International Journal of Applied Information Systems (IJAIS) – ISSN : 2249-0868
Foundation of Computer Science FCS, New York, USA
Volume 12 – No. 16, October 2018 – www.ijais.org

Architectural Framework for Intelligent Vehicle-Pedestrian Traffic Control

Oyenike M. Olanrewaju
Federal University Dutsinma
Computer Sciences and IT
P.M.B 5001, Dutsinma, Katsina State, Nigeria

A. A. Obiniyi
Ahmadu Bello University, Zaria
Computer Science Department
ABU Zaria
Kaduna State, Nigeria

S. B. Junaidu
Ahmadu Bello University, Zaria
Computer Science Department, ABU Zaria
Kaduna State, Nigeria

ABSTRACT
There exist different modes of transportation in which many flow entities have to share the transportation infrastructures. Of particular concern is the safety implication of sharing road infrastructures that bring pedestrians and vehicles into close contact. This make the issue of dynamic traffic control paramount in other to ensure safety of lives. Intelligent transportation research mostly focuses on sensitive system that manages signal timing for vehicular signals without incorporating adequate pedestrian facilities. This research work designed an architectural framework incorporating pedestrian facility into vehicular traffic control with intelligent reasoner for optimized management of both pedestrian crossing and vehicle driver's demand. The methodology involves review of related literatures, architectural design of the framework and intelligent fuzzy logic model. MATLAB was used to implement the reasoner that harmonized both vehicular traffic's variables and pedestrian traffic's variables to dynamically generate the signal timing. A four-way intersection road network in Kano, Nigeria was modeled using VISSIM traffic simulator as test bed. The interfacing of MATLAB and VISSIM was done with VISSIM COM for the communication flow. Traffic network scenario experiments were performed as signalized fixed time traffic control and as Fuzzy Intelligent Traffic Control (FITC) using the developed framework. From the evaluation of the system, the FITC achieved average improvement of 53.19% over fixed time traffic control, FITC Pedestrian delay improved by 13.13% over fixed time.

Keywords
Fuzzy Logic, Intelligent, Pedestrian, Vehicular traffic control

1. INTRODUCTION
Road Transportation system can be defined as the combination of road fixed facilities, flow entities and the control system that permits people and goods to overcome the friction of geographical space efficiently in order to participate in a timely manner in some desired activities (Papacostas and Prevedouros, 2008). Fixed facilities are the physical components that are fixed in space and constitute the network links in transportation system. Examples of these are roadways, railway track, pipes and transit terminal. Flow entities are the units that traverse the fixed facilities. These include all categories of vehicles, drivers and pedestrians. The control system consists of all entities that control the movement of road users such as vehicles and pedestrians. These permit the efficient and smooth operation of streams of vehicles for the reduction of conflict between the vehicles and other road users especially the pedestrians. The control combines signing, markings, signal systems and their underlying rules of operations. The signal system over the years has gone through various stages of automation (Chen et al., 2012)

Understanding of pedestrian traffic needs is of practical importance when planning for road infrastructures. Quantitative models of vehicular traffic have long been incorporated in various town planning works without corresponding modelling of pedestrian traffic (Aworemi et. al, 2010; Kheradmandi & Strom, 2012; Alam & Pandey, 2014).

There exist Many roads in cities without pedestrian crossing facilities, meaning that pedestrians are left to cross at their risk on such roads, hence models and observation of pedestrian traffic has not received much attention and resources as vehicular traffic (Johansson, 2013). During planning for new infrastructures for vehicular traffic, it is a common thing to make predictions of future traffic situation to enable prioritization among various projects. This is also necessary for pedestrian's traffic.

1.1 Vehicle-Pedestrian Interactions and Safety Implications
Due to the dramatic growth in the number of motor vehicles and the frequency of their use around the world – as well as the general neglect of pedestrian needs in roadway design and land-use planning – pedestrians are increasingly susceptible to road traffic injury (Agarwal, 2011; Papacostas & Prevedouros, 2008).

It is then clear that a pedestrian has to share roads, street, roundabout, walk ways and such likes with other users like motorbike, bicycle, vehicles and co pedestrians as the case may be. This makes the safety of lives a serious issue that deserves road safety considerations. Looking at the nature of Nigerian roads for instance, level of literacy of drivers and care free attitude to road safety rules, there is no doubt that pedestrians are vulnerable road users(Akomolafe, 2014).

1.2 Road Traffic control
The conventional traffic light control scheme is the fixed time allocation control which changes right of way at allocated fixed cycle times which obviously cannot yield the optimal solution. The fixed time system disregards the dynamic nature of the traffic load, which if managed effectively can reduce congestion and enhance safety (Alam and Pandey, 2014). The typical conventional traffic light controls are still associated with heavy traffic which will not allow pedestrians to cross and at times lanes without vehicles are allocated right of way leading to a higher delay. Consequently, there is need for an intelligent traffic control algorithms to accommodate the

International Journal of Applied Information Systems (IJAIS) – ISSN : 2249-0868
Foundation of Computer Science FCS, New York, USA
Volume 12 – No. 16, October 2018 – www.ijais.org

dynamic nature of urban traffic that experienced long vehicular and pedestrian delay due to inefficient traffic light controls so as to improve pedestrian's safety. Dynamism encourages a fair share of right of way among various road users.

Traffic management that will reduce crash rate must effectively consider the conflicting interest of waiting pedestrians and anxious drivers. An intelligent system that will take into consideration major underlying variables such as pedestrians waiting time, walking speed, total number of pedestrians that characterized the crossing situation of pedestrians traffic and vehicular traffic such as number of vehicles on each lane and vehicular delay will manage the signal timing more efficiently (Zadeh, 1975; Hoogendoorn-Lanser, 1998).

1.3 Microscopic Road Traffic Modeling

Models can be defined as the use of symbolic notation and mathematical equations to represent a system. A model constructs a conceptual framework that describes a system. The behavior of a system that evolves over time is studied by developing a simulation model.

A simulation is the imitation of the operation of a real-world process or system over time. Whether done analytically or using a computer software, simulation involves the generation of an artificial behaviour of a system and the observation of that artificial behaviour to draw inferences concerning the operating characteristics of the real system (Banks et al., 2013).

