J Ambient Intell Human Comput
DOI 10.1007/s12652-017-0453-0

ORIGINAL RESEARCH

A new traffic route analyzer for commuter's guidance in developing countries: application study in Islamabad, Pakistan

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Received: 10 August 2016 / Accepted: 20 November 2016

Abstract Growth of population in the capital city of Pakistan—Islamabad—is too high. This growth rate has caused a negative impact on the smooth flow of traffic system. The aim of this paper is to provide a solution to facilitate the car-based commuters to pick the route with minimal bottlenecks and to minimize the distance to reach the destination. The proposed solution is to manage and control the traffic system in the city of Islamabad. The current traffic data collection system in Islamabad and other urban areas does not provide timely and reliable data that can be useful to the Regional Transportation Authority for planning activities. To overcome this problem, our approach is based on collecting the missing data using a custom-built mobile app. Our system analyses and manipulates the collected information based on artificial neural network scheme that can indicate the bottlenecks for each route and predicts the shortest route based on the user's severity levels. To validate our proposed approach, we tested six different randomly selected routes in Islamabad with different bottlenecks.

Keywords Evolutionary algorithm · Neural network · Nodes · Routes · Traffic flow · Telemetry

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1 Introduction

Rapid growth of population in Pakistan in general, and particularly in Islamabad capital area is too high. This growth rate has caused a negative impact on the smooth flow of traffic system. Frequent unplanned and unwanted changes in the road infrastructure created hindrances in the smooth flow of traffic system. The current traffic data collection system in Islamabad and other urban areas does not provide timely, reliable data that can be useful to the Regional Transportation Authority for planning activities. With anticipated future growth rate in Islamabad, and in general Pakistan need an efficient data collection system. This system should provide accurate, timely, reliable, and directly applicable data to make traffic operations and other planning activities more efficient. There are many solutions available for collecting, processing, reporting, and disseminating traffic data, however these solutions are either very expensive or required pre-requisites or resources to implement such services. Developing countries, which have various other priorities, cannot afford such solutions to implement and get optimal results. Data collection varies by the type of information collected, accessible formats, which

Published online: 11 February 2017

cannot synchronize with the real facts of the situation of the traffic flow in the specific region.

In traffic flow systems the usage of Google map tools provides the facility of route analysis to ease the driving conditions to commuters but cannot calculate the accurate time, however in most cases distance system does not respond the actual ground realities which ignore the behavioral issues. The proposed traffic route analyze system identifies the factors are taking into consideration for rush during driving including hindrance factors which are causing delay in the flow of smooth traffic system. In our system the collected data is on real basis, which provides more effective information as compare to using sampling techniques in making estimates on the driving conditions and effect of bottlenecks on the flow of traffic. On the basis of critical analysis the authors will use this technique for future planning for having new routes, avoid bottlenecks, removing bottlenecks for smoothing the flow of traffic (Syed et al. 2014; Saukh et al. 2014).

In this domain, driving conditions and as well effect of bottlenecks on the flow of traffic are estimated with mathematical models, or manually calculated in order to update data in the database. This database may be maintained and updated with daily, weekly, monthly real statistics. Further, if it is observed the traffic flow rate is beyond the national or international standards than it becomes mandatory to enforce actions and penalties to the node stations or the vehicle owners which make bottlenecks (Astarita et al. 2006). The verification of the current flow of data, and estimation of the future flow of traffic in light of considering possible hindrances is at the genesis of this paper. We propose a traffic route analysis system based on selected AI techniques. The main selected is ANN.

This paper is structured as followed. Section 2 gives details on the problem at the heart of this paper. Section 3 provides a short state-of-the-art on artificial techniques related to the stated problem. Section 4 describes our methodology for building and evaluation our traffic route analysis system. Section 5 describes the proposed model. Section 6 presents experimental results. Section 7 is the conclusion in which perspectives are also presented.

