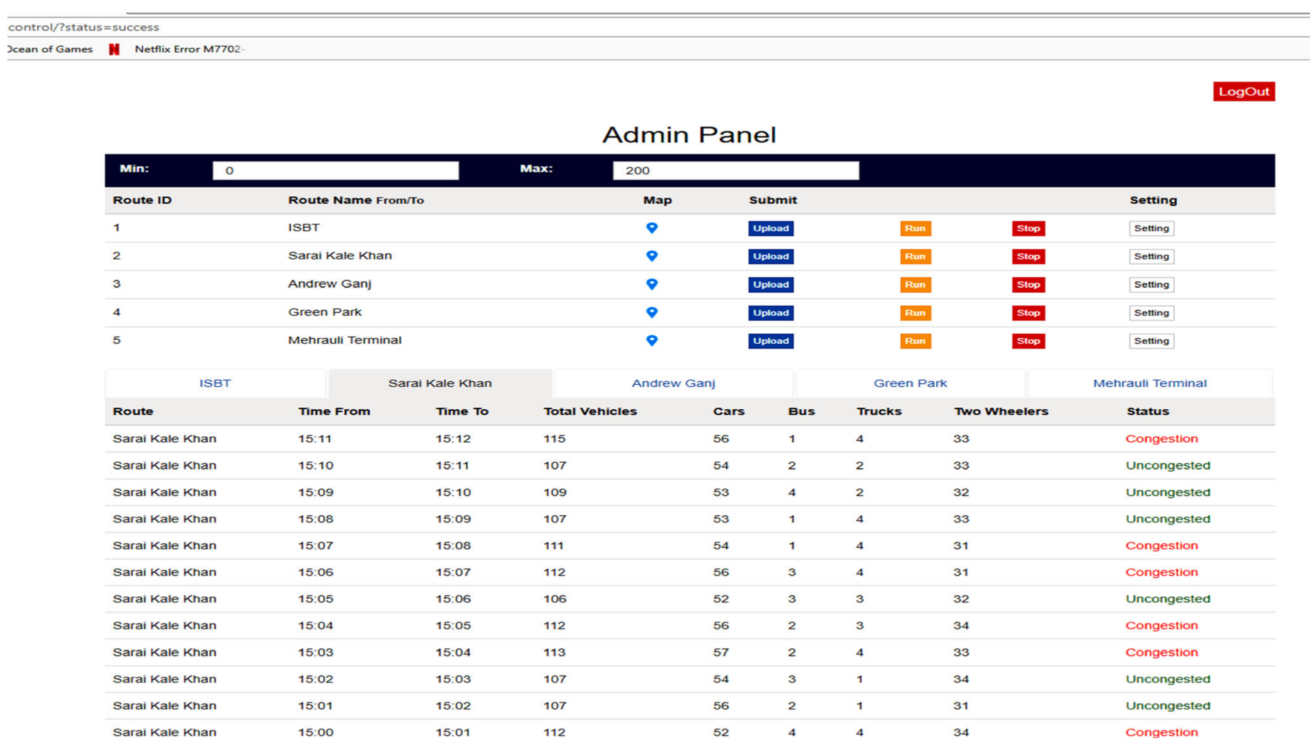

Fig. 5 Ongoing analysis view of admin panel

"Congested" in "Status" column, otherwise, "Uncongested" is displayed.

Mobile application has been developed to deliver the traffic information requirements to the users. Application requires permission to access precise location (GPS and network based). Internet connection is required to operate the application.

Working of Presto ITS

Presto ITS, the ITS system developed as a part of the research study, works as a rerouting agent that shifts the traffic from congested segments to uncongested road network to reduce the travel time and mitigate the congestion. The cameras mounted at the congested road section continuously transmit the traffic data to UTDMC. In UTDMC, the data are analysed by considering various factors. If congestion is detected, all the alternate routes possibilities are analysed based on the historical traffic data available for those routes. After analysing all the alternate routes, the route with minimum congestion and travel time is chosen as the best possible alternate. Then, notifications are sent to the users of developed mobile application to suggest the chosen alternate uncongested route.

Role of Developed ITS During COVID-19

The COVID-19 pandemic has been an enormous global disruption with immense economic, environmental and social impacts throughout the world. It is clear that people around the world are experiencing significant suffering as a result of the pandemic. However, Intelligent Transportation System has a role in mitigating the negative effects of the current pandemic and future disruptive events. A novel aspect of the COVID-19 pandemic has been the speed of its global spread. A high percentage of infected people was asymptomatic, which led to high transmission rates and a resulting exponential growth in many cases. In current situation, passenger and freight transportation are primarily a derived demand. That is, the demand for movement is directly related to participation in other economic activities (e.g. work, shopping). The COVID-19 pandemic has demonstrated this fact on a global scale. Because of individual choices, public health appeals and stay-at-home regulatory requirements, travel volumes severely declined throughout the world as individuals practised social distancing to avoid infection. The pandemic has demonstrated the importance of understanding the connection between the transportation system and its users. The developed Intelligent Transportation System plays an important role during COVID-19. For example, in Fig. 6, the app user wants to move from source A to destination B, but there are many quarantine hot spots are detected on the route ahead (marked in BLUE). The camera transmits the video footage of the infected segment to the UTDMC, which in turn analyses the feed and sends notification to the user, suggesting the alternate route which is generally safe based on the analysis of historical data available. Thus, the user reaches his destination in shortest amount of time by following the safe route having less or no quarantine hot spots in between (marked in RED), avoiding all other infected areas.