Once a model is developed and validated, a model can be used to investigate a wide variety of questions about the real-life system. Potential changes to the system can first be simulated, in order to predict their impact on system performance. Microscopic traffic modeling is a technique that takes into consideration the detail characteristics of the entity in view. It is a tool that can be used to bring to picture the interactions between the traffic components and the pedestrians (Alexandersson and Johansson, 2013)

Traffic simulation is an indispensable instrument for transport planners and traffic engineers. Microscopic modeling of traffic flows is a technique based on the detail description of the characteristics of each individual pedestrian and vehicle composing the traffic stream. This implies modeling the actions – e.g., acceleration, decelerations, and lane changes of vehicles as well as detail vehicle characteristics, driver behavior and pedestrians (Papacostas and Prevedouros, 2008). Microscopic approaches are represented by VerkehrInStädten-SIMulationsmodell (VISSIM) German for "Traffic in cities - simulation model".

This paper presents framework of crosswalk incorporated intersection to test the proposed framework for intelligent traffic control that can effectively managed traffic control for both vehicles and pedestrians.

The rest of the paper is organized as follows; Section 2 contains review of related literatures, the proposed framework was discussed in Section 3 while the implementation algorithms were discussed in Section 4. Section 5 contains results and discussions, Section 6 contains conclusions while Section 7 has recommendation for future research

2. LITERATURE REVIEW

Kheradmandi and Strom (2012) present a prototype Case-based Reasoning (CBR) system to execute traffic at a signal controlled pedestrian crossing. Intention-based Sliding Doors system was integrated for interpreting the intention of pedestrians at the crossing. The system was created as an Open Services Gateway Initiative framework (OSGI) bundle and uses the Cooperative Vehicle-Infrastructure System (CVIS) framework to communicate with other traffic systems. The architecture of the case based system is represented in Figure 1. The limitation of the design is that the computation time will increase as the number of cases increases. Pedestrian detection was determined by an intention based system that identified the pedestrian that intend to cross from those just walking around. The tendency that some pedestrians might have even cross before the system finish analyzing their intentions is very high.

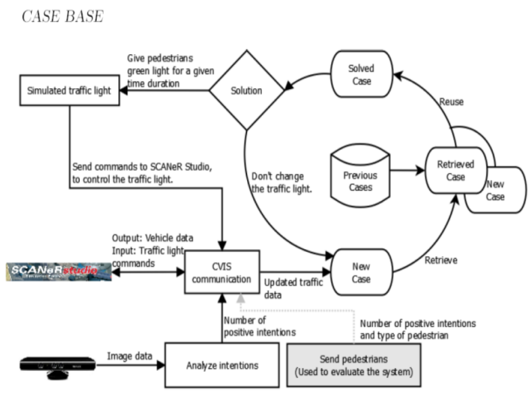

Figure 1: Case based pedestrian traffic controller (Kheradmandi and Strom, 2012)

Kuan-min *et al.* (2010) developed a pedestrian delay estimation model for intersections considering automobile-pedestrian conflicts induced by driver's behaviour of not giving way to pedestrians. In order to test the effectiveness of this proposed delay estimation model, VISSIM simulator was used to model signalized and unsignalized intersections. The delay values derived from this proposed model had a closed range with the observed values. The work confirmed pedestrian delay as a parameter contributing to crash rate; the research did not include effective traffic control

Kothuri (2014) made use of micro-simulation software VISSIM to analyze delays resulting from varying pedestrian and vehicle volumes on a network of three intersections in Portland. From a pedestrian's point of view, free operation was found to be always beneficial due to lower pedestrian delays. However, from a system wider perspective, free operation was found to be beneficial only under low-medium traffic conditions, while coordinated operation showed higher performance under heavy traffic conditions. Investigation into Safety and efficiency tradeoffs was not considered but one of the areas of recommendation for further research.

2.1 Application of Fuzzy Logic in Intelligent Traffic Control System

In trying to make controlling traffic light more efficient, Chavan et al. (2009), exploited the emergence of intelligent traffic light controller that makes use of Sensor Networks along with Embedded Technology. The timings of Red, Green lights at each crossing of road were intelligently decided

International Journal of Applied Information Systems (IJAIS) – ISSN : 2249-0868
Foundation of Computer Science FCS, New York, USA
Volume 12 – No. 16, October 2018 – www.ijais.org

based on the total traffic on all adjacent roads. The work aims at optimization of traffic light switching to increase road capacity and traffic flow, and thereby prevent traffic congestions. GSM cell phone interface was provided for users who wish to obtain the latest position of traffic on congested roads which is very useful to car drivers who may wish to take an alternate route in case of congestion. Use of GSM cell phone while driving might cause distractions and increase risk of pedestrian/vehicular conflict.

According to Zadeh (1975), expressing any natural phenomenon by mathematical expressions does not always guarantee exact capturing of the phenomenon and its implications. When phenomenon on human ideas is expressed linguistically, chance of proper capturing of the phenomenon increases. Fuzzy logic based on approximate reasoning can be expressed linguistically to capture the inherent vagueness of human mind; thus, it can be applied to the areas which involve human decision making like supervision, monitoring, planning, and scheduling (Olanrewaju et al, 2017). Intelligent transportation system is part of town planning solutions. Applications of Fuzzy Logic in Transportation Engineering also include: Traffic Flow Modeling, Car Following Behaviour Traffic Flow Modeling, and Traffic Control at Signalized Intersection, Parking Garage and State Estimation. (Hoogendoorn-Lanser, 1998 and Moreland, 2015).

Tan et al. (1996) describes the design and implementation of an intelligent traffic lights controller based on fuzzy logic. This design is diagrammatically represented in Figure 2. The distance D is the distance between the two sensors. This was used to count incoming vehicles and the number of vehicles discharged. A simulation experiment was carried out to compare the performance of the fuzzy logic controller with a fixed-time conventional controller. It was observed from the results that the fuzzy logic control system provides better performance in terms of total waiting time as well as total moving time. The research work did not consider pedestrian right of way.

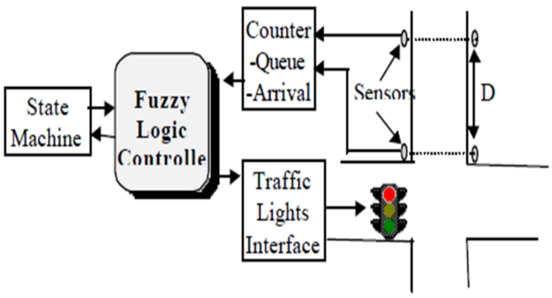

Figure 2: Representation of Fuzzy logic based traffic controller (Tan et al., 1996)

Hassan (2013) proposed an upstream and volumetric pedestrian algorithm for effective traffic time management. The upstream pedestrian detection was placed between 3 – 5metres from the traffic junction. The aim is to prevent delay for pedestrians by signifying the intention to cross using push button before walking to the junction. Sensors were used to determine the total number of pedestrians. The work accomplished more opportunities for pedestrians to cross but incurred greater delay for vehicles. The signal control is also connected with pedestrian walking speed which can be unstable. Pedestrian can push button 5meters away and turn a different direction. Therefore a better system is still required to intelligently manage the traffic without incurring avoidable stops and delay for vehicles.