2 Problem statement

We have identified a problem related to the traffic system for Islamabad city related to congestion and route selection. In Pakistan it is very difficult to overcome the load of traffic due to driving conditions, bottlenecks and behavior of the drivers that create difficulty in improving the smooth flow of traffic system. Majority of roads in Pakistan especially in metropolitan cities are jammed because of bottleneck, which are not being faced in other metropolitan cities in the world. Drivers face two types of bottlenecks, one is permanent and other are temporary bottlenecks. The temporary bottlenecks are for short period which may also face by in other countries, such as weather, construction, public protest, but permanent bottlenecks which are schools, hospitals, markets, which are being built in residential areas and not following the urban planning rules and regulations. As an example, a road which have 3–4 schools in 2 km of span create large amount of rush due to these schools during morning and afternoon time. Similarly same conditions are being faced at the Hospitals, and huge congestions especially in the morning hours. Although these congestions due to such bottlenecks are for limited time period but create unhealthy environment which directly relate to the human behaviors and increase stress level prior to start of the day. We identify various bottlenecks which are the major cause in slowing the traffic flow and in result create difficulties for commuters to plan their visits especially in the peak hours (In Pakistan there are three peak hours in a day, which are morning, afternoon and evening, however in other countries mainly there are two peak hours morning and evening) the afternoon peak hour when school closing time. People avoid planning their visits during afternoon peak hours if it's necessary then they have to face real challenges to beat the traffic rush hours and look for alternative routes to reach their destination within time. The bottleneck problem is at the heart of the proposal in this paper. Our goal is to provide a model and a tool for is able to compute, predict and analyze the route choices from a real time data collection in order to minimize the traveling time (and not the traveling distance). We advocate our solutions may ease the driving conditions for drivers, and to reach their destination in time.

3 Literature review

In the following section a brief overview of artificial intelligence models and techniques is presented. The goal of this review is to analyze and understand different traffic flow systems, the possible hindrances and their weights; and the time travelling models in order to select the best approach for solving the problem described in Sect. 3.

3.1 Path computation elements (PCEs)

Path computation elements (PCE) requires an accurate and timely Traffic engineering database (TED). Traditionally this database is obtained from a link state (LS) routing protocol-supporting traffic engineering extensions. The TED contains all relevant information that a Path computation element (PCE) needs to perform its computations. It is important that the TED should be complete, accurate

each time when refreshed; further the PCE performs a path computation.

The current traffic data collection system Islamabad and other Urban areas does not provide timely, reliable data that can be useful to the Islamabad Regional Transportation Authority for planning activities. With anticipated future growth in the Islamabad and in general Pakistan need a data collection system that would provide accurate, timely, reliable, and directly applicable data to make traffic operations and planning activities more efficient (Lopez et al. 2010).

3.2 Telemetry process

The process of streaming real-time data by using telemetry involves defines streaming frequency e.g., flow of data after minutes, kilometer, etc. It specifies user-defined format for data collection and transmitting collected data to a user-specified receiver pool such as Traffic Engineering Database (TED). This tool helps how to view and analyze the data.

3.3 Streaming telemetry process

Streaming telemetry process provides a machine to select required traffic data from source, nodes, routes, and destination. The conveyed data to the remote running stations for monitoring the flow of traffic should be in a planned design. This mechanism enables automatic adjustment of the traffic based on real-time data. Collecting data for analyzing and bottlenecks has always been an important aspect in monitoring the working traffic control system in a network. If the flow of traffic has effected in a bad way than the streaming telemetry process will automatically provide protective troubleshooting tonic to help quickly to notice the cause of congestion the traffic and provide a speedy route analysis. This process will prevent the cause of failure states and provide an effective solution to solve the challenging solution in a lowest possible time.

3.4 Wireless sensor network (WSN)

WSN based traffic flow forecasting based on prediction algorithm. Fuzzy Risk Analysis Scheme is deployed in case of extending scenario, which is based on probability distribution scheme. Further, a mathematical model may play important role in solving traffic flow problem. In the past many people proposed mathematical models to solve simulator problems (Akvildiz et al. 2002; Chen et al. 2016).

3.5 Vehicular ad-hoc network (VANET)

VANET also known as vehicular ad-hoc network is an enhanced form of mobile ad-hoc network (MANET). It is a technology that uses moving cars as nodes that altogether builds up a mobile network. Every moving car is turned to a node and becomes a part of network. These cars are not only the nodes but they are also known wireless routers. The approximate distance between the moving cars should be between 100 and 300 m thus creating a wide range network. When one car goes out of the network range; the other car, which comes into the range becomes the part of network. Through the help of VANET the cars that are moving on highways and roads are informed about the road conditions, weather conditions or any other bottleneck or information necessary for the drivers driving those cars. This approach is not feasible in our Traffic Flow System in Islamabad environment.