Evaluation of Presto ITS

Presto ITS is an ITS implementation that provides the users with real-time traffic information. So for this system to work as advertised, the time between the capturing of video to the receiving of the notification should be minimum. It is physically impossible with the present available technology to provide the user with instantaneous traffic information. The causes of lag can be due to low Internet bandwidth or higher ping for the camera, slower server configuration, technical difficulties or even unavailability of proper Internet to the users. For Presto ITS to be considered as a real-time application of ITS, it is of utmost importance to determine the delay time of the entire process.

It is to be noted that the test carried out always works with 1 min delay which is constant. This is due to the fact that STA analyses the data for a minute then provides the output. This delay cannot be mitigated with the present setup as it is the shortest duration allowed by STA to produce a result. The remaining delays are not constant and vary depending on the Internet connection, feed lag, hardware incapabilities, server response time and time to process. These delays can be minimized but cannot be totally eradicated. In other words, there is bound to be some amount delay and Presto ITS cannot work on instantaneous real-time basis because of the limitations of currently available technologies. However, some of these delays can be reduced like, feed delay can be minimized using better Internet connection for the camera, and same goes with data upload time to server and data receive time for mobile devices.

The delay for STA to provide output can also be reduced by using better configuration of the server used to calculate the results. Also, every time STA is started, it takes about a minute to analyse the video to figure out the road configuration and start giving results depending on this analysis. This delay can be reduced by increasing the hardware specifications of the server. This delay along with the 1 min delay talked about before is a one-time delay on server start and does not cumulate or affect the working of the application in any way except a slower start to the system. To determine the delay, many tests were conducted to test the lag time on all the five nodes at various timings of the day.

The tests were conducted for peak and non-peak hours during morning and evening phases. The tests were carried out over a period of 5 days, each day dedicated to one of