Yulianto and Setiono (2012) described the design and evaluation of an adaptive traffic signal controller based on fuzzy logic for an isolated four-way intersection with specific reference to traffic in developing countries. The controller is designed to be responsive to real-time traffic demands. Video image processing has been proposed to capture traffic data such as maximum queue length (in meters) and average occupancy rate from each approach of the intersection. The research uses maximum queue lengths and average occupancy rates collected during the previous cycle in order to estimate the number of seconds of green time required by each set of signal groups (stage) during the next cycle. The drawback of this design is that traffic volumes can vary considerably within a short time. Using previous signal circle time to estimate the next signal stage will not produce optimal results in a dynamic traffic environment.

Koukol and Přibyl (2013) demonstrated that VISSIM can also be used for the evaluation of advanced control algorithms, even without the use of API. That is without the knowledge of classic programming languages such as C ++ or Java. The fuzzy control algorithm was implemented directly in the micro simulation tool and its effect on traffic evaluated. The result presented 35.59% improvement over fixed time control. The research affirms the use of VISSIM as effective traffic simulator.

3. METHODOLOGY AND OVERVIEW OF PROPOSED INTELLIGENT PEDESTRIAN-VEHICLE TRAFFIC CONTROL

3.1 Research Methodology and Procedures

Having reviewed related literatures, the methodology of this research involves Architectural design of the proposed system with the procedural algorithms, development of intelligent fuzzy logic reasoning system using MATLAB where the inference system was developed and rules were formulated, modeling of the road traffic network using VISSIM and the interfacing of MATLAB and VISSIM achieved with VISSIM COM. Traffic model scenarios simulations were run to mimic various real life traffic scenarios for a justifiable performance evaluation.

3.2 The Overview of the Intelligent Pedestrian-Vehicle Traffic Control Framework

The proposed system is represented by the architectural framework in Figure 3. This consists of vehicular traffic module, pedestrian traffic module and fuzzy logic based reasoner and the traffic control actuator to form the major parts of the framework. The directional arrow indicates the information flow between the various components of the framework.

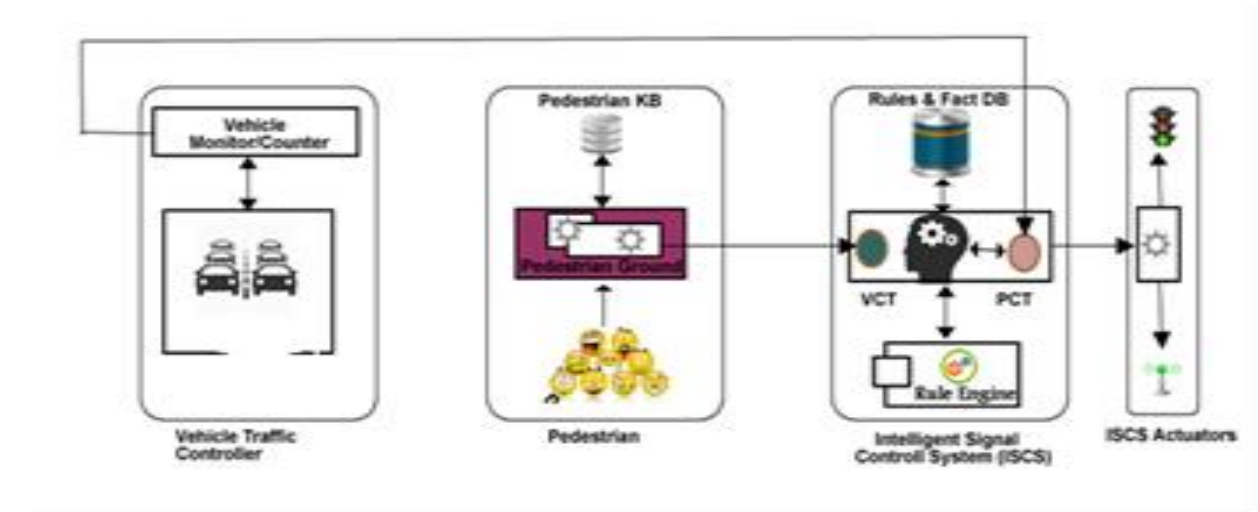

Figure 3: Architecture of Intelligent Traffic Control System

3.2.1 Vehicular Traffic Component

Vehicular module implemented in road network comprises of infrastructures such as road links, vehicle detectors and flow entities such as vehicles and bicycles. Detectors are embedded for vehicular detection and vehicle counts. A four-way intersection with embedded detector was modeled for the implementation of road network. Vehicle counts, vehicle time of entrance and departure, as well as vehicle queue information were obtained from road network.

3.2.2 Pedestrian Traffic Component

The pedestrian component encompasses pedestrian crossing facilities, pedestrian detectors and pedestrian as flow entity. Each of the four vehicle lanes were intercepted by a two way crosswalks. The crosswalks were modeled with embedded sensors for pedestrian movement detection. The microscopic simulator capture the pedestrian data and forward to the reasoner while Vehicles and Pedestrian trajectory data were captured as pedestrians walk from opposite direction across the road lanes and save same in trajectory file for safety analysis.

3.2.3 The Intelligent Reasoner Component

The intelligent reasoner is the harmonizer of the vehicular traffic demand with the pedestrian traffic demand to produce an optimal signal time that is sensitive to the immediate traffic condition. The reasoner was implemented with Fuzzy logic based algorithm. The generated signal time from the reasoner controls the actuator.

3.2.4 Actuators

Actuators are devices assigned to each lane on the road network. It receives signal time output from the reasoner and display signal time to give right of way to the flow entities on the lane.

3.3 The conceptual view of the Framework

The conceptual framework represented in Figure 4 is a diagrammatical representation of the flow of information between the different parts of the framework.