3.6 Neural network

For the purpose of traffic flow interconnectivity it is essential to use a neural network to collect real time data on the basis of flow of the traffic and store data in Database. Several methods have been developed to use the current available data for suitable period to perform accurate long-term traffic load behavior. These methods are normally classified into two categories i.e., conventional approaches, and techniques based on artificial intelligence. Traffic forecasting approaches based on conventional methods forecast current value of a variable based on the mathematical combination of the previous values of that variables and current values of other variables. Traditionally Reversion models have been the most popular in traffic load to verify current data and also forecasting it. The data is used to model the relationship between the traffic load and outer factors such as time, weather. Further advantage is that the relationships between input and output variables are easy to understand. Artificial Neural Network (ANN) is working by using Mat lab simulation tool. In the following is figure (Fig. 1) to show Inputs, which may be nodes (routes), hidden layers which as weights.

Hint The hidden layer is used in processing stage in which the proposed neural network based algorithm is used in hidden layer. Different weights are used to tune the layer to achieve the required output. An alert for shortest travelled time i.e., the traffic flow output is smooth.

4 AI technique evaluation methodology

Our research is Evaluation of Proposed Traffic Route Analysis System in Islamabad using Artificial Intelligence approach to solve real time problem. From the beginning till the end numerical data will require building an Artificial Intelligence based model and simulate it

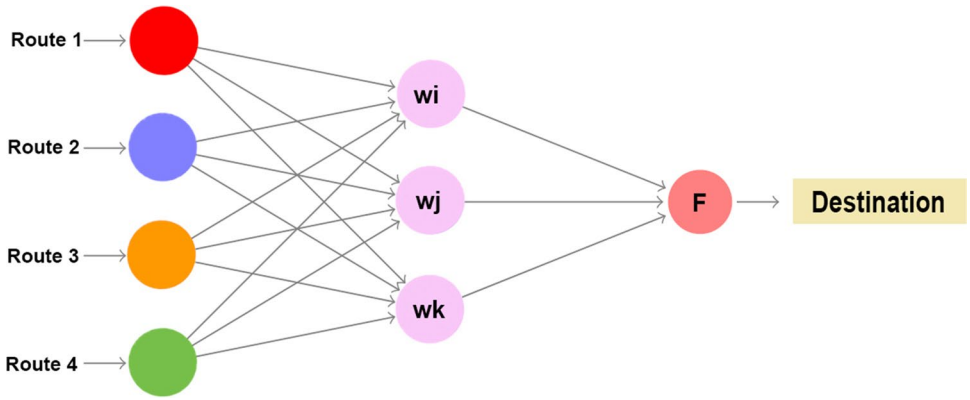

Fig. 1 Artificial neural network based scheme

by using 20% available data. Later, using rest of 80% data of the actual data will validate the results.

We pick start and end point and evaluate various possible routes by considering the bottlenecks on each route. Our purposed ANN technique calculate path of route system including their bottlenecks. Giordani et al. (2016) used a similar technique for emergency management. It calculates the wait at each bottleneck and distance from one bottleneck to other and summation of time consumed at each bottleneck for specific route, same will be calculated for all possible routes available for that starting point and destination. We analyses the real time scenario for calculating distance, time involved due to bottlenecks for each route. We select specific region from Islamabad city in which starting destination F11/3 Margalla Avenue and end destination Habib Bank Limited Tower Blue Area routes we define all possible bottlenecks on real basis implement in our system of Islamabad street view (Bar-Gera 2007).

4.1 Evaluation scenarios

In this section, five different scenarios are presented. They are used in the evaluation of our proposal in order in Sect. 7.

4.1.1 Route 1

Figure 2 shows the route along with the permanent bottlenecks, route 1 starting point from F11/3 Magalia Ave via 9th Ave to the destination at Habib Bank Limited (HBL) tower this route has two lane with sequence of bottlenecks, the first bottleneck starts from bottleneck (1) security barrier (HBa), bottleneck (2) traffic light (HTa), bottleneck (3) traffic (HTk), bottleneck (4) Barrier (HBb) after passing these bottlenecks driver faces two more bottlenecks named bottleneck (5) School (HSa) and bottleneck (6) School (HSb), if driver takes this route 1 during the morning (7:00–8:00 a.m.) and afternoon (1:00–2:00 p.m.) time then driver will face big delays due to the bottlenecks HSa and HSb, however in other timings driver won't face any delays and move within the imposed speed limit.

