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Design and Development of Intelligent Transportation System (ITS)

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Abstract: The number of people killed in automobile accidents in India is notably higher than the global average. The mortality toll from automobile accidents is especially high in the country's intermediate cities, much exceeding that of the country as a whole and even the country's largest cities. The creation of technical services within the context of so-called Intelligent Transportation Systems is one way that cities and mobility agencies have attempted to address these issues (ITS). Interoperability and integration of services are not possible, entail large costs, and are difficult to deploy because they are not based on an effective ITS design. Due to the lack of an established ITS architecture, it is not being used in the creation of these services. Although there are publications about regional ITS architectural design techniques, no such framework exists that takes into account both the city's specific setting and a wide variety of reference materials. We provide a technique to build an ITS architecture suitable for an intermediate city in a developing nation, with the goal of fostering the growth of mobility services in this sector. We established a straightforward, logical approach by reviewing the relevant paperwork, identifying the best practices, taking into account the scope and context, and so on. In this essay, we show the design process we developed and the outcomes we gained from using it. The developed methodology not only served to facilitate the design of an ITS architecture, but we also believe it may be used as a resource for the growth of ITS architectures in comparable settings. The city's mobility services can be planned and implemented effectively thanks to the ITS architecture that has been developed.

Keywords: Architecture; mobility; intelligent transportation systems (ITS)

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Introduction

As a result of globalization, urbanization, and the rise of the automobile, major metropolitan centers have advanced significantly in their road transport infrastructure. Increases in delays, resource waste, traffic accidents, blocked lanes, severe traffic congestion, economic losses, environmental pollution, and other issues have all been linked to the rising automobile population. The aforementioned issues may be remedied by using an intelligent transportation system. Building an ITS means using cutting-edge technologies like Intelligent public transportation systems make use of cutting-edge technologies in transportation engineering, such as information technology (IT), computational intelligence, system control technology, and system engineering. The intelligent transportation system contributes significantly to the decrease of gridlock, the prevention of accidents, the amelioration of air and water pollution, the lessening of energy needs, and the betterment of road safety. As a result, public transportation systems in urban areas face higher costs for things like incident and disaster management, public transit management, traffic management, security, and privacy. An urban area's transportation network is there to facilitate the smooth transfer of people, products, animals, and vegetation between their many points of origin and final resting place. Road users (such as cars, transit passengers, pedestrians, cyclists, and motorcyclists); roads and highways; traffic control and conventions; laws and enforcement policies; lighting; etc. are all part of the system [1]. Several factors are associated with quantity of needs, services, and resources in a city.There are three distinguishing features of the metropolitan transportation system: One, it is complex and dynamic, making it difficult to anticipate emergent behavior even if the behaviors of individual transportation system components can be predicted. Two, even modest changes in input parameters may have huge effects on behavior. As a result, transportation networks exhibit dynamic behavior. Because of the non-linear interactions between road users, cars, bus station units, commuters, and transit operators, the dynamic character of vehicular traffic in a metropolitan region is intimately associated with the spatio-temporal behavior and its complexity rises. Trading goods and services with one another is crucial to the development of civilizations in a metropolitan region, and transportation plays a crucial role in making that possible.The term "metropolitan public transportation" is used to describe the many forms of public transportation utilized by the general public, such as buses, trains, the metro, and so on.While it is challenging to deliver high-quality services in terms of reliability and timeliness, public transportation networks are increasingly being implemented. As more people move into cities and more cars are used in those cities, the transportation network inside those cities grows in size and complexity. Intelligent decision making and control systems are crucial for a metropolitan area's public transportation network management, which benefits both passengers and transit network authorities. In addition, cutting-edge ICTs are required for information sharing, traffic control, and the coordination of transportation networks [1, 2, 3]. An intelligent public transportation system (IPTS) allows all of these systems in a city to communicate with one another and work together.

Major Functionality Units of IPTS

IPTS are cutting-edge programs that help commuters in a metropolitan region in real time with issues like traffic management, pollution reduction, and making better, safer use of public transportation. In order to serve commuters and transit operators in a metropolitan region with real-time services, the IPTS has the following primary functionality units:

• Predicting when commuters will arrive is important for the smooth operation of public transportation networks in densely populated areas, where both predictable and erratic traffic patterns are common. As a result, it is important to examine, at varying intervals, the commuting traffic pattern and forecast in each zone and region of a metropolitan area[4-6].