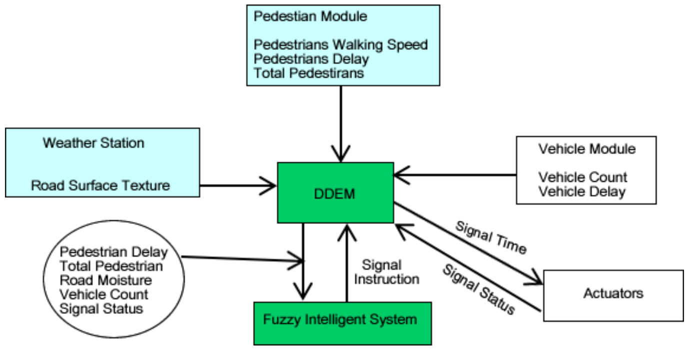

Figure 4 Conceptual view of the pedestrian incorporated intelligent traffic control system framework

DDEM is the information management center of the system. DDEM receives the information from other modules and serves each module with the necessary information received from other modules. DDEM also keeps record of necessary information.

The Pedestrian module records pedestrian traffic data such as pedestrian count, pedestrian delay using detectors and transmits to other modules through DDEM. In the same way vehicular module and weather station transmit and receive information through the dynamic data exchange module. The DDEM supplies necessary information to the reasoner and receives the fuzzy logic based reasoned signal time for the signal actuator.

4. IMPLEMENTATION USING CROSSWALK INCORPORATED FOUR-WAY INTERSECTION

The Road traffic network algorithm was implemented using traffic simulator VISSIM. Traffic actuators in VISSIM are especially programmable and can be interfaced with external modules, MATLAB in this case. From the simulation runs, network evaluation parameters such as vehicle and pedestrian trajectory, vehicle and pedestrian delay, distance travels and detector readings are captured. The fuzzy logic reasoner used vehicle’s and pedestrian’s information to intelligently generate signal time for traffic control. This is to optimize signal timing and reduce delay.

International Journal of Applied Information Systems (IJAIS) – ISSN : 2249-0868
Foundation of Computer Science FCS, New York, USA
Volume 12 – No. 16, October 2018 – www.ijais.org

4.1 The Algorithm

4.1.1 Four way signal control algorithm

This Algorithm encapsulates the operations of the conceptual framework. The road network is a four way network with each road having a signal control head. The signal time sequence of four chances rotating in a loop until the end of the simulation hour set. Each of the lanes has pedestrian crossing on which detectors are placed to detect the presence of pedestrians waiting for right of way to cross. The inputs to the algorithm are vehicle queue length, vehicle count and pedestrians volume. All other functions are called within this algorithm. The output is the signal time which is supplied through the intel_fuzzy_sys for the actuation control.

```
Algorithm 1 – Four way signal control algorithm
Input: Vehicle_Volume, Pedestrian_Volume, Min_Signal_time
Intermidiary variable: signal_time_countdown, Road_Surface_Moisture
Output: Signal_Time
//System receives Data from pedestrian module and vehicle module, weather algorithms
Foreach lane do
  Call Pedestrian_Module Algorithm
  Call Vehicle_Module Algorithm
  Call Weather_Station Module Algorithm
  If Pedestrian_Volume > 0 // if there is detection of pedestrian input then
  // Evaluate on going traffic situation as follows
    IF Signal_time_countdown >0 AND < Min_Signal_Time THEN
          complete on current green phase until Min_Signal_time
    else // coordination of information flow to reasoner for signal time computation
     Call DDEM_Algorithm (Vehicle_Volume, Pedestrain_Volume, Pede_delay)
   End-IF
  Else {no pedestrian input}{
  Vehicle traffic flow continue
 end-if
endfor
```


4.2 Implementation of Fuzzy Inference System in MATLAB

The inference system implementation includes Fuzzification of membership functions, application of fuzzy operators in the antecedent and evaluation of the implication from antecedent to subsequent consequent linguistic values. The aggregations of all consequent values according to the rules are then deffuzzified to obtain single signal time output value.

Fuzzification is the process of changing a real scalar value into a fuzzy value. This is achieved with the different types of fuzzifier's membership function. Figure 5 is a functional flow structure of the fuzzy logic based system. The system receives pedestrian inputs, vehicular traffic inputs from the traffic simulator for fuzzification, the fuzzified values are passed to inference engine for evaluation using the rule based inference engine, and the resultant fuzzified result is then passed to deffuzifier for conversion to crisp output which can be used to control the traffic actuator.

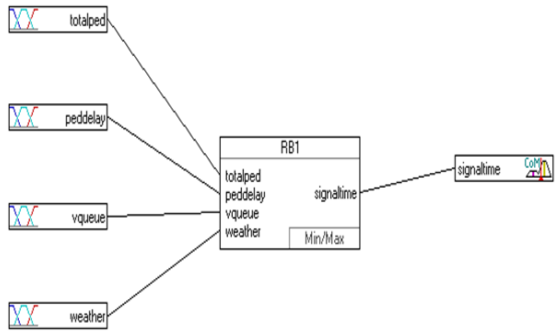

Figure 5: The Fuzzy Logic system for the proposed intelligent traffic control

4.2.1 Fuzzy Rules Formation

Fuzzy-based systems use rules to represent the relation among the linguistic variables and to derive actions from the inputs. Production rules consist of a condition (IF-part) and a conclusion (THEN-part). The IF-part can consist of more than one precondition linked together by linguistic conjunctions like AND and OR.

To Control the timing of traffic signal intelligently demand evaluation of traffic situation constantly within a defined possible space of time. The total number of rules is the product of the number of each variable's membership function involved in traffic situation. In this case VQueue(3), peddelay(3), Totalped(3), weather(2) and signtime(3). The total number of rules was one hundred and sixty-two (162); a snapshot of the rule formation platform with some of the rules is in Figure 6.