4.1.2 Route 2

Figure 3 The start and destination points are same for Route 2, however some bottlenecks are the same but few new bottlenecks on Route 2, and the details are: bottleneck (1) security barrier (HBa), bottleneck (2) traffic light (HTa), bottleneck (3) University (HU), bottleneck (4) Traffic light (HTb) bottleneck (5) school (HSa), and bottleneck (6) school (HSb). Under this route three

Fig. 2 Route 1 Margalla Ave via 9th Ave

Fig. 3 Route 2 Margalla Ave. +7th Ave

bottlenecks are critical which are (HU), HSa and HSb, again these bottlenecks create delays in certain times during the day, likewise for the Route 1. The data was gathered manually through this route at various times of the day, and it is observed that during 7:00–8:00 a.m., If one maintains the average speed of 55 km then average time is 17.42 min for a distance of 10.2 km.

4.1.3 Route 3

Figure 4 The start and destination points are same for Route3, however route Margalla Ave via Faisal Ave start the route for the destination of HBL tower and have two lane with bottleneck (1) Bottleneck barrier (HBa), Bottleneck (2) Traffic Light (HTa), Bottleneck (3) university (HU) then again Bottleneck (4) traffic (HTb), Bottleneck (5) traffic (HTc) after passing these bottlenecks driver can face intersecting point of Bottleneck (6) called bottleneck signal (HSa) passing these bottleneck user can reached to the destination. In this route 3 user average speed of 50 but now have 3 lane that increased the speed so the complete duration take 16 mint/10.2 km while having three lane.

4.1.4 Route 4

Figure 5 define The Start and Destination point for route 4 Margala Ave and destination HBL Tower This route can follow the service road E via Jinnah Ave with Average Speed of 50 km and bottlenecks are Bottleneck (1) traffic (HTi), Bottleneck (2) school (HS), Bottleneck (3) Traffic (HTj) and Bottleneck School (HSb), Bottleneck (4) Traffic (HTk), Bottleneck (5) Barrier (HBb) this route have three lane now user have possibility to increase the speed but facing interesting point bottleneck (6) Signal (HSa) and Bottleneck (7) school (HSb) create delay during crossing these bottlenecks to reach the destination.

4.1.5 Route 5

Figure 6 The start F11/3 Margalla Ave and destination HBL Tower using Service Road E via Kashmir Highway with Average Speed 50 km and facing Bottleneck (1) Traffic (HTi) increasing the speed due to less bottlenecks this route face Bottleneck (2) Traffic (HTL), now route smooth so user can easily move towards with 60 speed because now this route have Four lane that optimize the route while moving toward destination one more bottleneck are