• Keeping track of public transportation depot resources is essential in a large city, because demands, incidents, and passenger arrival rates may all change at any given moment. All transportation hubs require vigilant oversight that includes the systematic collection, estimation, analysis, and distribution of data. In order to properly manage resources in a metropolitan region, metrics such as passenger waiting times and resource usage are tracked at each transportation hub.

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• Reliability of Transport Resources Metropolitan dwellers and transportation providers alike depend on punctual service, short wait times, and increased security. It is possible to do this by guaranteeing the availability of necessary resources and the timely arrival of designated vehicles along the predetermined path. Privacy methods used to public transportation terminals in a city have several benefits, including satisfying the expectations of passengers and transit operators while also boosting economic development and decreasing fuel consumption and commuters' average waiting times.

• Transportation in Context: The context plays a significant role in the dynamic behavior of a metropolitan area's transportation system. Commuters and transit operators in a metropolitan area benefit from services like demand management, traffic management, transportation management, incident management, etc. because of the context information of various transportation entities like vehicles, staff, bus station units, routes, and commuters[7-9]

Intelligent Public Transportation Systems (IPTS)

The intelligent transportation system for public transportation is referred as IPTS and is a novel field, in which information and communication technologies (ICT) [2, 3] are applied to empower entities involved in transportation of metropolitan area, specifically vehicles, staff, bus station units, commuters, transit networks and highway operators having sufficient amount of information to make better decisions, like choosing routes; choosing mode shift; when to travel; optimization of resources; sharing right amount of resources with right entity at the right time; and prediction of real time traffic density and resources requirement, and also to achieve safer, reliable and more efficient transportation system, and leads to a smarter use of network[10]

Hence, IPTS may be seen as a catch-all phrase for the public transportation sector's use of communication, controls, and information processing technology. Information gathering, processing, integration, and provisioning are the primary goals of intelligent transportation systems. A metro area's operators, transportation and traffic authorities, both private and public transport companies, and specific road users all benefit from reliable information like this. [11-12]

Sourabh Jain *et.al* (2021) Worldwide prosperity and progress depend critically on reliable modes of transportation. The most important aspects of every city is its public transportation system. Congestion, delays, pollution, accidents, excessive energy consumption, low resource productivity, community segregation, and insufficient access are all symptoms of inadequate urban transportation. Flyovers and highways have been built in metropolitan regions, yet commuters still rely heavily on intermediate and private vehicles due to traffic, pollution, and a lack of public transit options. Hence, an intelligent transportation system is required to make the transportation system appealing and user-friendly in terms of safety, dependability, journey time, and comfort (ITS). The goal of this research was to provide a systematized approach to building and managing the Presto ITS mobile application, which is part of an intelligent transportation system. The Urban Traffic Data Management Centre and the Android app, Presto ITS, collaborate to assist drivers make better route selections and thereby minimize traffic congestion. This aids in preventing more cars from entering an already clogged road network, enabling them to be spread out throughout the various routes and so lowering congestion everywhere. When implemented citywide, this technology will significantly aid in the reduction of congestion and the distribution of traffic.

Guangchuan Yang, *et. al.*, (2019) When demand for an on-ramp exceeds the ramp's metering capacity, a line of cars forms in front of the meter. When a metered on-ramp is added to an already existing unmetered ramp, it is crucial to provide sufficient queue storage capacity to avoid spillover to the upstream feeding facility. In this research, we look at how the arrival profile of on-ramp traffic affects the wait times at four different kinds of metered on-ramps. A nonlinear link between demand and capacity was discovered via field research at 13 ramp metering sites, suggesting that wait length is often impacted by the stochastic character of on-ramp traffic flow. The arrival profile of on-ramp traffic was modelled using an analytical technique for each kind of metered on-ramp, and the findings showed that the profile had an impact on the queuing process.

