DEVELOPMENT OF A FRAMEWORK USING INTELLIGENT NEURO-PETRINETS FOR URBAN ROAD TRAFFIC MODELING WITH SPECIAL EMPHASIS ON CONGESTION

By

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Submitted

IN PARTIAL FULFILLMENT OF THE REQUIREMENT OF THE DEGREE OF DOCTOR OF PHILOSOPHY

To

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

DEHRADUN

March, 2012

ACKNOWLEDGEMENT

I am highly indebted to my internal guide **Dr. Neelu Jyoti Ahuja** who has guided me all through the completion of this PhD thesis. My enthusiasm in this subject is inspired by her profound knowledge in this area and her elegant research style. She has helped me with wise advice, useful discussions, comments and facilities. She has never hesitated to spend her precious time and effort to guide my work. She helped me to overcome the various difficulties and challenges that were raised at various stages of the project. It is just ineffable to express my deep gratitude towards her.

I am very grateful to my external guide **Prof. (Dr.) Manuj Darbari.** His incessant enthusiasm, support, knowledge and inspiration have given me new dimension to work with proper attitude. Without his sustained and sincere efforts, this thesis would not have taken this shape.

I would also like to pledge my deep sense of gratitude to **Prof (Dr.) Parag Diwan**, Vice Chancellor, University of Petroleum and Energy Studies, Dehradun. For extending all the facilities required for carrying out this thesis work.

I am thankful to **Prof. (Dr.) Shrihari**, Dean College of Engineering Studies, for his guidance related to research norms of the institute at all stages.

I would also like to give special thanks to **Prof. (Dr.) Manish Prateek**, Center for Information Technology and **Dr. Nihal Anwar Siddique**, Department of Civil Engineering and Environmental Science, for providing me necessary guidance during crucial times I am also thankful to **Mr. Praveen Kumar Shukla**, Senior Lecturer, Department of Computer Science, Babu Banarasi Das University, Lucknow for his support during this research work.

I would like to thank my wife **Ranjana** and son **Shashank** for helping me in carrying out my research work. Lastly, I would like to dedicate this work to my parents, **Mr. R. C. Asthana** and **Mrs. Rita Asthana** for being present with me all the time with their blessings.

Rishi Asthana

DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

Rishi Asthana

THESIS COMPLETION CERTIFICATE

This is to certify that the thesis entitled **"Development of a Framework using Intelligent Neuro-Petri nets for Urban Road Traffic Modeling with Special Emphasis on Congestion"** submitted by **Rishi Asthana** to **University of Petroleum and Energy Studies** for the award of the Degree of Doctor of Philosophy (Engineering) is the bona fide record of the research work carried out by him under our supervision and guidance.

The content of the thesis, in full or parts have not been submitted to any other Institute or University for the award of any other degree or diploma

External Guide

(Prof (Dr.) Manuj Darbari)

Internal Guide

(Dr. Neelu Jyoti Ahuja)

CONTENTS

EXECUTIVE SUMMARY

The traffic congestion in urban areas is a very critical problem. The major reasons of the traffic congestion are population growth in urban cities, growth in number of vehicles, limited capacities of road infrastructure etc. It results in many drawbacks to the society and people in terms of pollution in environment, wastage of time, health hazards, economic cost etc. The development of control systems to deal with the traffic congestion in urban areas is a critical research issue. Various traditional methods have been applied to reduce the problem of traffic congestion. Some of these include road pricing, supporting the green traffic, parking enforcement, fuel levies, expansion of existing road networks, elimination of roundabout and so many others. Non-linearity and unpredictability of traffic movement and the high cost associated with the expansion of the existing infrastructure of road networks and other related problems, the traditional methods have become very unusual.

During this time, the technology has been integrated to develop some intelligent control systems to deal with the traffic congestion issues, specifically in urban areas. Many intelligent approaches have been integrated to model and simulate or implement the real time traffic control systems, like activity theory, neural network, fuzzy logic, Petri nets, genetic algorithms and their hybrid approaches.

In this thesis, the work carried out is to model and simulate the real traffic control system in the urban city, Lucknow, the Capital of Uttar Pradesh, India. The proposed work consists of modeling at one traffic intersection and handling traffic congestion with minor sub lane bypass in a road network. The work has been done in two phases, first phase includes the conceptual framework modeling of the proposed system by activity theory and model driven engineering flavored with Petri net modeling in a fuzzy environment as

well. Subsequently, the neural network is used to make the system intelligent and genetic algorithms are utilized to optimize the weights associated with the system. In the second phase, the conceptually modeled system is simulated through the MATLAB 7.0 and it is proved that the results are found competitive and satisfactory as well.

The work is summarized in the following steps:

Step -1 Development of framework for urban traffic simulation using model driven engineering and activity theory

A framework for modeling the urban traffic control system has been developed using model driven engineering and activity theory. Activity theory is utilized to model the conceptual, behavioral and philosophical aspects of the system. The concept of abstract platform provides effective methods of exchange of signals between various traffic agents. Model Driven Engineering leads to successively refine models from analysis to design and then automatically generates the associated code. A common pattern in MDA development is to define a platform- independent model of a distributed application and to apply (parameterized) transformations to PIM to obtain one or more platform specific models (PSMs). When pursuing platform - independence one could strive for PIMs, that are neutral with respect to all different classes of middle ware platforms.

Activity theory is a philosophical and cross disciplinary framework for studying different forms of human practices as development processes, with both individual and social levels interlinked at the same time. It is commonly used within Enterprise Modeling community although it is not a fully developed theory but a framework from which several ideas, theories and methods for conceptualizing human practices (activity) in relation to computers could emerge.

A set of Activity Theory relations with Traffic Agents has been developed using Model Driven Engineering. In order to incorporate both the methodologies the Platform Independent Model of an Urban Traffic Control System is represented in UML of MDE framework to combine Activity Theory with MDE. The two major components, traffic signaling and physical road networks are further elaborated for reducing the traffic congestion at intersections and main roads for achieving smooth flow of traffic.

Step -2 Development of Fuzzy MDE environment

Humans are capable to use linguistic information precisely in their decision making. Due to imprecise and uncertain nature of the linguistic information, machines are not capable to use them in decision making processes using traditional methods. To make the machines intelligent and to deal with uncertainties, like humans in this regard, Fuzzy Techniques are used.

Fuzzy Logic is the technique to deal with uncertainty inherent in the system. It is defined as the logic to make the uncertain working of the system precise. Fuzzy Control Systems are highly applicable in developing the control systems for handling congestion in urban traffic. The fuzzy extended MDE for general activity diagram for urban traffic system is developed. MDE supports both behavioral and structural aspects of a system so fuzzy MDE concepts are propounded in the present study as: Fuzzy structure and Fuzzy Behavior. The use of fuzzy with MDE covers the General Activity Diagram linked with Urban Traffic System.

In order to represent the Fuzzy PIM, linguistic variables and fuzzy rules for entering the uncertainty into the performance computations are used. The classical binary relation represents the presence or absence of connection or absence of a connection or interaction or association between Model Driven Engineering Concepts and Activity Theory framework with reference to Urban Traffic System. The help of relationship link of fuzzy set theory achieves the mapping of various entities of abstract model. The existence of uncertainty in message passing and control between different entities is evaluated by Cartesian framework to generate membership functions.

Step -3 Development of n-dimensional self-organizing grid network for lane by - pass system

Petri nets are graphical and mathematical modeling tool applicable to many systems and it is proved to be a promising tool for describing and studying information processing systems that are characterized as being concurrent, asynchronous, distributed, parallel, nondeterministic, and/or stochastic. As a graphical tool, Petri nets can be used as a visual-communication aid similar to flow charts, block diagrams, and networks. In addition, tokens are used in these nets to simulate the dynamic and concurrent activities of systems. As a mathematical tool, it is possible to set up state equations, algebraic equations, and other mathematical models governing the behavior of the systems.

Various extensions of the Petri net approaches are introduced, like Colored Time Petri Net (CTPN), Variable Speed Petri Net (VSPN) and Timed Control Petri Net (TCPN) etc. A neuro Petri net approach is used to model a physical road network. The forward propagation Petri net model is used for focusing on the simple cause effect framework, integrating continuous Petri net learning mechanism. The model is divided into two basic parts. The forward propagation Petri net model focusing on simple Cause-Effect framework. The second part focuses on continuous Petri Net Learning mechanism. The model of Forward Propagation of Petri nets which uses the concept of producer consumer network by producing minor sub lane by-pass system near the congested intersection is developed and its algorithm for training is provided. The single unit producer-consumer is extended to N dimension self organizing Grid Network which helps two dimensional grid of producer - consumer link with buffer interlocked and virtual counter which keeps the track of diversion of Token based on the congestion in the road network (i.e. consumer), supply of new minor sub lanes (i.e. producers) and diversion of traffic through VMS maintains smooth flow of traffic. For training of above grid network an algorithm is proposed. The counter (M) keeps track of token numbers stamped by the layer through which is it is being generated and finally arriving at particular layers.

Step – 4 Enhancing the capabilities of n-dimensional self-organizing Petri net grid network using neuro-genetic algorithms

Genetic Algorithms are search and optimization techniques based on Darwinian’s principle of Natural Selection. The basic idea behind the natural selection is “select the best, discard the rest”. The optimization strategies by genetic algorithms are implemented by simulating evolution of species through the natural selection.

Artificial neural networks (ANN) have been developed as generalizations of mathematical models of biological nervous systems. First wave of interest in neural networks (also known as connectionist models or parallel distributed processing) emerged after the introduction of simplified neurons. The basic processing elements of neural networks are called artificial neurons or simply neurons or nodes.

These Genetic Algorithm and Neural Network approaches are integrated and utilized with Petri net modeling, called Neuro-Genetic Petri Nets.

Neuro-Genetic Petri Nets are utilized to make intelligent urban traffic control system. The combination of genetic algorithm provides dynamic change of weight for faster learning and converging in Neuro-Petri Net. The use of genetic learning method performs rule discovery of larger system with rules fed into a conventional system. The genetic algorithm is used to search for the appropriate weight change in neural network which optimizes the learning rate of the entire network. A good Genetic Algorithm can significantly reduce Neuro-Petri Net in aligning with the traffic conditions, which other-wise is a very complex issue.

Step – 6 Experimental evaluation/simulation by using the concept of Fuzzy Logic in MATLAB7.0 environment.

In the first phase of implementation of the proposed approach, the efficient control of traffic movement is simulated at X junction by considering various parameters, like traffic queue, incoming flow, green time, etc. The three sensors are placed, Front Sensor, Middle Sensor and Rear Sensor. These sensors read the traffic flow, traffic density and number of vehicles, gradually. The system to be simulated has three modules, green phase, next phase and switch module. Green Phase module is responsible for managing the green time and switch module is responsible for phase sequence change with the help of next phase module having input traffic queue. The approach is implemented by Mamdani Type Fuzzy Rule Based System. The appropriate knowledge base is identified along with the generation of membership functions, representing real time environment. The outcomes in this phase are found satisfactory as compared with analytical decision making of the real system.

To deal with the limited infrastructure of existing road networks and traffic intersections that result in the Traffic Congestion, the minor lanes can be used to reduce the traffic density. This concept is implemented in the second phase of implementation to deal with the problem of traffic congestion. In this phase, an algorithm is developed and implemented for decision making of route diversion through the generation of minor lane by-pass system using VMS (Variable Message Sign Board). The outcomes of the algorithm are found satisfactory and applicable to handle the real situations of traffic congestion, as well. Overall, the proposed system constituted by both phases is found satisfactory as per experimental results.

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List of Publications

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CHAPTER 1

INTRODUCTION

PREAMBLE

The proposed work deals with the problem of Traffic congestion in the urban city, Lucknow, capital city of Uttar Pradesh, India. In this work, a Framework is proposed for modeling the traffic intersection along with its green time and phase sequence control using Activity Theory and Model Driven Engineering and simulated using Fuzzy Techniques. A lane by-pass system with minor lanes based traffic diversion is also proposed to efficiently overcome with the problem of Traffic Congestion using intelligent Neuro-Petri Net and also simulated in MATLAB 7.0.

1.1 NEED OF THE PRESENT WORK

1.1.1 TRAFFIC CONGESTION: AN OVERVIEW

Road traffic congestion [1] is a situation that is characterized by high number of vehicles on a road that leads to low speed and longer time taken for a trip. Population growth has increased the number of vehicles and passengers on the country's freeways and highways, resulting in the problem of traffic congestion. Traffic congestion can be described as either recurring or non-recurring [2]. Recurring congestion is associated with expected delays; it result from large number of vehicles at the same time (during peak commuting) at the same place(at busy intersection).Non-recurring congestion is associated with unpredictable delays that are caused by spontaneous traffic incidents, such as accidents.

Both recurring and Non-recurring congestion are associated with stop-start driving condition which has its negative effects on both the owners of vehicles and also to the environment. Some of the drawbacks of congestion include pollution, increased economic costs, stress, time wastage and increased health hazards to the individuals. As per 2003 Urban Traffic mobility survey (Urban Statistics, CPCB, 2003) published in Transportation Research India, traffic congestion in 2003 resulted in loss of 3.5 million hours of productivity valued at 34000 crores.

The approximate happening of the traffic congestion in urban city Lucknow is described by traffic density and time graph in a particular day, as shown in Figure 1.1. The graph shows that the congestion line is an extreme line after that the chances of traffic jam are too high due to the increment in the traffic density. This graph is also helpful to find the peak hours, when the traffic congestion is high.

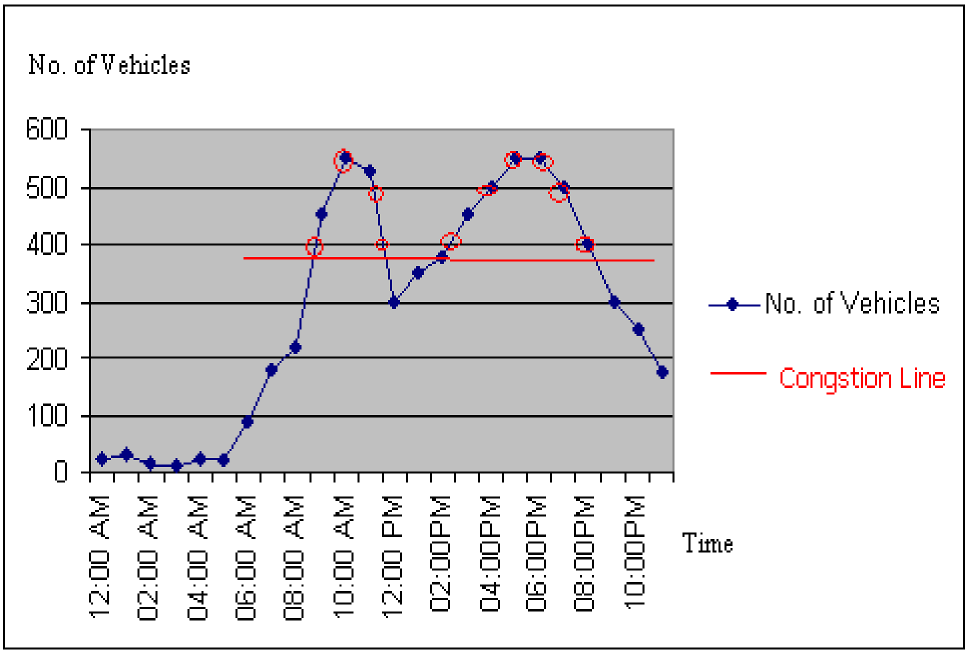


Figure1.1 Traffic Density and Time

1.1.2 REASONS OF TRAFFIC CONGESTION

It is important to identify the reasons of traffic congestion before going deep into its solutions. Population growth, leading demand of private vehicles, limited capacity of our traffic road networks infrastructure [2, 3, 4] are the major problems leading to the traffic congestion. Some of these are discussed here.

1. Population Growth in Urban Cities

The education, more job opportunities, business, comforts are many reasons that are attracting peoples from interior places to move towards the urban cities. This situation has lead to the exponential growth in the population [5] of urban areas. The urban population [3] has grown up by 10% in 1901 to 38% in 2011. It is known that 38% of the total urban population is located in metropolitan cities. This population growth has extreme impact on the traffic movement of any city. The limited space capacity of the traffic infrastructure is not capable to deal with this mob at peak times and result in a very complex problem, traffic jams.

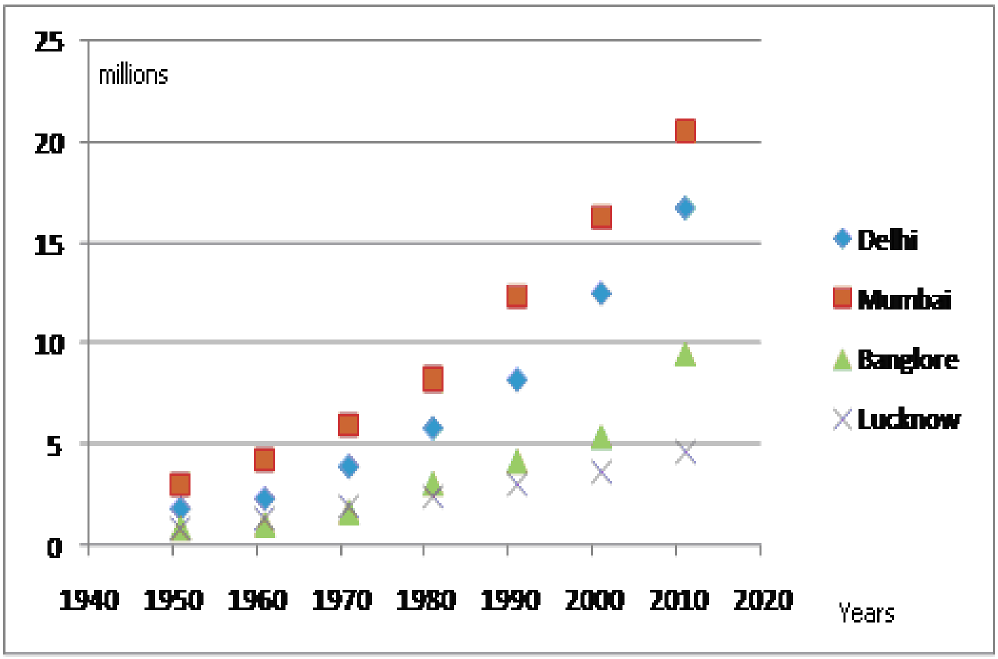


Figure 1.2 Status of Population in different cities

2. Growth in number of vehicles

Due to economic simplicity, the number of private vehicles [2, 3] has been increased too much, as given in Figure 1.3. The public transport facilities, like bus, train etc. should be preferred rather than to promote the use of private vehicles to overcome the consequences of traffic congestion. Car pooling is also a solution to the problem of increment in private vehicles.

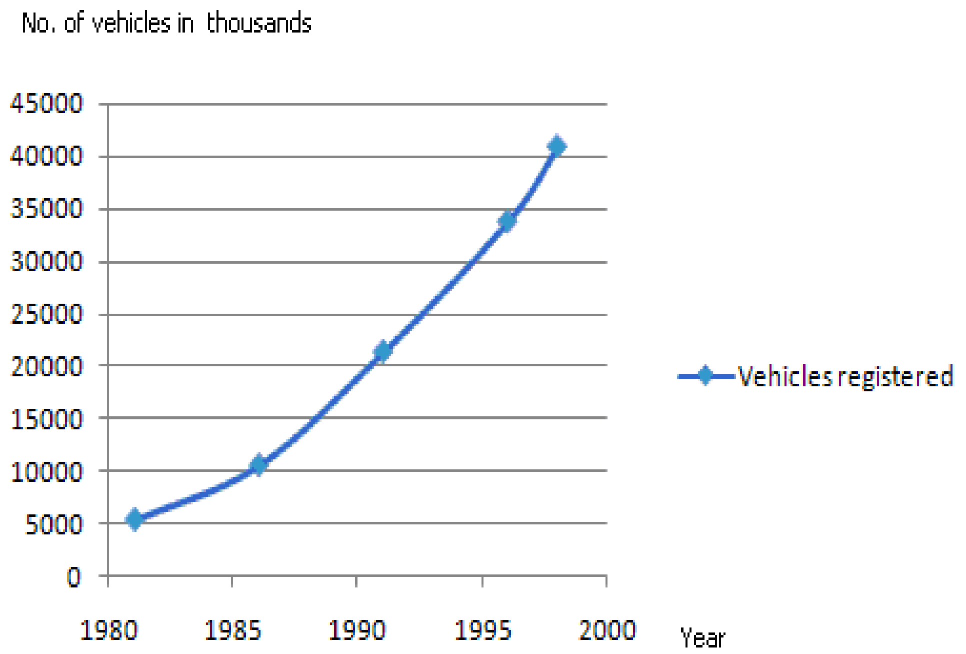


Figure 1.3 Vehicles registration in India

3. Limited capacities of road infrastructure

The infrastructure of road network [2, 3] is fixed and space capacity is also limited in mid cities. Extensions of the infrastructure like over bridge manufacturing are very expensive in terms of economic and financial circumstances. Due to these constraints, current infrastructure is not capable of dealing with incremented vehicles and populations for smooth traffic flow. Table 1.1 summarizes the issue of limited capacity of infrastructure along with population and vehicle growth.

Table 1.1

Major Statistics of Road, Population and Vehicles

Attributes	**1951**	**2009**	**Increase No. of Times**
Road Length	837	1900	2.27
Population (Lacs.)	29.9	160	5.35
No. of vehicles	35000	15.03 Lacs.	42.94

1.1.3 CONSEQUENCES OF THE TRAFFIC CONGESTION

Traffic congestion affects [2, 6] the daily life in various dimensions. Some of them are discussed here.

1. Environment

Traffic congestion increases the time used for a certain trip, this means that the vehicles will be more likely to emit more pollutant gases into the atmosphere as compared to travel where there is less traffic. Pollution includes both air and sound pollution. Air pollution degrades the environment. Some of the minerals present in gases emitted by vehicles which degrade the environment include sulphur, lead and carbon dioxide. Once the environment is degraded by these gases it poses some health hazards such as acid rain which may cause damage to property and also skin cancer. One of the major issues due to air pollution is Global warming. It is the current issue of concern and traffic congestion can be linked as a source of global warming.

2. Wastage of Time

Due to traffic congestion too much time is wasted that could have been used to conduct other economic activities. Many business opportunities are lost due to the inefficiency caused by traffic congestion. It can also be associated with causing lateness to a person who may be urgently needed somewhere. It may also hamper emergency cases such as ambulances may be unable to reach hospitals on time causing even loss of lives.

3. Health hazards

People caught in the traffic jams experience road rage. This leads to stress and other stress related diseases. Lives may be lost in traffic jams especially during emergencies due to slow emergency vehicles. Another health hazard is the exposure of commuters to the pollutant gases. The congestion of vehicles concentrates the pollutant gases and this poses great health danger.

4. Economic cost

The amount of excess fuel lost during traffic congestion is far too much and this cost is borne by the owner. Other cost could be associated with social cost such as the environment and also the cost incurred to repair vehicles which spend more time idling in traffic congestion. Acid rain may also lead damage of property leading to unnecessary loss to the economy. Thus the total economic cost is too high and strategies should be set in place to avoid these costs which are avoidable.

1.1.4 METHODS TO DEAL WITH TRAFFIC CONGESTION

To deal with the issue of traffic congestion, several approaches [7] are applied to the traffic movement. These are specifically sub-divided into two groups, Conventional Approaches and Intelligent Approaches.

A. Conventional Approaches

Road traffic congestion problem could be solved through the use of road pricing, tax levies on fuel prices, expansion and improvement of existing infrastructure, eliminating round about, parking enforcement and supporting green traffic. These solutions are individually analyzed below in terms of their advantages and disadvantages.

1. Road pricing

Road pricing [2, 6, 8, 9, 10, 11, 12] refers to charges levied on road users. This levies are collected directly from road users through setting up infrastructures called tolls and differentiation of pricing during peak and off peak hours would be a solution to road congestion because for one having the assumption that road users are rational and will try to utilize the roads during off peak hours due to low toll charges. Therefore this would help solve the problem of congestion. Another rationale concerning road pricing is that less people will use private means of transport due to the extra cost levied on vehicles and therefore they will use public means of transport. The advantages of this approach are,

1. It is a source of revenue to road authorities and this revenue could be used to improve the existing roads and even expanding the available road infrastructure that will help to decongest roads during peak hours.

2. It discourages private means of transport through the extra private cost imposed in form of levies and therefore in some way helps to reduce the negative effects of congestion such as pollution.

The Disadvantages of road pricing are,

1. The methods of road pricing cannot be used to resolve the problem of environmental degradation, caused by the traffic congestion.

2. It will force middle income earners to use public means of transport which will make them feel inferior in the society.

3. Higher income earners may find the toll charges very negligible and may not respond to the levies imposed and therefore the problem of traffic congestion will persist.

4. The process of setting up toll stations and employing a large number of people may tend to be cumbersome and may require high administrative costs.

5. The toll stations may themselves be a cause of traffic congestion as it will require serving many vehicles at the same time and therefore will slow the traffic flow.

2. Fuel levies

The government may impose fuel levies [2, 13] that may ease the problem of traffic congestion. Fuel levies will increase the retail price of fuel prices used by the vehicles and this will discourage people from using private means of transport and rather rely on public means of transport. However this will have some disadvantages which include inflation and loss of confidence in the existing government due to such policies.

3. Expansion and improvisation of existing roads

Another solution would be the expansion of road networks [6] through increasing the number of lanes available. Most of the time traffic congestion occurs in the morning and in the evening. At the time in the morning the lanes towards a town centres are usually congested while the other lanes are usually idle. In the evening the traffic out of the town centre are the ones that are jammed. If the lanes of roads are adjustable such that in the morning and evening (peak hour) the vehicles can use the other lanes that head in the opposite direction, the problem of congestion can be solved. The advantage of the expansion and improvisation of adjustable lanes will require less resource than building new roads. But the major disadvantage in this method is that shifting lanes may be very cumbersome and may be practically impossible, it may also cause confusion to drivers and may also increase accidents occurrence.

4. Elimination of Roundabout

Another solution to road traffic is the removal of roundabouts [2, 6] in the road network. Roundabouts are one of the factors that hinder traffic flow and they should be replaced with flyover where necessary. This would help to ease traffic control. One disadvantage of this method is that it would require a lot of money to construct the flyovers and also it would contribute to traffic congestion during the construction period. It is also not possible to eliminate every roundabout especially at local areas by making flyovers.

5. Enhancing and supporting green traffic

Green traffic is non-fuel consumption traffic, like bicycles, rickshaws, pedestrians etc. These should be promoted by ensuring road security and with other issues. The major disadvantage is that it takes long time to cover far distances in emergency.

6. Parking Enforcement

Controls on parking [2, 6] are at present perhaps the most important tool available to local authorities, since the availability of parking spaces and the cost of parking to the motorist can have a major influence on the level of traffic entering a town. The models presented in [6] considered five options for reducing car trips to city centers: halving public transport fares, raising fuel costs by 50 per cent, doubling parking charges, halving the number of parking spaces, and applying a central area cordon charge. The models predicted that the resultant decrease in car use would be 20 per cent if the number of parking places was halved.

B. Intelligent Traffic Control Systems

It is quite difficult to improve the performance of urban traffic control system efficiently by using conventional methods of modeling and control because of time-variability, non-linearity, fuzziness and non-determinacy in the system.

Since the transportation infrastructure has not kept pace with the growth in traffic demand, research to develop modern transportation systems has become an important issue. Hence, it is required to develop the modern control systems to deal with this problem. The previous models developed for vehicular studies only considered limited macro mobility, involving restricted vehicle movements, while little or no attention was paid to micro mobility and its interaction with macro mobility counterpart. The research community could not provide the realistic environment for modeling urban traffic that could provide a clear picture about traffic movements and its implications.

Subsequently, the technology is applied to the development of modern traffic control systems and results in successful implementation. Fuzzy Logic, Activity Theory, Model Driven Engineering, Neural Network, Petri nets, Genetic Algorithms and many others are the different technologies that are used to develop such type of systems.

The current research is proposed to develop framework providing an effective real time modeling encompassing various components of urban traffic systems and overcoming the limitations of previous approaches.

1.2 OBJECTIVE OF THE PRESENT WORK

Urban traffic control system has become the research hotspot in the area of soft computing. In this proposal, following objective have been identified for modeling and implementing proposed system:

1. Identification of requirements and issues relating to traffic

management.

2. Development of Framework for urban traffic Simulation
3. Algorithm design for the intelligent traffic control
4. Experimental evaluation of the entire framework.

1.3 RESEARCH METHODOLOGY

To design and implement the new system for overcoming the congestion problems in the Urban Traffic Control Systems (UTCS), the following methodology has been proposed and implemented.

1.3.1 PROBLEM IDENTIFICATION

The prime requirement of the developed system is, the system must not allow the ambiguous movement of the traffic and it must be clear that how/when the indication of messages/signals shown to be changed, in critical traffic congestion situations. Two other aspects to be handled are to take decisions about phase sequence in the control system to make the system well optimized and development of control logic for signal generation.