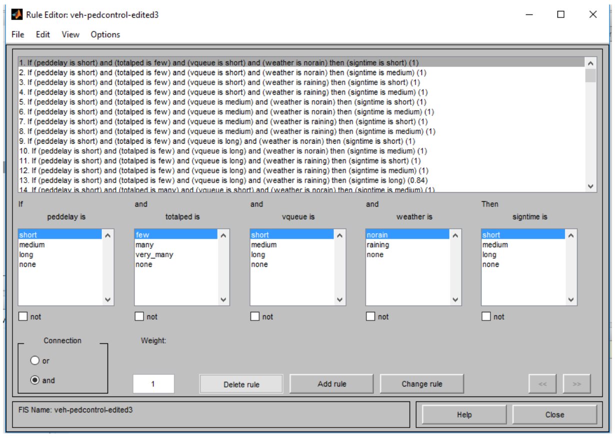

Figure 1: Fuzzy Rules

4.2.2 The Inference Model Evaluation Process

In the case of rule evaluation, inputs are applied to a set of if-then control rules and the rule firing strength $y_{w(i)}$ of each of the rules is calculated using AND operator;

Using 'and' operator, $y_{w(i)}$ can be determined using Equation (1).

$$y_{w(i)} = \left(Min(\mu_{vq(i)}, \mu_{pd(i)}, \mu_{tp(i)}, \mu_{w(i)}\right) \quad (1)$$

where

$\mu_{vq(i)}$ – vehicle count membership function for evaluation of rule *i*

International Journal of Applied Information Systems (IJAIS) – ISSN : 2249-0868
Foundation of Computer Science FCS, New York, USA
Volume 12 – No. 16, October 2018 – www.ijais.org

$\mu_{pd(i)}$– pedestrian delay membership function for evaluation of rule *i*

$\mu_{tp(i)}$ – total pedestrian membership function for evaluation of rule *i*

$\mu_{w(i)}$ – weather membership function for evaluation of rule *i*

i = 1 to 162 (total number of rules)

Using the centroid de-fuzzification method, the evaluation result of each rule denoted by y_i, is given by equation (2)

$$y_i = Max(\,(Min(\mu_{vq(i)}, \mu_{pd(i)}, \mu_{tp(i)}, \mu_{w(i)}),\ \mu si)) \quad (2)$$

The general combine consequences of the outcome of all the rules *ST* is given by Equation (3)

$$ST = \frac{\sum_i^m \mu_{y(i)} * y_i}{\sum_i^m \mu_{y(i)}} \quad (3)$$

For the FITC inference model, by incorporating equation (2), ST becomes

$$ST_{FITC} = \frac{\sum_i^m \mu_{y(i)} Max\left(Min\left(\mu_{vq(i)}, \mu_{pd(i)}, \mu_{tp(i)}, \mu_{w(i)}\right)\mu_{s(i)}\right)}{\sum_i^m \mu_{y(i)}} \quad (4)$$

Where

ST_{FITC} is the signal time slot for FITC

The evaluation structure for inference process is represented in Figure 7. This structure illustrates evaluation process from antecedence where inputs are fuzzified using membership functions, to rule formation (162) and then evaluation of each rule. The aggregation of various rule result gives fuzzified output result. Deffuzification of the fuzzy result gives crisp value as signal time.

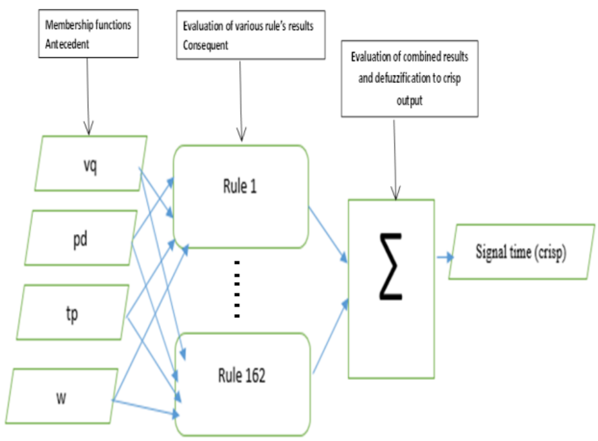

Figure 7: Illustration of Inference Process

The sample signal time outputs from the reasoner are represented in Table 1. This output serves as input to VISSIM simulator through VISSIM COM interface for a dynamic traffic control.

Table 1: Signal Time Output with Sample Input

Trial No.	Peddelay (Seconds.)	Totalped --	Vehicles Queues	Weather Variable	Green Light Duration
1	245	109	7	0.94	21.0
2	190	12	14	0.55	14.9
3	288	116	8	0.98	20.3
4	288	59	41	0.15	18.4
5	127	110	40	0.96	20.5
6	197	5	43	0.94	15.8
7	204	91	38	0.40	21.4
8	197	26	36	0.04	16.0
9	48	6	5	0.83	18.4
10	209	39	48	0.04	18.5

4.3 Implementation of four way intersection in VISSIM

4.3.1 Speed limit

Speed limit is the maximum speed expected of vehicles on the road within specified environment. Nigeria speed limit for various vehicle types and roadways represented in Table 2 was used as a guide to set the speed limit for vehicles in the modeled road network as summarized in Table 3

Table 2: Vehicular speed limit in km/hour (Nigeria Highway Code, 2013)

Vehicle type	Town and cities(km/hr)	Highway (km/hr)	Express way(km/hr)
Motorcycles	50	50	-
Private Cars	50	80	100
Taxis and Buses	50	80	90
Tankers and Trailers	45	50	60
Tow vehicles (while towing)	45	45	45
Tow vehicles (while not towing)	50	60	70

Table 3: Simulation speed limit

Types of vehicles	Max. Speed Distribution for simulated road network
Car	50 km/hr.
Bus	50 km/hr.
HGV	50 km/hr.
Bike	12 km/hr.
Pedestrians	5 km/hr.

4.3.2 General Model layout

The major process of model development comprises of the network geometry design, lane formation using network links, detectors and stop signs placement and configurations, modeling traffic parameters, placement of routing decisions and reduced speed areas for turn movements, assigning priority for movements in conflict areas and designing signals. Design of pedestrian links as crosswalks and detectors were placed for pedestrian detection. Road network models were developed using typical intersection characteristics along state road in Kano. Intersections were modeled at the length of 500 meters for sufficient queue length.

The built in Wiedemann 99-car following model was used for vehicle behavior, and default driving behavior parameters adopted (PTV, 2011). Pedestrians were modeled as a type of vehicles moving at the maximum speed of 5km per hour. The Crosswalks were modeled to allow pedestrians to follow each other as well as to overtake if required within the same directional link. The crosswalk comprises of two lanes in opposite direction for up-down movement.

4.3.2.1 General simulation settings

The purpose of the model is to build a four way intersection with multiple lanes and pedestrian crossing so as to generate various traffic types, create various scenarios based on traffic volumes to measure their interactions and evaluate the management of right of way amidst the road users. Scenarios vehicular volume ranges from 100 to 1000 on each link, at the increment of 100 per scenario. The vehicle volume was based on average vehicle counts obtained from Federal Road Safety corps in Kano, Nigeria. Pedestrian volumes range from 20 to 120 at the increment of 10 on each pedestrian crosswalk across each link.