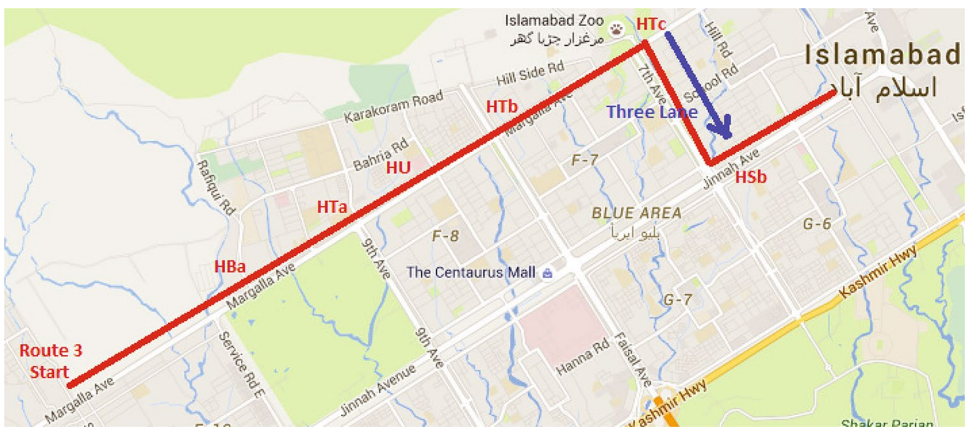

Fig. 4 Route 3 Margalla Ave via Faisal Ave

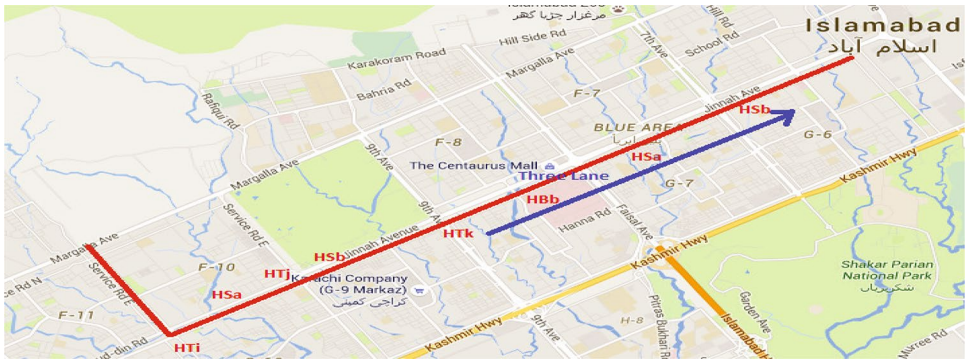

Fig. 5 Route 4 Service Road E via Jinnah Ave and Ibn-e-sina Road

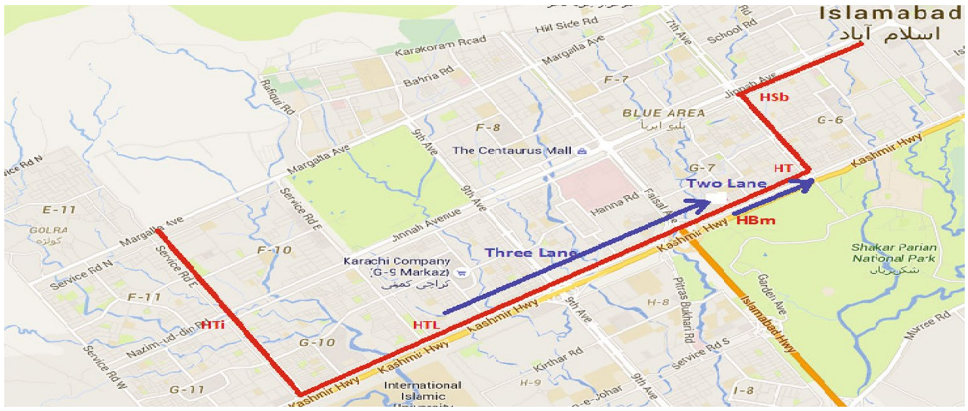

Fig. 6 Route5 (image) Service Road via Kashmir Hwy

Bottleneck (3) Barrier (HBm) and Bottleneck (4) traffic HT but between bottleneck HT and HTm have two lane and moving towards destination with one more Bottleneck (6) signal (HSb) now route 5 can reached to the destination to HBL Tower Blue Area.

5 Traffic route analysis system

We designed Traffic Route Analysis System based on Artificial Neural Network to optimize the shortest, less stressful, smooth driving conditions and reducing driving time for selected route. The proposed system will give the exact time duration spend while crossing the bottleneck at certain time in day this process continue for all bottlenecks faced during this specific route The system will analyze the duration of the journey for the selected route and gives the time spent on each bottleneck, the system can automatically calculate the distance for the route and stop while reached to the destination This system can maintain the record of bottlenecks with function of severity level, In Severity Level scaling factors are one to ten and their purpose is to maintain the condition of factors are:

- Factor (1): Weather Effect integrated with weather update,
- Factor (2): Construction Effect are temporary bottleneck,
- Factor (3): Commuter Behavior Effect when delay occurs due to bottlenecks,
- Factor (4): Lanes Effect Route have pre define lanes that indicate the Average Speed to reach the destination,
- Factor (5): Stress Effect can be evaluated through artificial intelligence.

Traffic route analysis system provides calculation for all routes available for certain journey with respect to bottlenecks their wait in term of time. In this Traffic Analysis System there is option to store the record in Traffic Database for all routes that provide facility for selection of options for each route and maintain the traffic database and checked option on arrival of bottlenecks.

Traffic data analysis provides result for each route in which route and bottlenecks times are displayed. Nevertheless, this system further provide severity level related to Islamabad region in which current conditions are mention for severity levels for example rain, construction, number of lanes, commuter behavior and stress, the severity levels are scaled from one to ten in which level 1 for least and 10 for maximum point based on real time condition. In traffic analysis system result option of traffic database, which can indicate the shortest route path while considering for all

routes with respect to time as validated every hour. Traffic Analysis route system can function these calculation based on Artificial Neural Network Scheme are shown below.