In this phase, two most common techniques have been identified for regulating and managing Urban Traffic System. These are:

1. Fixed-Time System
2. Traffic Responsive System

The first group has fixed on-off time periods for traffic flow. The second group employs actuated signal timing plans and performs an on-line optimization and synchronization of traffic signals. The real sense sensors/ detectors located on traffic intersection which feed information on the actual system state to the real time controller. To achieve traffic control using these strategies Traffic Network has to be appropriately modeled for simulation operations.

The proposed work would deal with this problem of traffic congestion using intelligent methods. Following are the different issues in the development of such a proposed system.

1. Modeling of X and T junction

2. Identification of incoming and outgoing traffic

3. Dealing with the uncertainties in the system

Another approach is also having the major concern to deal with critical traffic congestion, named minor sub lane by-pass system. In this approach, the road network with multiple minor sub lanes is considered as a graph. It is used to find the new paths through the minor sub lanes from source to destination and diverging the traffic from the congested main road traffic. The identified problems in this technique are,

1. To generate the optimized minor sub lanes new path for traffic movement.
2. To give the message to the vehicles before the congested place for route diversion.

1.3.2 DEVELOPMENT OF FRAMEWORK

The proposed framework has been taken from the Activity theory, which is philosophical, conceptual and analytical framework to study human practices, and Model Driven Engineering, which uses the concept of abstract platform.

In the first phase, the activity triangular model showing the components, like subjects Object, Community, Tools, Rules and division of labour is taken from Activity Theory and are referenced to urban traffic agents. In the second phase, it is proposed to use the Model Driven Engineering platform which provides effective methods of exchange of signals between various modeling agents. It successively refines models from analysis to design and then automatically generates code. A common pattern in MDA development is to define a platform- independent model of a distributed application and to apply (parameterized) transformations to PIM for obtaining one or more platform specific models (PSMs). As, MDE supports both behavioral and structural aspects of a system so to deal with uncertainties, fuzzy MDE concepts are propounded in the present study as: Fuzzy structure and Fuzzy behavior.

Finally, to integrate both the methodologies it is proposed to specify the platform independent model of a simple urban traffic control system, to be represented in UML of MDE framework to combine activity theory with MDE.

In order to represent the Fuzzy PIM the use of Linguistic Variables and Fuzzy rules for entering the uncertainty into the performance computations is also proposed. The Classical fuzzy relationship has been represented in the matrix between activity theory components and model driven engineering components with reference to Urban Traffic System (UTS) to generate membership degrees.

1.3.3 DEVELOPMENT OF ALGORITHMS FOR INTELLIGENT CONTROL

The proposed model to develop the algorithms is divided into two parts. The first part is the Forward Propagation Petri Net model which focuses on simple Cause-Effect framework. It is proposed to develop a model of Forward Propagation of Petri nets which uses the concept of Producer Consumer Network based Petri Nets with reference to the Urban Traffic system with the objective to reduce the congestion and to obtain free flow of traffic movement. To train this network for achieving balance condition an algorithm has been developed. Later on in the second part it is proposed to extend the single unit network with N- Dimensional representation to form a grid, where the focus to provide a buffer mechanism and virtual counter to keep track of the entire traffic flow across the grid. The training algorithm is proposed for the grid on the basis of Continuous Petri Net Learning mechanism. The proposed algorithm would be simulated using MATLAB 7.0 to judge its efficiency with training of each Producer- consumer unit as a single entity.

In this phase, it is also proposed to enhance the capability of an intelligent Urban Traffic control using Neuro-Genetic Petri Net. The combination of genetic algorithm provides dynamic change of weight for faster learning and converging of Neuro-Petri net.

The use of genetic learning method performs rule discovery of larger system with rules fed into a conventional system. The main idea to use genetic algorithms with neural network is to search for the appropriate weight change in neural network which optimizes the learning rate of the entire network. The proposed Genetic Algorithm would significantly reduce Neuro-Petri Net in aligning with the traffic conditions, which other-wise is a very complex issue.

1.3.4 EXPERIMENTAL EVALUATION AND RESULT ANALYSIS

In the fourth step, it is proposed to perform the experimental evaluation of the system in two phases. In first phase, Experimental evaluation for the model of X-Junction using Fuzzy Inference mechanism has been carried out in MATLAB 7.0. Also, it is proposed to develop a rule base applied to Petri Net Urban traffic system model and test the Heuristic using MATLAB 7.0 simulation.

The Traffic Control System (TCS) at intersection are fuzzy integrated. Fuzzy Traffic Control Systems (FTCS) uses sensors that not only indicate the presence of vehicle, but also sensors give estimation of traffic densities in the queue. Numbers of parameters are required to be identified for the implementation of actual traffic signal control system. The identification of parameters for performing the MATLAB simulation is also done in this phase.

The major steps in this phase includes,

1. Identification of the parameters
2. Designating the membership functions
3. Identification of fuzzy rules for traffic control
4. MATLAB simulation

In the second phase, it is proposed to develop an algorithm to reduce the traffic congestion by using minor sub lane by-pass approach in a road network, taking data of congestion from previous phase X – Junction modeling approach. The algorithm is to be implemented by using MATLAB.

1.4 CHAPTER SCHEME

The whole thesis is divided into 7 chapters.

In Chapter 1, the need of present work, objective and research methodology of the proposed work has been given. The various causes that lead to traffic congestion and problems associated with it and approaches to reduce the traffic congestion are discussed. The research methodology includes the steps, problem identification, and development of framework, design of intelligent algorithms and Experimental evaluation of proposed framework.

In Chapter 2, the literature about the identified problems in Urban Traffic Control System (UTCS) has been surveyed. Several Soft Computing techniques, like Neural Network, Genetic Algorithms, Fuzzy Logic and Activity Theory, Model Driven Engineering, Petri Net approach has been identified used for UTCS development.

In chapter 3, a framework for urban traffic control system has been proposed which integrates the model driven engineering and activity theory. In order to incorporate both the methodologies, the Platform Independent Model of an Urban Traffic Control System is represented in UML to combine Activity Theory and Model Driven Engineering.

In chapter 4, to deal with uncertainties of urban traffic system, the integration of Fuzzy Logic is introduced. MDE supports both behavioral and structural aspects of a system and to deal with uncertainties associated with this architecture, fuzzy constraints of abstract urban traffic system are developed.

In chapter 5, Urban Traffic modeling has been done using Petri Net based approach. This approach is based on minor sub lanes by-pass system using producer consumer network and grid network of Petri Nets. The capabilities are enhanced using neuron genetic algorithm to provide dynamic change of weights for faster learning and converging of neuro-petri nets.

In Chapter 6**,** the approach for reducing traffic congestion has been experimentally evaluated in two steps. In first phase, the modeling and simulation of an X Intersection along with its phase sequence control has been implemented using MATLAB 7.0. In second phase, minor sub lane by- pass approach as discussed in previous chapter 5 has been implemented and evaluated.

In Chapter 7, conclusion of the proposed system would be carried out. The future scope and further extensions of this system is also discussed.

CHAPTER 2
LITERATURE SURVEY

The development of control systems to deal with the congestion for smooth flow of Traffic in urban areas is a critical research issue. Several conventional methods [6-13] have been applied to reduce the problem of traffic congestion. Some of these are, road pricing, supporting the green traffic, parking enforcement, fuel levies, expansion of existing road network, elimination of roundabout and many more. But due to non-linearity and unpredictability of the traffic movement and the high cost associated with expanding the existing infrastructure of road network and other related problems, the Conventional methods are not very suitable.

In between this time, the technology has been integrated to develop some intelligent control systems to deal with the traffic congestion issues, specifically in urban areas.

Different approaches have been integrated to model and simulate the real time traffic control system, like activity theory, neural network, fuzzy logic, Petri Nets, genetic algorithms and their hybrid approaches.

The review work has been done in the two phases. In the first phase, the Activity Theory[75, 76] , Model Driven Engineering [77-79] , Petri Net [114, 115] and Neural Network [119-121] applications of traffic control systems are reviewed and second phase concentrates on the development of models and control systems using Fuzzy logic [101, 102] fulfilling different requirements of the traffic movement and flow.

The first phase of the literature review starts with the activity theory to develop the framework. It is more of a descriptive meta-theory or framework than a predictive theory. It considers entire work/activity system that includes teams, organizations, etc., beyond just one actor or user and accounts for environment, history of the person, culture, role of the artifact, motivations, complexity of real life action, etc.

A conceptual activity-based and time-dependent traffic assignment model is proposed in [14] by *William et. al.* The temporal utility profiles of activities are employed to formulate the temporal activity choice behavior of individuals as a multinomial logic model. Route choice behavior is then described as the ideal dynamic user equilibrium condition.

In [15], Hyponen presents an activity theory based framework for studying user needs for iterative evaluating developing technology. Curtis. B and Iscoc in [16] have argued the key concept of Software Engineering community that can be used to point possible research directions in operationalising the Activity Theory framework. The concept of Booch and Rambaugh[17] for application of Activity Theory in object oriented design is used. Similar work has been modified by Pavia and Hartley [18] who have explored the benefits of specific interpretations of Engestrom's refinement of Vyotsky's mediating artifacts and it's linking with necessary tools. McGarth [19, 20] has also highlighted the issues of application of activity theory in business process modeling tool with enhancement of 'how' and "why" factors being divided into two broad categories of 'hard' & 'soft' factors. He has developed meta-data levels in entity.

In spite of Activity Theory, Petri Nets are also very important tools for conceptual modeling of traffic control system to develop the algorithms.

Petri Nets, as stated by R. Zurawski et. al. in [21] are also known as a Place/Transition Net or P/T net. It is the mathematical modeling language for the description of Discrete Event Systems (DES). PN theory was developed in 1962 by Carie Asam Petri. These are highly applicable in graphical modeling, Mathematical modeling, simulation and real time control by the use of places and transitions. Different variations of the Petri Nets are applied in the modeling and control of traffic systems to deal with congestion for smooth flow of Traffic.

A Colored Timed Petri Net (CTPN) model is used for validating an Urban Traffic Network for reducing the congestion in [22] by Dotoli et. al.

A model for real time control of urban traffic networks is proposed by Dotoli et. al. in [23]. A modular framework based on first order hybrid Petri nets model is developed. The vehicle flows by a first order fluid approximation, in this approach. The lane interruptions and the signal timing plan controlling the area are developed by the discrete event dynamics integrated with Timed Petri Nets.

A new hybrid Petri Net model for modeling the traffic behavior at intersection is discussed in [24] by Vazquez et. al. The important aspects of the smooth flow dynamics in Urban Traffic Networks are interpreted very well in this work.

A new approach of continuous learning of Petri Nets with Variable Speed (VCPN) is proposed in [25] by Tolba et. al. The analysis and congestion control design in urban and interurban networks is done. A network model via hybrid Petri Nets is used to demonstrate and implement the solution of the problem of coordinating several traffic lights by Di Febbraro et. al. in [26]. It aims at the improvement in the performance of some classes of special vehicles, like public and emergency vehicles.

A model of TCPN (Timed Control Petri Nets) is used to demonstrate and solve the problem of coordinating several traffic lights in [27] by Yi-Sheng et. al. The analysis of the control of TCPN models is done by Occurrence Graphs (OG) techniques.

A Colored Petri Net Model of an urban traffic network for the purpose of performance evaluation is demonstrated by Frank et. al. in [28]. The subnets for the network, the intersections, the external traffic inputs and control are discussed by the authors.

Petri Nets [29, 30] is the technique that gives clear means for presenting simulation and control logic and also supports the generation of control code from the PN graph. The Petri net based models support the direct generation of control code with help of graphical tools such as NETMAN [31] and UltraSAN [32].

Also, the use of Petri Nets (PN) ensures the control model to enforce all the safety rules. It also ensures the acceptability of all the signal plans. Colored Petri Net (CPN) is used to model traffic control system as a scheduler [33-35].

The extended version of the Petri Net to deal with the uncertainty with traffic control system is Fuzzy Petri Net. These are used to develop Urban Traffic Control System as stated in [36] by Aziz et. al. and in [37] by Cheng et. al.

Neural networks are also applicable to the modeling of traffic control system to give some intelligent behavior in decision of phase sequence and route diversion in case of minor sub lane by-pass system. It is proposed to use neural network techniques for learning and parameter optimization.

Apart from these conceptual modeling approaches, Artificial Neural Network is used to make the system intelligent in decision making. An artificial neuron is a computational model inspired in the natural neurons. Natural neurons receive signals through synapses located on the dendrites or membrane of the neuron. When the signals received are strong enough (surpass a certain threshold), the neuron is activated and emits a signal though the axon. This signal might be sent to another synapse, and might activate other neurons. The network developed on this theory in called Artificial Neural Network (ANN) [38] by *Graupe et. al.*. The ANNs are highly applicable in the design of models for traffic control systems.

An intelligent model with two levels of neural network in [39] by *Chengqian et. al.* for the traffic control system. The first level is a traffic flow neural network model to predict the traffic flow changes in road tunnel. The result of predicting will be used as an input of the second level neural network. It is used to describe an intelligent model of urban road ventilation system through the different states of predicted traffic flow to establish an intelligent model of urban road tunnel ventilation system based on multi-level neural network for reducing the congestion.

A neural network model is proposed for forecasting crossroads traffic flow using Back Propagation (BP) neural network in [40] by *Xiaojian et. al.* The work gives a new reliable and effective way of forecasting short term traffic flow of crossroads to reduce congestion in urban road network.

A commonly used macroscopic dynamic deterministic traffic flow model for traffic congestion control is analyzed in [41] by *Guojiang et. al.*. The neural network model for the urban expressway traffic flow is established and the urban expressway multi-variable neural control strategy with both the on-ramp control and the road speed control is implemented.

MTL (Multi Task Learning) based neural networks are used for traffic flow forecasting in [42] by *Feng et. al*. For neural network MTL, a back propagation (BP) network is discovered by incorporating traffic flows at several contiguous time instants into an output layer. Nodes in the output layer can be seen as outputs of different but closely related STL tasks.

A back propagation artificial neural network model, which utilizes the characteristics of urban signalized intersections for occurrence prediction of intersection related traffic crashes, along with its application for crash reduction, are proposed in [43] by *Liu*. With the ANN model, a proposed decision-making scheme for intersection rehabilitation was suggested.

Shen has analyzed a commonly used macroscopic dynamic deterministic traffic flow model in [44]. The 1.5-layer feed-forward network modeling for the urban expressway traffic flow is implemented.

A novel intelligent identification method is proposed in [45] by *Zhanquan et. al.* to reduce the computation cost due to congestion and to improve the identification rate. The proposed method combines principal component analysis (PCA) method with higher-order Boltzmann Machine (BM). PCA is applied to reduce the dimension of input feature space. It can not only reduce the computation cost but also filter noise of the source data. BM is a kind of stochastic network that is used to get the global optimum solution. Higher-order BM without hidden units can save lots of computation cost without decreasing modeling power. The trained higher-order BM is used to identify traffic state.

Short-term forecasting of traffic parameters such as flow and occupancy is an essential element of modern Intelligent Transportation Systems research and practice. An advanced, genetic algorithm based, multilayered structural optimization strategy that can help both in the proper representation of traffic flow data with temporal and spatial characteristics is presented in [46] by *Vlahogianni*. After that, it evaluates the performance of the developed network by applying it to both univariate and multivariate traffic flow data from an urban signalized arterial.

The second phase starts with the introduction of the Fuzzy Logic, an excellent theory and tool to deal with the uncertainty associated with the system. Because the behavior of the traffic movement and congestion is totally unpredictable and uncertain in its nature, it is desired to integrate fuzzy logic in the Urban Traffic System. Several approaches and technologies have been developed; some of them are reviewed here to make the orientation strong.

Ross has defined Fuzzy logic in his book [47] that it is a form of many-valued logic; it deals with reasoning that is approximate rather than fixed and exact. In contrast with traditional logic theory, where binary sets have two-valued logic: true or false, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy Logic theory is highly applicable in the design strategies for modeling traffic control systems.

The coordination of Urban Traffic Flow Guidance System (UTFGS) and Urban Traffic Control System (UTCS) can give decision support to navigate and signal timing at the same time. It realizes basic information sharing and to get the optimal results from the point of system integration. A combined model of traffic assignment and signal control is presented in [48] by *Dai et. al.* with the object to minimize congestion degree both at links and intersections. To avoid the complexity and difficulties in solving the optimal model, a fuzzy control algorithm is put forward, the input collected input of the traffic data is described, and then the fuzzy control rules are used to get the optimal link volumes.

The automated urban traffic congestion control systems in [49] by *Cao et al.* are based on deterministic algorithms. They have a multi-level architecture. To achieve global optimality, hierarchical control algorithms are generally employed. An alternative approach is to use a fully distributed architecture in which there is effectively only one (low) level of control. These systems are aimed for increasing the response time of the controller, these often incorporate computational intelligence techniques.

Due to congestion in main route a new route choice model taking account of the imprecision and the uncertainties lying in the dynamic choice process is proposed in [50] by *Vincent*. This model makes possible a more accurate description of the process than those (deterministic or stochastic) used in the literature. It is assumed that drivers choose a path all the more than it is foreseen to have a lesser cost. The predicted cost for each path is modeled by a fuzzy subset which can represent imprecision on network knowledge (e.g. length of links) as well as uncertainty on traffic conditions (e.g. congested or un-congested network, incident).

To deal with the complicated situation, the application of hybrid approaches of fuzzy logic, neural network, Petri nets are invented. More specifically, these hybrid approaches are becoming highly successful because of their robust capabilities to make complex decision making and control.

A hybrid model for single point short term traffic flow forecasting in an urban traffic network is proposed in [51] by *Srinivasan et. al.* . The hybrid model consists of two main modules: a Fuzzy Input Fuzzy Output filter (FIFO-filter) and a multi-layer feed-forward artificial neural network architecture optimized using evolution strategies (MLFN-ES). The FIFO-filter does the data clustering operation and results in a rough forecasted prediction value based on the input data to the MLFN-ES associated with each cluster for modeling the input–output relation to provide accurate short term forecast value.

A hybrid adaptive model, based on a combination of colored Petri nets, fuzzy logic and learning automata has been studied in [52] by *Barzegar et. al.*

An original method using high level Petri nets for the specification and design of interactive systems is presented in [53] by *Ezzedine et. al*. . An agent oriented architecture based on the classic components of an interactive application (application, dialogue control, and interface with the application) is demonstrated.

Incident based traffic jam control systems are one of the best control systems. Effective control strategies are required to disperse incident based traffic jams in urban networks. In [54], Long et. al. has developed a control strategy and their effectiveness in dispersing incident-based traffic jams in two-way rectangular grid networks. The spatial topology of traffic jam is proposed for propagation, the concept of vehicle movement ban is implemented, which is frequently adopted in real urban networks as a temporary traffic management measure.

A vehicle routing problem at the time of congestion in dynamic urban traffic network with real-time traffic information is presented in [55] by *Yanfeng et. al.* . Both recurring and non-recurring congestion are handled in the problem. A method to solve the problem by combining the initial routes arrangement with the real-time route adjustment has been implemented. The genetic algorithm is also integrated in this work.

The prediction of traffic situations is a vital issue in modern Intelligent Transport Systems (ITS). A situational algorithm of real time traffic is proposed in [56] by *Leihsa et. al.*.

Urban transportation system consists of surface-way networks, freeway networks, and ramps with a mixed traffic flow of vehicles, bicycles, and pedestrians. In [57], *Zhao et. al.* has carried out a survey for control and management of recurring and non-recurring congestion in traffic network using computational intelligence techniques.

The three factors important for tuning the network traffic system are: (i) the topology of underlying infrastructure; (ii) the distribution of traffic resources; (iii) the routing strategy. The optimization of network capacity based on complex network theory is done in [58] by *Mao-bin et. al.* . The optimization method of network traffic in several situations corresponding to the real cases has been studied.

Route network model, construction of route network database and optimization route algorithm has been studied in [59] by *Yue-Zhen et. al.*. In the urban route network model, which includes direction, crossing delay and restraint of urban traffic is introduced. The resolution to optimization of route turning delay and restraint is presented based on improved Dijkstra algorithm and programs.

Some advanced model-based control methods for intelligent traffic networks are discussed by *Schutter et. al.* in [60] in which model predictive control (MPC) of integrated freeway and urban traffic networks were specially discussed in his work. The basic principles of MPC are presented for traffic control including prediction models, control objectives, and constraints. The proposed MPC control approach is modular, allowing easy substitution of prediction models and the addition of extra control measures or the extension of the network.

The mathematical model was formulated by *Xaufei et. al.* in [61] to describe the effectiveness of traffic jams information under the assumption of simple network and linear cost function. The impact of traffic congestion information on congestion propagation was discovered by using two models namely stochastic and deterministic user equilibrium assignment.

In [62], Skordylis et. al. discovered the problem of efficiently collecting and disseminating traffic information in an urban setting. The traffic data acquisition problem and explore solutions in the mobile sensor network domain while considering realistic application requirements is formulated.

In the last decade, economic approaches based on computational markets have been proposed as a paradigm for the design and control of complex socio-technical systems, such as urban road traffic systems. The control problem of an urban road traffic system can be modeled as a distributed resource-allocation problem to apply market-based techniques as solution methods. A competitive computational market is designed in [63] by *Vasirani et. al.* where driver agents trade the use of the capacity inside the intersections with intersection manager agents.

Traffic congestion in urban road and freeway networks leads to a strong degradation of the network infrastructure and accordingly reduced throughput, which can be countered via suitable control measures and strategies. A comprehensive overview of proposed and implemented control strategies is provided for three areas: urban road networks, freeway networks, and route guidance as discussed in [7] by *Papageorgiou et. al.*.

The automation of highways as part of the intelligent vehicle highway system (IVHS) program is seen as a way to alleviate congestion on urban highways. The concept of lane assignment in the context of automated highway systems (AHS) is discussed by *Ramaswami et. al.* in [64]. Lane assignments represent the scheduling of the path taken by the vehicle once it enters an automated multilane corridor. The classification of lane assignment strategies is developed into non-partitioned (totally unconstrained, general, and constant lane) and partitioned (destination monotone, origin monotone, and monotone) strategies. An optimization problem is also formulated with the performance criterion being a combination of travel time and man oeuvre costs.

A congestion propagation model of urban network traffic is proposed in [65] by *Long et. al.* based on the cell transmission model (CTM). The proposed model includes a link model, which describes flow propagation on links, and a node model, which represents link-to-link flow propagation. A new method of estimating average journey velocity (AJV) of both link and network is developed to identify network congestion bottlenecks.

Intelligent transportation systems (ITS) are effective on solving the problem of traffic jam in cities. Prediction of crossroads' traffic volume is the key technology in ITS. In [66], *Yuming et. al.* used BP neural network in prediction of crossroads' traffic volume.

In reality, the individual's day-to-day route choice behavior is a long-time evolution process, and travelers choose their traveling routes according to the combination of historical experience and real-time traffic information. Considering two classes of users, one equipped with advanced traveler information systems (ATIS) and the other without, the travel efficiency under two different information feedback strategies, namely, travel time feedback strategy and mean velocity feedback strategy, has been investigated in [67] by *Tiana et. al.*

A discrete-time, link-based dynamic user-optimal route choice problem using the variational inequality approach is formulated in [68] by *Chen et. al.* The proposed model complies with the dynamic user-optimal equilibrium condition in which for each origin-destination pair, the actual travel time experienced by travelers departing during the same interval is equal and minimal.

Several mathematical algorithms, control strategies and programming are integrated with soft computing techniques, like Fuzzy Logic, Neural Network, Petri Nets etc. for the development of automatic traffic control systems. SCOOT [69] is the major real time traffic control systems. Several systems have been developed for traffic control systems, like SCATS [70], PRODYN [71], OPAC [72], UTOPIA [73], TUC [74] etc.

Chapter Summary

In chapter 2, the literature review of the recent approaches for traffic control system has been carried out, specifically in the last decade.

Initially, several conventional methods have been introduced like, road pricing, green traffic etc., but due to lack of inherent capabilities in conventional methods, many intelligent methods have been introduced using several artificial intelligence methods. The chapter surveys these approaches in two parts.

First part introduces the activity theory, model driven engineering, Petri net, neural network applications in traffic control systems. The second part introduces the fuzzy logic applications to deal with inherent uncertainty associated with traffic control systems.

Various extensions of the Petri Net approaches are introduced, like Colored Time Petri Net (CTPN), Variable Speed Petri Net (VSPN), Timed Control Petri Net (TCPN) etc. To make the system intelligent, neural network approaches are integrated. Multi task learning, Back Propagation are different learning techniques used in traffic Control System. Also these approaches, like neural network, fuzzy logic, Petri nets etc. are considered to develop more robust hybrid traffic control systems. Few of these systems are FIFO Filter, MLFN-ES, etc.

Several mathematical algorithms, control strategies, programming are integrated with soft computing techniques for the development of automatic traffic control systems. SCOOT is the major real time traffic control systems. Several systems have been developed for traffic control systems, like SCATS, PRODYN, OPAC, UTOPIA, TUC etc.

Finally, the chapter concludes the proposed work in two steps,

1. Intelligent modeling and simulation of traffic signal on the congested traffic junctions.

2. Removal of traffic congestion through the use of minor sub lane by- pass system.

CHAPTER 3

MODEL DRIVEN ENGINEERING-ACTIVITY THEORY FRAMEWORK FOR URBAN TRAFFIC SIMULATION

3.1 INTRODUCTION

Software modeling for control system plays an important role in order to develop better usability and understandability of the system. The Model driven Engineering and Activity oriented Modeling is used to develop the Framework for Urban Traffic simulation in this chapter.

The Activity Oriented Model is derived from the basics of Activity Theory philosophy. Activity Theory is a philosophical, conceptual and analytical framework to study human practices. Activity Theory [75, 76] has their origins from Vygotskyian concept of tool mediation and Leontev's notion of Activity. Vygotsky's explanation of his concept tool mediation encompasses both physical and psychological tools namely: signs and symbols. The notion of tool mediation is central to Vygotsky's theory because tool allows human to interact more effectively with objects. Later on Vygotsky's model was refined and expanded by A.N. Leontev and Engestrom’s. They developed a final model which represents both the collaboration and collective nature of human activity. The model developed is known as "Activity Triangle Model" incorporating components like: Subjects, Object, Community, Tools, Rules and Division of Labour.

Model Driven Engineering [77, 78, 79] successively refines models from analysis to design and then automatically generates code. A common pattern in MDA development is to define a platform- independent model of a distributed application and to apply (parameterized) transformations to PIM to obtain one or more platform specific models (PSMs). When perusing platform - independence one could strive for PIMs, that are neutral with respect to all different classes of middle ware platforms.

In Model driven Engineering the concept of abstract platform, which provides an effective method of exchanging signals between various modeling agents is integrated with Activity Theory to develop the framework of proposed work.

3.2 ACTIVITY THEORY: A BRIEF INTRODUCTION

"Activity Theory is a philosophical and cross disciplinary framework for studying different forms of human practices as development processes, with both individual and social levels interlinked at the same time".

Activity Theory is commonly used within Enterprise Modeling community although it is not a fully developed theory but a framework from which several ideas, theories and methods for conceptualizing human practices (activity) in relation to computers could emerge. Activity theory is therefore, committed for understanding both individual and collective aspects of human practices from a cultural and historical perspective. The following are the key points important to the problems:

Key points from Activity Theory those are important to problem:
• **The motives of those involved in Activity.** • **The operational structure of an Activity.** • **Issues surrounding the development and use of tools to support Activity.**

3.2.1 HISTORICAL DEVELOPMENT OF ACTIVITY THEORY

The ideas presented in Activity Theory have their origins in Vygotskyian concept of tool mediation and Leontev's notion of Activity. Vygotsky [80] originally introduced the idea that human being's interactions with their environment are not direct ones but are instead mediated through the use of tools and signs.

3.2.2 VYGOTSKY'S THEORY

Vygotsky elaborated his ideas of socially and culturally mediated tools by introducing the principle of internalization in which he explains that individual's consciousness does not exist inside individuals head, but exists instead outside the individual through interactions with his environment. Vygotsky reiterates the idea of transformation through internalization with reference to the functions of the tool and the sign in mediating human activity.

"The tool's function is to serve as the conductor of human influence on the object of Activity; it is external oriented; it must lead to changes in objects. It means by which human external activity is aimed at mastering, and triumphing over nature. The sign, on the other hand, changes nothing in the object, of a psychological operation. It is a means of internal activity aimed at mastering oneself; the sign is internally oriented".

Vygotsky's explanation on tool mediation encompasses both physical and psychological tools namely: signs and symbols. The notion of tool mediation is central to Vygotsky's theorising because tools allow humans to interact more effectively with objects. Therefore, enabling them to relate more efficiently to their external environment and to control it is necessary.

Vygotsky used the operational structure of the sign to represent unmediated or elementary forms of behavior, as is the case with animals that normally react 'directly' to their environment. He expressed this representation by Figure 3.1.

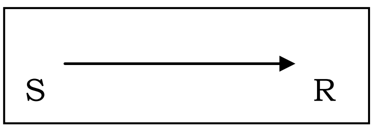


Figure 3.1 'Unmediated' Behavior (as reflected in animals).