Miao Yu *et.al.*, **(2019)** This research proposes an efficient variable speed limit (VSL) method for a motorway stretch with several bottlenecks in a connected autonomous vehicle (CAV) environment. Using an enhanced cell transmission model (CTM) that accounts for capacity loss and mixed traffic flow (i.e., both human-driven vehicles (such as automobiles and trucks) and autonomous vehicles), the VSL control was created (AVs). To boost operational efficiency and ease the shift in velocity, a multi-objective function was developed. The issue of integrated VSL regulation was addressed by using a genetic algorithm (GA). The chosen control structure was put to the test on a section of actual highway. The effects of various parameters, such as the CAV penetration rate and the communication range, were studied using sensitivity analysis. The designed VSL control was shown to enhance overall efficiency and decrease tailpipe emission rate in simulated performances. Moreover, simulation findings shown that the VSL control incorporating V2V, V2I, and I2V communication works better than the VSL control alone. Better results are also attainable when the number of CAVs in use grows.

Paolo Intini et.al., (2019) There are a number of traffic modeling tools available now that may help with emergency evacuation planning and provide on-the-spot decision assistance. In the context of wildland-urban interface (WUI) fire-evacuation operations, this research discusses several traffic-modeling strategies. Fire-related, geographical, and demographic aspects; intended use (planning or decision assistance); and temporal concerns are used to assess existing modeling methodologies and features. This research synthesis highlights the significance of dynamic modeling frameworks that take into account behavioral variability and route choice, activity-based models for rapid evacuation planning, and macro-level traffic simulation for real-time evacuation management. Next, the benchmark characteristics selected for WUI fire applications are compared to the modeling features of 22 existing traffic models and applications from practice and the literature. Recommendations for further research and development of traffic models, including potential linkages with wildfire and pedestrian models, are provided based on this review study.

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Proposed Plan

Commuters' Arrival Prediction: Using commuter density, resource availability, spatio-temporal data, and dynamic commuter and vehicle arrivals as inputs, we offer a commuters' arrival prediction in a metropolitan region that can assess and forecast commuters and resources. For the purpose of resource allocation and traffic diversion, the suggested approach offers a qualitative form of commuter density. The suggested approach is tested in a simulated urban region, with space, time, demand, and resource variations accounted for.

• Public Transport Resource Allocation: In this paper, we present an EI-based strategy for allocating resources for urban public transportation systems. Based on predicted commuter arrival times, resource needs, resource availability, recorded historical data, and the surplus and deficit resources of neighborhood depots, the suggested strategy effectively manages and supplies resources throughout time and space. The Emergent Intelligence method is used to data collection, analysis, collaboration, and distribution. We have established closed form formulas for the optimum usage of resources in a metropolitan region by modeling the suggested method using the Discrete Time Markov Chain (DTMC) concept. Matlab, in conjunction with the MobileC agent platform, is used for simulation and implementation of the suggested strategy[13].

• Public Transport Resource reliability: We suggest analyzing the resource distribution method for public transportation in a city for dependability. The suggested reliability analysis model calculates the dependability of many factors, including resources, journey time (route), time delays experienced while retrieving resources from a nearby depot, and the efficiency with which these resources are shared. To ensure that commuters and transit operators in a metropolitan region can always rely on the services they get, the predicted reliability criteria are put to good use in the best allocation of dependable vehicles to the intended destination. Matlab is used to implement the suggested analytical model and transportation resource allocation method[13-14].

• Privacy Preservation: Using the EI method, we present a solution to protect the privacy of public transportation depots in densely populated areas. The suggested approach has two parts: the first protects depot workers' privacy via a set of policies, and the second protects communicating agents' privacy through a system of pseudonymous authentication. Because of the secrecy afforded by both stages of communication, data pertaining to resource abundance and deficiency, vehicle allocation and dispatch, vehicle revocation and financial and maintenance stability is preserved. Staff members and communication agents in a metropolitan area transportation depot may impersonate other people, engage in harmful activity, or behave greedily if the suggested system does not protect their privacy. These irregularities provide false data, which in turn causes serious problems such lane obstruction, traffic congestion, accidents, waiting time, resource waste, and discordance amongst cars. The Crypto++ package is used to implement and evaluate the proposed system[15].

• Context based Transportation: We present an EI approach using agents for context-based mobility in a city. To gather, analyze, and disseminate vehicle, crew, commuter, route,

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environmental, and BSU context information, the proposed system employs IPTS technologies and EI method in conjunction with the agents. Some examples of context information utilized for controlling and delivering appropriate IPTS services in a metropolitan region include current route condition, traffic density, number of available routes, traffic congestion, and vehicles movement. We have utilized context data to create plans for redistributing traffic flows, controlling travel demand, and optimizing route capacities in a major metropolis. These services promote telecommuting, altering commute patterns, and the usage of public transit. MATLAB is used to develop the system, and the interface between Matlab and the MobileC agent platform has been tested and assessed.