Simulation run length is 3600 sec. The simulation speed is set to maximum speed depending on the speed of the processor. The snapshot of this setting is in Figure 8 while Figure 9 is the snapshot of driver's behavior settings window.

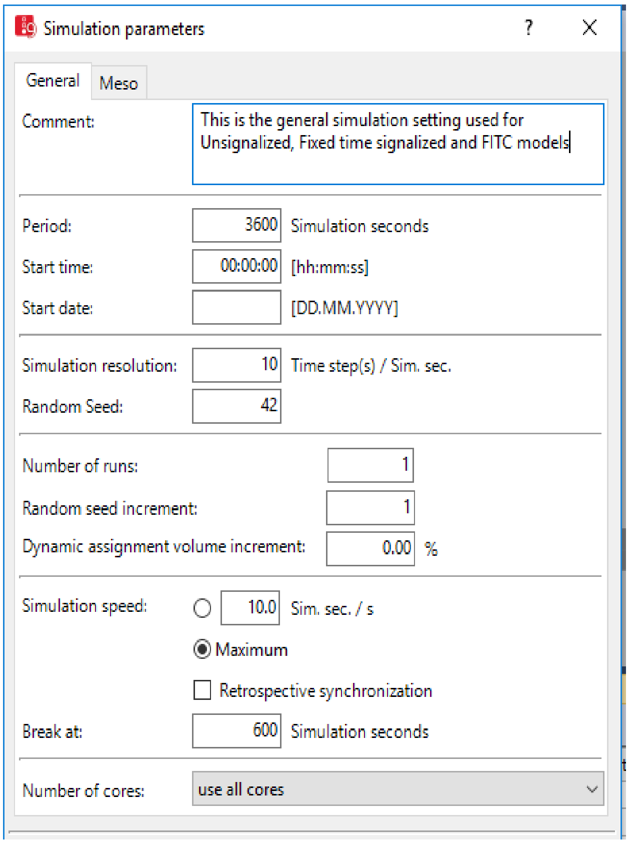

Figure 8: General simulation settings

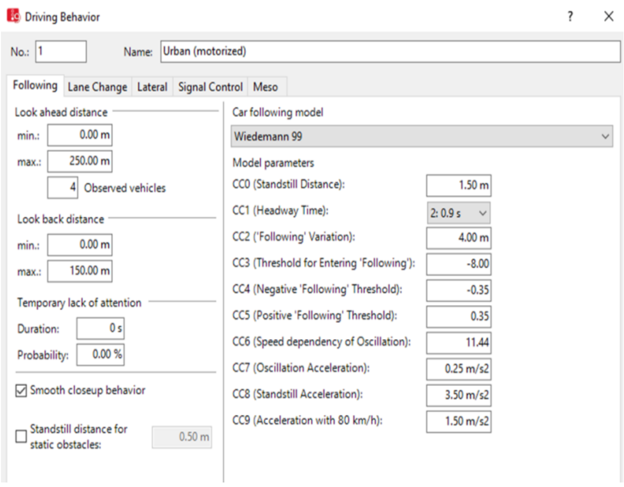

Figure 9: Driver's Behavioral settings

4.3.3 Signalized four Way Intersection model with Fixed Time Traffic Signal Control

A model of four ways intersection was developed in VISSIM for fixed time signal control, the snapshot of this model is in Figure 10. The actuated signal controller consists of one signal head for each motorized lanes and two signal heads for each pedestrian crosswalks. The signal heads are controlled by signal programs which consist of signal sequence (red/green/amber) and their time schedules.

The intersection model comprises of Maiqwan Road, Tarauni road, farm center road and state road.

International Journal of Applied Information Systems (IJAIS) – ISSN : 2249-0868
Foundation of Computer Science FCS, New York, USA
Volume 12 – No. 16, October 2018 – www.ijais.org

The delay measurement for the vehicles and pedestrians were evaluated and used for network performance analysis.

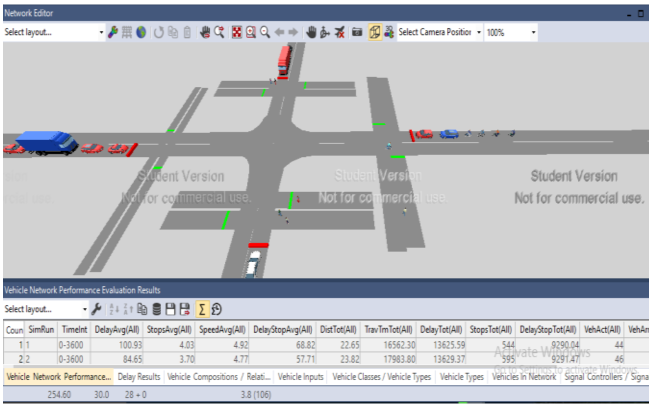

Figure 10: Model of Crosswalk incorporated four ways intersection with fixed time traffic actuator

4.3.4 Model of Fuzzy Intelligent Traffic Control Network

The fixed time actuated program was replaced with FITC program from MATLAB using COM interface to control the signal timing allocation.

The various scenarios were used varying pedestrian volumes within each vehicle volume variants. Vehicle volumes varied from 100 to 1000 on each link and pedestrian traffic volumes from 20 to 120 within each vehicle traffic volume as implemented in fixed time traffic control model. Figure 11 is the snapshot of the model network.

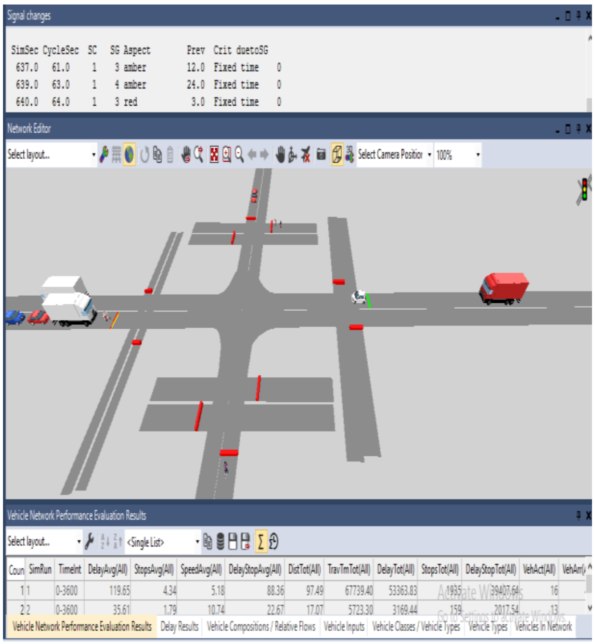

Figure 11: Model of FITC Road Network

5. EVALUATION RESULTS AND DISCUSSIONS

The evaluation and result discussions were discussed in this section according to the control strategies.