To show the structure of mediated or ‘indirect’ from of behavior, which is common to humans, Vygotsky introduced “an intermediate link between the stimulus and the response” represented by an ‘X’.

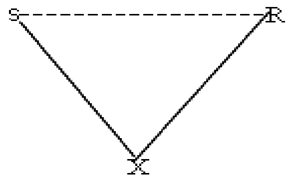


Figure 3.2: ‘Mediated’ Behavior (as evident in human)

The S-R-X triangle model can now be currently represented as shown in Figure 3.2.

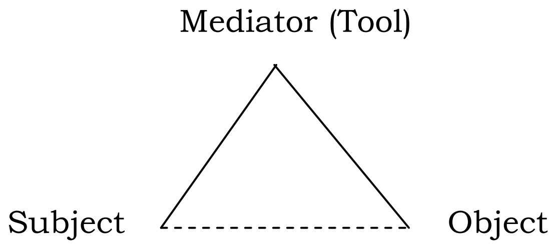


Figure 3.3 Meditational Model as usually represented in current literature.

The two diagrams presented are conceptually equivalent. They both depict the same notion – the meditational aspect of human activity. These two figures are shown twice so as to illustrate the differences in representation between Vygotsky’s original representation for mediated behavior (Figure 3.2) and the model commonly used in current work (Figure 3.3).The current representation of the mediation model (Figure3.3) is used in all future references to the mediation model.

3.2.3 INTERPRETING AND APPLYING VYGOTSKY’S IDEAS

Vygotsky’s main concern was to establish basic principles of his theory and method. The generality of the summaries from his experiments makes it difficult to interpret and practically apply his concepts, because there are no statistical tests or raw data on which the records and observations can be based.

Furthermore, Vygotsky’s principle of the social origins of human mind seems to take a narrow view of individual's behavior within a much broader context of society. These views are expressed in writings of several authors including, Engestron and Miettinen. Engestron [81, 82] has made the following comments about the mediational model: "Mediation by other human beings and social relations was not theoretically integrated into the triangular model of action".

It is therefore, difficult to recognize the roles played by other human beings within the social and cultural matrix from which the individual's behavior emerges when using the original meditational model. Collaborative aspects of the individual's behavior are reflected in interactions and relations with others within society, and they influence how an individual behaves in a particular context. Given this instance, the unit of analysis in Vygotsky's model is therefore, the object-oriented individual interacting with the environment using mediating signs or words.

3.2.4 LEONTEV CONCEPT OF ACTIVITY THEORY

In recognition of the importance of the collective aspect of human activity A.N. Leontev[83], expanded Vygotsky's work by conceptualizing the 'theory of activity'. According to Leontev, activity is a complete system that has structure. This structure he named as hierarchical levels of activity as shown below in Figure 3.4.

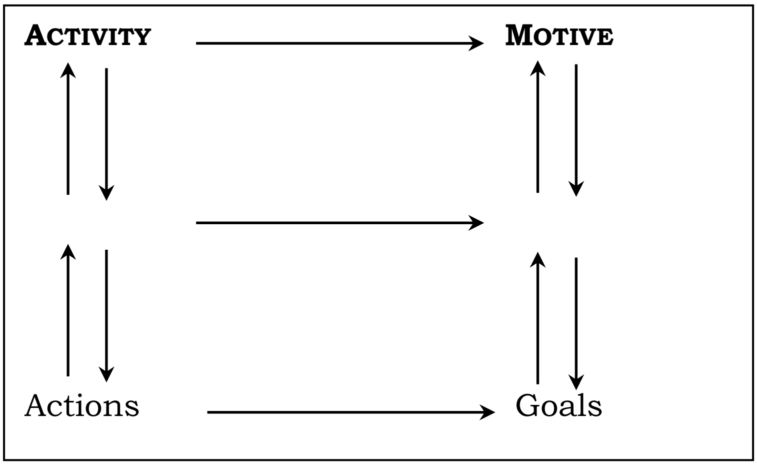


Figure 3.4 Hierarchical Model of Activity

The three level of activity consists of an activity that has a motive (objective) or a need; actions that are directed towards achievement of desired goals; and operations that are controlled by the conditions of execution. Leontev's hierarchical model of human activity has been strongly criticized for putting emphasis on 'what is being done' – activity; therefore, paying little attention to those engaged in carrying out activity – the human subjects. Even though Leontev's model helps to conceptualize the inter-relatedness of various actions in an activity, and also how these are linked to goals and shared objective of that activity, it does not say much about the roles and responsibilities of individuals involved is carrying out activity. Whilst both the 'subjects' and 'division of labour' are hypothetically addressed in Leontev's theory of activity, these components of human activity are not represented in his hierarchical model of human activity.

3.2.5 ENGESTROM MODEL

Engestrom [81, 82, and 84] expanded Vygotsky's original representation for mediated human behavior 'meditational model'.

"Engestrom's approach extended Vygotsky's representation of mediated behavior by producing a model that reflects both the collaboration and collective nature of human activity. In addition, Engestrom's approach also expanded Leontev's work by incorporating the 'subject' components, to represent those engaged in carrying out activity, also the division-of-labour component, to represent and make the various responsibilities of those engaged in activity explicit".

His model was also known as 'Activity System' which is generally referred as 'Activity Triangle Model' as shown in Figure 3.5 incorporating the components: Subjects, Object, and Community with mediators of human activity, namely, Tools, Rules and the Division of labour.

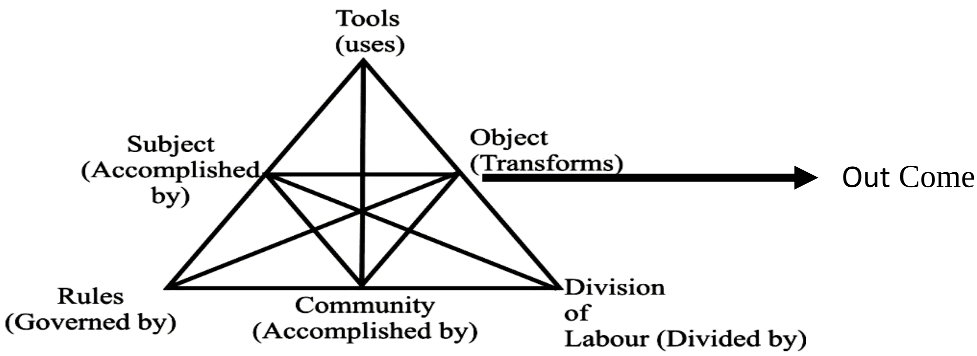


Figure 3.5 Activity Triangle Model

Components of the activity triangle are discussed below:

The ‘object’ component portrays the purposeful nature of human activity, which allows individuals to control their own motives and behavior when carrying out activity.

The ‘subject’ component of the model portrays both the individual and collective nature of human activity through the use of tools in a social context so as to satisfy desired objectives. The subject’s relationship with the object or objective of activity is mediated through the use of tools.

The ‘tool’ component of the model reflects the meditational aspects of human activity through the use of both physical and psychological tools. Physical tools are used to handle or manipulate objects, they therefore extend human being’s abilities to achieve targeted goals and satisfy *objectives*. Psychological tools are used to influence behavior in one way or another.

The ‘Community’ component represents stakeholders in a particular activity or those who share the same overall objective of an activity. The community puts the analysis of the activity being investigated into the social and cultural context of the environment in which the subject operates.

The ‘Rules’ component highlights the fact that within a community of actors, there are bound to be rules and regulations that affect in one way or another means by which the activity is carried out. These rules may either be explicit, or implicit, for example, cultural norms that are in place within a particular community. The component of the Activity triangle model also helps to establish environmental influences and conditions in which activity is carried out.

The “Division of Labour” component reflects the allocation of responsibilities and variations in job roles and responsibilities amongst subjects involved in carrying out a particular activity within a community.

The ‘Activity System’ consists of several sub-activities that are interconnected and united through the shared objective on which activity is focused. As a result of this inter-connectedness, disturbances or contradictions can occur *within* and *between* sub activities that could affect the transition of the collective activity system. The term ‘*contradictions’* used in Activity Theory refers to misfits, disturbances, problems or breakdowns, that occur in an Activity System or human practices being examined.

3.2.6 MODELING USING ACTIVITY THEORY

Software Modeling practitioners have failed to model even the minutest details of the organization mainly because of the lack of established methods of operationalising concepts of Activity Theory[85] within the system design process, filling the pragmatic vacuum by introducing a considerable number of challenges. The use of this theory for system design requires the justification of the method applied to operationalising the theory, together with a provision of clear evidence of mapping between Software Modeling and Activity Theory [85-88].

3.3 MODEL DRIVEN ENGINEERING

OMG [89] was founded in 1989 and today has a consortium from over 800 companies over the world. Some of OMG’s accomplishments are the Common Object Request Broker Architecture (CORBA), Unified Modeling Language(UML),Meta Object Facility (MOF), XML Metadata interchange (XMI) and the Common Warehouse Metamodel (CWM). All of these standards contribute to making the idea of model driven development [90] a reality. Roughly around 2001 OMG adopted a new framework called the Model Driven Architecture (MDA) [77, 78, and 79]. Unlike the other standards of the OMG, the MDA offers a way to use models instead of the traditional source code.

3.3.1 REASONS FOR USING MODELS

Model [91] is an abstraction of a system or a part of it. Depending on the type of the model it can provide a simple view of the system or a more detailed one. Designers often use models for planning their projects or explaining them to someone. These models are normally simple sketches that don’t contain any relevant information of the way the project is to be implemented. Nowadays the most commonly used models are the UML [92-94] models. In his book Martin Fowler explains three uses for the UML: UML as a Sketch, UML as a Blueprint and UML as a Programming language.

Today a large percent of the developers use the Model Driven Architecture models parallel with the software systems they design. It provides an effective way for communication between the designers especially if the systems are complex and involve a number of teams in the design.

3.3.2 IMPORTANCE OF MDA IN SOFTWARE DEVELOPMENT

Usually when working on a software project the requirements are often written documents with bullet points or textual scenarios, models are frequently just pictures with annotated details of programming interfaces, programs are almost always source code in a programming language and “bug” reports are kept in databases or logs. But none of the relationships between these parts of the project is usually stored. This removes the possibility of automation of some task and does not provide any consistency between the various aspects of the software project. This is problematic especially in cases of refactoring or reusing a project or even extending one. This is where the Model Driven Development [95-97] comes in.

It is an approach to software development that uses a single source that contains all of this information. The main goals are simplifying and standardizing the activities included in a project’s lifecycle. It raises the programming to an even higher level of abstraction. MDA defines standards for Model driven development.

The higher abstraction level is supposed to make MDA easier to use and easier to understand. It also provides to certain degree of platform independence. Some of the other key benefits from using MDA are:

Portability, increasing application re-use and reducing the cost and complexity of application development and management, now and into the future.

Cross-platform Interoperability, using rigorous methods to guarantee that standards based on multiple implementation technologies all implement identical business functions.

Platform Independence, greatly reducing the time, cost and complexity associated with re-targeting applications for different platforms-including those yet to be introduced.

Productivity, by allowing developers, designers and system administrators to use languages and concepts they are comfortable with, while allowing seamless communication and integration across the teams.

This brings to a reduced cost throughout the application life-cycle, reduced development time for new applications, improved application quality, increased return on technology investments and rapid inclusion of emerging technology benefits into their existing systems.

But this is not always the case. There is also a down side in using MDA.

“Raising the level of abstraction may lead to oversimplification when there is not enough detail for any useful purpose.”

For instance it creates the issue of redundancy. According to the MDA principles there are multiple representations of artifacts inherent in a software development process, representing different views of or levels of abstraction on the same concepts. When these are manually created, duplicate work and consistency management are required.

Another problem that comes from modeling is the round-trip problem. In complex systems a lot of models and artifacts are required, and several different levels of abstraction. This also increases the complexity of the relationships between them. So when a change needs to be done in an artifact that affect other artifacts and relationships in some cases it is impossible to automate the entire process. So a manual intervention is needed and this is especially difficult if a change is done in the lower levels given fact the most of the models at the lower levels are automatically generated.

3.3.3 WORKING OF MDA

Some of the basic concepts of the MDA are the models: Computation Independent Model (CIM), Platform Independent Model (PIM), Platform Specific Model (PSM) and Platform Model and the transformation techniques, mainly mapping, trace and notation.

Models

CIM is basically a simple representation of a system without specific information about how it is to be implemented. It only shows the system in an environment in which it will operate and helps to represent what the system is supposed to do. By MDA specifications a CIM is usually a simple UML model [98] which should be traceable to the PIMs and PSMs that implement it.

PIM is somewhat more detailed view of a system containing more details but from a platform independent viewpoint. It contains details about business functionality and behavior but no information about the technical details or the platforms on which it may be implemented. A common technique for achieving platform independence is to target a system model for a technology-neutral virtual machine.

PSM is a view of a system from the platform specific viewpoint. A PSM contains the specifications from a PIM but with details about the usage on a concrete platform. PSM usually contains enough information to allow code generation Platform Model contain technical information about a specific platform and the services it provides. The Platform Model provides concepts for use in the PSM.

3.3.4. MODEL TRANSFORMATION

Model transformation is the process of converting one model to another model of the same system. The platform independent model and other information are combined by the transformation to produce a platform specific model. This transformation can be done in many ways. However it is done, it produces, from a PIM, a model specific to a particular platform. In cases where the PIM is based on virtual machine, transformations are not necessary. Instead the PIM of the virtual machine is transformed to a PSM for a particular platform. The PSM can then be transformed in a concrete implementation for that platform.

The transformation from one model to another can be done with mapping. Mapping in MDA provides specifications for the transformation of a PIM to PSM. There are different kinds of approaches in using mapping. There is the Model type mapping which specifies how models are built using types defined in the PIM language and transformed into types defined in the PSM language as shown in Figure 3.6.

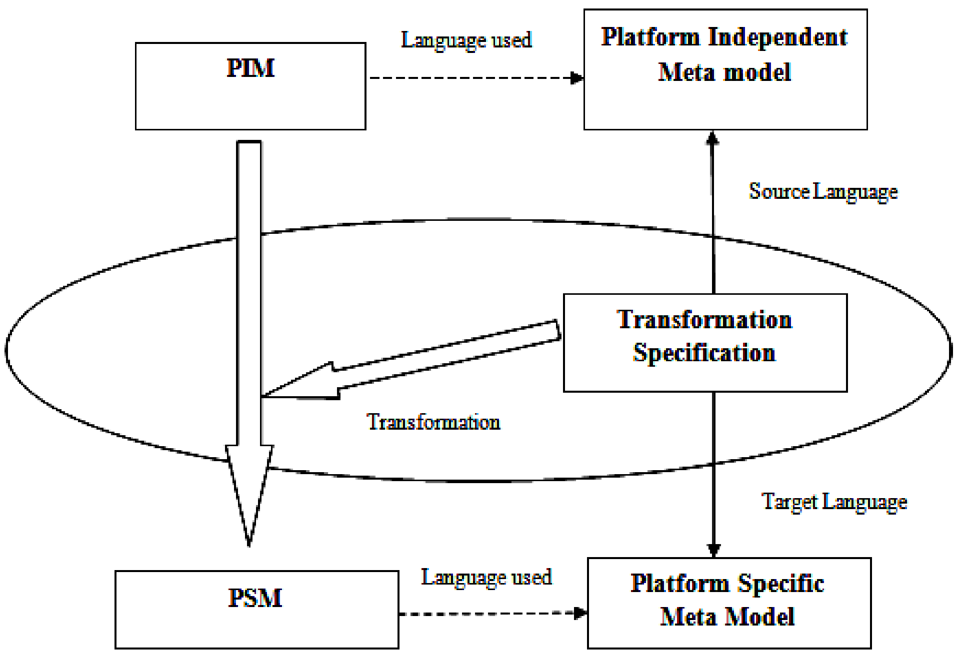


Figure 3.6 Meta Models of PIM and PSM Language

Another type of mapping is the Model Instance Mapping. This type of mapping usually uses Marks. This technique identifies model elements in the PIM that should be transformed in a specific way depending on the platform and marks them. Marks represent a concept in the PSM and specify how a marked object in the PIM is to be transformed as shown in Figure 3.7.

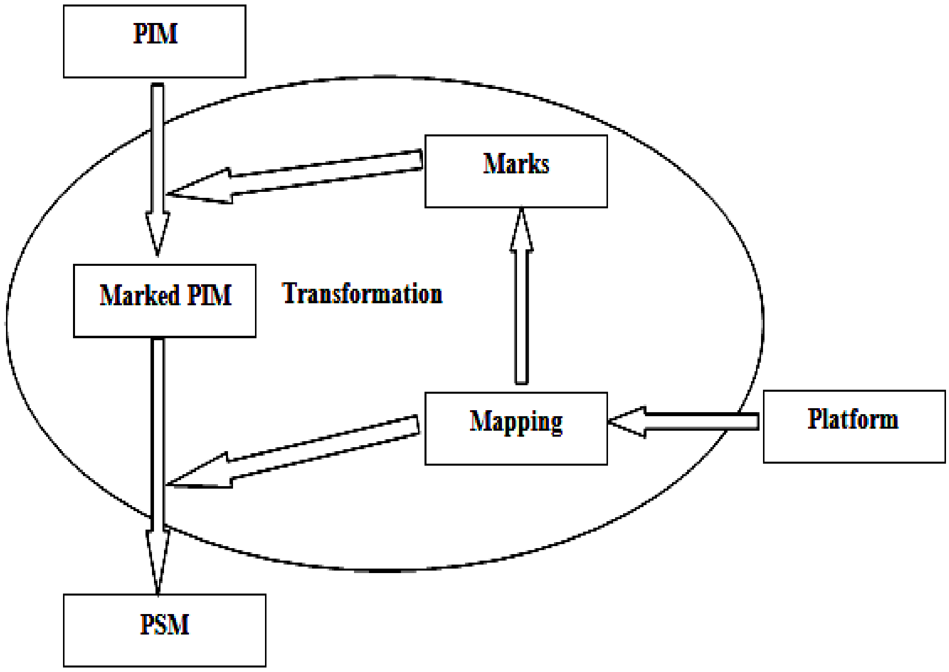


Figure 3.7 Concept of marked PIM for transformation

Also a combination of the two types of mapping can be used. A mapping may also include templates. Templates are parameterized models that specify particular kinds of transformations. These templates are like design patterns, but may include much more specific information to guide the transformation. In some cases additional information can be added to the transformation process. This additional information is provided by the developer and usually defines specific choices of implementations, quality of service etc. In Figure 3.8 is the MDA pattern for this type of a transformation.

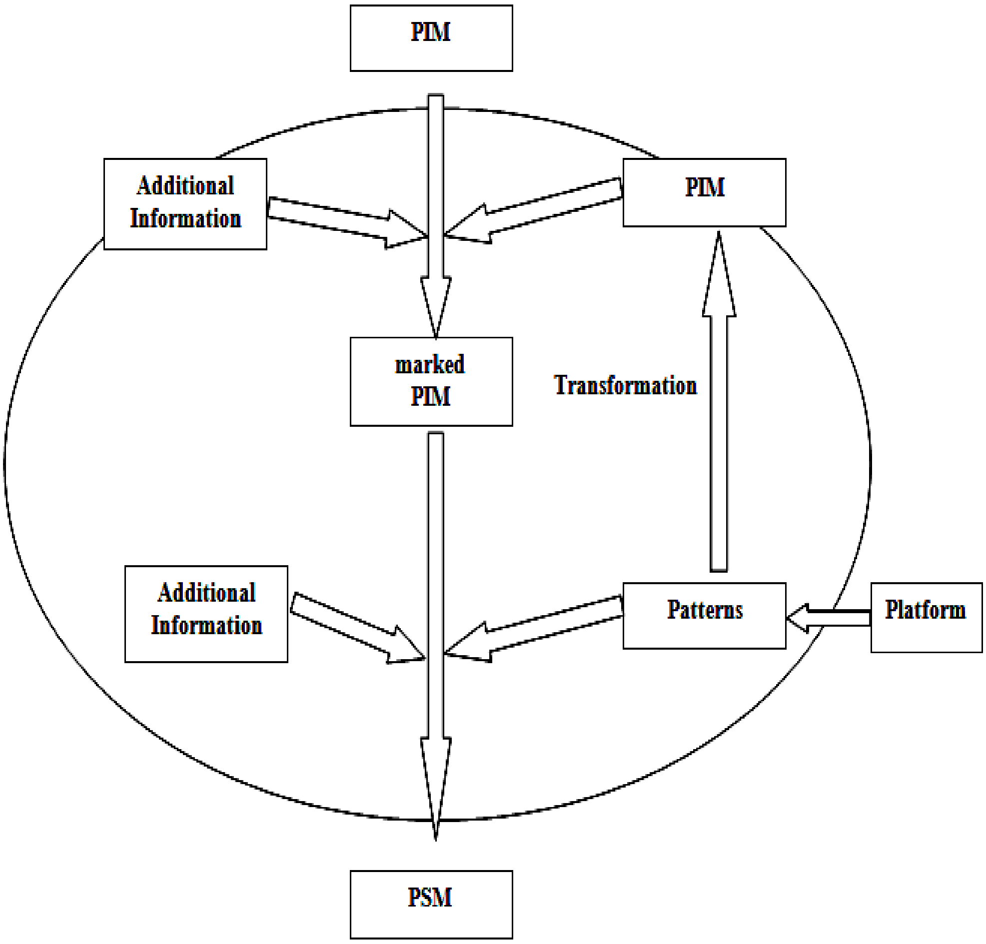


Figure 3.8 MDA pattern for transformation

3.4 MAPPING OF ACTIVITY THEORY WITH MODEL DRIVEN ENGINEERING WITH SPECIAL REFERENCE TO URBAN TRAFFIC SIMULATION

The main focus of the work is to develop the Framework using Activity Oriented Model [99] integrated with Model Driven Architecture. The work mainly summarizes on Vygotsky's Theory, Leontev's Theory, Engestrom's Activity oriented Model and finally mapping of Activity Theory Models with Model Driven Engineering.

The use of MDE covers the General Activity Diagram linked with Urban Traffic System. The Table 3.1 represents various parameters of Urban Traffic agents which correspond to Activity theory terminology.

Table 3.1 Mapping A.T. with MDE with Special reference to urban Traffic System

S.NO.	A.T. Terminology	Traffic Agents
1	Activity	Set of Modeling elements of Urban Traffic Activity
2	Subject	Urban Traffic System
3	Objects	Traffic Movements, Road Network
4	Outcome	Smooth Flow of Traffic/ Traffic Information
5	Objective	Real Time Traffic Movement Control
6	Tool	Resource such as S/W and H/W Platforms
7	Community	Traffic Police Departments / Stake Holders
8	Rules	Information Processing Rules
9	Division of Labour	Workflow Design which will help in
10	Artifact	Elements of Urban Traffic Simulation & Control

From the above table a simple AT-MDE flow diagram starting from modeling of Urban Traffic System to the tool used to achieve it is shown in Figure 3.9.

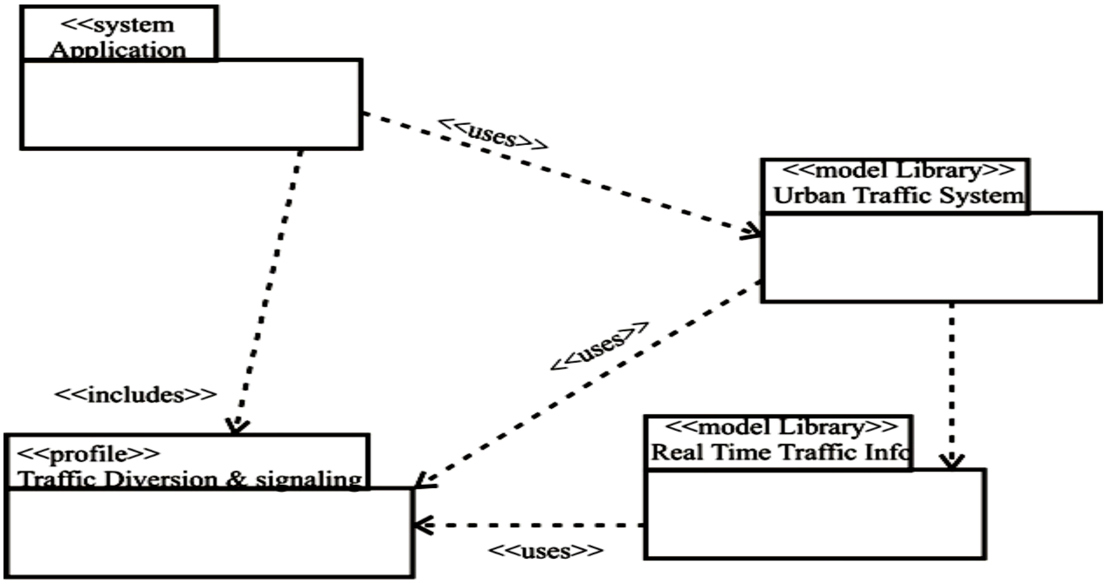


Figure 3.9 MDE representation of Platform Independent Modeling

The MDE Abstract platform consists of Model Library packages which can be imported by the PIM of the application.

3.5 THE PROPOSED MODEL

An abstract platform can have an arbitrarily complex behavior and structure, varying from a simple one-way message passing mechanism to a communication system that maintains a log book entry of sequence of operations.

In order to incorporate both the methodologies the Platform Independent Model of an Urban Traffic Control System is represented in UML of MDE framework to combine A.T. with MDE as shown in Figure 3.10.

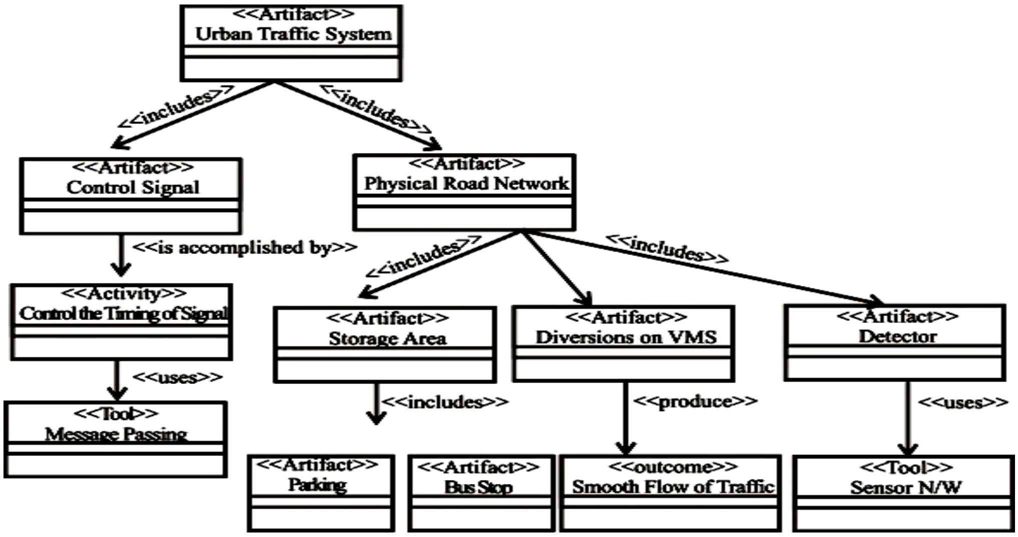


Figure 3.10 Generalized Activity Theory Frameworks

The two major component of the Framework developed are elaborated further for modeling and simulation to reduce traffic congestion and obtaining smooth flow of traffic.

3.5.1 TRAFFIC SIGNALING

Figure 3.11 refers to Traffic Signaling that relates the control aspect of Urban Traffic based on the traffic condition. Control the Timing Signal Meta class gets activated which is related to activity theory and the type of signal control reaching to the various crossing are defined through Message Passing. Message Passing is done by the help of <<Tool>> (i.e. Networking Device).

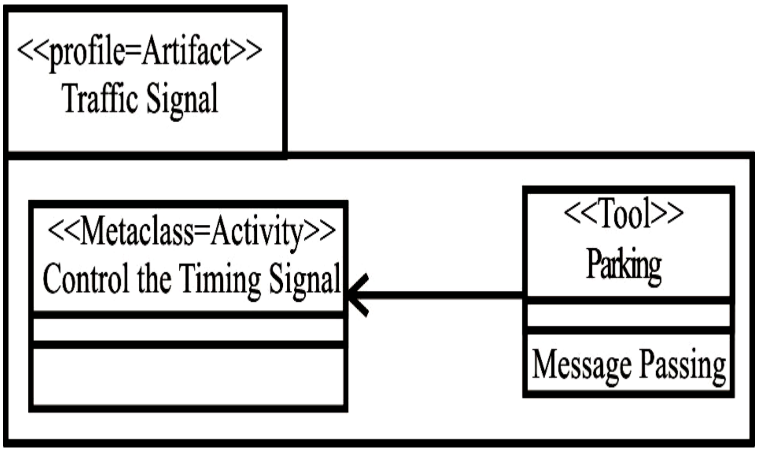


Figure 3.11 MDE-AT profile for the Artifact Traffic Signaling

3.5.2 PHYSICAL ROAD NETWORK AND TRAFFIC DIVERSION:

Physical Road Network consists of all the activity which is done for smooth flow of traffic. It consists of the Meta class, Diversion on VMS, which is an Interface in terms of MDE and an Artifact in Activity Theory semantics. Storage Area also forms a part of the physical Network.