• Public Transportation Management: We suggest a public transportation management method to move people safely from catastrophe areas to secure areas in a city. With the collection, analysis, and dissemination of data on victim density, resource availability, and route availability, the evacuation management system is able to keep track on the situation of victims in disaster zones. The mobile agents gather and evaluate disaster-related data, which the static agent uses to estimate how many people can be evacuated from various locations and where they will ultimately end up. MATLAB is interfaced with NS2 to assess the efficacy of the suggested evacuation mechanism.

Intelligent Fuzzy Multi – Agent System for Traffic Control

The traffic lights at an urban crossroads are crucial to the efficient flow of traffic. The purpose of traffic lights is to improve traffic quality and maintain a safe flow of vehicles.

The general representation of the traffic intersection is represented in the figure 1.

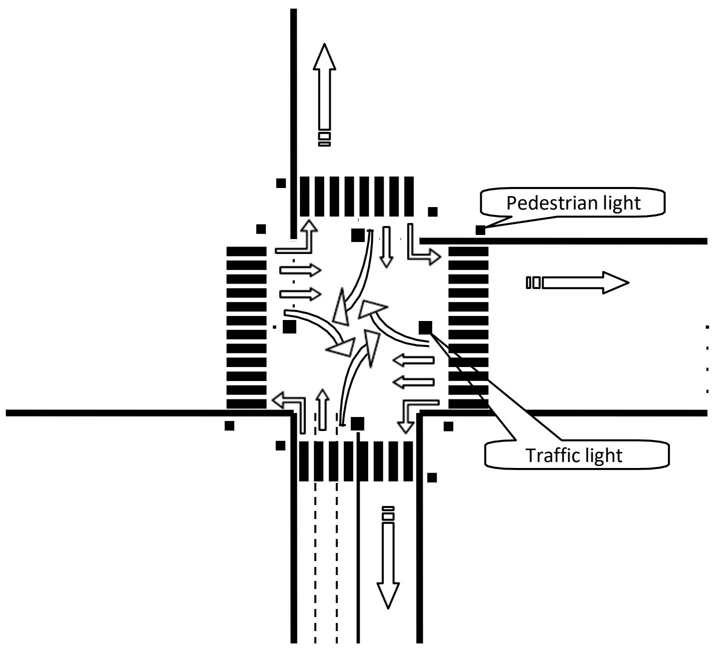

Figure 1 General representation of traffic intersection

Four rays meet at the junction seen above. The secondary road has three lanes, whereas the main road has four. It's important to plan ahead and use the appropriate lanes before turning

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left, proceeding forward and then turning right. Many numbers and types of phases are imaginable in this paradigm as shown in Figure 2 Fuzzy logic, as contrast to crisp logic, deals with uncertainty and fuzziness in data. Under the strict logic of Boolean expressions, there are only two possible outcomes. For instance, there are only two possible descriptors for a person's height: tall or short. Similarly, there are only two possible descriptors for many other situations: true or false, or, more broadly, zero or one. Fuzzy logic excels in situations of ambiguity, when it is necessary to draw inferences or arrive at conclusions based on probabilities but only partial information is available.

It is erroneous to assume that every kind of uncertainty can be dealt with using probability theory. In this theory, we are interested on the probability of an occurrence rather than its relative value, in contrast to fuzzy logic. As probability theory's models aren't compatible with the way humans make choices, it can't be utilized to address these types of problems.