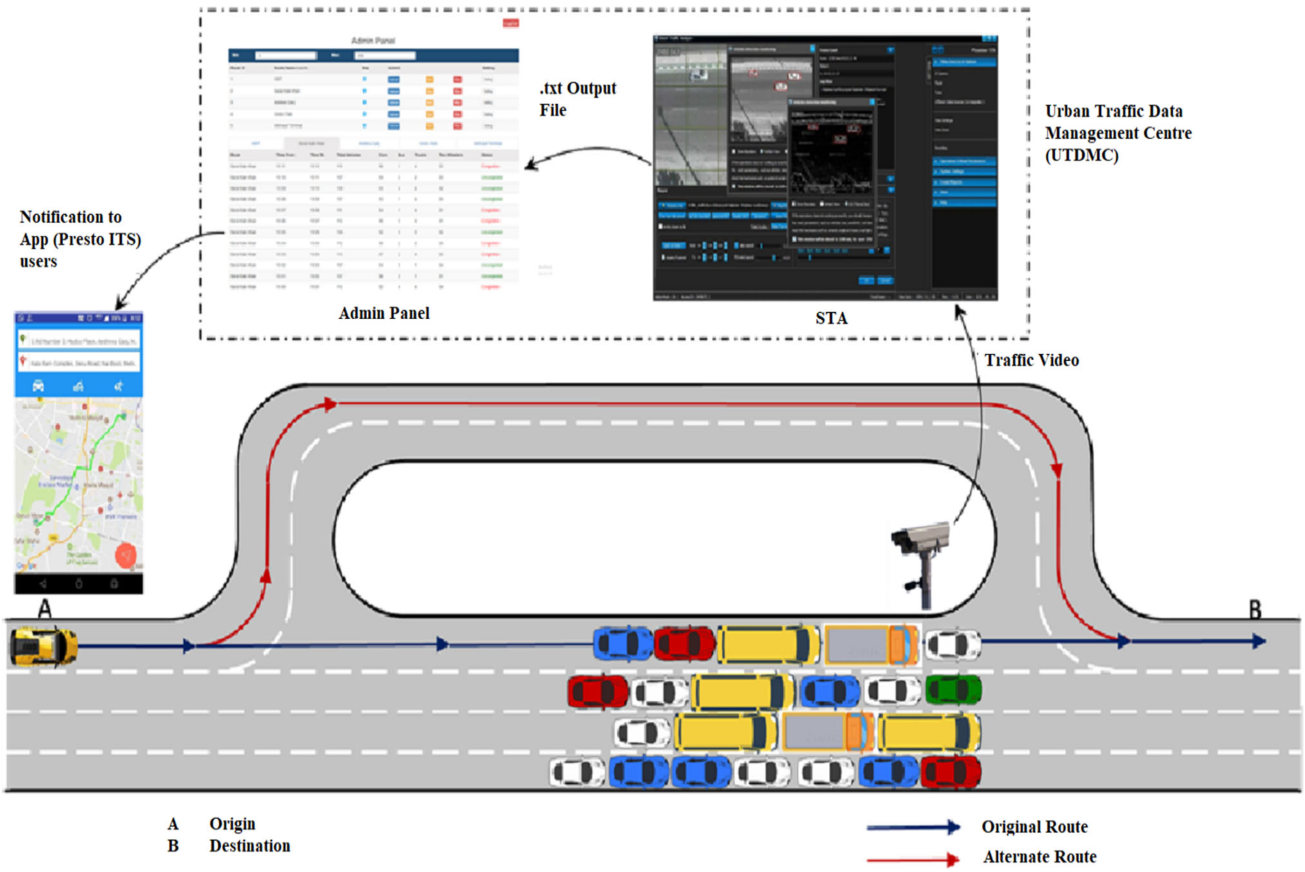

Fig. 6 Working of Presto ITS

the nodes. The timing of tests is listed in Table 1. In these tests, however, the camera was directly connected to the local server which is a laptop due to unavailability of proper Internet connection, so the delay for receiving the video feed is eliminated. But there will be delay in video feed receiving time if the camera is connected to the Internet.

The tests were conducted for a period of 2 h during morning and evening peak and non-peak hours for all the 5 nodes. During these tests, the server was restarted at every 15 min interval giving eight different test runs during each shift. The server was restarted to test the server starting times. Completing these tests gave 32 test samples for each nodes to test the performance of Presto ITS at various levels of congestion. The tests concluded that the delay times were independent of the location and time of study or congestion. Delay times were dependent only on the availability and strength of Internet connection and configuration of the server. The test results were recorded and converted into a form of charts as shown in Figs. 7 and 8. Figure 7 shows the delay in server start time, whereas Fig. 8 shows the delay time to receive notification on the mobile device.

Table 1 Testing times

Slot ID	Traffic type	Start	End
1	Morning peak	8:00 AM	10:00 AM
2	Morning non-peak	11:00 AM	1:00 PM
3	Evening peak	5:00 PM	7:00 PM
4	Evening non-peak	10:00 PM	12:00 PM

From the tests, it is found that average time taken from the server to start is 114.7 s and minimum and maximum values being 111 and 118 s, respectively.

Also, it can found that delay time for receiving notifications being 19 s, while minimum and maximum being 14 and 23 s, respectively. The total average lag time was found out to be 133.7 s. These tests reveal that the speculations of the system being independent of location, time and congestion characteristics. The lesser variations in server starting time indicate that it is mostly dependent on the performance of the local server as the performance of the hardware is somewhat consistent as seen in Fig. 7. As stated before, this lag can be reduced by increasing the specifications of the server running STA. But it can be seen in Fig. 8 that the delay time for receiving notification is

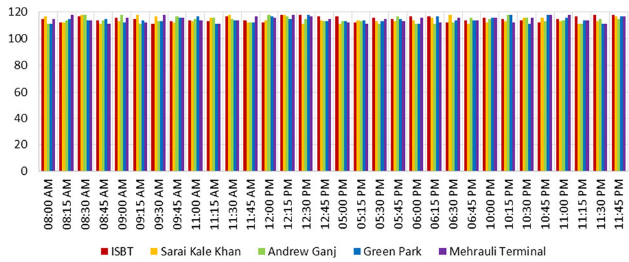

Fig. 7 Server starting time (in seconds)

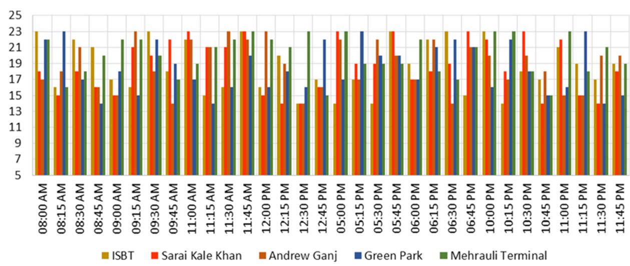

Fig. 8 Delay time for receiving notifications (in seconds)

small but varies to a great extent. This is due to the factor that Internet connection tends to be highly unstable and does not provide consistency. This is also due to the fact that the test performed used mobile Internet connection which is more unreliable than other stable networks like LAN, optic fibre, etc. Thus, to reduce this delay time to some extent, optic fibre may be used to provide reliable connection at the admin's end at least.

Conclusions

The study demonstrated various features and capabilities of the UTDMC and Presto ITS mobile application working in unison in reducing congestion. The detailed working procedure of the UTDMC as well as the Presto ITS application is discussed in this study. In order to evaluate the mobile application, tests were conducted on the study nodes at morning and evening peak and non-peak hours.

The tests concluded that the delay was independent of location or congestion and only depended upon Internet connection and server computational specifications. The total average delay was found out to 133.7 s, which can be reduced by providing better tools.

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