5.1 Fixed Time Traffic Control Delay Results

For each vehicular volume, number of simulated pedestrians were varied, average of this variant were calculated for each network scenario group as given in equation (5).

$$AVD(j) = \frac{\sum_{i=1}^{n} T_{tm(i)} - T_{ac(i)}}{n} \quad (5)$$

where

AVD(j) – average vehicle delay for scenario(j)

$T_{tm\ (i)}$ - Theoretical travel time if no obstruction or interruption on the path of vehicle (i)

$T_{ac(i)}$ - The actual travel time of the vehicle(i) on the road network

n - number of simulated vehicles on the network

Likewise for pedestrians, average pedestrian delay for each scenario were computed using equation (6)

$$APD(j) = \frac{\sum_{i}^{n} pd(i)}{n} \quad (6)$$

Where

APD(j) - average pedestrian delay for scenario(j)

Pd(i) - individual pedestrian delay

n - total number of simulated pedestrians

Average vehicle delay increases from 22.43 sec to 114.68 sec as traffic volume increases across the groups. The average pedestrian delay ranges from 12.98 sec. to 22.53sec as traffic volume increases across the groups. This delay result for vehicles and pedestrians is summarized in Table 4.

Table 4: Fixed Time Traffic control Vehicle and Pedestrian delay result

Vehicle./Pedestrian Volume	Fixed Time Average Vehicle delay(sec)	Fixed time Average Pedestrian delay(sec)
100/20	22.43	12.98
200/30	45.23	11.83
300/40	66.04	14.13
400/50	76.85	15.63
500/60	82.67	16.78
600/70	83.56	17.93
700/80	103.57	19.08
800/90	109.01	20.23
900/100	110.57	21.38
1000/110	114.68	22.53

5.2 Fuzzy Intelligent Traffic Control Scenarios Result

The FITC road network model performance evaluation result follows the same format as fixed time traffic control using Equations (5) and (6). For the scenario groups, the average vehicle delay ranges from 19.12sec to 67.48sec, while the pedestrian delay ranges from 9.05sec to 21.7sec as traffic volume increases. This results for average vehicle delay and average pedestrian delay for all the groups are displayed in Table 5.

Table 5.2: FITC delay result

Veh. /Ped.	Vehicle delay FITC(sec)	Ped. FITC delay (sec)
100/20	19.12	9.05
200/30	25.83	10.39
300/40	40.83	12.32
400/50	48.29	13.66
500/60	47.25	15
600/70	44.75	16.34
700/80	67.59	17.67
800/90	69.02	19.01
900/100	69.94	20.35
1000/120	67.48	21.7

5.3 Comparative Performance of FITC and Fixed Time Traffic Control Results

Average vehicle delay for fixed time control network was compared with the delay result obtained from FITC system. The percentage improvement was computed for each compound scenarios using equation (7)

$$P_g = \frac{D_{Ft} - D_{FITc}}{D_{FITc}} x\ 100\% \qquad (7)$$

Where

P_g - Percentage gain/improvement

D_{Ft} - fixed time average delay

D_{FITC} - FITC average delay

Table 6 is the presentation of the vehicle's comparative result. Across the scenarios, average of 53.19% performance improvement was obtained. This comparism was plotted as displayed in Figure 8.

Table 6: Average Vehicular Delay Comparism for fixed time control and FITC

Veh./Ped.	Fixed time delay	FITC	Percentage improvement
100/20	22.43	19.12	17.31
200/30	35.23	25.83	75.11
300/40	66.04	40.83	61.74
400/50	76.85	48.29	59.14
500/60	82.67	47.25	74.96
600/70	83.56	44.75	86.73
700/80	103.57	67.59	53.23
800/90	109.01	69.02	57.94
900/100	110.57	69.94	58.09
1000/120	114.68	67.48	69.95

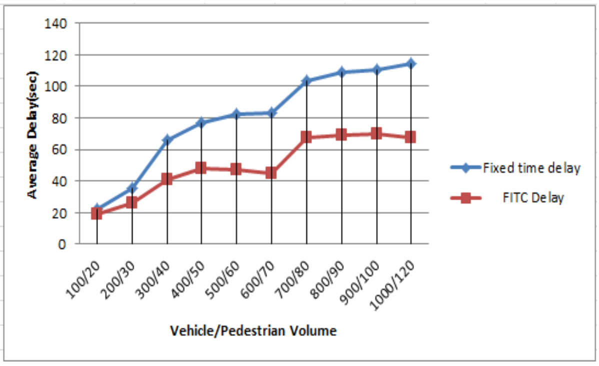

Figure 8: vehicle delay plot for fixed time and FITC

Table 7 is the presentation of the pedestrian comparative result. Across the scenarios, average of 13.13% performance improvement was obtained from FITC. This comparism was plotted as displayed in Figure 9.

Table 7: Comparing Pedestrian delays for Fixed time control and FITC

Traffic Scenarios	Fixed Time ped delay (sec)	FITC ped delay (sec)	Percentage improvement
100/20	12.98	9.05	43.49
200/30	11.83	10.39	13.86
300/40	14.13	12.32	14.69
400/50	15.63	13.66	14.42
500/60	16.78	15.00	11.87
600/70	17.93	16.34	9.73
700/80	19.08	17.67	7.98
800/90	20.23	19.01	6.42
900/100	21.38	20.35	5.06
1000/120	22.53	21.7	3.82
		Average Improvement	13.13%

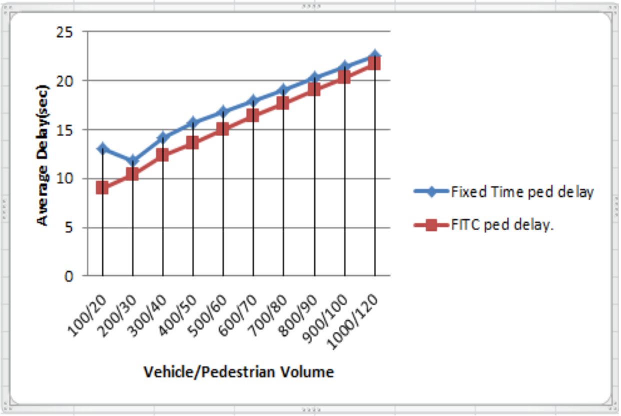

Figure 9: Pedestrian Delay Plot for Fixed Time and FITC

6. CONCLUSION

This research designed an architectural framework for vehicle-pedestrian interaction for a four-way intersection. Fuzzy logic intelligent system was developed for a sensitive interaction between the vehicles and pedestrians. The system is sensitive to both pedestrian and vehicular traffic in allocating signal time, hence harmonizing the conflicting interest of vehicle drivers and pedestrians. The system was implemented using a four way intersection. The traffic model was built in VISSIM traffic simulator. The model was evaluated using traffic delays for both vehicles and pedestrians. Evaluation results indicate optimized performance that will help to reduce traffic delay for drivers and pedestrians.

