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# **Developing Models of Road Tunnels with Petri Nets**

**MASTER THESIS**

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# **Developing Models of Road Tunnels with Petri Nets**

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guidelines on plagiarism and cheating, and I certify that this submission  
fully complies with these guideline**

## Abstract

According to the survey about 50% of human deaths occurred due to road accidents among which some of the extreme accidents happened in tunnels. Norway is well known for its highest road tunnels length with nearly 900 road tunnels on both national and country side. The department of Norwegian Public Roads Administration has therefore decided to do a research study on different traffic accidents based upon police reported accidents. This thesis focus on an important aspect of the tunnel safety by developing model of road tunnels with modular petri nets to explore the traffic capabilities. A novel control and sensor scheme has been implemented with the Petri net model to insure safe, control and secure traffic in road tunnels. GPenSIM is a Petri net based simulator tool that offers significant benefits to model structures. The purpose of the proposed work is to provide a cost effective measures to improved tunnel traffic security. The proposed work has been analyzed, evaluated and presented in a structured way. Future research directions are also discussed in the end.

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## DEDICATION

This dissertation is dedicated to

my **Father & Mother**

Who supports all aspects of my life journey

## **Thesis outline**

To complete this dissertation the data has been collected through different sources. which include the interviews of the tunnel operators in different countries, through PIARC reports and available publications, articles and books.Fig1

**Chapter 1** of the dissertation explains about the Literature study on the tunnels, different parameters involved in road traffic and the alarming threats.

**Chapter 2** represents the classification of the tunnels into a few generic cases. The section is further defined with parameters involved in road tunnels such as types of vehicles, roadway parameter including number of lanes, length, emergency exits, nodes, etc. and traffic parameters with flow rate and speed.

**Chapter 3** represents the mathematical model of the tunnels by using modular Petri net.

**Chapter 4** Where the final results of the simulation of road tunnels using data from different road authorities is presented in this chapter. The results are compared with the previous studies based on the cost effectiveness for tunnels in Norway. Lastly



**Chapter 5** represents the future work, references of the work and conclusion.

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## Developing Models of Road Tunnels with Petri Nets

### Abstract

According to the survey about 50% of human deaths occurred due to road accidents among which some of the extreme accidents happened in tunnels. Norway is well known for its highest road tunnels length with nearly 900 road tunnels on both national and country side. The department of Norwegian Public Roads Administration has therefore decided to do a research study on different traffic accidents based upon police reported accidents. This thesis focus on an important aspect of the tunnel safety by developing model of road tunnels with modular petri nets to explore the traffic capabilities. A novel control and sensor scheme has been implemented with the Petri net model to insure safe, control and secure traffic in road tunnels. GPenSIM is a Petri net based simulator tool that offers significant benefits to model structures. The purpose of the proposed work is to provide a cost effective measures to improved tunnel traffic security. The proposed work has been analyzed, evaluated and presented in a structured way. Future research directions are also discussed in the end.

# **CHAPTER 1 INTRODUCTION**

Human life is the most important thing in this entire world which cannot be ignored when the loss happens in traffic accidents. According to the survey about 50% of human deaths occurred due to road accidents among which some of the extreme accidents happened in tunnels. It is mentioned in the handbook of tunnels fire safety (Beard and Carvel, 2005) (Beard, A., Carvel, C., January 1, 2005. The Handbook of Tunnel Fire Safety. Thomas Telford Publishing, London) that over 90% of fire cases in tunnels are due to vehicle crashes. The average age of the tunnels in Norway is more than 35years. Tunnels is a very complex topic when it comes in the manufacturing, safety and maintenance of it. Tunnels are built according to the type, width, length, type of traffic and technique involved in its manufacturing. due to the closed structure of the tunnels the chances of collision of vehicles with other vehicles and the infrastructure of the tunnel itself is more severe and deadly, which makes them difficult to design fire safety in road tunnels. For example, in the Mont Blanc Tunnel from france to Italy in 1999, about 39 people lost their lives in fire tragedy and another disaster that happened in Tauern Tunnel Austria, took the lives of 12 people (PIARC, 2008). PIARC Technical Committee C3.3 Road Tunnel Operation, 2008. Risk Analysis for Road Tunnels, May 2008, [http://publications.piarc.org/ressources/publications\\_files/4/2234,TM2008R02-WEB.pdf](http://publications.piarc.org/ressources/publications_files/4/2234,TM2008R02-WEB.pdf), accessed 19 May 2011. more over the structure of the tunnels also plays its contribution in the cause of collision. For drivers whether motorists or vehicle drivers, tunnels give a feeling of unease while entering into the darkness inside a tunnel. The black hole effect due to the changing light on entering the tunnel and other reasons acts as a cherry on top of these accidents. Sub-sea tunnels with sharp vertical curves be likely to increase the feeling of unease. These accidents have forced human to scratch their head to find ways to increase road tunnel safety. However through

literature review and the previous data from the transportation agencies we could give generally observe the risk of tunnel fire.