It is connected by Parking and Bus Stop Detector which forms one of the <<interface>> shown as <<Artifacts>>, connected to a <<Tool>> named Sensor N/W, providing necessary inbound and outbound signals, hence placed in <<Signal>>. The entire behavioral pattern can be shown by the Figure 3.12.

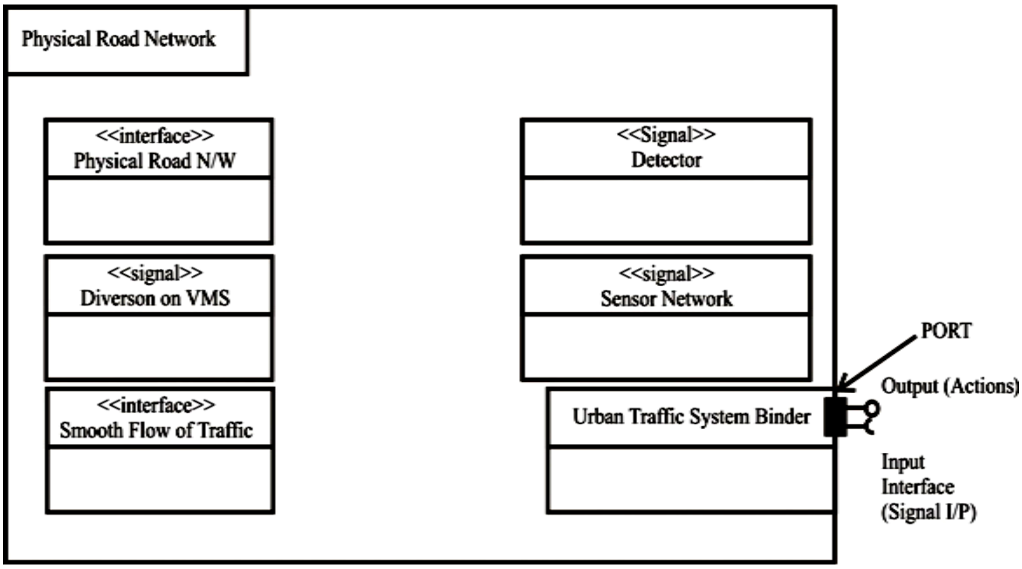


Figure 3.12 Physical Road Network Abstract Platform

3.6 CHAPTER SUMMARY

In this chapter a framework for modeling the urban traffic control systems has been developed using model driven engineering and activity theory. Activity theory is utilized to model the conceptual, behavioral and philosophical aspects of the system.

The concept of abstract platform provides effective methods of exchange of signals between various traffic agents. Model Driven Engineering successively refines models from analysis to design and then automatically generates code. A common pattern in MDA development is to define a platform- independent model of a distributed application and to apply (parameterized) transformations to PIM to obtain one or more platform specific models (PSMs). When pursuing platform - independence one could strive for PIMs, that are neutral with respect to all different classes of middle ware platforms.

A set of Activity Theory relations with Traffic Agents has been developed using Model Driven Engineering. In order to incorporate both the methodologies the Platform Independent Model of an Urban Traffic Control System is represented in UML of MDE framework to combine Activity Theory with MDE. The two major components, traffic signaling and physical road networks are further elaborated for reducing the traffic congestion at intersections and main roads for achieving smooth flow of traffic.

CHAPTER 4
FUZZY SET THEORY & CONTROL SYSTEMS

4.1 INTRODUCTION

Humans are capable to use linguistic information precisely in their decision making. Due to imprecise and uncertain nature of the linguistic information, machines are not capable to use them in decision making processes using traditional methods. To make the machines intelligent and to deal with uncertainties, like humans in this regard, Fuzzy Techniques are used.

The idea of the Fuzzy Logic was first introduced by Professor Lotfi Ahmad Zadeh, at University of Berkeley, California in his seminal paper "Fuzzy Sets" [100].

Fuzzy Logic [101, 102] is a form of multi-valued logic derived from fuzzy set theory to deal with approximate reasoning. It provides the means to represent and process the linguistic information and subjective attributes of the real world. Fuzzy Logic is the extension of Boolean Crisp Logic to deal with the concept of partial truth. Fuzzy Logic is applied in a number of areas, like engineering applications, medical applications, economics and management, industrial applications and many more.

In the early stage of the Fuzzy Logic, a number of misconceptions were created. Here, few points about fuzzy logic are introduced to make the concept very clear.

1. Fuzzy logic is not fuzzy.
2. Fuzzy logic is precise.
3. Fuzzy Logic is a precise system of reasoning, deduction and computation in which the objects of discourse and analysis are associated with information which is or is allowed to be imperfect.

4. Any formal system can be fuzzified.

Rule Base Systems [103] are highly applicable in decision making, control systems and forecasting. To deal with imprecise, uncertain and inexact real world knowledge, in rule based systems, fuzzy techniques are used. Fuzzy logic is the way to represent the complex situations in terms of simple natural languages.

4.2 BASIC CONCEPT: FUZZY LOGIC

The theory of Fuzzy Logic can be developed using the concepts of Fuzzy Sets similar to how theory of crisp bivalent logic can be developed using the concept of crisp sets. Specifically, there exists an isomorphism between sets and logic. In view of this, a good foundation of the fuzzy sets is necessary to develop the theory of Fuzzy Logic.

A fuzzy set is a set without clear or sharp (crisp) boundaries. Partial membership degree is possible in fuzzy sets. In other words, softness is associated with the membership of elements associated.

Examples may include like TRAFFIC QUEUE of Urban Traffic System. This fuzzy variable may take fuzzy values, like SMALL, LARGE, EXTRA LARGE, OVERFLOW.

4.2.1 UNIVERSE OF DISCOURSE

If universe of discourse is represented by X, is a set that contains every set of interest in the context of a given class of a problem.

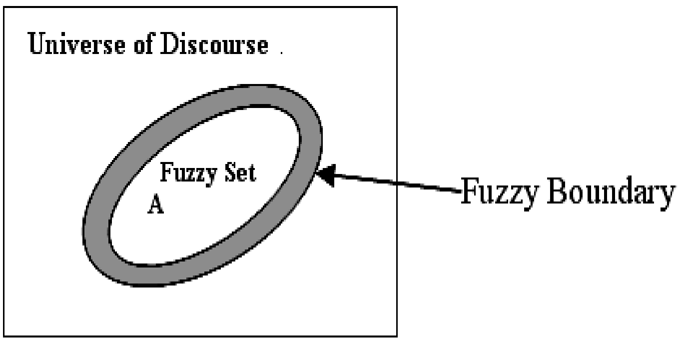


Figure 4.1 Venn diagram of Fuzzy Set

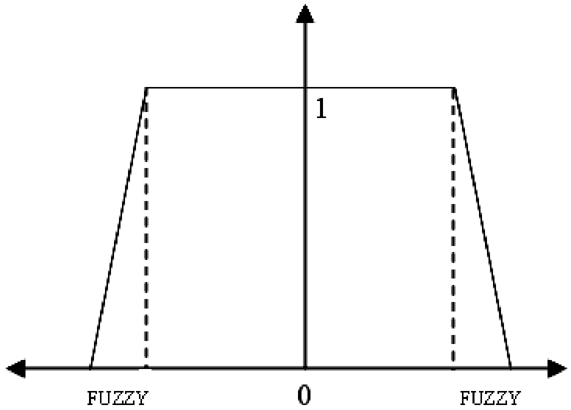


Figure 4.2 Fuzzy Membership Functions

4.2.2 REPRESENTATION OF FUZZY SETS

There are two representation techniques of fuzzy sets, membership function method and symbolic representation.

Membership Function Method

This function gives the grade (degree) of membership within the set of any element of Universe of Discourse. The membership function maps the elements of the universe on to the numerical values in the interval [0, 1].

$\mu_A(x): X \rightarrow [0,1]$

Here, $\mu_A(x)$ is the membership function of the fuzzy set A in the universe X. It is defined as follows:

$A = \{(x, \mu_A(x)); x \in X, \mu_A(x) \in [0,1]\}$

The membership function represents the grade of possibility that an element x belongs to the set A. It is a possibility function, not a probability function.

Symbolic Representation

A fuzzy set may be symbolically represented as follows: $A = \{x \mid \mu_A(x)\}$. They can also be represented as a formal series, when the universe is discrete in the nature.

$$A = \mu_A(x_1)/x_1 + \mu_A(x_2)/x_2 + \ldots\ldots\ldots \quad \text{or} \quad \mu_A(x_{i1})/x_i + \ldots\ldots\ldots$$

$$A = \sum_{x_{i \in X}} \frac{\mu_A(x_i)}{x_i}$$

If the universe is continuous then it can be represented as follows:

$$A = \int_{x \in X} \frac{\mu_A(x)}{x}$$

4.2.3 ALGEBRAIC OPERATIONS ON FUZZY SETS

Let X is a set of objects with elements denoted by x, i.e. X={x}

A fuzzy set A in X is characterized by a membership function $\mu_A(x)$, which maps each point in X on to the real interval [0.0, 1.0]. As $\mu_A(x)$ approaches 1.0, the grade of membership of X in A increases.

1. A is empty if for all x, $\mu_A(x)$ =0.0

2. If A and B are the two fuzzy sets, then A=B iff for all x: $\mu_A(x) = \mu_b(x)$.

3. $\mu_A(x)'$ =1- $\mu_A(x)$

4. A is contained in B iff $\mu_A(x) <= \mu_b(x)$

5. $C = A \cup B \Rightarrow AUNIONB$, where $\mu_C(x) = \max(\mu_a(x), \mu_b(x))$

6. $C = A \cup B \Rightarrow AINTERSECTIONB$, where $\mu_C(x) = \min(\mu_a(x), \mu_b(x))$

4.2.4 SUPPORT SET

This is a crisp set of a fuzzy set containing all the elements (in the universe) whose membership grade is greater than 0. The support set S of a fuzzy set A with membership function $\mu_A(x)$ is given by

$$S = \{x \in X \mid \mu_A(x) > 0\}$$

4.2.5 α -CUT OF THE FUZZY SET

The α -cut of the fuzzy set A is the crisp set denoted by A_α formed by those elements of A whose membership function grade is greater than or equal to a specified threshold value α .

$$A_\alpha = \{x \in X \mid \mu_A(x) \geq \alpha\}, \alpha \in [0,1]$$

The strong α -cut is defined by

$$A_{\alpha} = \{x \in X \mid \mu_{A}(x) > \alpha\}, \alpha \in [0,1]$$

When α =0 then α -cut will become the support set of a fuzzy set.

4.3 FUZZY RULE BASED SYSTEM (FRBS)

Fuzzy Rule Based Systems (FRBS) constitute an extension to classical rule based systems, because they deal with IF – THEN rules whose antecedents and consequents are composed of fuzzy logic statements, in place classical logical ones.

The most common applications of FRBS include Fuzzy Modeling [104], Fuzzy Control [105] and Fuzzy Classification [106]. In a FRBS, fuzzy logic used to perform the operations like, representation of different form of knowledge, modeling the interactions and relationships that exist among its variables. The main features of the knowledge captured by fuzzy sets involve handling of uncertainty. Due to this, inference methods have become more robust and flexible with the approximate reasoning methods using Fuzzy Logic.

Linguistic variables and values are used for the enhancement of the Knowledge Representation. These variables and their values are defined by the context dependent fuzzy sets whose meanings are specified by gradual membership function.

Two major types of FRBSs proposed are, Mamdani Fuzzy Rule Based Systems **[**107**]** and Takagi-Sugeno-Kang FRBSs **[**108].

4.3.1 MAMDANI FUZZY RULE – BASED SYSTEMS

These are the FRBS with fuzzifier and defuzzifier, more commonly these are known as Fuzzy Logic Controllers (FLC). The major constituents of the Mamdani FRBS are shown in Figure 4.3.

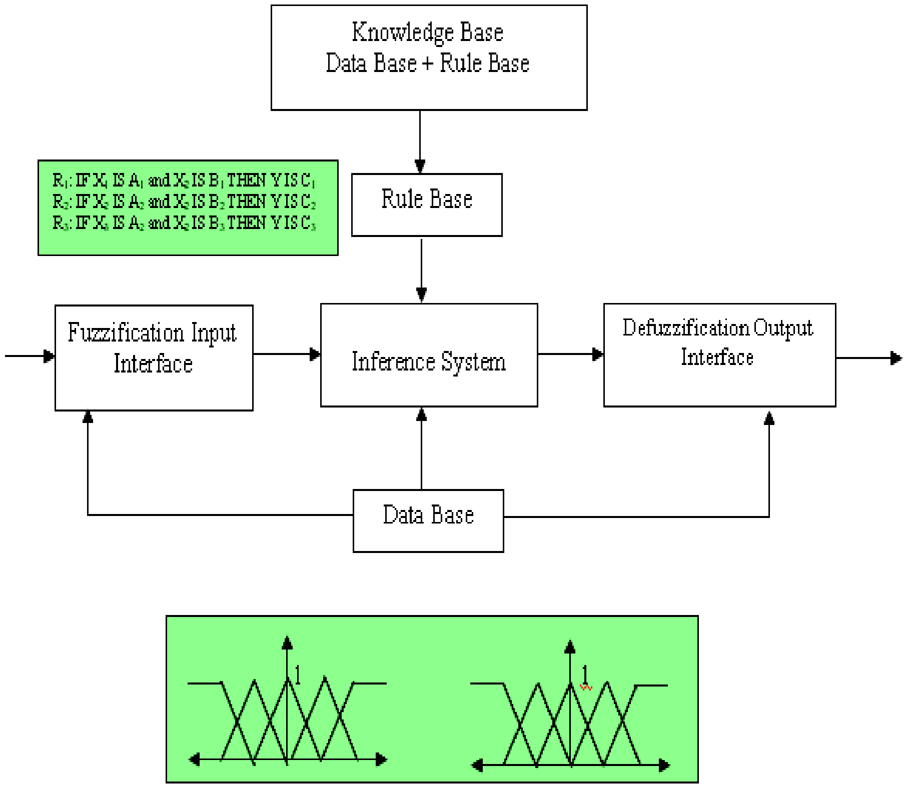


Figure 4.3 Mamdani Fuzzy Rule Based Systems

1. Knowledge Base: The Knowledge Base (KB) stores the available knowledge about the problem in the form of fuzzy "IF THEN" rules. It is composed of two main components, Data Base (DB) and Rule Base (RB). Data Base (DB) stores the membership functions of fuzzy sets and scaling functions for context adaptation purpose. Rule Base (RB) stores the FUZZY IF THEN rules for the purpose inference and decision making. Multiple rules can be fired simultaneously for the same input.

2. Fuzzification Interface*:* It transforms the crisp input data into fuzzy values that acts as input to fuzzy reasoning process.

3. Inference System*:* It infers from the fuzzy input to several resulting output fuzzy sets according to the information stored in the Knowledge Base (KB).

4. Defuzzification Interface*:* It converts the fuzzy sets obtained from the inference process into a crisp action that constitutes the global output of the FRBS.

4.3.2 TSK FUZZY RULE BASED SYSTEMS

A new FRBS model is proposed, based on rules whose antecedent is composed of the linguistic variables and the consequent is represented by a function of the input variables.

IF X_1 is A_1 and…………and X_n is A_n THEN $Y=p_1.X_1+……+p_n.X_n+p_0$

Here, X_i is the system input variable, Y as the output variable p= (p_0, p_1,…….., p_n) is a vector of real parameters. A_i is the direct specification of a fuzzy set or linguistic label that points to a particular member of a fuzzy partition of a linguistic variable.

The output of a TSK FRBS using a KB composed of m rules is obtained as a weighted sum of the individual outputs provided by each rule, Y_i is given by

$$\frac{\sum_{i=1}^{m} h_i . Y_i}{\sum_{i=1}^{m} h_i}$$

Here, i=1, 2, m. $h_i = T(A_{i1}(x_1),........, A_{in}(x_n))$ is the matching degree between the antecedent part of the i[th] rule and the current inputs to the systems, $x_0 = (x_1,......x_n)$. T stands for the conjunctive operator modeled by a t-norm.

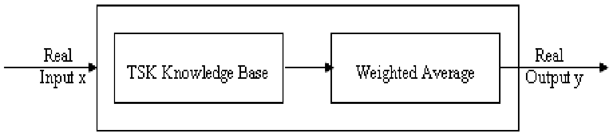


Figure 4.4 TSK Type Fuzzy Rule Based Systems

4.4 FUZZY CONSTRAINT OF ABSTRACT URBAN TRAFFIC SYSTEM (UTS)

As MDE supports both behavioral and structural aspects of a system so to deal with uncertainties, Fuzzy constraint of Abstract urban traffic system is developed.

Figure 4.5 depicts the final realization of Abstract Urban Traffic system using Fuzzy Logic. The interaction point that corresponds to Port- 1 exchange the signals received from the detector network and accordingly sends the control signal for various junctions and VMS.

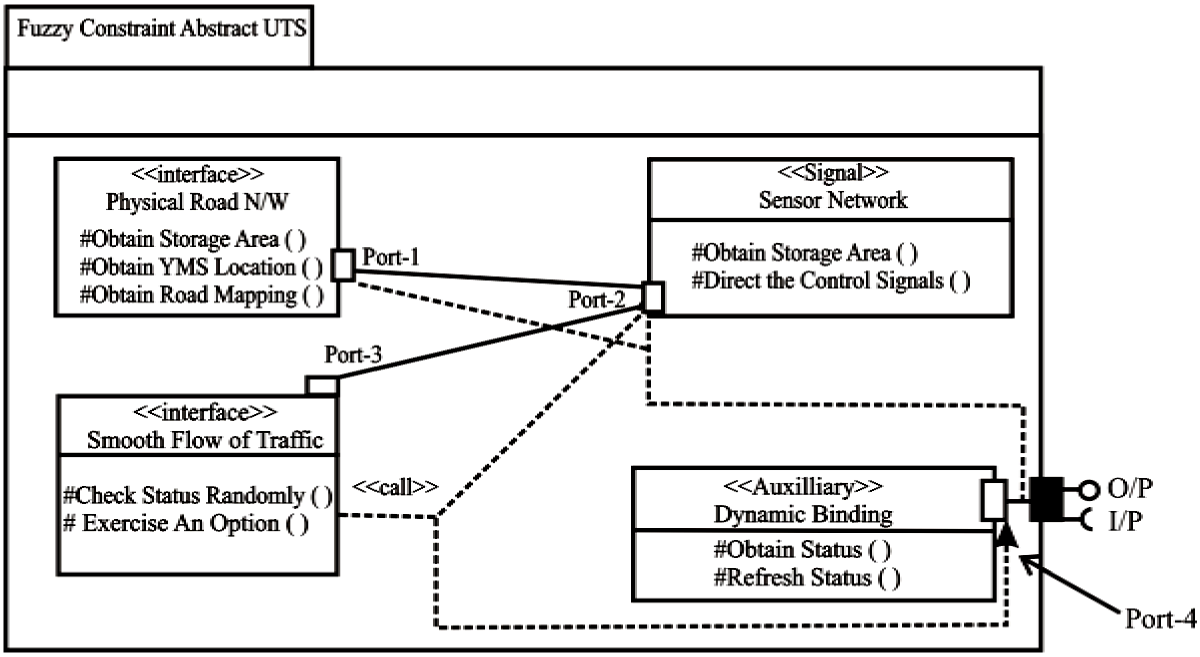


Figure 4.5 Fuzzy PIM Distributed Entity Component Platform

In order to represent the Fuzzy PIM Linguistic Variables and Fuzzy rules for entering the uncertainty into the performance computations are used. The Fuzzy rule are based on Activity Theory notation given by Linguistic description set

$$\text{A.T.} = \left\{ \frac{\underset{\sim}{\text{include}}}{\text{Artifact}} \quad \frac{\underset{\sim}{\text{uses}}}{\text{Tool}} \quad \frac{\underset{\sim}{\text{produce}}}{\text{Outcome}} \quad \frac{\underset{\sim}{\text{persue}}}{\text{Objective}} \quad \frac{\underset{\sim}{\text{transform}}}{\text{Object}} \quad \frac{\underset{\sim}{\text{divided by}}}{\text{Division of Labour}} \quad \frac{\underset{\sim}{\text{accomplished by}}}{\text{Community}} \quad \frac{\underset{\sim}{\text{Governed by}}}{\text{Rules}} \quad \frac{\underset{\sim}{\text{accomplished by}}}{\text{subject}} \right\}$$

The Fuzzy Relationship within various ports of elements of Fuzzy PIM Abstract Platform is implemented.

The fuzzy relation is a fuzzy set defined on the Cartesian product of elements. {X, X2, ...Xn} where types (x1, x2.........xn) may have varying degree of membership $\mu R\,(x_1,x_2,\ldots\ldots\ldots x_n) = \int \mu R\,((x_1,x_2,\ldots\ldots\ldots x_n)$

Applying the above Cartesian Rule to A.T. - MDE framework:

The elements R (Physical Road N/W, Sensor Network, Smooth Flow of Traffic, Dynamic binding).

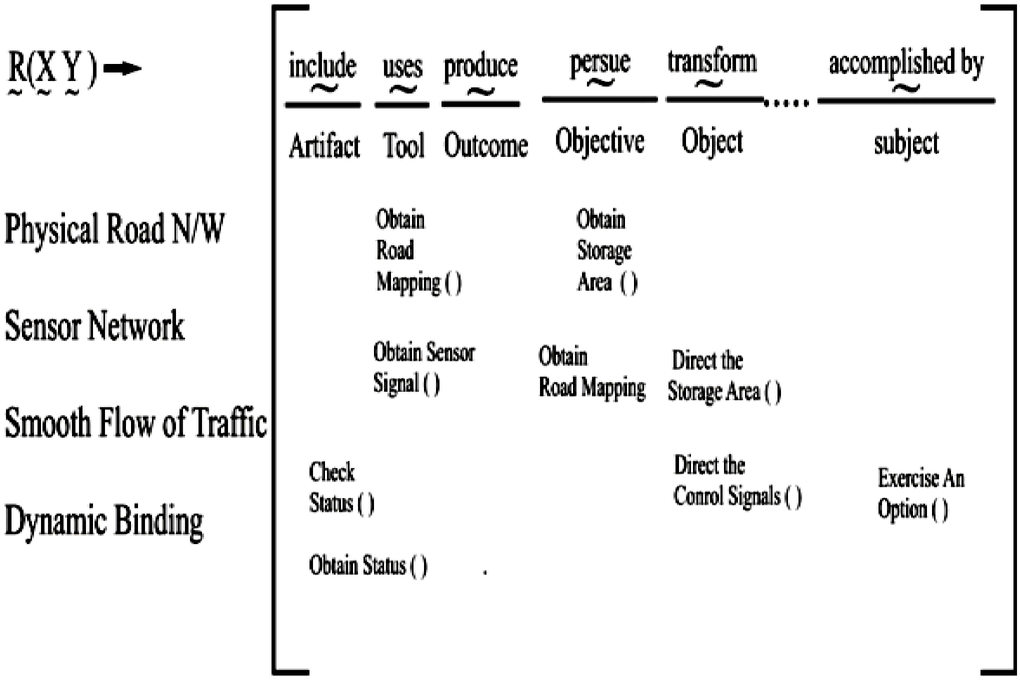
= ∫ μR (obtain Storage Area (), Obtain VMS (), Obtain Road Mapping ( ), Obtain Sensor Signal ( ) ....).

Let $\underset{\sim}{X}$ = {Obtain Storage Area ( ), Obtain VMS ( ), Obtain Road Mapping ( ), Obtain Sensor Signal ( ) ....}

$\underset{\sim}{Y}$ =

$$\left\{ \frac{\underset{\sim}{\text{include}}}{\text{Artifact}} \quad \frac{\underset{\sim}{\text{uses}}}{\text{Tool}} \quad \frac{\underset{\sim}{\text{produce}}}{\text{Outcome}} \quad \frac{\underset{\sim}{\text{persue}}}{\text{Objective}} \quad \frac{\underset{\sim}{\text{transform}}}{\text{Object}} \cdots\cdots \frac{\underset{\sim}{\text{accomplished by}}}{\text{subject}} \right\}$$

Fuzzy Relationship R (X, Y) can be expressed by n_{xm} matrix as follows:



The R relationship finally can be stated as:

$$\underset{\sim}{R} = \frac{\text{Obtain Road Mapping ( )}}{\text{Physical Road N/W, } \frac{\text{Uses}}{\text{Tool}}} + \frac{\text{Obtain Storage Area ( )}}{\text{Physical Road N/W, } \frac{\text{Persue}}{\text{Objective}}} + \frac{\text{Obtain Road Mapping ( )}}{\text{Physical Road N/W, } \frac{\text{Persue}}{\text{Objective}}}$$

$$+ \frac{\text{Obtain Sensor Signal ( )}}{\text{Sensor N/W, } \frac{\text{Uses}}{\text{Tool}}} + \frac{\text{Direct the Control Signal ( )}}{\text{Sensor N/W, } \frac{\text{Transform}}{\text{Object}}} + \ldots\ldots$$

$$+ \ldots\ldots \frac{\text{Exercise an Option ( )}}{\text{Dynamic Binding Accomplished by}}$$

Relationships between objects are the concepts involved in dynamic system applications. The Classical binary relation represents the presence or absence of connection or absence of a connection or interaction or association between Model Driven Engineering Concepts and Activity Theory (A.T.) framework with reference to Urban Traffic System (UTS). The help of relationship link of Fuzzy Set theory achieves the mapping of various entities of Abstract Model. The existence of uncertainty in message passing and control between different entities is evaluated by Cartesian framework.

4.5 CHAPTER SUMMARY

Fuzzy Control Systems are highly applicable in developing the control systems for handling congestion in urban traffic. In chapter 4, the basic concepts of fuzzy logic and fuzzy rule based systems are discussed along with the fuzzy extended MDE for general activity diagram for urban traffic system. Fuzzy Logic is the technique to deal with uncertainty inherent in the system. It is defined as the logic to make the uncertain working of the system precise. The Rule Based Systems are extended to deal with the uncertainties in rules, linguistic variables etc with fuzzy logic. These systems are called FRBS (Fuzzy Rule Based Systems). Mamdani and TSK FRBS are the two main FRBS that are widely applicable in developing different fuzzy urban traffic control systems.

The fuzzy extended MDE for covering the general activity diagram of Urban Traffic system is developed. MDE supports both behavioral and structural aspects of a system so fuzzy MDE concepts are propounded in the present study as: Fuzzy structure and Fuzzy Behavior.

In order to represent the Fuzzy PIM the linguistic variables and fuzzy rules for entering the uncertainty into the performance computations is used. The classical binary relation represents the presence or absence of connection or absence of a connection or interaction or association between Model Driven Engineering Concepts and Activity Theory framework with reference to Urban Traffic System.

The help of relationship link of fuzzy set theory achieves the mapping of various entities of abstract model. The existence of uncertainty in message passing and control between different entities is evaluated by Cartesian framework to generate membership functions.

CHAPTER 5

N-DIMENSIONAL SELF ORGANIZING PETRI NETS FOR URBAN TRAFFIC MODELING

5.1 INTRODUCTION

In this chapter, a Neuro Petri Net approach is used to model a Physical Road Network. The approach uses the producer consumer based Petri Net networks to model the system by producing minor sub lane by-pass system near the congested intersection for achieving smooth flow of traffic. This Petri Net approach is then extended to model the N- dimensional self organizing trained grid network for reducing traffic congestion from entire grid network. Later on the capability of learning process in the proposed approach is enhanced by Neuro Genetic approach.

5.2 PETRI NETS: A BRIEF OVERVIEW

Petri net was first introduced by C M Petri in 1960. Petri nets [109, 110] are graphical and mathematical modeling tool applicable to many systems and proved to be a promising tool for describing and studying information processing systems that are characterized as being concurrent, asynchronous, distributed, parallel, nondeterministic, and/or stochastic. As a graphical tool, Petri nets can be used as a visual-communication aid similar to flow charts, block diagrams, and networks. In addition, tokens are used in these nets to simulate the dynamic and concurrent activities of systems. As a mathematical tool, it is possible to set up state equations, algebraic equations, and other mathematical models governing the behavior of systems. Petri nets can be used by both practitioners and theoreticians. Thus, they provide a powerful medium of communication between them: practitioners can learn from theoreticians how to make their models more methodical, and theoreticians can learn from practitioners how to make their models more realistic.

These Petri Nets are applicable in many areas, like discrete event dynamic system [111], supervision [112], urban traffic control system [113, 114, 115] and many more. The non-primitive recursive complexity and non-decidability of Petri Nets are discussed in [116]. Several extensions and variations are also developed, like Colored Petri Nets [117, 118], Timed Petri Net and Hierarchical Petri Net.