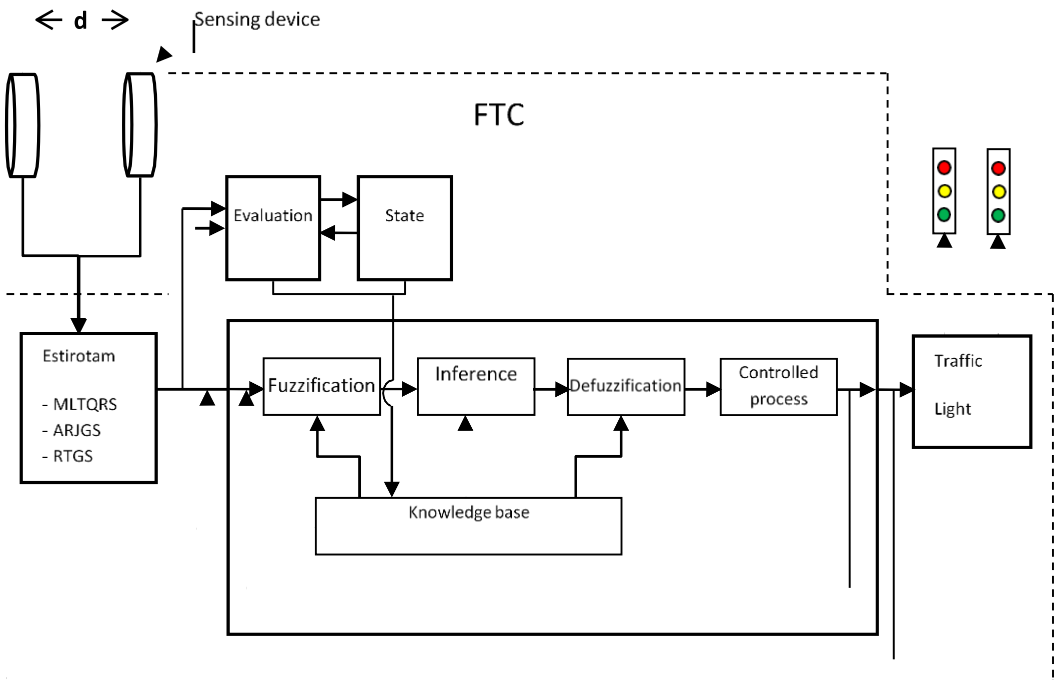

Figure 2 The structure of fuzzy traffic control system

The length of the road shown in Figure 3 corresponds to the distance x (m) between the speed estimator and the crossroads. The first sensor is designed to measure vehicle weight, while the second provides a rough estimate of the mean velocity (v). With this information, the control system may predict when a large number of cars will arrive at once.

$$t = \frac{x}{\bar{v}}$$

These vehicles will arrive to the intersection in *t* seconds.

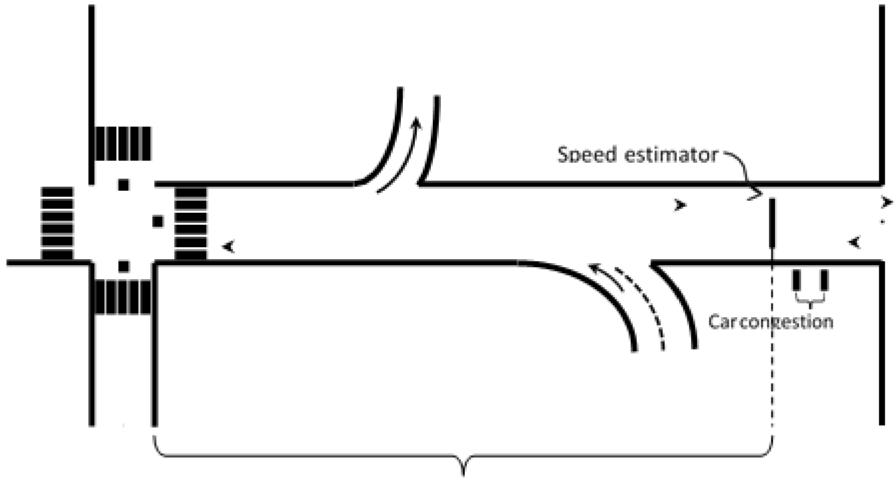

Figure 3. Example of Traffic Congestion Forecast

As show in in Figure 3 The sole effect the fuzzy traffic controller has is to lengthen the duration of the green light. The Extension value is adjusted dynamically in response to traffic conditions. It seems to reason that the traffic lights' green phase should be longer in the lane where there are more approaching cars and shorter in the lane where there are fewer arriving vehicles. To further optimize the length of the green phase at the junction, the traffic demand on other lanes must also be taken into account.

The maximum length of cars behind a red light is determined by the total number of vehicles. Each car in the line must wait at least 60 seconds until the light turns green again. We require information on the arms that occur in a certain order of phases. Data for arms 2, 3, and 4 are shown statistically in the table below.