Figure 7 represents the traffic System Database Artificial Neural Network Scheme can summarize the route path their distance with respect to bottleneck time and speed, this scenario process by traffic database (TD), and provide results for all available routes.

Average travel time can analyses complete process for routes and take judgment for shortest route with minimum bottleneck. It provide updates for routes with validation as number of users increase Average travel time can further processed through Traffic Database for vehicle time per bottleneck their function activate when user define checked option for selected bottleneck.

$$\text{Traffic Database System TD} = \frac{\text{Sum of vehicle time per hurdle}}{\text{Vehicle time per route}}.$$

TD Traffic Database System that maintain complete record of each bottlenecks and routes with severity levels.

ANN can calculate the time for all selected route in every hour and provide update to traffic database with respect to time and severity levels.

6 Experiments and results

Our experiment and result through Traffic Route Analyze System are implemented (see Fig. 8 for a screenshot example) with all bottlenecks and database maintain according to number of users that increased with real time factors for Islamabad city and we design Route Map Decision tree for all routes to compare each routes and their result as shown below.

Figure 9 Route Map Decision Tree with bottlenecks as stored in traffic route analysis system the scenario based on ANN Scheme are showed to gather there updates for all routes.

We started to move from Margalla Avenue, F11/3 and our destination is HBL Tower. In our experiment we selected five different routes (examples Route 1, Route 2,