5.2.1 BASIC ELEMENT OF PETRI NETS

The basic elements of Petri net models are “places”, “transitions” (represented by bars or boxes), “directed arcs” and “tokens”. A very simple Petri Net is used in Figure 5.1 to illustrate how these elements connect and play. If there is a directed arc connecting a place to a transition, the place is described as the input place to the transition so P1 represents the input place to transition T1. Similarly, if there is a directed arc connecting a transition to a place, then the place is an output place of that transition. A single place can be connected to a single transition with more than one arc. This weighted connection is represented by having the arc labeled with a natural number called arc weight. Thus, P1 is connected to T1 with weight two. By default, unlabeled arcs are weighted one. Conforming to these basic rules, multiple places and transitions can be connected to form very complex net to model the static view of a complex system.

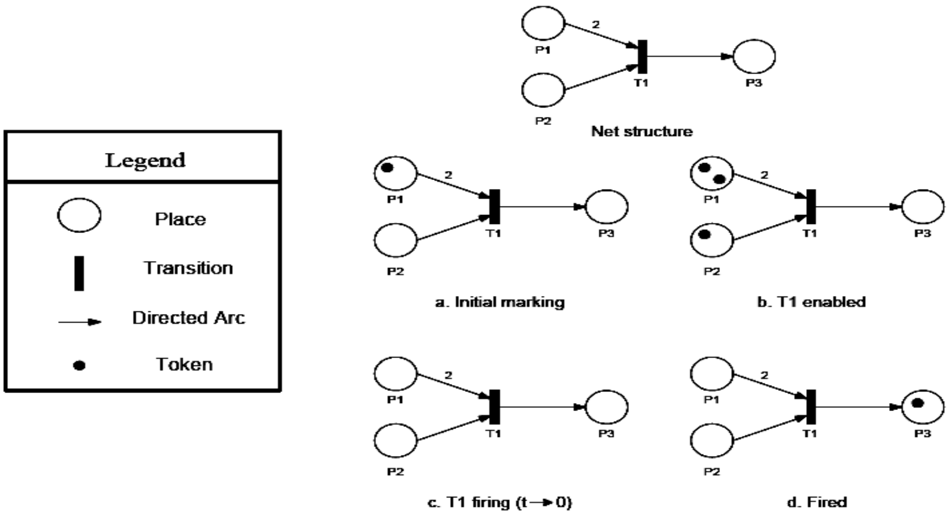


Figure 5.1 Petri Net elements and firing sequence (a to d).

Petri net models consist of two parts: (1) the net structure that represents the static part of the system and (2) a marking that represents the overall state on the structure. The token distribution among the places of a Petri net is called its marking. When one or more tokens reside in a place, the place is said to be marked, otherwise it is unmarked. The number of tokens at a place represents the local state of the place so that the marking of the net represents the overall state of the system.

5.2.2 DYNAMICS OF PETRI NET

Figure 5.1 (a) captures the initial marking of the net, which represents the initial state of the system. The dynamic behavior of the system is then modeled by the flow of token and the firing of transitions. Superficially, transition firing means that tokens in the input places are apparently moved to the output places.

Transition firing involves the following steps:

(1) A transition is said to be enabled if each input place has at least as many tokens as the weight of the arc connecting them (Figure 5.1b).

(2) Enabled transition may be fired by removing from each input place the number of tokens equal to the weight of the arc connecting them (Figure 5.1c).

(3) When the transition is fired, tokens will be added to the output places connected to the transition.

The number of tokens to be added to each output place is equal to the weight of the arc joining them (Figure 5.1d).

For step 2, it should be noted that enabled transitions are never forced to fire. In practical modeling, transitions can be related to external conditions that determine whether they may fire or not when enabled. Besides, in ordinary Petri net model with no temporal feature, firing occurs instantly (Figure 5.1c).

The above-described mechanism is usually called firing rule or informally, “token game”. While this token game governs the dynamic behavior of Petri net models, the meaning of this process is determined by the net interpretation. A token in a place would then indicate the resource is in that state or it is available respectively. Events and activities are modeled by transitions. The firing of a transition is used to trigger an action or event, or to indicate the start or termination of an activity. Assuming infinite input and output buffer size and part supply is never starved. Both places and transitions can be associated with actions and events depending on the net interpretation, as in Figure 5.1.

5.2.3 CHARACTERISTICS AND PROPERTIES OF PETRI NET

Petri nets are characterized by their ability to handle operation sequence, concurrency, conflict and mutual exclusion in systems. These features make them a promising tool for describing and analyzing concurrent and real-time systems. Figure 5.2 depicts how Petri nets can be used to model the mentioned system features.

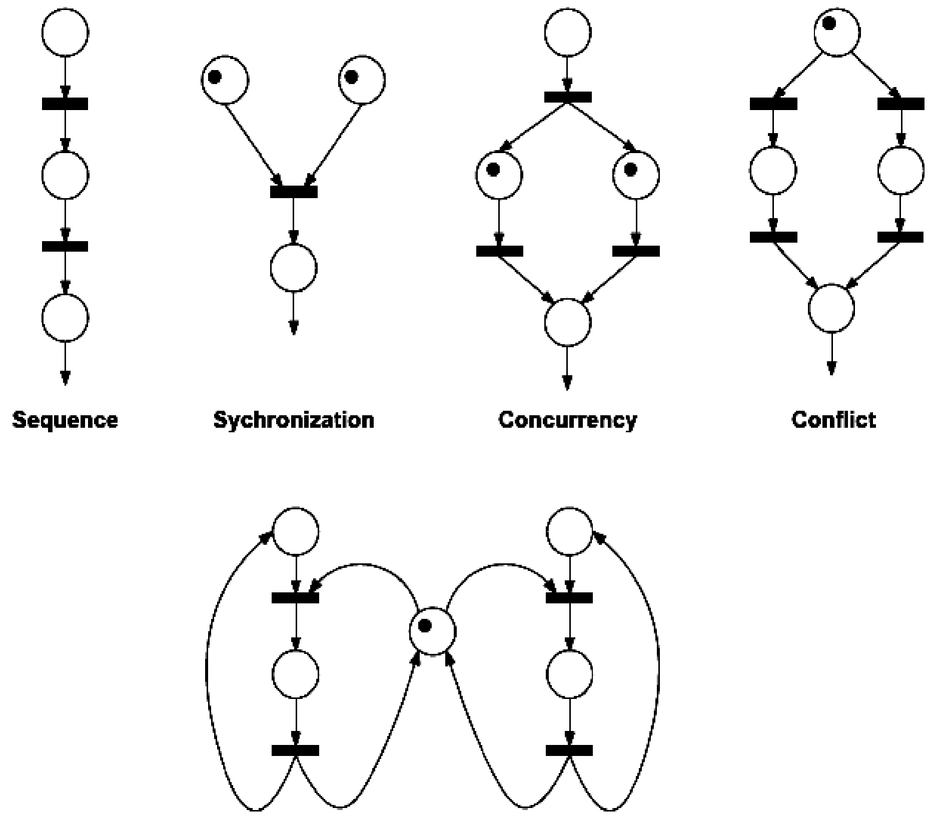


Figure 5.2 Using Petri nets to model some of the real-time system features

In addition to their modeling power, Petri nets are described as both a graphical tool and a mathematical tool. As a graphical tool, they provide a visual medium for modeler to describe complex system and present to users. As a mathematical tool, a Petri net model can be represented by linear algebraic equations, which opens a possibility for the formal analysis of the model. Again, mathematical properties of Petri net can be distinguished into (1) structural **Shared resource** properties that depend on the net structure and (2) behavioral properties that depend on the initial and subsequent markings. Mathematically, analysis of Petri nets can be based on enumerating of all possible markings to form reachability trees and/or through methods and theories in discrete mathematics like matrix equations. The properties of Petri nets are described below:

1. Reachability — this determines whether a system can reach a specific state or exhibit a particular functional behavior. The reachability set can be denoted by *R* (*M*0), where 0 *M* is the initial marking.

2. Liveness - this detects whether deadlock situation will be occurred in the system or not.

3. Boundedness and Safeness — a Petri net is said to be bounded and safe if no overflow condition is detected.

4. Conservativeness -a Petri net is described as conservative if the number of tokens in the model remains constant irrespective of the markings it takes on.

5. Reversibility - a Petri net is reversible if 0 $\forall M \in R$ (M), M is reachable from M, where M denotes a specific marking. This property determines whether system reinitialization is possible or not.

5.2.4 ADVANTAGES AND DISADVANTAGES OF USING PETRI NET

With respect to modeling, Petri nets offer the following advantages:

1. Using Petri nets to model features like precedence relation, concurrency, conflict and mutual exclusion of real-time system is simple and straightforward.

2. The formal graphical representation provides a medium of visualizing the complex system under modeling for both modelers and users.

With respect to analysis, Petri nets have the following advantages:

3. Having a well developed mathematical foundation; analysis can be carried out to detect deadlock, overflow and irreversible situations, etc.

4. Performance evaluation is possible through mathematical analysis of the model of the system (using Deterministic Timed Petri Nets or Stochastic Timed Petri Nets).

The major disadvantages of Petri nets are:

1. To model the notion of time is not straight forward

2. As the system size and complexity evolve, the state-space of the Petri net grows exponentially, which could become too difficult to manage both graphically and analytically.

3. Control logic is hard-wired, i.e. inflexible to cope with system change.

A lot of research has been carried out in order to tackle, in particular the first two weaknesses. Most of them attempt to enrich the modeling power of ordinary Petri nets by incorporating the notion of time, which leads to Timed

Petri nets and associating data to the token, leading to high level Petri net like Colored Petri nets, Fuzzy Petri nets, etc. Another important research area to manage the complexity of system modeling using Petri nets is Petri net synthesis. The major idea behind the method is to build a complex model through systematically synthesizing some well-defined Petri-net modules. Researchers in this area endeavour to provide the theories and methodologies for preserving the system properties during net synthesis.

5.3 PRODUCER- CONSUMER NETWORK BASED PETRI NETS

The producer-consumer network based Petri Net is a resource allocation network with a variable number of resources that are limited to a maximum number. There is a producer that generates new units and makes them available to a consumer. The consumer takes one unit of the resource at a time. The primary synchronization constraints are:

• *Overflow*: the producer cannot produce a new unit unless the number of units is below the maximum number allowed, and

• *Underflow*: the consumer cannot take a unit unless there is at least one available.

The Petri net shown in Figure 5.3 is a model of a producer-consumer network where the maximum number of units is limited to 3. In this model, there are two places that are used to represent the number of units produced but not yet consumed and the number of additional units that can be produced. These places are named Full and Empty, respectively. The names Full and Empty reflect that the units are often contained in a fixed sized buffer of size N, where N is the maximum number of units allowed. The number of buffer entries that are full contain produced units that are available to the consumer and the number of buffer entries that are empty contain spaces available to the producer to store new units. An invariant in this model is that number (full) + number (empty) = N. The buffer is modeled in Figure 5.3 by two places in the middle named Empty and Full. The three tokens in the Empty place represent the initial state of the system with three empty buffer elements. The absence of tokens in the Full place represents the initial state of the system where there are no buffer elements with information.

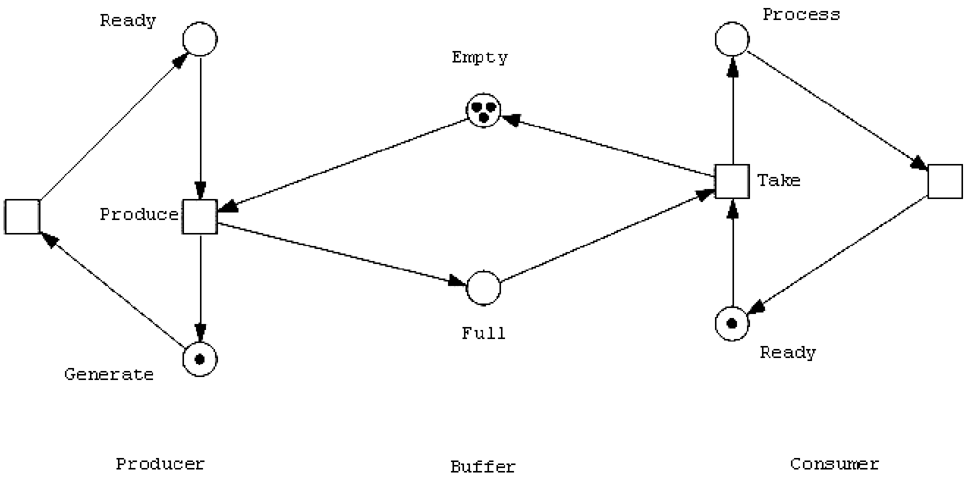


Figure 5.3 Producer Consumer network based Petri Net

The producer in Figure 5.3 is modeled as a subsystem with two places. The Generate place represents the condition of the producer when it is generating the next unit of information to transmit to the consumer. The Ready state represents the condition where the producer is ready to insert the newly generated information into the buffer where it will be available to the consumer. The transition Produce for the producer can only fire when the producer is Ready and there is at least one token in the Empty place (denoting a currently empty buffer element into which the new information can be placed).

The consumer in Figure 5.3 is modeled as a subsystem with two places. The Ready place represents the condition where the consumer is ready to receive the next unit of new information that was generated by the producer. The transition Take for the producer can only fire when the producer is Ready and there is at least one token in the Full place (denoting a buffer element containing new information which can be retrieved). The Process place in the producer represents the condition of the consumer when it is processing the new information most recently retrieved from the buffer.

It can be observed that the producer-consumer system in Figure 5.3 satisfies the two primary synchronization constraints noted above. The overflow constraint is satisfied because the producer cannot fire its Produce transition unless there is at least one token in the Empty place. Thus, it is not possible for the Produce transition to fire four (or more) times in a row without the Take transition firing one or more times. The underflow constraint is satisfied because the consumer cannot fire its Take transition unless there is at least one token in the Full place. Thus, it is not possible for the Take transition to fire four (or more) times in a row without the Produce transition firing one or more times.

5.4 INTRODUCTION TO NEURAL NETWORK

Artificial neural networks (ANN) [119-121] have been developed as generalizations of mathematical models of biological nervous systems. First wave of interest in neural networks (also known as connectionist models or parallel distributed processing) emerged after the introduction of simplified neurons. The basic processing elements of neural networks are called artificial neurons, or simply neurons or nodes. In a simplified mathematical model of the neuron, the effects of the synapses are represented by connection weights that modulate the effect of the associated input signals, and the nonlinear characteristic exhibited by neurons is represented by a transfer function. The neuron impulse is then computed as the weighted sum of the input signals, transformed by the transfer function. The learning capability of an artificial neuron is achieved by adjusting the weights in accordance to the chosen learning algorithm.

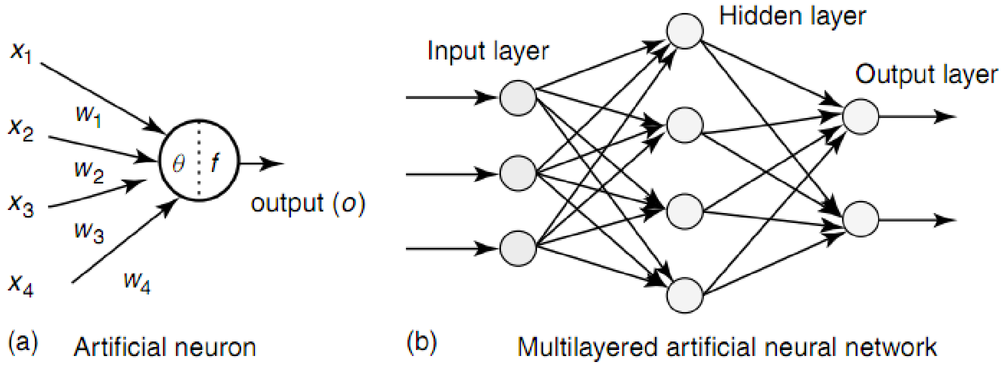


Figure 5.4 Artificial Neural Network

Mathematically, this process is described in the Figure.5.5.

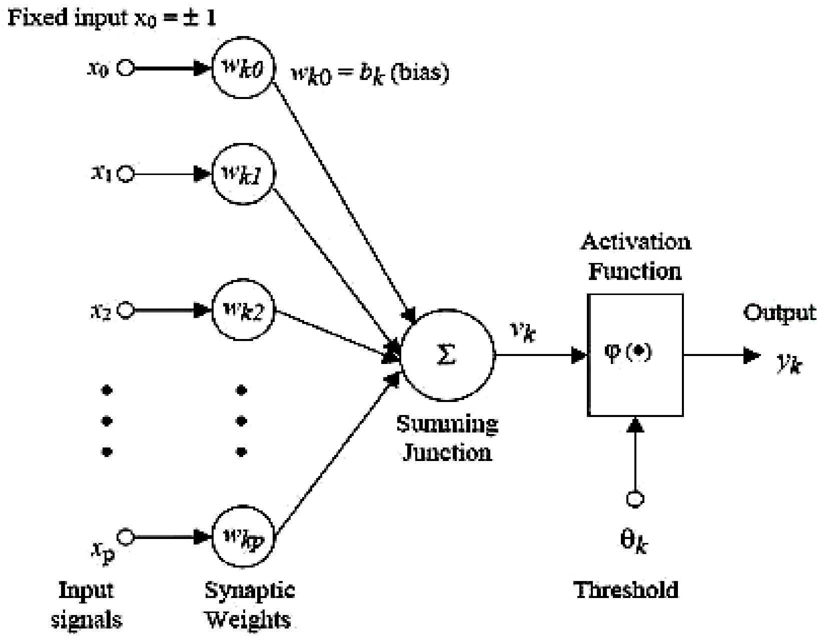


Figure 5.5 Artificial Neural Network Descriptions

From this model the interval activity of the neuron can be shown to be:

$$v_k = \sum_{j=1}^{p} w_{kj} x_j$$

Activation functions

As mentioned previously, the activation function acts as a squashing function, such that the output of a neuron in a neural network is between certain values (usually 0 and 1, or -1 and 1). In general, there are three types of activation functions, denoted by Φ(.) .First, there is the Threshold Function which takes on a value of 0 if the summed input is less than a certain threshold value (v), and the value 1 if the summed input is greater than or equal to the threshold value.

$$\varphi(v) = \begin{cases} 1 & \text{if } v \geq 0 \\ 0 & \text{if } v < 0 \end{cases}$$

Secondly, there is the Piecewise-Linear function. This function again can take on the values of 0 or 1, but can also take on values between that depending on the amplification factor in a certain region of linear operation.

$$\varphi(v) = \begin{cases} 1 & v \geq \frac{1}{2} \\ v & -\frac{1}{2} > v > \frac{1}{2} \\ 0 & v \leq -\frac{1}{2} \end{cases}$$

Thirdly, there is the sigmoid function. This function can range between 0 and 1, but it is also sometimes useful to use the -1 to 1 range. An example of the sigmoid function is the hyperbolic tangent function.

$$\varphi(v) = \tanh\left(\frac{v}{2}\right) = \frac{1 - \exp(-v)}{1 + \exp(-v)}$$

Learning in Artificial Network

A **neural network** has to be configured such that the application of a set of inputs produces (either 'direct' or via a relaxation process) the desired set of outputs. Various methods to set the strengths of the connections exist. One way is to set the weights explicitly, using a priori knowledge. Another way is to **'train' the neural network** by feeding it teaching patterns and letting it change its weights according to some learning rule.

The learning situations can be categorized in three distinct sorts. These are:

- **Supervised learning** or Associative learning in which the network is trained by providing it with input and matching output patterns. These input-output pairs can be provided by an external teacher, or by the system which contains the neural network (self-supervised).

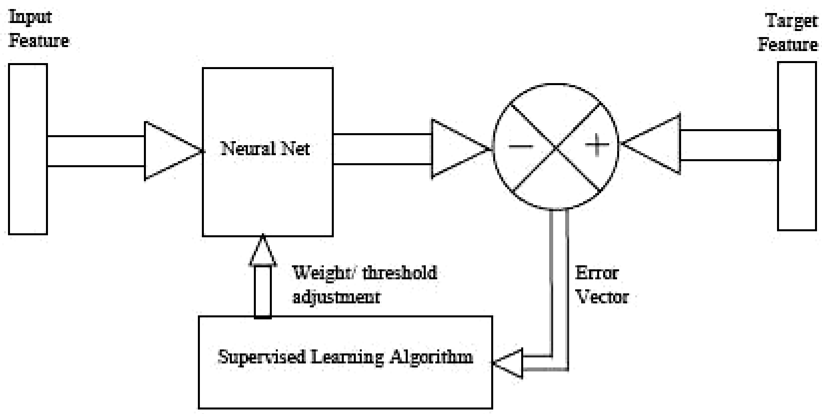


Figure 5.6 Supervised learning

- **Unsupervised learning** or Self-organization in which an (output) unit is trained to respond to clusters of pattern within the input. In this paradigm the system is supposed to discover statistically salient features of the input population. Unlike the supervised learning paradigm, there is no a-priori set of categories into which the patterns are to be classified; rather the system must develop its own representation of the input stimuli.
- **Reinforcement Learning** This type of learning may be considered as an intermediate form of the above two types of learning. Here the learning machine does some action on the environment and gets a feedback response from the environment. The learning system grades its action good (rewarding) or bad (punishable) based on the environmental response and accordingly adjusts its parameters. Generally, parameter adjustment is continued until an equilibrium state

occurs, following which there will be no more changes in its parameters. The self organizing neural learning may be categorized under this type of learning.

5.5 INTRODUCTION TO GENETIC ALGORITHMS

Genetic Algorithms [122-126] are search and optimization techniques based on Darwinian's principle of Natural Selection (Figure 5.7). The basic idea behind the natural selection is "select the best, discard the rest". The optimization strategies by genetic algorithms are implemented by simulating evolution of species through the natural selection. The fundamental technique behind the GA includes the three steps: 1. Evaluation of individual fitness, 2. Formation of gene pool, intermediate population through the selection mechanism, 3. Recombination through the crossover and mutation operators. Each problem to be solved by the GA must be associated with a Fitness Function.

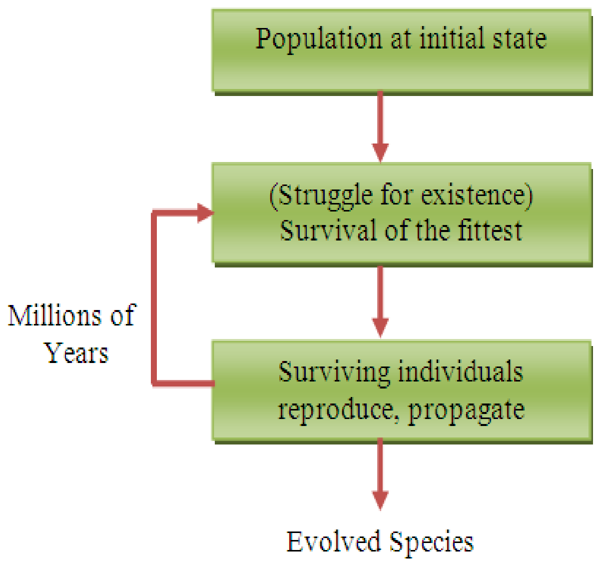


Figure 5.7 Evolution based on Natural Selection

The working of the GA can be well expressed by the following data flow diagram, clearly in Figure 5.8.

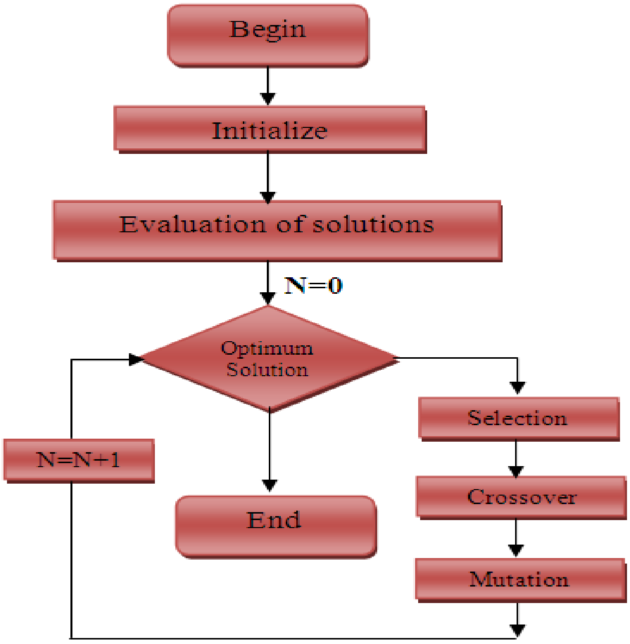


Figure 5.8 Working of Genetic Algorithms

5.6 PROPOSED MODEL OF TRAFFIC X-JUNCTION OF PHYSICAL ROAD NETWORK USING PETRI NETS

The proposed model considers a simple graphical model with Hazratganj, Lucknow as the Nodal point, that is from this point traffic converges and diverges. Figure 5.9 shows the main Hazratganj crossing and its interconnectivity with Botanical garden crossing.

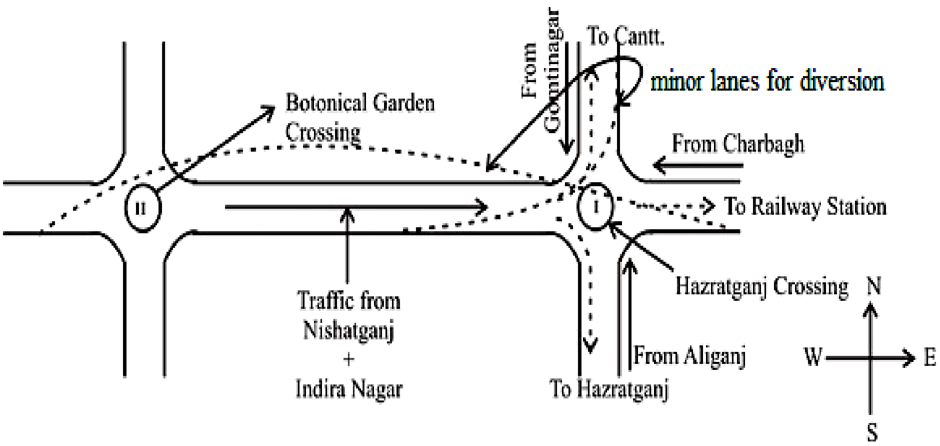


Figure 5.9 Main Hazratganj Crossing and its interconnectivity

In the first instance, the proposed model considers all the traffic moving towards crossing (I) i.e. Hazratganj Crossing from other localities like Indira Nagar, Aliganj, Gomti Nagar and Charbagh. The basic model is being derived from stochastic Petri net Modeling by Wang J. in [127].

It consists of flow of vehicle from one location to another in the direction of east to west or to south along with Petri net representation of Traffic light control. In order to avoid congestion at Hazratganj Crossing (crossing -I) it is proposed to introduce lane by-pass system by generating two minor sub lanes, one of the lane starting just before Botonical garden (crossing II) and ending after crossing -I for the commuters whose destination is Charbagh and another minor sub lane just before the crossing one for the commuters whose destination is Gomtinagar. The traffic flow of 4 phase intersection is represented by Petri Net as shown in Figure 5.10.

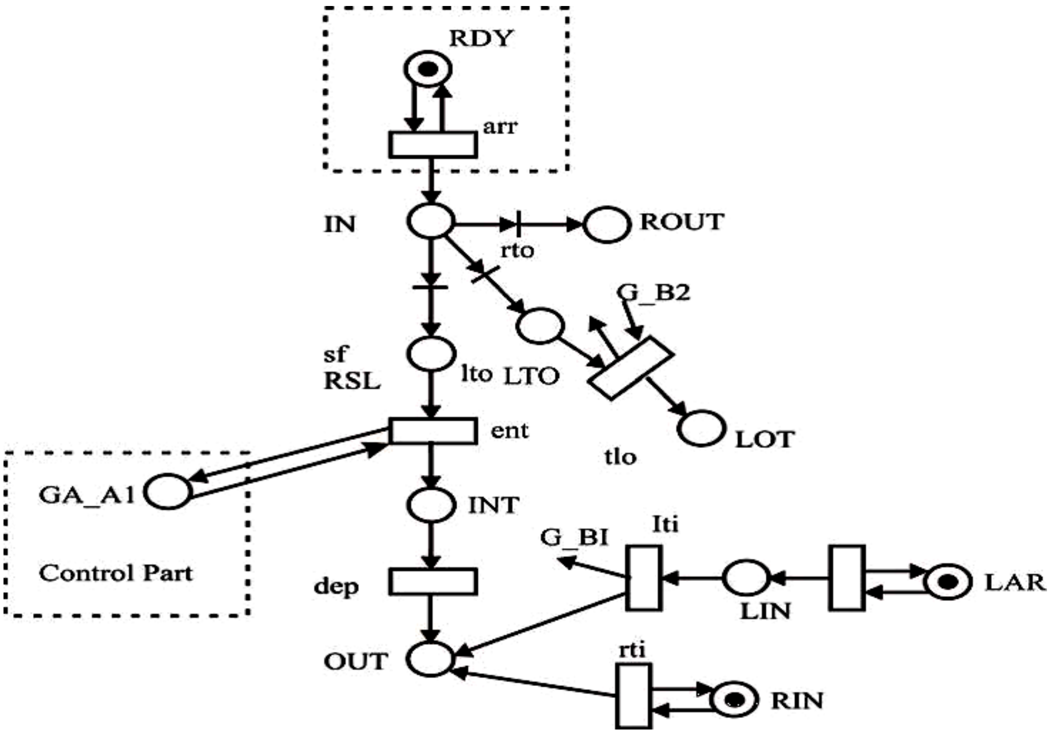


Figure 5.10 Traffic Flow of four phase intersection represented by Petri Nets.