7. RECOMMENDATION FOR FUTURE WORK

Incorporation of Intelligent Transportation System with the internet of everything is a needful research direction that will make all elements of road transportation system to communicate better.

The intelligent system can also be implemented with other Artificial Intelligent methods.

Incorporation of priority pedestrian or VIP service at intersections can also be considered. It is also necessary to have priority crossing in case of emergency.

Other road infrastructure such as Roundabouts can be designed with pedestrian crossing intelligently incorporated.

8. REFERENCES

[1] Agarwal, N. K., (2011) Estimation Of Pedestrian Safety At Intersections Using Simulation And Surrogate Safety Measures. University of Kentucky Doctoral Dissertations. Paper 835. http://uknowledge.uky.edu/gradschool_diss/835 retrieve on 5/10/2015

[2] Akomolafe B. (2014) Transport Leave a comment daily newswatch, http://www.mydailynewswatchng.com/author/web-officer-2/ July 17, 2014

[3] Alam J. and Pandey M. K.(2014) Development of Intelligent Traffic Light System Based on Congestion Estimation Using Fuzzy Logic; IOSR Journal of Computer Engineering(IOSR-JCE) Vol. 16 Issue 3, Ver. VI, pp 36-44.

[4] Alexandersson S. and Johansson E. (2013) Pedestrians in microscopic traffic simulation Comparison between software Viswalk and Legion for Aimsun; Department of Civil and Environmental Engineering Division of GeoEngineering, Chalmers University Of Technology Othenburg, Sweden pp 69-75

[5] Aworemi, J. R., Abdul-Azeez, I. A., Olabode, S. O.(2010) Analytical study of the causal factors of road traffic crashes in southwestern Nigeria International Research Journals Vol. 1(4): 118-124 May 2010 http://www.interesjournals.org/ER

[6] Banks J., Carson J. S., Nelson B. L. and Nicol D. M.(2013) Discrete-Event System Simulation Fourth Edition.

[7] Chattaraj U and Panda M. (2005) Some Applications Of Fuzzy Logic In Transportation Engineering. Http://dspace.nitrkl.ac.in/dspace/bitstream/2080/1179/2/fuzzy_transportation%20[Read-Only]%20[Compatibility%20Mode].pdf

[8] Chavan S. S., Deshpande R. S., and Rana J. G. (2009); Design Of Intelligent Traffic Light Controller Using Embedded System. Second International Conference on Emerging Trends in Engineering and Technology, ICETET-09. GH Raisoni College of Engineering, Nagpur, India

[9] Chen L., Chen C.and Ewing R. (2012) The Relative Effectiveness of Pedestrian Safety Countermeasures at Urban Intersections — Lessons from a New York City Experience TRB 2012 Annual Meeting.

[10] Hassan S. A. (2013) Improving Pedestrian Facilities At Signalized Crossings, Thesis For The Degree Of Doctor Of Philosophy University Of Southampton Faculty Of Engineering And The Environment. http://eprints.soton.ac.uk Retrieve 6th June 2016.

[11] Hoogendoorn–Lanser, S. (1998), Structured modelling of multi Structured modelling of modal urban travel choice behaviour, 4th TRAIL PhD Congress.

[12] Johansson F. (2013) Microscopic Modeling and Simulation of Pedestrian Traffic Department of Science and Technology, Linköping University, SE-Norrköping, Sweden.

[13] Kheradmandi Q.S.B and Strøm F. (2012) Controlling a Signal-regulated Pedestrian Crossing using Case-based Reasoning, Norwegian University of Science and Technology.

[14] Koukol M. and Přibyl O. (2013) Design Methodology of a Fuzzy Control System in PTV Vissim Transactions On Transport Sciences Volume 6 Number 4 DOI: 10.2478/v10158-012-0045-9, pp177, https://www.researchgate.net/publication/264638114

[15] Kuan-min C. ,Xiao-qiang L., Hai J. and Yang-dong Z.(2010) Towards the pedestrian delay estimation at intersections under vehicular platoon caused conflicts Scientific Research and Essays Vol. 5(9): pp. 941-947, ISSN 1992-2248 © 2010 Academic Journals.

[16] Kothuri S. M. (2014) Exploring Pedestrian Responsive Traffic Signal Timing Strategies in Urban Areas, Portland State University,

http://pdxscholar.library.pdx.edu/open_access_etds May 10th 2016

[17] Moreland M. (2015) Pedestrian Bridges: Safety vs. Convenience http://www.mikeontraffic.com/pedestrian-bridge-safety-vs-convenience/

[18] Olanrewaju O. M., Obiniyi A. A. and Junaidu S. B. (2017) Fuzzy Logic Concept for Safety Driven Vehicle-Pedestrian Traffic Interaction International Journal of Computer Applications (0975 – 8887) Volume 167(1), pp 24-28 www.ijcaonline.org/archives/volume167/number1/olanrewaju-2017-ijca-914058.pdf

[19] Papacostas C.S. and Prevedouros P. D.(2008) Transporation Engineering and Planning, third Edition, Prentice-Hall of India Private Limited.

[20] Tan K.K., Kalid M. and Yusof R.(1996) Intelligent Traffic Lights Control by Fuzzy Logic; *Malaysian Journal of Computer Science,* 9(2):29-35

[21] Yulianto B. and Setiono (2012) Traffic Signal Controller for Mixed Traffic Conditions IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN: 2278-1684 Volume 4, Issue 1 (Nov-Dec. 2012), PP 18-26 www.iosrjournals.org.

[22] Zadeh L. A. (1975) The Concept of a Linguistic Variable and its Application to Approximate Reasoning-Information Sciences 8, 199-249, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.320.7063&rep=rep1&type=pdf