Table 1 Numbers for the 2nd, 3rd, and 4 arms

Next round of the sequence of phases / **The number of the way**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
2	2	13	8	1	9	7	2	1
3	4	10	7	13	10	1	6	4
4	3	5	5	6	8	4	5	9
Car Data	4	13	8	13	10	7	6	9

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Congestion can be reduced by using an Intelligent Transportation System (ITS), which has already been tried and proven. One definition of ITS is "the use of technology to the task of enhancing The transit network. With as few observed and stored speed data as feasible, an ITS must be able to estimate traffic speed along the branches connecting the numerous nodes in a traffic network for short time periods into the future in near real time. Such forecasts enable quick ITS responses, such as re-routing guidance and estimated times to destination, to changing traffic circumstances, such as accidents or volume-induced slowdowns.

The goal of the project is to improve traffic flow in congested metropolitan areas by the implementation of an intelligent transport system that will educate and empower commuters to utilize public transportation more safely and efficiently. Congestion relief strategies are always being refined, but one that shows promise is the Intelligent Transportation System (ITS). Rapid industrialization and increased population have contributed to a rise in traffic congestion. Also, there were several places when the number of automobiles exceeded the capacity of the route. When the capacity of a certain region is exceeded, congestion results. Numerous traffic studies have recently been made public.

Several experts and institutions have studied the causes and effects of traffic congestion and accidents. Current rates of resource use have been proven to be unsustainable, and might ultimately lead to extinction. Most studies have shown that ITS significantly contribute to decreasing both travel duration and frequency. Since there is no silver bullet for the transportation sector's energy and environmental problems, a multifaceted strategy is necessary. There are a number of limitations, including as the need to decrease the overall growth in travel and the development and deployment of ecologically friendly automobiles and fuels. So, we may implement such factors judiciously, resulting in maximum benefits, by comparing the lowest implementation cost for such parameters to the advantages customers may gain. Hence, the parameters should be profitable, and the benefits we may get from them should be user-friendly, for ITS parameters to be widely used in road infrastructure by the general public.

Figure 4 Real picture of traffic intersection in Nagpur city (from Google Earth)

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In Figure 4 Shows Real picture of traffic intersection in Nagpur city. In this context, we investigate many instances wherein input parameters are fuzzy variables. Two distinct scenarios are simulated in MATLAB software utilizing four and three input parameters, respectively. In all cases, the length of the green light is 45 seconds, and the time it takes to anticipate how many cars will arrive in the following 10 seconds is 10 seconds.