Similarly the general control model will be complex Petri Net network as shown in Figure 5.11.

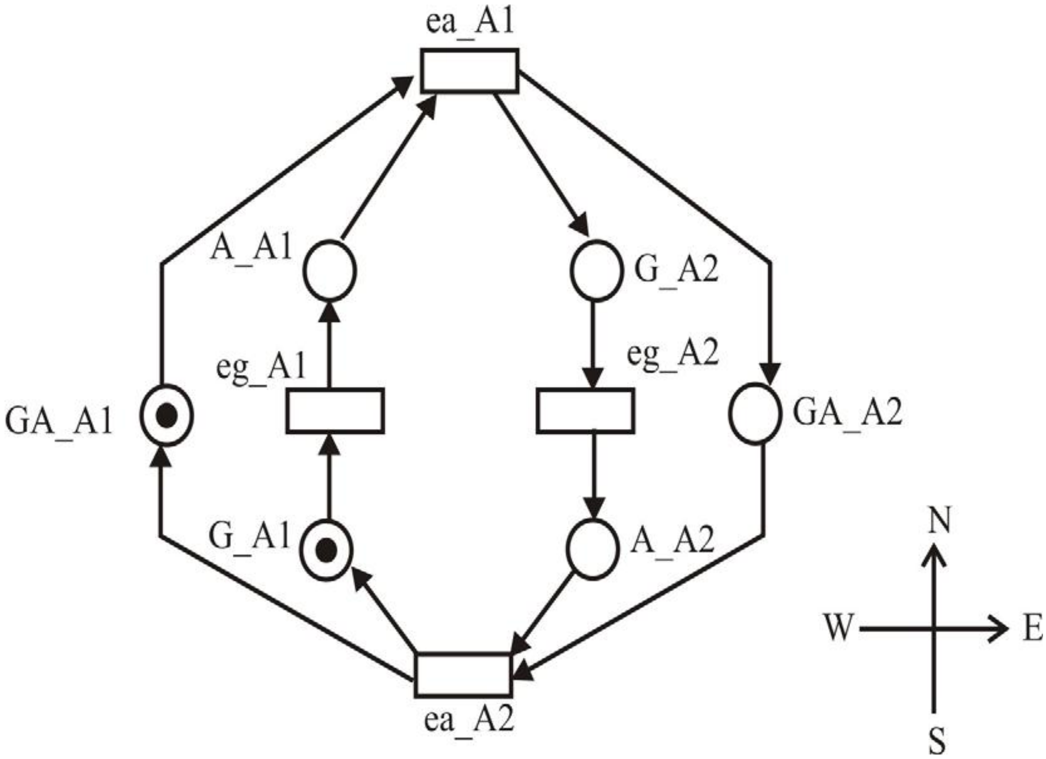


Figure 5.11The control section Model represented by Petri nets

5.7 EXTENDED MODEL FOR MINOR SUB LANE GENERATION THROUGH PRODUCER CONSUMER THEORY IN PETRI NETS

The proposed model for the generation of the minor sub lanes is based on producer –consumer network, which is divided into two parts. The first part focuses on the forward propagation Petri Net model which focuses on simple cause effect framework. The second part focuses on continuous Petri net Learning mechanism.

In Figure 5.12 the task of producer is to produce the free sub lane for diverting the traffic to free sub lanes from main roads. The consumer (Traffic flow) demands free sub lanes. The task of buffer is to add the free lanes/sub lanes from the producer (Traffic controller) and divert them to consumer (Traffic flow). When there is enough free sub lanes Blocked status becomes false with the release of one free sub lane.

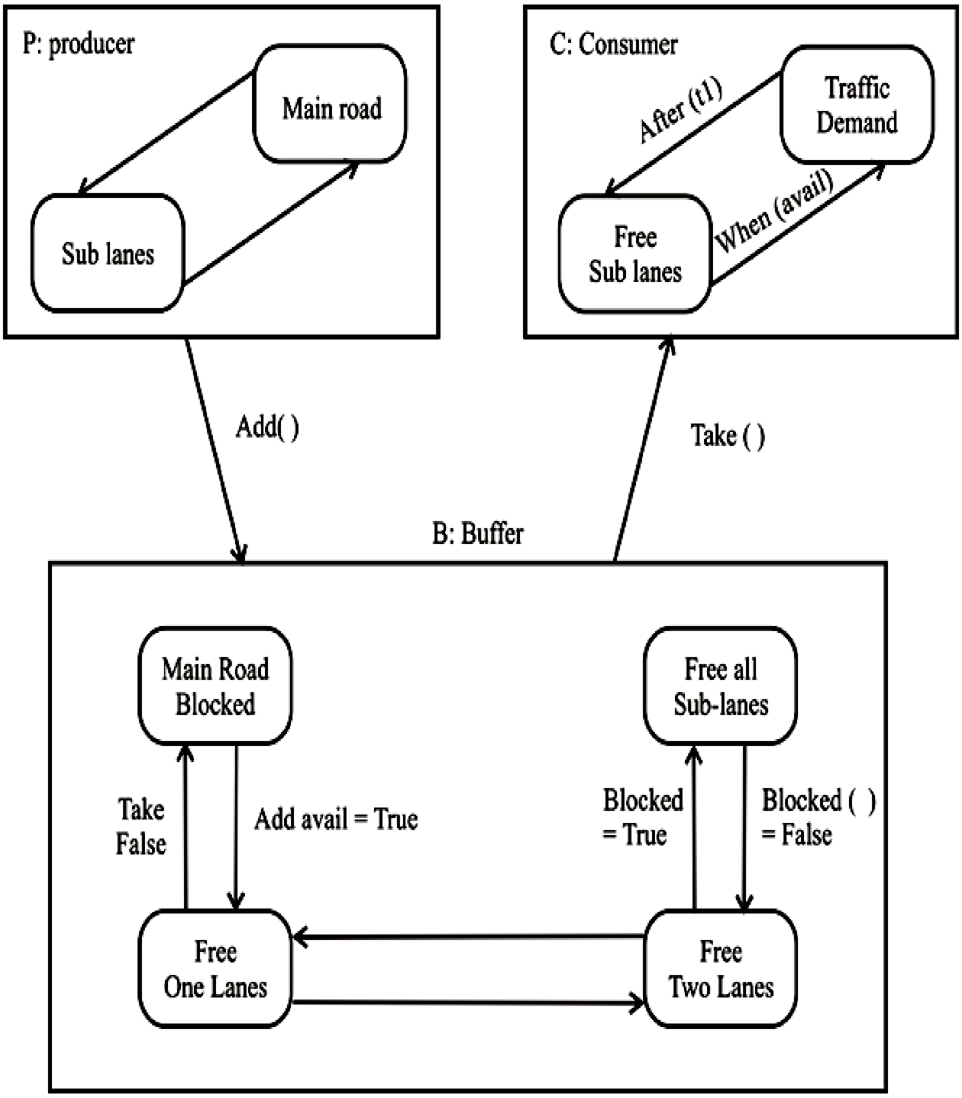


Figure 5.12 Combined Collaboration State Diagram for Producer/ Consumer of Urban Traffic System

The buffer has the capacity between the producer and consumer. The producer is blocked until consumer takes its product. The consumer is blocked until producer makes its product available. Each then spends time either producing or consuming something.

Through these minor sub lanes the traffic outflow have been increased from the main road, resulting in the reduction of traffic congestion at intersections on the main road. Simple producer- consumer base Petri Nets representing the workflow of the entire traffic dynamics is shown in Figure 5.13.

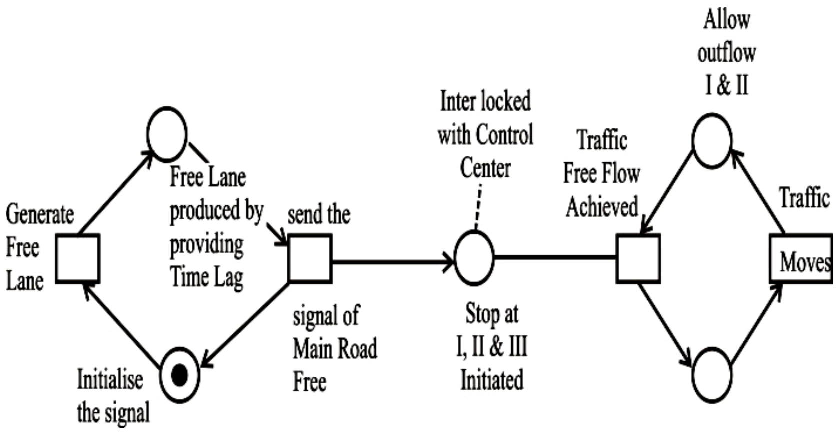


Figure 5.13 Causal Run of Producer - Consumer of Traffic Flow

Consider this producer - consumer as one single unit denoted by ‘X’. This main - road itself is a part of the entire road grid of the city. Assuming that there is same pattern of traffic movement, which is present at various interval of time. Applying Unidirectional Petri net Model with tokens moving in Feed Forward mode as shown in the Figure 5.14, the balancing condition for dynamic traffic flow in road grid of the city can be achieved by following algorithm:

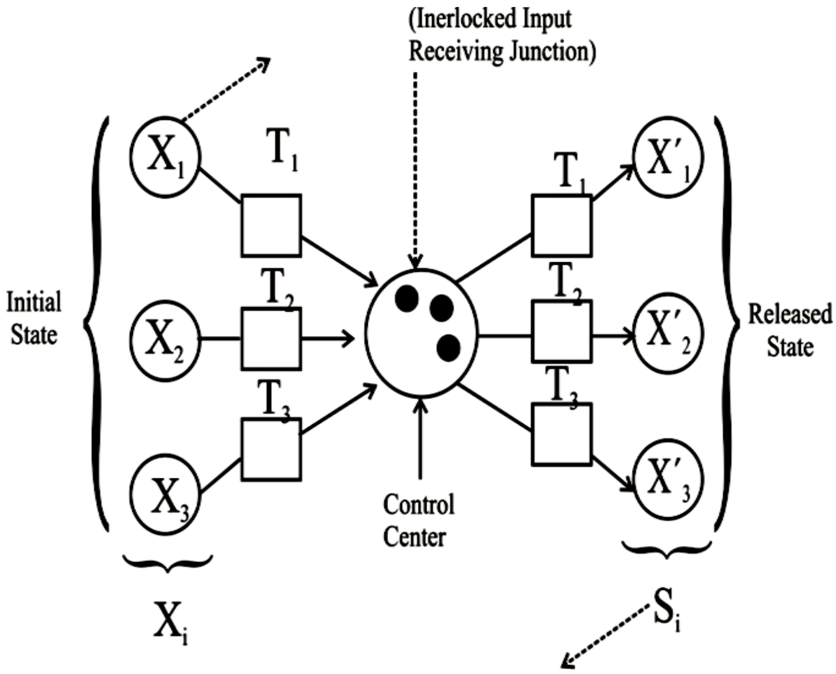


Figure 5.14 Dynamic Producer Consumer with Buffer Interlocked with Control Center

Algorithm

Step1: *Initialize each of the Producers- Consumers situations (x). Set the pattern learning rate as 'γ'.*

Step 2: *Set the control center such that:*

Xi = Si is achieved.

Step 3: *Let the Token release rate is defined as 1/N; where N is defined as the number of producer consumer initial states.*

Step 4: *The release of Token are updated as:*

x: (producer- old) = xi (producer - new state) + r (pre- post)

Where 'r' is the bulk arrival rate of Tokens.

Step 5: *Stop when system has transferred all the tokens and traffic reaches a balancing state.*

5.8 PROPOSED MODEL FOR N-DIMENSIONAL SELF ORGANIZING PETRI NET FOR URBAN TRAFFIC GRID NETWORK

Considering a situation of the producer consumer network to be trained and the combination of Control Center and Producer - Consumer as one single unit denoted as 'Y' for the first layer, 'Z' for the second and 'N' for the third layer

The Figure 5.15 shows the two dimensional grid of producer – consumer based Petri Net link with buffer interlocked with Virtual Counter which keeps the track of diversion of Token based on the congestion in the road network (i.e. consumer), generation of minor sub lanes (i.e. producers) and diversion of traffic through VMS. The counter (M) keeps track of tokens number stamped by the layer through which it is being generated and finally arriving at particular layers.

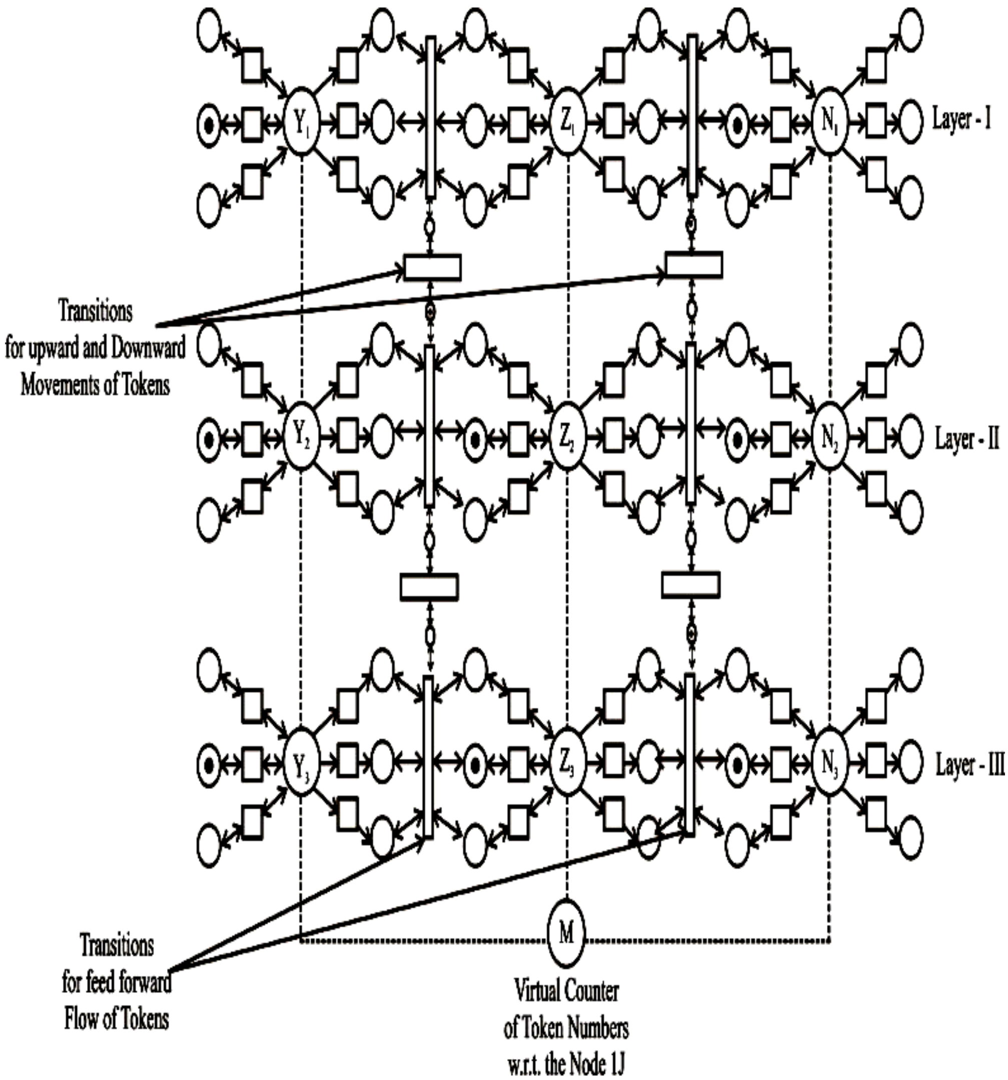


Figure 5.15 Grid Network of Producer- Consumer Structure

The purpose of showing the arrow in both the direction has special significance, during the first instance the token moves in forward learning mode and this state is now stored in Virtual Counter.

During the next cycle there is a change in sequence and it will behave in vice-versa mode, the road network which is now having heavy traffic movement will eventually settle down with lesser frequency of traffic with time. This requires a signal from the consumer end to the producer end to check the new status.

This process of adjustment and training of producer- consumer from their nearest neighbors goes on till the entire system becomes stable.

5.8.1 TRAINING ALGORITHM

Step 1: Set the Virtual Counter to value; set the stability session the grid has to perform.

Step 2: While stopping condition is false; perform step 3-8.

Step 3: For each layer the compute the complexity of link of the token movement is given as:

$x(n) = \sum(\text{Layer } 1 - \text{Layer } n)^2$

Where 'n' is the layer - n to which token moves.

Step 4: For each of the movement of token freeze the producer - consumer network which has become stable and these are no more to be initiated.

Step 5: After all the forward steps has been performed. Log the virtual counter to current state.

Step 6: Move in the reverse direction this time consumer driving the producer for necessary action calming.

Step 7: This Forward and Backward movement of Tokens takes place till the time entire network is Self- Organized and further flow of token is not required within a particular time frame.

Step 8: Test and store the stopping condition.

bottleneck situation in the entire city traffic network and then flow of token starts layer - by- layer to achieve the final stability. The grid works in two modes:

(i) The Initial formation of back- forward flow of tokens.

(ii) Convergence to a stable state.

5.9 ENHANCING THE CAPABILITIES USING NEURO-GENETIC APPROACH

The capabilities of the dynamic control strategy of urban traffic system are enhanced by combining neuron-genetic approach on Petri net. The main idea to use Genetic Algorithm with neural network is to search for the appropriate weight change of neural network which will optimize the learning rate of entire network. The algorithm developed can significantly reduce Neuro Petri net in aligning with traffic conditions.

The Algorithm for Dynamic Producer Consumer is given as:

Step1: *Initialize each of the Producers- Consumers situations (x).*

Set the pattern learning rate as 'γ'.

Step 2: *Set the control center such that:*

Xi = Si is achieved.

Step 3: *Let the Token release rate is defined as 1/N; where N is defined as the number of producer consumer initial states.*

Step 4: *The release of Token are updated as:*

x: (producer- old) = xi (producer - new state) + r (pre- post)

Where 'r' is the bulk arrival rate of Tokens.

Step 5: *Stop when system has transferred all the tokens and traffic reaches a balancing state.*

Assuming the initializing condition to be Xi and after successive training it reaches to 9.

The stabilising condition is reached after 'n' iteration given as :

$\{x; = t (x_1 ..... x_n\} \mid I \in \{ 1 .....n\}$

if there are N - dimensional node the equation will become.

$x_i = t (x_1 ..... x_n)$

..

...

$x_n = t_n (x_1 ..... x_n)$

x_i represents the recursion variables and $t(x_1 .... x_n)$ shows the process terms with possible occurrence of the recursion variables.

N- Dimensional Self-Organizing Petri Net Model of Urban Traffic Systems

Let '0' and '1' be defined as Low and High learning rate of the grid network of Petri net showing the simulation of Traffic in a mesh network.

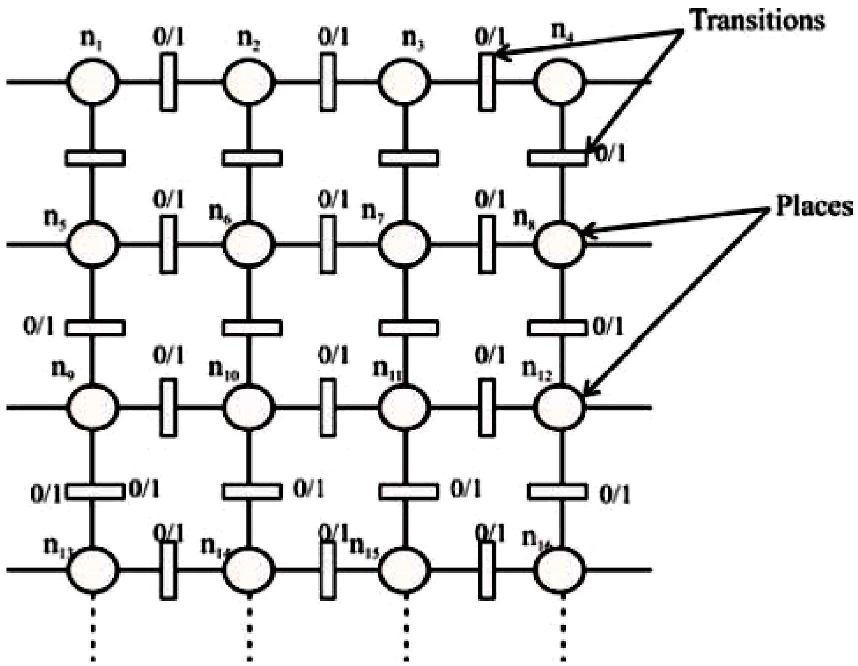


Figure 5.16 Process Representation of Petri Net with 0/1 learning rate in N-Dimensions

We can define the movement of tokens and 0/1 learning rate by a single recursive equation as:

Si = in (0) (X || out (0)) + in (1) (X || out (1)) (1)

The process graph of Neural Petri net Framework represents bisimilar relationship in Recursive mode. The Recursion can be achieved by using Genetic Algorithm with learning rate of modes $[n_1 \ldots . n_n]$ with a particular time frame.

Let the total function be defined as:

$n_t = \int (n_{t-1}, n_{t-2}, n_{t-3}, \ldots.. n_{t-M})$ (2)

which predicts the current value of node n^{th} from past input conditions.

The nodes which will learn first will survive and based on them the traffic control network will converge. The Fitness Value (F.V.) is defined as:

$$\left[F.V. = \frac{1}{N} \sum_{t=1}^{N} (f(n_t) - (f(n_n))^2) \right]$$

Where $f\ (n_t)$ is the value of the function represented by GP individual (Genotype).

The algorithm for Procedure Trained Node selection by Genetic Algorithm

BEGIN

Set the values to initial trained conditions.

Generate as many nodes as possible;

Evaluate each node in the set of Nodes selected;

WHILE termination NOT coverage DO

BEGIN

Select the Cube of Nodes with faster learning rates;
Generate offspring cube of Nodes by applying crossover and mutation on the selected cube or nearest neighbor cube;

Evaluate the equilibrium condition;

Generate new nodes to be trained further in combination with older node cube;

END

Return the best trained Cube Node from the Mesh;

END

The first phase of the algorithm deals with controlling parameters, such the population of Cube (P) and Offspring (O), the maximum number of crossover probability and mutations are set. The offspring Cube of Node is then evaluated and traffic is stabilized accordingly completing one cycle of operations. After several iterations the entire control Network converges to optimal solutions.

5.10 CHAPTER SUMMARY

In this chapter, a neuron Petri net approach is used to model a physical road network. The forward propagation Petri net model is used focusing on the simple cause effect framework, integrating continuous Petri net learning mechanism.

The Model is divided into two basic parts: The forward propagation Petri Net model focusing on simple Cause-Effect framework. The second part focuses on continuous Petri Net Learning mechanism. The model of Forward Propagation of Petri nets which uses the concept of producer consumer network by producing minor sub lane by-pass system near the congested intersection is developed and its algorithm for training is provided. The single unit producer-consumer is extended to N dimension self organizing Grid Network which helps two dimensional grid of producer - consumer link with buffer interlocked and virtual counter which keeps the track of diversion of Token based on the congestion in the road network (i.e. consumer), supply of new minor sub lanes (i.e. producers) and diversion of traffic through VMS maintains smooth flow of traffic. For training of above grid network an algorithm is proposed. The counter (M) keeps track of tokens number stamped by the layer through which it is being generated and finally arriving at particular layers.

This chapter also highlights intelligent Urban Traffic control using Neuro-Genetic Petri Net. The combination of genetic algorithm provides dynamic change of weight for faster learning and converging in Neuro-Petri Net. The use of genetic learning method performs rule discovery of larger system with rules fed into a conventional system. The genetic algorithm is used to search for the appropriate weight change in neural network which optimizes the learning rate of the entire network. A good Genetic Algorithm can significantly reduce Neuro-Petri Net in aligning with the traffic conditions, which other-wise is a very complex issue.

CHAPTER 6

EXPERIMENTAL EVALUATION

Traditional controllers [128] which are built based on historical data to create optimized timing plans are no longer giving the ideal solution to traffic intersections due to fluctuating traffic volumes and the ever increasing number of vehicles on the road. Traffic controllers that are able to think like the way of human thinking are designed using Artificial Intelligence (AI) techniques such as fuzzy logic. An AI traffic controller is to be designed that is capable to adapt to the real time data from sensors to perform constant optimizations on the traffic signal timing plan for intersections (X Junction) in a network in order to reduce traffic congestions, which is the main concern in traffic flows control nowadays at traffic intersections. In the second phase the concept of minor lane by-pass system is used to deal with the limited infrastructure of existing physical road network that result in the Traffic Congestion.

The major requirements of the developed conditions are, the signal messages must not allow the ambiguous movement to the traffic and it must be clear that how/when the indication of signal and messages shown to be changed. Two other aspects to be handled are to take decisions about change in phase sequence in the control system to make the system well optimized and development of control logic for signal generation.

6.1 MODELING AND SIMULATION OF OPTIMIZED TRAFFIC SIGNAL CONTROL OVER X JUNCTION

Movement and phase are the two terms that are very important in traffic signal control theory. A movement is defined as a specific traffic flow that occurs at the intersection.

Phases are the paired combinations of the movements. For example, when a phase is selected GREEN is displayed for both the movements involved, while the other will receive the RED signal.

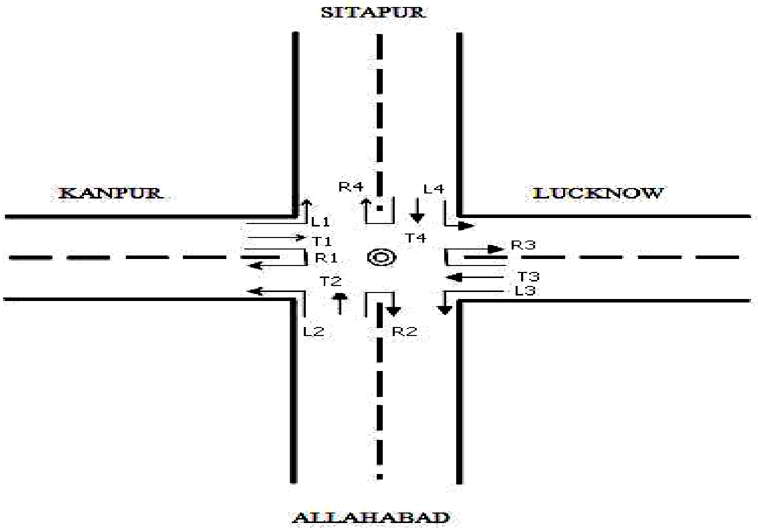


Figure 6.1 X-Junction showing phases and movements

The movement combination or phases are found like, (T1, T3), (T2, T4), (R1, R3), (R2, R4). At a time one phase will get the green signal and other will receive the red signal. The optimum design methodology of the signal control system is that no vehicle should stop at the Intersection.

Several kinds of control strategies have been identified:

1. Determined: In this control strategy, the phase sequence are fixed and durations are also fixed.

2. Fully actuated: The phase sequence depends on the demand of traffic, detected by the sensor technology.

3. Semi Actuated: The mirror street phase are demand responsive.

4. Queue management: Queue length will decide the signal switching.

The parameters required to be identified for the implementation of actual traffic signal control system.

1. Green Time (GT): Maximum duration that a signal can display green with its extension.
2. Phase sequence change according to Traffic Queue in other phases.

6.1.1 PROPOSED FUZZY SYSTEM

Four phases have been identified for isolated intersection model with eight traffic movement and one server traffic light. Each phase has two movements which are one through movement and one right turn movement.

The model is based on the queuing and applies FIFO (First In First Out) for the system. This model is based on MM1 queues theory and three major concepts are customer, queues and servers. The first and second M stands for "memory less" distribution of inter-arrival times and service time respectively, according to Markovian Process. The 1 in MM1 indicates that isolated intersection has single server, which means one traffic signal to service single traffic phase at one time.

In this model, vehicles are known as the customers while services time is the time for vehicles to cross the intersection and delay for which the vehicle get the green signal. Traffic arrival and service time at the intersection are independent random variables with Poisson distribution.

This means that vehicle arrival at the intersection is Poisson process with arrival rate λ and the mean of the inter-arrival times between vehicles are 1/λ. Number of vehicles in the system over time period follows the Poisson distribution function.

$$p(q_{in}(t) = k) = \frac{(\lambda \Delta t)^k e^{-\lambda \Delta t}}{k!}$$

Here, λ (λ>0) is the arriving rate which is equivalent to the number of arriving vehicles per time period and k = 0, 1, 2………………..

To extend the capability of Traffic Control Systems (TCS) of the traffic management at intersection, fuzzy techniques are integrated. Fuzzy Traffic Control Systems (FTCS) uses sensors that not only indicate the presence of vehicle, but also sensors gives estimation of traffic densities in the queue.