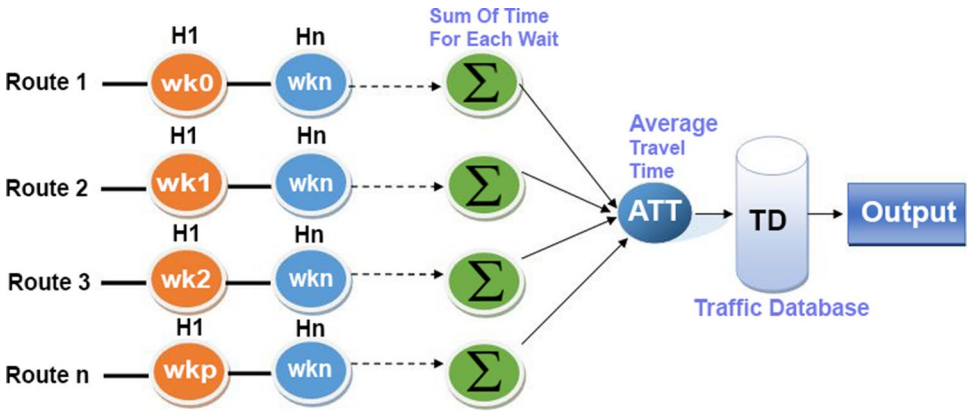

Fig. 7 Traffic system database ANN scheme

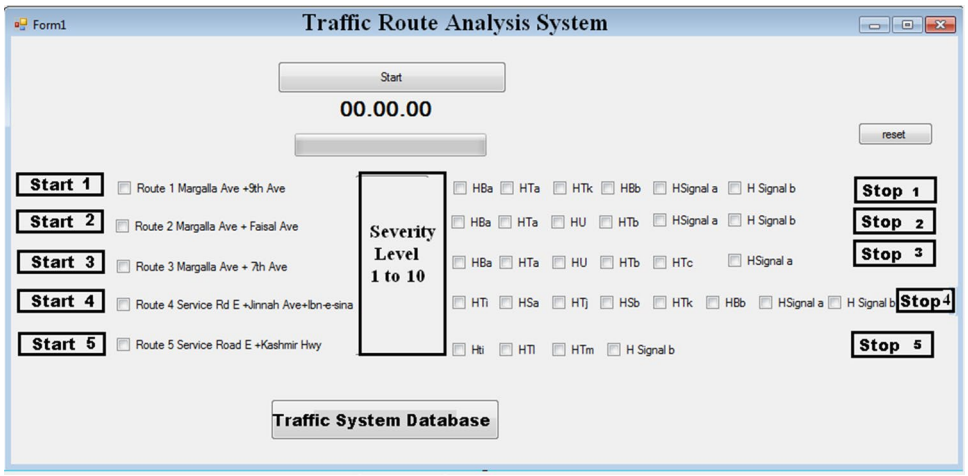

Fig. 8 Screenshot of the user interface to the traffic route analysis system

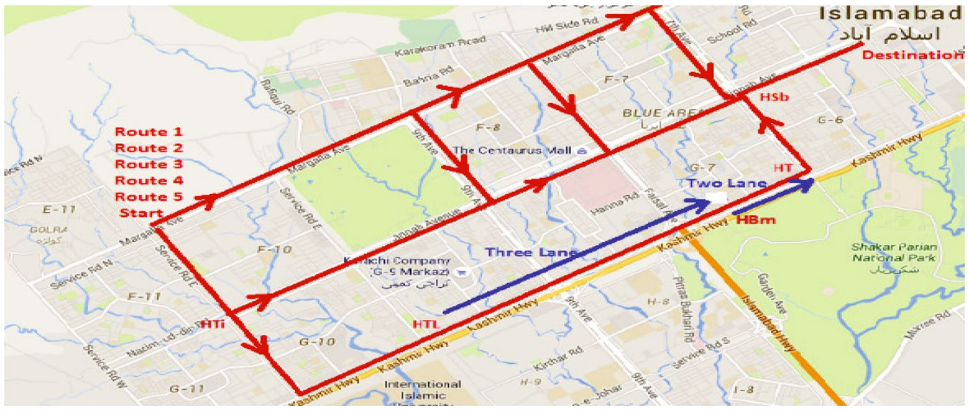

Fig. 9 Route map decision tree

Route 3, Route 4, Route 5) having diverse bottlenecks to find the minimum possible time to reach said destination it could be more than five route from selected destination but we consider whose have maximum number of bottlenecks with stress factor, number of lanes effect, construction effect, behavior effect for severity level so that we could have better picture of each route and bottlenecks like school in morning and afternoon time create rush for entire route same as traffic light driver have to wait for three time while signal changed. In this paper our system can check the update of real time data and provide accurate result from starting route to destination user can check the available route whose distance is shortest including specification of speed and time. It can processed through bottlenecks temporary and permanent that are pre-defined in our database which cause easiest to analyses the total distance of the route. Route Map Decision Tree based on traffic route analyses system aim is to explore the shorted route in terms of total travelling time for specific route and average travel time with respect to all routes (Jeong and Rilett 2004) (Table 1).

- Route 1 total travel time 23.35 of the route distance 10.2 km and average speed.
- Route 1, 2, 3, 4 have intersection point Bottleneck Traffic (HTk), (HTa), (HTb) that caused rush and route distance increased.
- Route 2 = 17.42 mint 42 s with 12.2 km, with three lanes.
- Route 3 = 16 mint with 11.2 km.
- Route4 = 14.5 mint 0.5 s with 10.2 km, with Two lane and Three lane = 12.75 min.
- Route 5 = 20.4 mint with 10.2 km, average speed 50 = 20.4 min with four lanes.

We analyses these based on average travel time we will add timing (calculated in minutes) factors as shown below.

6.1 Timing factors

1. If user can take 7:30 a.m. with 10.2 km it can take 23.35 min due to bottlenecks school it increased rush at due to intersection point traffic load increased
2. If user can take 7:45 a.m. with 10.2 km it can take 29.4 min due to bottleneck school timing rush increased at intersection point so that's why speed can decreased
3. If user can take 8:00 a.m. with 10.2 km it can take 29 min due to bottleneck school timing rush increased at intersection point so that's why speed can decreased
4. If user can take 8:30 a.m. with 10.2 km it can take 25 min due to bottlenecks and timing rush speed can decreased
5. If user can take 9:00 a.m. with 10.2 km it can take 19.35 min due to rush decreased at intersection point speed increased that's why time optimized

Table 1 Route map decision tree result

User	Time	Route 1	Route 2	Route 3	Route 4	Route 5
User 1	7.30 a.m.	23.5 mint/10.2 km	17.42 mint/12.3 km	16 mint/11.2 km	22.5 mint/10.2 km	16.4 mint/10.2 km
User 2	8:00 a.m.	29 mint/10.2 km	26 mint/12.3 km	22 mint/11.2 km	31 mint/10.2 km	18 mint/10.2 km
User 3	9:00 a.m.	19.5 mint/10.2 km	27 mint/12.3 km	19 mint/11.2 km	26 mint/10.2 km	15 mint/10.2 km
User 4	4:00 p.m.	15 mint/10.2	18 mint/12.3 km	18.5 mint/11.2	29 mint/10.2 km	13 mint/10.2 km
User 5	6:00 p.m.	30.2 mint/10.2	16 mint/12.3 km	17.5 mint/11.2	30 mint/10.2	11 mint/10.2 km

6. If user can take 4:00 p.m. with 10.2 km it can take 15:15 min due to minor rush at intersection point speed can increase and easily reached to the destination.
7. If user can take 5:30 p.m. with 10.2 km it can take 25:20 min due to rush at intersection point so that's why speed can decrease while reaching toward destination.
8. If user can take 6:00 p.m. with 10.2 km it can take 30:02 min due to rush at intersection point speed can decrease while reaching toward destination.