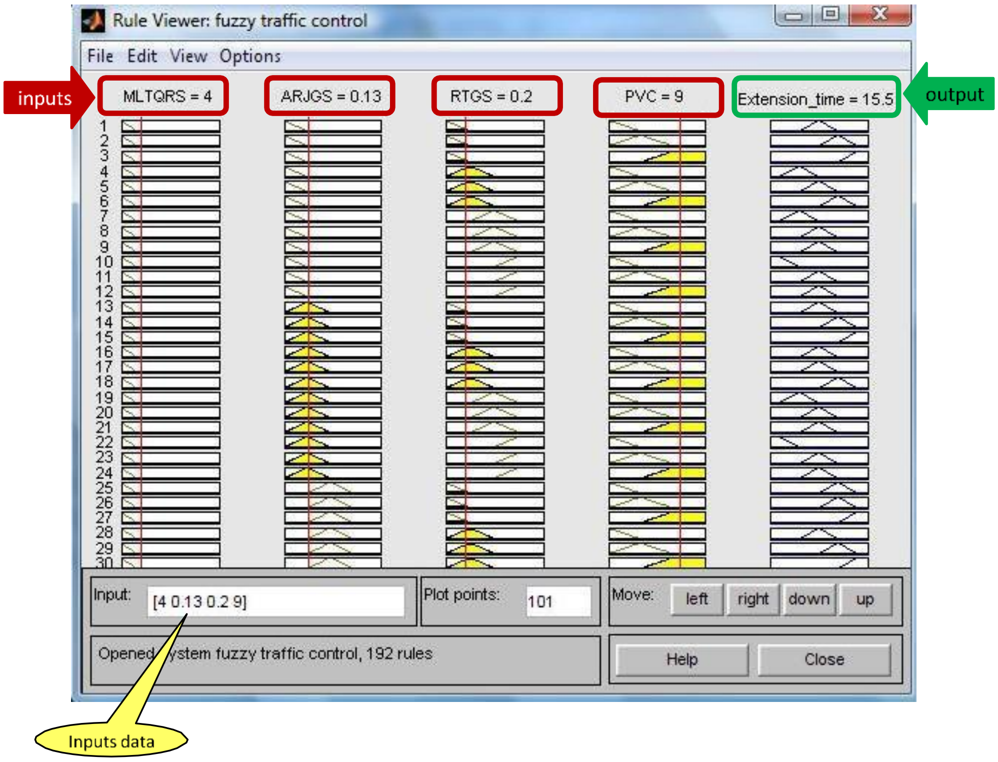

Figure 5 Result of extension time with considering PVC in first scenario

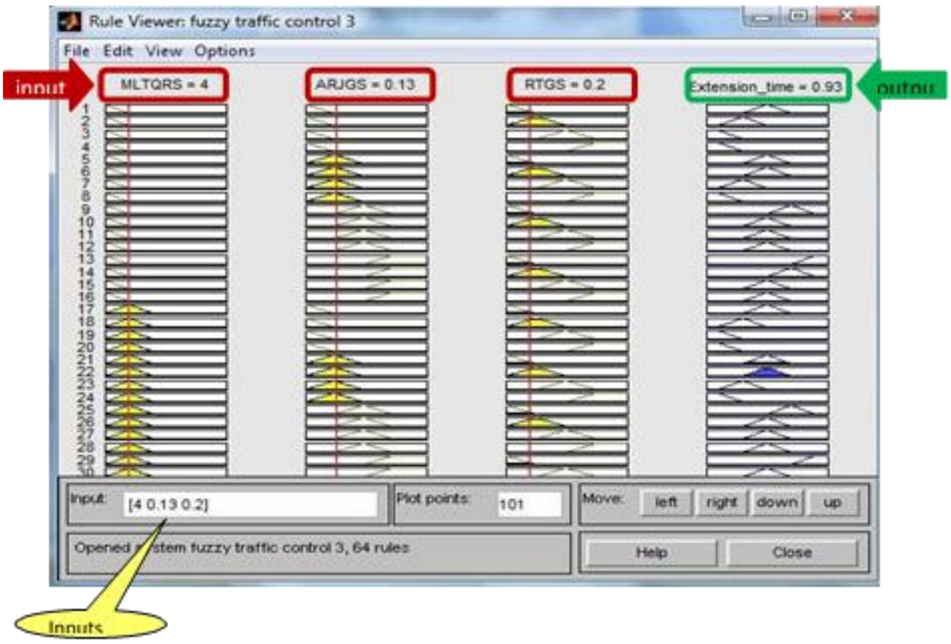

Figure 6 Result of extension time without considering PVC in first scenario

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Figure 5 shows that there are still 9 seconds till the green light goes out. The control system's efficiency with respect to PVC is shown in Figure 4.8; the extension time is seen to have increased by 15.5 seconds, and the total remaining time has increased to 9 + 15.5 = 24.5 seconds. That's plenty of time for the traffic to clear the junction.

The calculated value of 0.93 may be seen in Fig. 6. This indicates the control system is adding 0.93 seconds to the current time, bringing the remaining time for the green signal to 9.93 seconds. Given that PVC estimates that 9 cars will have reached the junction within 10 seconds when the light becomes green, we can calculate that the light will change to red in 9.93 seconds. In reality, in a relatively short amount of time, all nine cars (the group of vehicles) should remain behind the red light. This causes other arms, even ones with a "moderate" ARJGS, to see less time under the green signal.

Conclusion

This work discusses why and how different ITS technologies are being used to ensure the security of urban transportation routes. It incorporates software for both informing drivers and monitoring their compliance with traffic laws. The technologies described include well-established methods from across the world that might be adapted for use in Indian cities.Globally, both developed and developing nations are seeing the revolutionary effects of Intelligent Transport Systems (ITS). ITS ideas and implementations have essentially supplanted the conventional TSM methods that were in vogue after the 1980s. As the industrialized world is already known to have superior transportation systems, ITS stands to greatly enhance such networks. In a world where transportation infrastructure is lacking, ITS is expected to have far-reaching positive effects. Hence, ITS is most useful for developing nations that cannot afford transport intensive land uses and the transportation consequences of these uses.

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