The placement of sensors at traffic intersection in Figure 6.2 can be explained as follows.

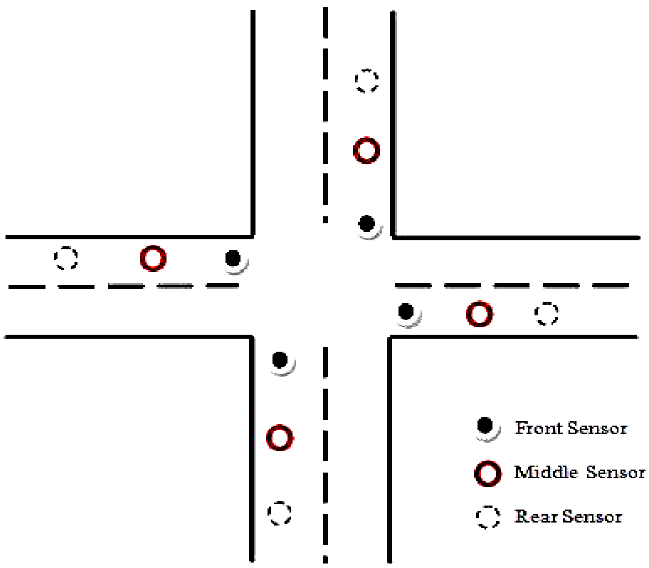


Figure 6.2 Sensor placements at X Junction

There are three types of electromagnetic sensors that are put at the intersection.

1. Front Sensor,
2. Middle Sensor,
3. Rear Sensor.

Front Sensor counts the number of vehicles passes **(traffic flow)** the traffic intersection. Middle sensor counts the **traffic density (Traffic Queue)** in the direction from the signal. Rear sensor counts the incoming number of vehicles towards the intersection.

Now the fuzzy logic controller is responsible for estimating the length of green time.

6.1.2 SIMULATION OF TRAFFIC CONTROL SYSTEM

The Mamdani Type Fuzzy Inference system is used to implement this system. The design of the system is divided into three components:

1. Green Phase Module

2. Next Phase Module

3. Switch Module

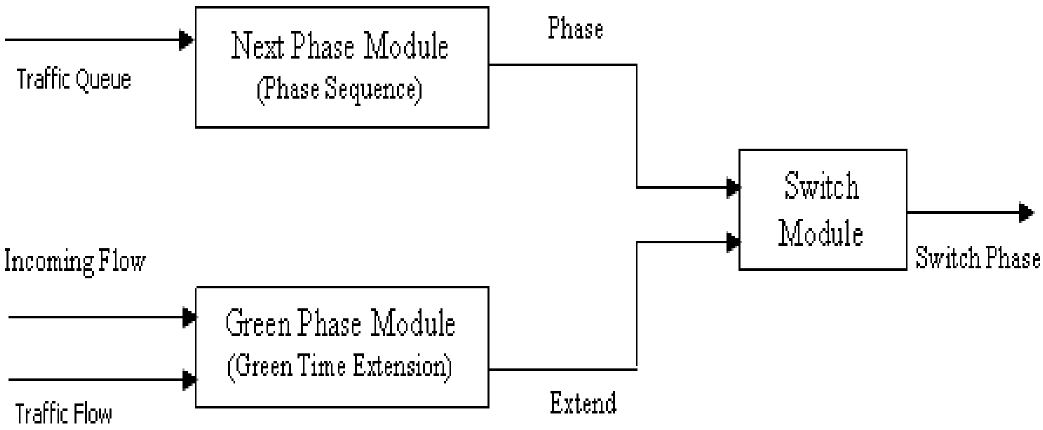


Figure 6.3 Block Diagram of Fuzzy Traffic Controller

1. Green Phase Module

Green signal extension time of the green phase is produced by this module according to the condition of observed traffic flow. The green phase module is the module having a number of rules with a Fuzzy Inference System (FIS). These rules take the vehicle Incoming Flow and vehicle queue length at the current green phase as its antecedents and generate “extension” as output.

Incoming Flow (ICF) and vehicle queue length (TQ) are used as the two input variables for fuzzy inference system in traffic signal controller, Figure.6.4.

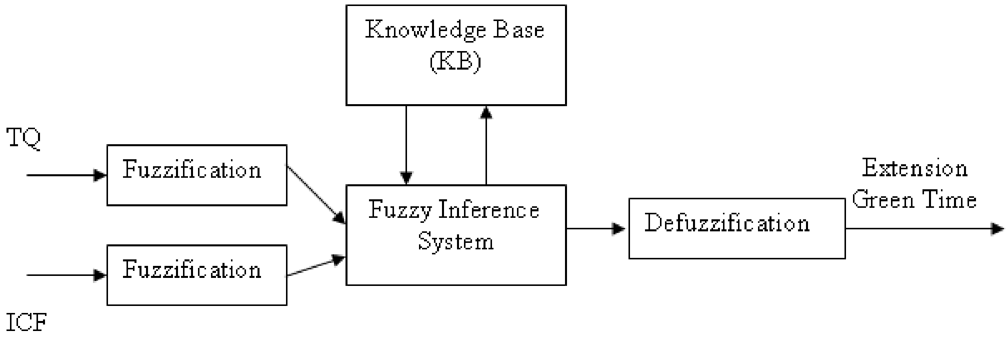


Figure 6.4 Basic Model of Fuzzy Inference System

2. Next Phase Module:

Next phase module controls the phase sequence based on the vehicle's queue length and extension time of green signal from Green Phase module.

This module selects one candidate for the green phase and it extends the green time of green phase based on traffic conditions of all phases. A phase is skipped if the phase has zero queue length.

These are 4 phases in this module, considered phase 1, 2, 3 and 4. Green signal in east direction is phase 1, green signal in south direction is phase 2, green signal in west direction is phase 3 and green signal in north direction is phase 4 as output.

3. Switch module

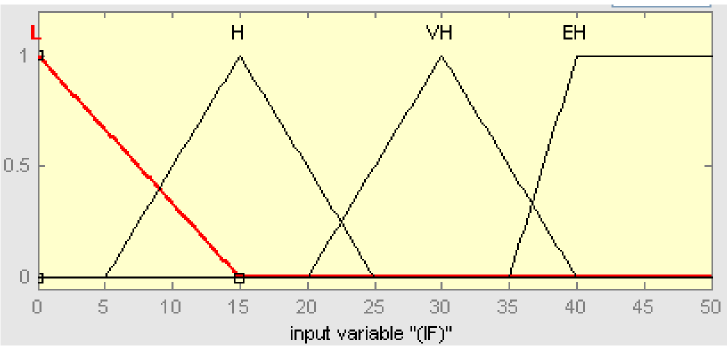
The outputs of next phase module and green phase module are given to switch module that is responsible for phase sequence change.

6.2. SIMULATION OF PROPOSED SYSTEM

6.2.1 DEFINITION OF MEMBERSHIP FUNCTIONS

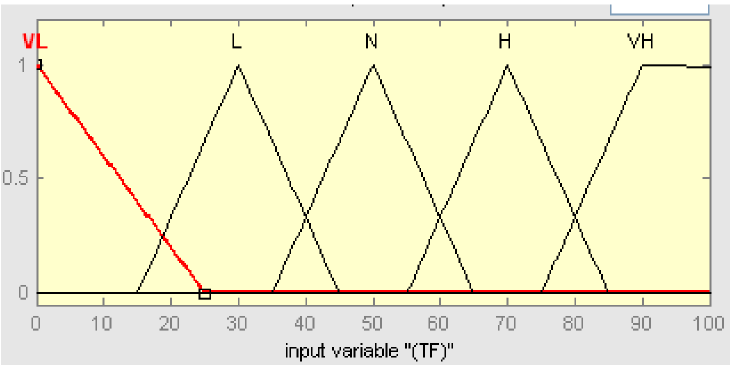
For MATLAB SIMULATION of the proposed traffic control systems, three input fuzzy membership functions and one output fuzzy membership functions are developed. At input, we have Traffic Flow (TF), Traffic Queue (TQ) and Incoming Flow (IF) and at output the membership function is Green Time (GT).

1. Input Membership Functions



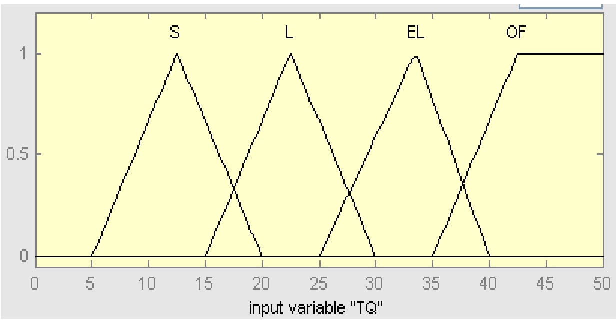
L-Low, H-High, VH- Very High, EH- Extremely High

Figure 6.5 MF of Incoming Flow (IF)



VL-Very Low, L-Low, N-Normal, H-High, VH-Very High

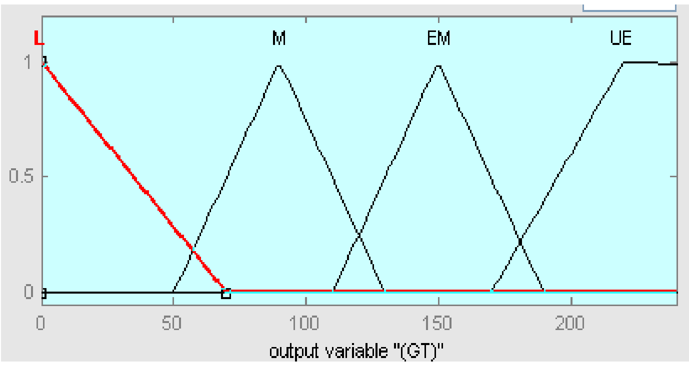
Figure 6.6 MF of Traffic Flow (TF) Variable



S-Small, L-Large, EL- Extra Large, OF-Over Flow

Figure 6.7 MF of Traffic Queue (TQ)

2. Output Membership Functions



L-Less, M- More, EM-Extremely More, UE- Unacceptable

Figure 6.8 MF of the Green Time (GT)

6.2.2 KNOWLEDGE BASE DEFINITION

The knowledge base of the system is defined by the following rule matrices.

Table 6.1

RULE MATRIX

GREEN TIME

Traffic Flow (TF)	Incoming Flow (IF)	Green Time (GT)
VL	L	L
L	L	L
N	L	M
H	H	L
H	N	M
N	H	L
L	VH	EM
VL	VH	M
VL	VH	EM
VH	H	M
VH	H	U

The phase sequence change is realized by the Traffic Queue data on the remaining phases, as discussed in Table 6.2. P1, P2 and P3 are the phases (T1,T3), (T2, T4), (R1,R3), where as the phase P4 (R2, R4) is assumed to be fix and described in Figure 6.1. These phases will be dynamically changed by the switch module, as in Figure 6.3.

Table 6.2

Rule Matrix

Phase Sequence change

TQ1	TQ2	TQ3	NEXT PHASE
S	S	S	P1
S	L	S	P2
S	S	L	P3
L	S	S	P1
L	EL	L	P2
EL	L	S	P1
L	S	EL	P3
S	EL	L	P2
EL	L	L	P1
EL	EL	L	P1
L	EL	S	P2

6.2.3 SYSTEM EVALUATION

The proposed system has been implemented using MATLAB 7.0. The system is simulated with two input membership functions and one output membership function. The system is developed using Mamdani Type Fuzzy System, having multiple rules in the knowledge base (KB).

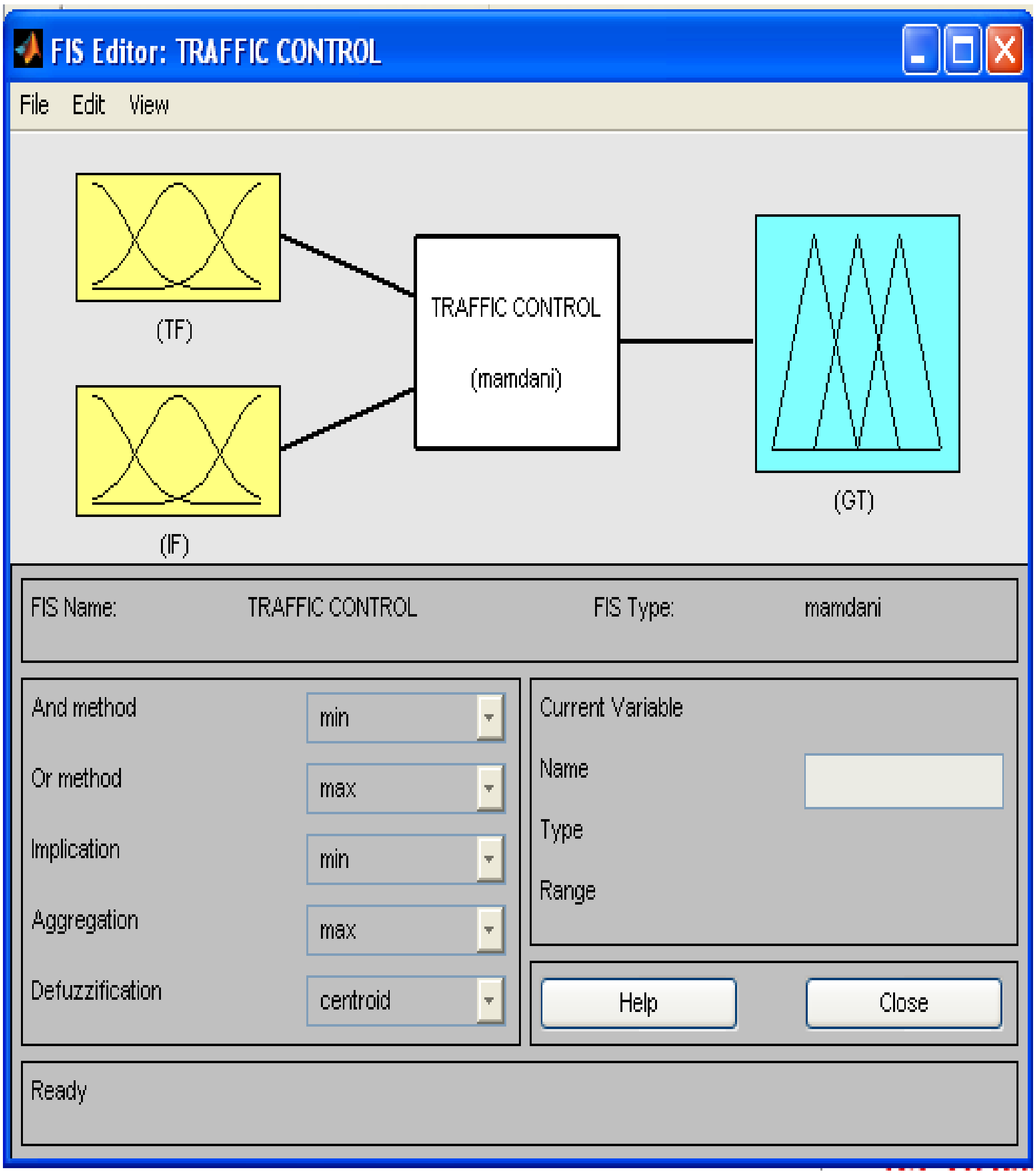


Figure 6.9 MATLAB Fuzzy Inference System (FIS)

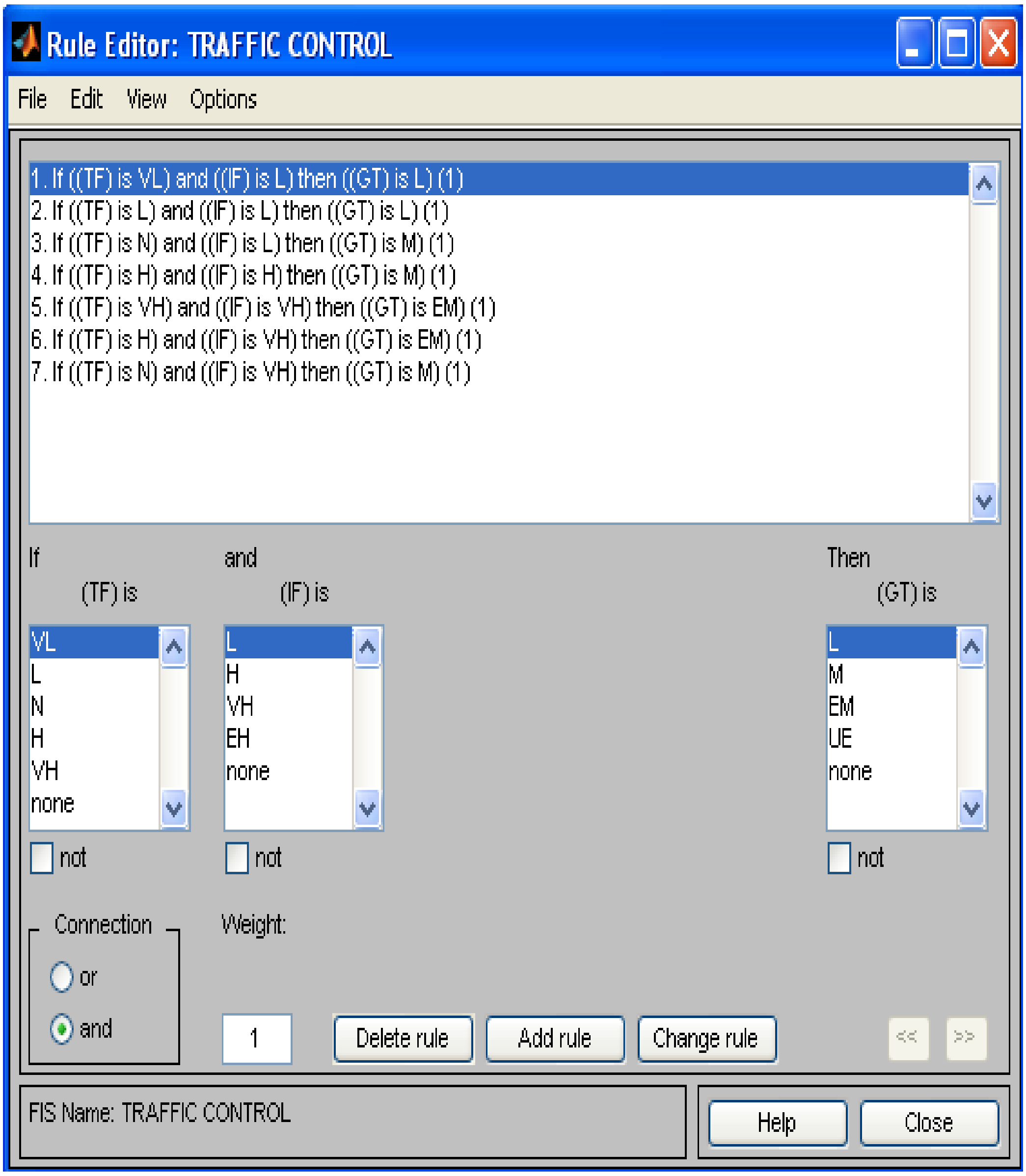


Figure.6.10 Rule Editor in MATLAB for proposed system

6.2.4 RESULT ANALYSIS

The following results have been obtained by the simulation and the results are found satisfactory. The Traffic Flow, Incoming Flow and Green Time are discussed and realized in Table 6.3.

Table 6.3

Simulation Result (Green Time)

S. No.	Input1 [Traffic Flow]	Input2 [Incoming Flow]	Output [Green Time]
1	10	5	20
2	10	10	27
3	20	17	50
4	30	25	100
5	50	55	120
6	60	65	155
7	70	74	170
8	80	70	240
9	90	95	270
10	100	110	320

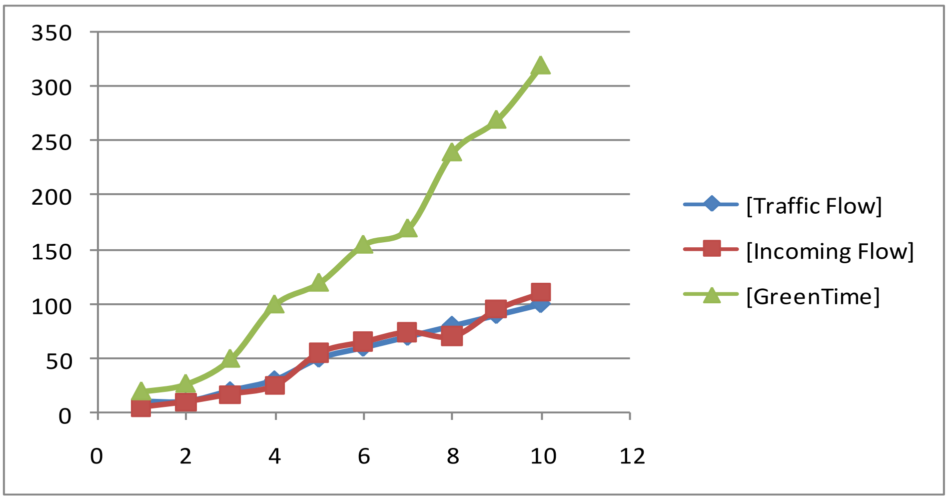


Figure 6.11 Relations among Traffic Flow, Incoming Flow and Green Tim

The phase sequence change is realized in Table 6.4 which is based on the rules of Knowledge Base.

Table 6.4

Simulation Result (Phase sequence)

TQ1	TQ2	TQ3	NEXT PHASE
6	6	6	P1
8	15	8	P2
9	9	18	P3
25	21	21	P1
21	59	21	P2
56	10	23	P1
15	45	75	P3
30	75	40	P2

As far as the traffic flow and delay is concerned, the analysis has been given in Figure 6.12. The average delay is considered as the extension in the green time and Total flow ratio = Traffic Flow at a particular time / Maximum Traffic Flow Capacity.

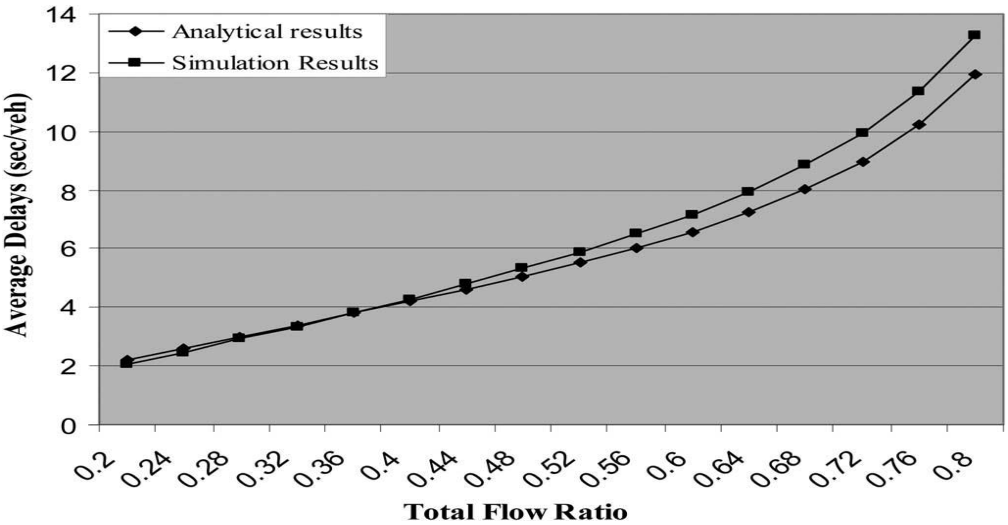


Figure 6.12 Simulation result (Average Delay vs Total Flow Ratio)

6.3 TRAFFIC CONGESTION CONTROL OVER A PHYSICAL ROAD NETWORK BY LANE BYPASS SYSTEMS THROUGH GENERATION OF MINOR SUB LANES AND DIVERSION BY VMS

The system developed and simulated is implemented on the real time network wide signal control system. It is based on the store-and-forward modeling paradigm. The system has been studied at Lucknow, the capital city of Uttar Pradesh, India, for the road network. A snapshot of different road networks has been attached in Figure 6.13

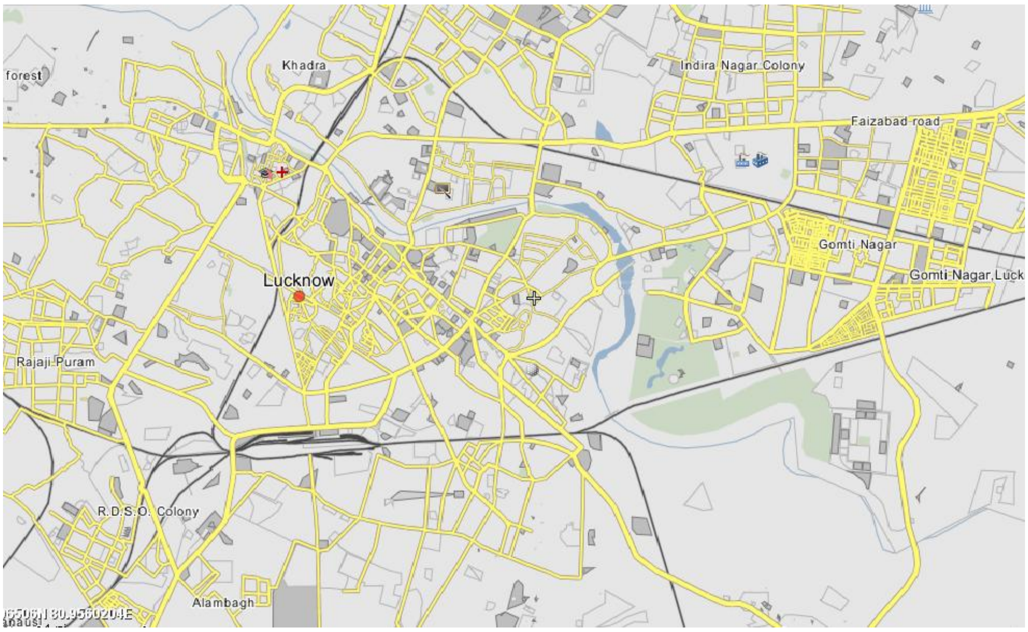


Figure 6.13 Real Models for Road Network in Lucknow (captured from wikimapia.org)

6.3.1 DESCRIPTION OF THE ROAD NETWORK WITH LANE BYPASS

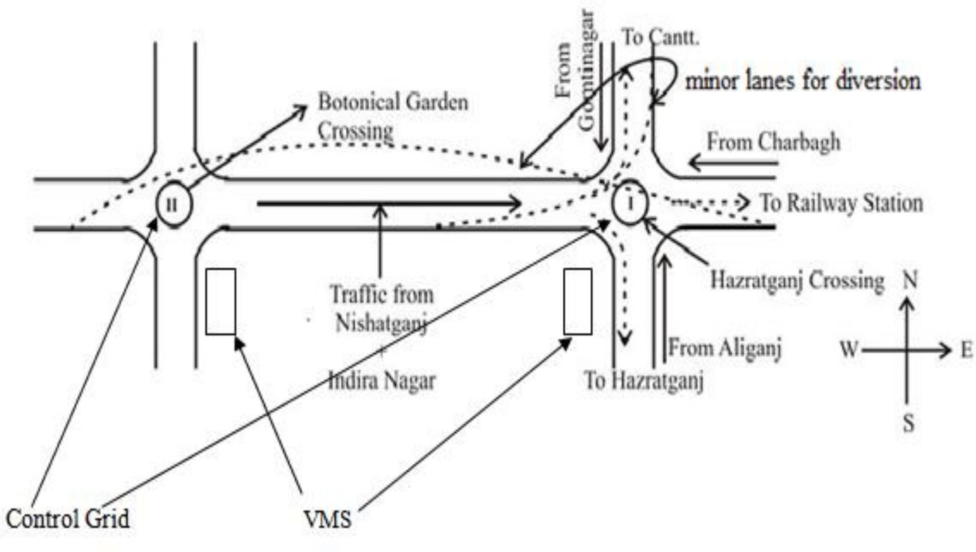


Figure 6.14 Lane By-Pass Systems

In the Lane By-Pass system the generation of minor sub lane and dynamic route information issue is an important research area in the traffic control system. The modeling of above system is done in previous chapter by Petri net approach. The information is expressed to the commuters by the VMS (Variable Message Sign Boards) and results in reducing the traffic congestion in Lucknow city. In this system three node types are identified in the road network.

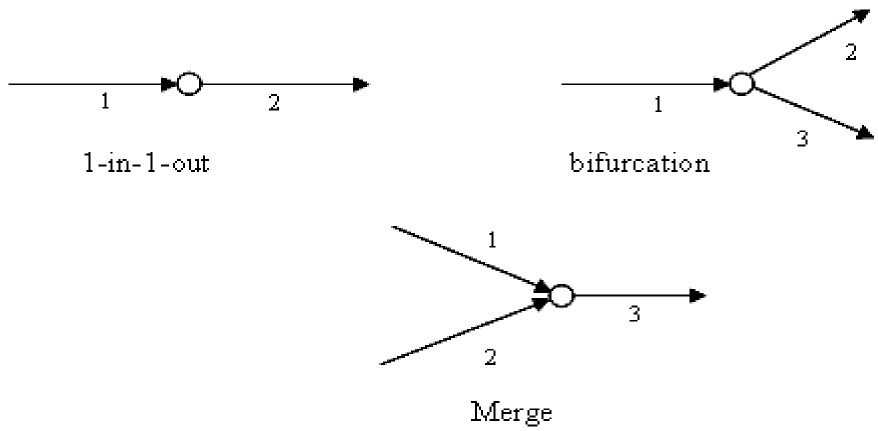


Figure 6.15 Specific cases in road network junctions

Three major activities have been identified in this approach.