6.2 Other factors

Figure 1 Traffic Route Analysis System scale factors for severity levels are repeatedly scale the aspect including feature of weather effect that integrate with whether updates in the selected region, Construction for temporary bottlenecks in the proposed methodology and Commuter behavior effect, Lane effect because majority of route have one, two, three and four lanes which are based conditions of different route in Islamabad region and Stress Effect are important role in driving condition because in mostly condition due to one lane it create rush users are not having patient so their stress level increased and majority violate the traffic rules while driving and leave the sequential flow of traffic (Table 2).

6.3 Result summary

Our experiment with Google Maps, Fig. 10 shows the result for Route 4 Service Road E via Jinnah and Ibn-e-sina Road 20 min without traffic but on real basis in our evaluation this route have major bottlenecks that create rush so that based on real factor it cannot same as 20 min for analyzing according to bottlenecks, severity levels and human behaviors our proposed system are based on real factors according to our proposed system route 4 take 31 min during timing 8.00 a.m. and it will less than 20 min at 9.30 a.m. our proposed system eventually update the database according to time user can easily avail the opportunity of route that have less bottlenecks with minimum time duration.

Table 2 Traffic route analysis systems factor

Weather effect	Scale 1–10, where 1 is least effect and 10 is maximum (Severity level)
Construction effect	
Commuter behavior effect	
Lanes effect	
Stress effect	

7 Conclusion and future work

Rapid increase in the population of Islamabad caused a negative impact on the smooth flow of traffic system. In this paper the authors, provide a solution to facilitate the car-based commuters to pick the route with minimal bottlenecks and to minimize the distance to reach the destination. Our proposed solution is to manage and control the traffic system in the city of Islamabad. The current traffic data collection system in Islamabad and other urban areas does not provide timely, reliable data that can be useful to the Regional Transportation Authority for planning activities. The authors have tried to overcome this problem by collecting this missing data using a custom-built mobile app. Our system analyses and manipulates the collected information based on Artificial Neural Network (ANN) scheme that can finally indicate the bottlenecks for each route and predicts the shortest route based on the user's severity levels. Optimizing the travel time was a major concern for our solution; because we had to look into different factors such as mode of transport, travel distance, type of road and bottleneck. In summary, there is need of enhancement and development of a new unique traffic system in Pakistan, which will ease the traffic flow faced by the daily-commuters (motorized). We believe that our proposed system is a first step towards this direction and can help the commuters to select the right-route that will reduce the level of stress by limited driving distance and time.

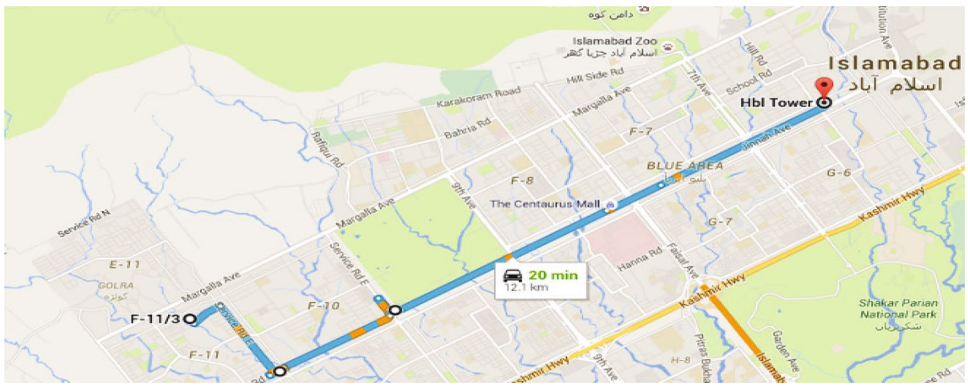

Fig. 10 Google maps: Route 4 plot

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