1. Identification of Route Network in the city, showing the relationship between all the roads (routes).
2. Identification of Traffic Jams and then identification of alternative minor sub lane route information.
3. Coordination among all the decision (alternative traffic routes) to ensure the smooth traffic flow from source to destination.

The road network is described graph with links $z \in Z$ and junctions $j \in J$. For each signalized junction j, we define the sets of incoming I_j and outgoing O_j links. Let the cycle time C_j of junction j are fixed, but it can be calculated in real time by some specific algorithm.

For offset coordination, we assume that $C_j = C$ for all junction $j \in J$. The signal control plan of junction j is based on a fixed number of stages that belong to the set, whereas v2 denotes the set of stages where link 2 has right of way.

Finally the saturation flow S_2 of link $z \in Z$ and the turning movement rates $t_{w,z}$, where $w \in I_i$ and $z \in O_j$,are assumed to be known and constant.

By definition, the constraint

$\sum_{i \in F_j} g_{j,i} + L_j = C$ holds at junction j, where $g_{j,i}$ is the green time of state i at junction j and L_j is the total lost time at junction j. It follows the constraints,

$g_{i,j} \geq g_{j,i,\min} \quad i \in F_j$

Consider the following N Dimensional road network:

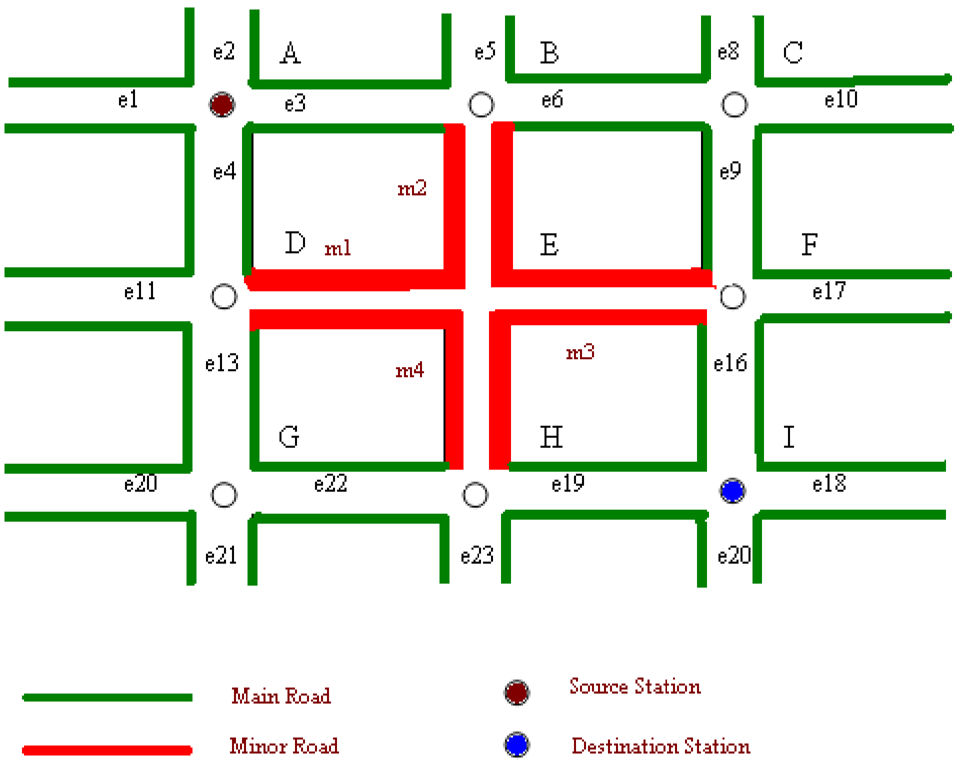


Figure 6.16 N Dimensional Road Network

A, B, C……., I am the junctions (Places) at the traffic road network (and connected by road connectives (Transition). The modeling of each junction will be done as discussed in the first section. The phases and movements will be done in the same way.

6.3.2 PROPOSED SYSTEM

The problem is identified and mathematically formulated as:

Set of junctions J = (A, B, C, D, E, F, G, H, I)

Set of connectives E = (e_1, e_2, e_3 ……….e_{23})

The traffic flow will be decided by the set of connectives from source to destination. Few of the connectives are the bypass connectives that are used by transfer office by pass when the major connectives are full with traffic jam.

In this approach, the VMS technology is used. The commuters will find the signal for route diversion before one crossing through minor sub lane generation if there is any traffic jam at the next crossing. But overall it is also considered that the path from source to destination should be as minimum as possible.

To deal with this problem, the sensors will be placed at each junction for intimating the traffic jam to the previous junction by VMS.

Let the commuter is travelling from station A to I as shown Fig. 6.16. Now consider the situation, where the commuter identifies traffic congestion at junction G through VMS where he is on the route e4 at junction D. Now to deal with this situation the control system would generate the signal for route diversion through minor lane by pass and the commuter would get the signal to choose the route m1 and m4 to reach his destination.

The procedure of route diversion should be integrated with the approach traffic phase and movement decision approaches.

According to the fluid dynamic algorithm,

Traffic flow = traffic density x mean velocity

The formula from the Kinematic wave theory based on lane changing is obtained by

$(\rho + V(1+e)) = 0$

where ρ is the density , V is the velocity and e represents the value of lane changing effect parameter where it is presented by the subtraction of two queue length in two lanes where merging is connected.

Therefore, substituting the value of density the equation becomes (traffic flow /mean velocity) + V (1+e) = 0

To implement it follows the following architectural network for this road network:

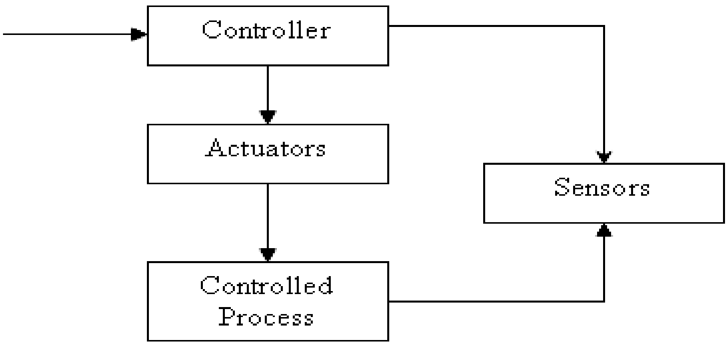


Figure 6.17 Architecture of the controlled systems

A fuzzy implementation of the proposed approach is as follows:

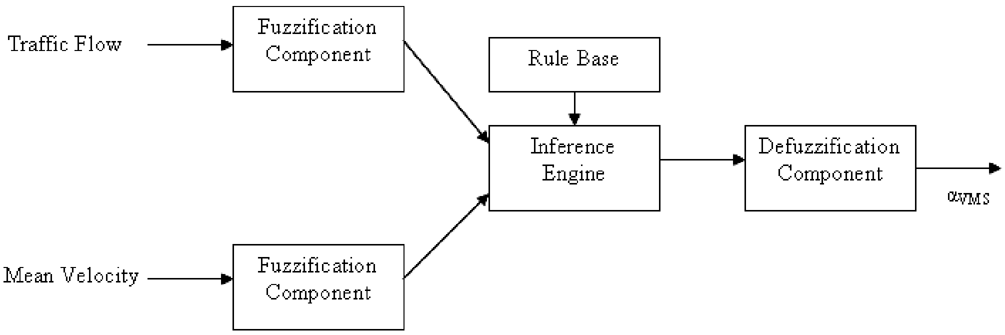


Figure 6.18 Fuzzy Control System for the road network

The proposed system takes two inputs, Traffic Flow and Mean Velocity. This system would generate the value of a constant α_{VMS}. The algorithm proposed for the route selection in a road network is as follows.

6.3.3 ALGORITHM ROUTE DIVERSION THROUGH MINOR SUB-LANE

Algorithm ROUTE DIVERSION

1. Start
2. Generate α_{VMS} for each junction at different intervals of time.

   α_{VMS} = Traffic Flow / Mean Velocity

The value of Traffic Flow will be estimated by the Sensors and Mean Velocity is analytically calculated at different time intervals.

Repeat steps 3 to 5 until the desired destination,

3. Collect the values of α_{VMS} (update them on time intervals) for all junctions in different paths from a specified source to destination, at a control centre.
4. Generate the maximum value of α_{VMS} from which the traffic congestion will start and it is denoted by αM_{VMS}.
5. Apply minimization function F_{min} on the values of α_{VMS} to get the next node, iteratively.
6. If F_{max} (α_{VMS}, αM_{VMS})≥ α_{VMS}

   then

   Send the signal to previous junction's VMS for route diversion, if the selected junction is different from the regular path,

   otherwise

   Follow the main route decided previously.

6. End.

6.3.4 RESULT ANALYSIS

The two cases are considered here for result analysis. Let the source station is A and destination station is I.

The selected route by commuter is (A, B, C, F, I). Now according to the space capacity of the junction, αM_{VMS} =9.5 (for junction C).

Table 6.5

Traffic Flow & Mean Velocity (Junction C)

Time	**Traffic Flow**	**Mean velocity (km/h)**	α_{VMS}
7:00 AM	10	60	0.16
7:30 AM	20	40	0.50
8:00 AM	40	30	1.33
8:30 AM	60	25	2.40
9:00 AM	100	20	5.00
9:30 AM	150	15	10.00
10:00AM	200	10	20.00
10:30 AM	250	05	50.00

Case 1 At time 9:00 AM,

Fmax (α_{VMS} , αM_{VMS}) =Fmax (5, 9.5) < α_{VMS}

Hence according to the algorithm, no diversion is required through the minor sub lane by- pass. This case is shown in Figure 6.19

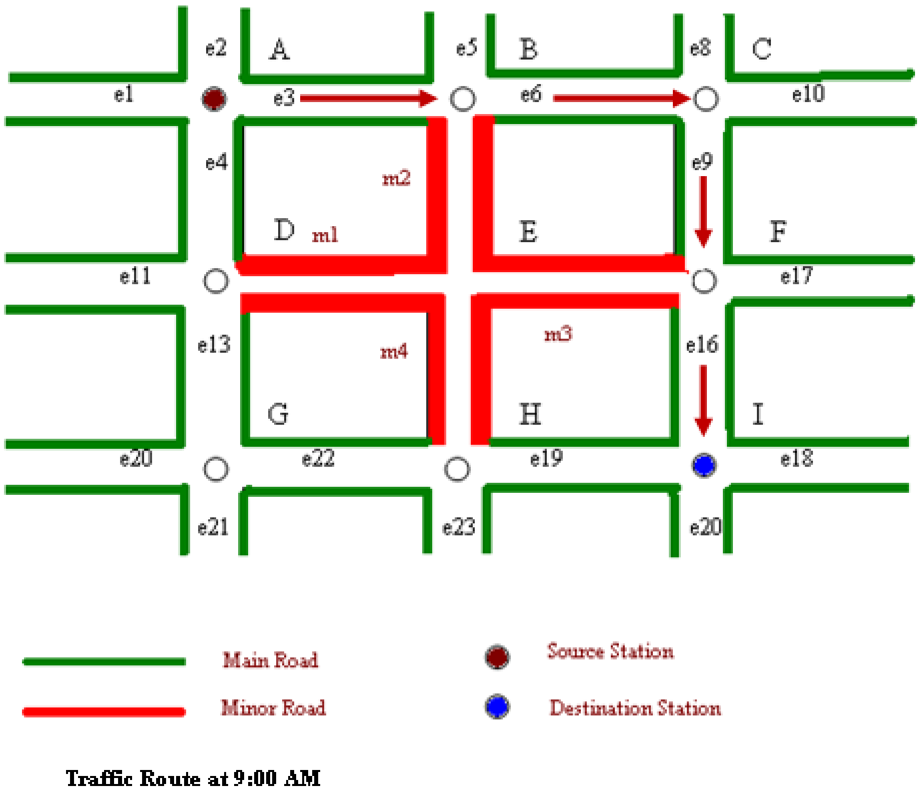


Figure 6.19 Case 1

Case 2 At time 9:30 AM,

Fmax (α_{VMS} , αM_{VMS}) =Fmax (10, 9.5) > α_{VMS}

Hence according to the algorithm, the minor lane by pass would be generated and the commuter will get the signal to divert the route at minor lane m2. This case is shown in Figure 6.20

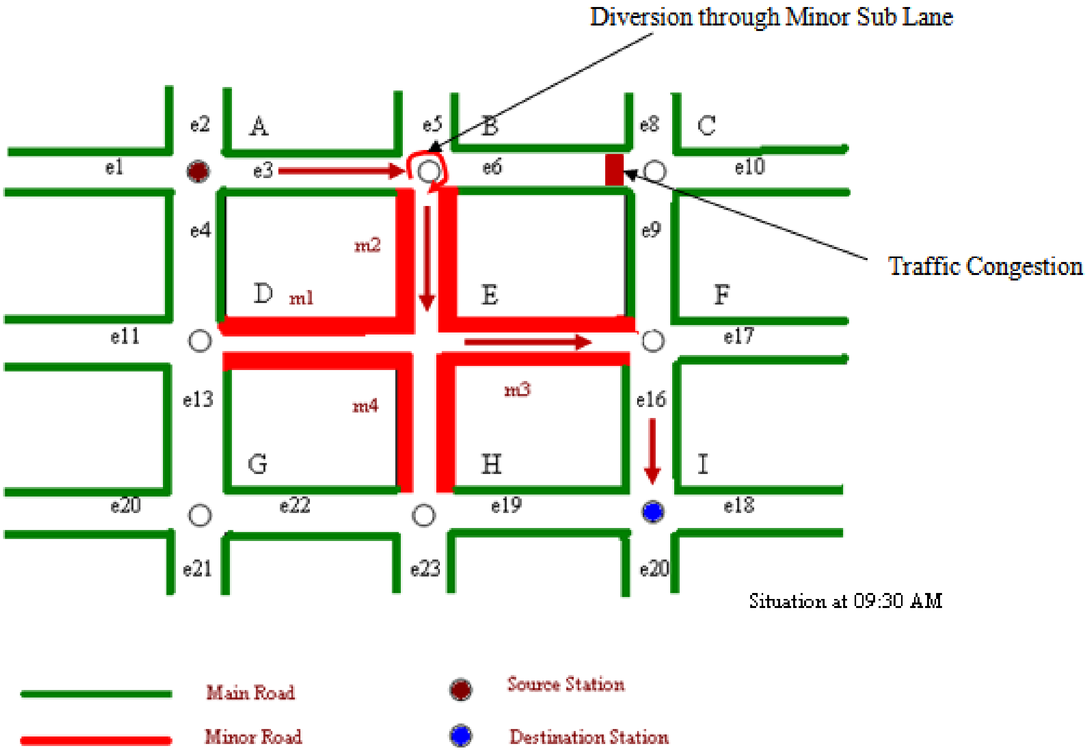


Figure 6.20 Case 2

The variations of α_{VMS} are represented as follows at both the junctions,

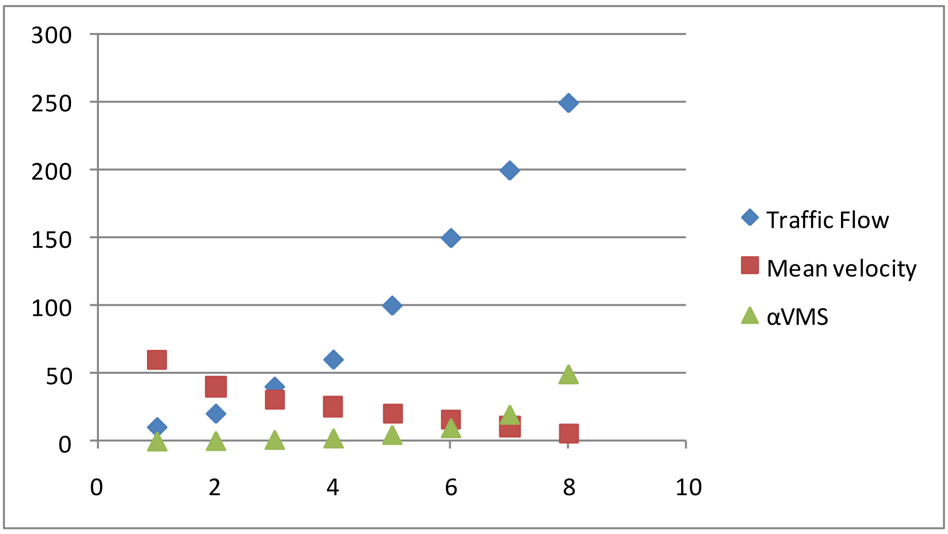


Figure 6.21 Traffic Flow, Mean Velocity and α_{VMS} at Junction C

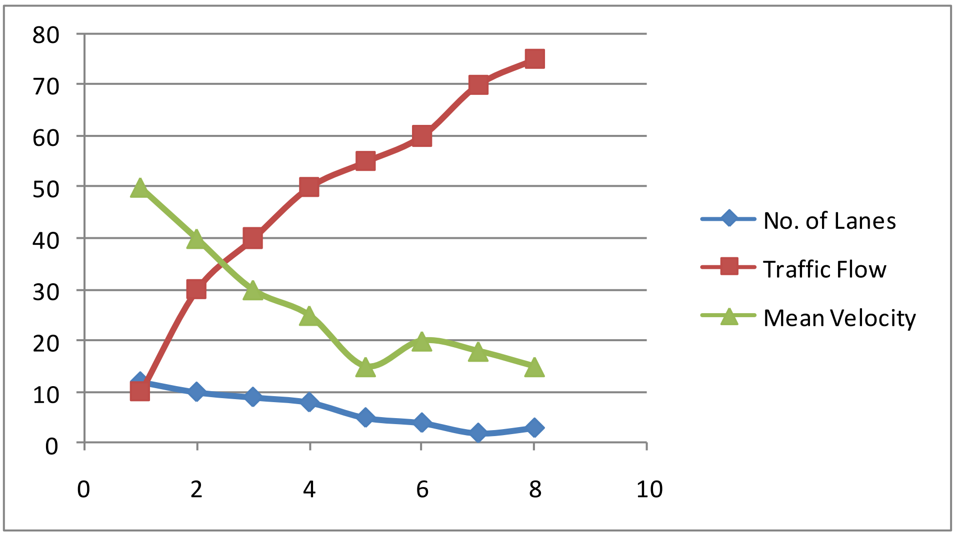


Figure 6.22 Simulation result (Showing importance of Minor Role)

The results are shown in Figure.6.22 and indicate that the closure of minor roads could improve the travel time. The estimation of routing is usually performed by calculating the feedback costs associated with each link network-wide for every pre-specified interval (5 min in this case). This causes the vehicles to opt for major links, thereby achieving better optimization and lesser travel delay time. However, when multiple lanes were closed, a slight degradation is seen during the first peak traffic period, which subsequently settles down in the later peak periods to a slightly higher delay value than in the normal operation.

6.4 CHAPTER SUMMARY

In chapter 6, the proposed system is implemented through simulation in MATLAB 7.0. The implementation phase is carried out in two phases.

In the first phase, the efficient control of traffic movement is simulated at a X junction by considering various parameters, like traffic queue, incoming flow, green time, etc. The three sensors are placed, Front Sensor, Middle Sensor and Rear Sensor. These sensors read the traffic flow, traffic density and number of vehicles. The system to be simulated has three modules, green phase, next phase and switch module. Green Phase module is responsible for managing the green time and switch module is responsible for phase sequence change with the help of next phase module having input traffic queue. The approach is implemented by Mamdani Type Fuzzy Rule Based System. The appropriate knowledge base is identified along with the generation of membership functions, representing real time environment. The outcomes in this phase are found satisfactory as compared with analytical decision making of the real system.

To deal with the limited infrastructure of existing road networks and traffic intersections that result in the Traffic Congestion, the minor lanes can be used to reduce the traffic density. This concept is implemented in the second phase to deal with the problem of traffic congestion. In this phase, an algorithm is developed and implemented for decision making of route diversion through the generation of minor lane by pass system using VMS (Variable Message Sign Board). The outcomes of the algorithm are found satisfactory and applicable to handle the real situations of traffic congestion, as well.

Overall, the proposed system constituted by both phases is found satisfactory as per experimental results

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

The development of control systems to deal with the traffic congestion in urban areas is a critical research issue. Various traditional methods have been applied to reduce the problem of traffic congestion. Some of these include road pricing, supporting the green traffic, parking enforcement, fuel levies, expansion of existing road networks, elimination of roundabout and so many others. Non-linearity and unpredictability of the traffic movement and the high cost associated with the expansion of the existing infrastructure of road networks and other related problems, the traditional methods have become very unusual.

During this time, technology has been integrated to develop some intelligent control systems to deal with the traffic congestion issues, specifically in urban areas. Many intelligent approaches have been integrated to model and simulate or implement the real time traffic control systems, like activity theory, neural network, fuzzy logic, Petri nets, genetic algorithms and their hybrid approaches.

In this thesis, the work carried out is to model and simulate the real traffic control system in the urban city, Lucknow, the Capital of Uttar Pradesh, India. The proposed work consists of modeling at one traffic intersection and handling traffic congestion with minor lane bypass in a road network. The work has been done in two phases, first phase includes the conceptual modeling of the proposed system by activity theory and model driven engineering flavored with Petri net modeling in a fuzzy environment as well. Subsequently, the neural network is used to make the system intelligent and genetic algorithms are utilized to optimize the weights associated with the

system. In the second phase, the conceptually modeled system is simulating through the MATLAB 7.0 and it is proved that the results are found competitive and satisfactory as well.
A framework has been developed using MDE and Activity Theory, defining a set of activity theory with traffic agents incorporating MDE and AT, the PIM of UTCS is represented in UML. The two major components, traffic signaling and physical road networks are further elaborated for reducing the traffic congestion at intersections and main roads for achieving smooth flow of traffic.

In order to represent the Fuzzy PIM, linguistic variables and fuzzy rules for entering the uncertainty into the performance computations are used. The classical binary relation represents the presence or absence of connection or absence of a connection or interaction or association between Model Driven Engineering Concepts and Activity Theory framework with reference to Urban Traffic System. The help of relationship link of fuzzy set theory is the mapping of various entities of abstract model. The existence of uncertainty in message passing and control between different entities is evaluated by Cartesian framework there by generating membership functions.
A neuron Petri net approach is used to model a physical road network. The forward propagation Petri net model is used for focusing on the simple cause-effect framework and integrating continuous Petri net learning mechanism. The model is divided into two basic parts: The forward propagation Petri Net model focusing on simple Cause-Effect framework. The second part focuses on continuous Petri Net Learning mechanism.

The model of Forward Propagation of Petri nets which uses the concept of producer consumer network by producing minor sub lane by-pass system near the congested intersection is developed and its algorithm for training is provided. The single unit producer-consumer is extended to N dimension self organizing Grid Network which helps two dimensional grid of producer - consumer link with buffer interlocked and virtual counter to keeps track of diversion of Token based on the congestion in the road network (i.e.

consumer), supply of new minor sub lanes (i.e. producers) and diversion of traffic through VMS maintains smooth flow of traffic. For training of above grid network an algorithm is proposed. The counter (M) keeps track of tokens number stamped by the layer through which is it is being generated and finally arriving at particular layers.

Neuro-Genetic Petri Nets are utilized to make intelligent urban traffic control system. The combination of genetic algorithm provides dynamic change of weight for faster learning and converging in Neuro-Petri Net. The use of genetic learning method performs rule discovery of larger system which is fed into a conventional system. The genetic algorithm is used to search for the appropriate weight change in neural network which optimizes the learning rate of the entire network. A good Genetic Algorithm can significantly reduce Neuro-Petri Net in aligning with the traffic conditions, which other-wise is a very complex issue.

In the first phase of implementation of the proposed approach, the efficient control of traffic movement is simulated at X junction by considering various parameters, like traffic queue, incoming flow, green time, etc. The three sensors are placed, front sensor, middle sensor, rear sensor. These sensors sense the traffic flow, traffic density and number of vehicles, gradually. The system to be simulated has three modules, green phase, next phase and switch module. Green Phase module is responsible for managing the green time and switch module is responsible for phase sequence change with the help of next phase module having input traffic queue. The approach is implemented by Mamdani Type Fuzzy Rule Based System. The appropriate knowledge base is identified along with the generation of membership functions, representing real time environment. The outcomes in this phase are found satisfactory as compared with analytical decision making of the real system.

To deal with the limited infrastructure of existing road networks and traffic intersections that result in the Traffic Congestion, the minor lanes can be used to reduce the traffic density. This concept is implemented in the second phase of implementation to deal with the problem of traffic congestion. This phase deals with development of an algorithm and implementing it for decision making of route diversion through the generation of minor lane by pass system using VMS (Variable Message Sign Board). The outcomes of the algorithm are found satisfactory and applicable to handle the real situations of traffic congestion, as well. Overall, the proposed system constituted by both phases is found satisfactory as per experimental results.

In future, the authors are interested to extend the proposed work by expanding its capabilities to manage the traffic on high way through satellite Global Positioning Systems (GPS). The extension of the work will include modeling of the road networks at district and state level connected through the GPS and Satellite Imaging Techniques to predict the traffic flow and routing in traffic road network.

For the purpose of optimization, authors would be interested to use Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO) etc. Finally, the authors are also interested to use the developed framework in the modeling, design and implementation of the Intelligent Vehicle Highway System (IVHS).

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LIST OF PUBLICATIONS

[1] Rishi Asthana, Manuj Darbari, V K Singh, Integrating Fuzzy Mde- AT Framework For Urban Traffic Simulation, International Journal of Software Engineering (IJSE), Volume (1): Issue (2), 2010.

[2] Rishi Asthana, Manuj Darbari, V K Singh and S. Prakash , N-Dimensional Self Organizing Petrinets for Urban Traffic Modeling, IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 4, No 2, July 2010.

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WORK EXPERIENCE

- **October 5, 1999 - till date**

  Working as an **Assistant Professor & Head, Department of Electrical Engineering and Information Technology** at **Babu Banarasi Das National Institute of Technology & Managment**, Lucknow.

- **March 2, 1997 to Oct. 4, 1999**

  Worked as a **Lecturer, Department of Electrical Engineering, G B Pant Engineering College Pauri Garhwal.**

- **Aug. 14, 1996, to Feb 15, 1997**

  Worked as a **Lecturer (Part Time), Department of Electrical Engineering, MMM Engineering College Gorakhpur.**

PROFESSIONAL/ ACADEMIC QUALIFICATION

Course / Duration	Name of Institute / College (University / Board)	Total %/ Division
Ph.D.	University of Petroleum & Energy Studies, Dehradun	Submitted March 2012
M. S. (2001-03)	BITS, Pilani	7.87/ First **With Honors**
B. Tech. (1992-96)	MMMEC, Gorakhpur, Gorakhpur University	75.26 / First **With Honors**
Intermediate (1991)	Mahanagar Boys, Inter College, Lucknow(U.P. Board)	68.8 / First
High School (1989)	Mahanagar Boys, Inter College, Lucknow(U.P. Board)	76.0 / First **With Honors**

SEMINAR /WORKSHOP/CONFERENCES ATTENDED

1. **A four day workshop on** Adaptive Control of Nonlinear Systems Using Fuzzy and Neural Networks at IIT Kanpur from 05.09.11 to 09.09.11.

2. **A three day workshop on** System Engineering at IIT Kanpur from 26.10.10 to 28.10.10.

3. **A short term course on** Wireless Networks at IITM Gwalior from 08.12.08 to 12.12.08.

4. **All India National Seminar on Communication Convergence at** Institution of Engineers (IE) (India), U.P. State, IETE, Lucknow Local Centre & IE (I) Anpara Local Centre from 08.09.07 to 09.09.07.

5. **A two day workshop on** National Programme on Technology Enhanced Learning at IIT Kanpur from 27.06.07 to 28.06.07.
6. **A five day winter school on** Laboratory Teaching in Electrical Engineering at KNIT Sultanpur from 24.11.06 to 27.11.06.
7. **A two day winter school on** Construction and Working of Contactors, Relays and Starters at L&T Service and Training Centre, Lucknow from 09.01.06 to 10.01.06.
8. **Workshop on Industrial Interaction at** Microsoft - Taj Residency, Lucknow on 13.11.2005
9. **Workshop on** Future of IT at NASCOM – Taj Residency, Lucknow on 07.09.2005
10. **Workshop on** Wireless Networks (Research Issues) at MNNIT, Allahabad on 05.02.2005.

PROFESSIONAL MEMBERSHIP

1 IEEE, USA

2 IET, UK

3 Computer Society of India, India

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