- ◁ Tunnels have risky environment by nature. We could not say that a tunnel is absolutely safe regardless of the design and safety system installed in it. The key factor is to prevent fire in tunnels.
- ◁ Almost every tunnel experience fire once or twice a year whether the cause are accidents or collisions.
- ◁ One of the main cause of fires in tunnels are due to the heavy goods vehicles that carries dangerous cargos such as fuel tanks or exploding chemicals.
- ◁ The severity of the tunnel fire is more dangerous for its structure, occupants and the economy as compared with the open road accidents.
- ◁ Fires in tunnels cannot be removed until and unless vehicle fires are eliminated.

In the last few years a number of projects have been proposed on how to increase the road tunnel safety and somehow reduce the accidents. The EU have proposed and funded many new Directives [1] in 2002 to achieve high level of protection for all the people while driving through tunnels and to improve road tunnel safety. Different network [3] have also been successfully launched with objectives to reduce the number of accidents through safety measurements inside road tunnels. Where SafeT network are aimed to improve and generate guidelines for the current methods on tunnel safety policies. A vast area of research has been dedicated for different types of



road accidents [10] and the causes of it. It is clear that the number of accidents are high outside than inside the tunnels, but if we talked about the deadly disaster and the accidents severity it is higher inside the tunnel than outside the tunnel.

Study shows that a proper mechanism is to be adopted to reduce the causes of disturbances in the flow of traffic by avoiding the congestion and the presence of obstructions. The road tunnel safety in Norway is followed on two main studies from the 1980s. Safe and secure traffic could only be achieved if suitable measures are to be taken to prevent speed traffic when exceed a certain critical level. this thing has lead automotive industry to become more programmable with electronic systems [9].it will not only provide safety functions but also help in improving the safety related onboard electronic equipment to improve the safety of the vehicle.

## **1.1 Different causes of accidents**

There are a number of reasons and causes for collisions in tunnels. It could be from drunk driver, use of mobile phones to vehicle type, different aspects related to the roads, types of tunnels and characteristics of traffic. not all these causes comes in the vicinity of collision but could be one of the cause of collision . the same is consider for the types and its severity of the collision. It is therefore very important for the tunnel manager to look upon the safety level and terms of tunnels and should have defined policies and measures to control the risks involved in tunnel collisions. Similarly black hole effect is also one of the main cause of tunnel collision as it doesn't v " j c r r g p g f " q p " v j g " q r g p " t q c f 0 " Q v j g t " sight in a curve or bend position inside the tunnel. more over the chances of collision is higher with broken-down vehicle due to the limited cross-section of the tunnel, with

a smaller amount area for evasion. no matter what the cause is tunnel walls also plays a difficult obstacle in collision.

## **1.2 Research Phase**

A complete GANTT chart in the end of this thesis, that shows the time frame and project plan. Appendix A shows this chart.

## **1.3 Objective Of The Study**

This paper focus on an important aspect of the tunnel safety by developing model of road tunnels with modular petri nets to explore the traffic capabilities. The purpose of the proposed work is to provide a cost effective measures to improve traffic security in road tunnels and in subsea and dual tube tunnels in particular. This work also presents different causes of accidents in tunnels and explains the effects that deteriorates the health of tunnels such as weather, different road conditions, traffic volumes and lengths of tunnel.

The proposed work has been Analyzed, evaluated and presented in a structured way. By taking guidance from the previous reports PIARC-report2007/R07[1] ([road tunnel safty.1](#)) and updated them with more defined and sleek values to proposed a more secure safe approach to road tunnel safety.

## **1.4 Petri Net and other tools:**

Petri net is one of the most convenient, versatile and widely accepted tool by the research world for modeling and simulation of discrete and real time event-driven systems **Cheng & Yang, 2009; Shih, Chiang, & Lin, 2007**) such as computer system

, manufacturing system and communication system are the well known examples. Petri net can handle real-time situations easily such as conflict situation, synchronous and asynchronous communication, shared resources and superior constraints. due to its difficult modeling techniques it has a number of tools for free academic use PNWorld (Petri Net World, 2009), flexible enough to model complex and vast systems. This tool has been applied in reasrech of traffic control such as railway traffic control (Cheng & Yang, 2009)tunel1) and air traffic control (Huang & Chung,2011)tunnle1).

There are number of other tools that support simulation of discrete event systems such as Automata, Stateflow and Petri nets. Automata comes with a short coming of lack of structure. It does not decompose a system into modules (**Avinor, 2009**). State flow is a complex and complicated software that operates in Matlab (**Extend, 2009**) and also demand for Simulink knowledge. **However it is similar to petrinet but with its syntactic, semantic, and graphical details makes it difficult for learning and understanding.**

This paper presents the model of a Petri net simulator to road tunnel traffic control.there are a number of petri net models available and has been already developed for the betterment of traffic safety purpose but the main purpose for building a new simulator is that it should be flexible, easy to use and extensible enough to work in future of electronic and programmed automated world. the simulator should be flexible enough to be used in combination with other tools and libraries to support hybrid models such as Fuzzy Petri nets with Fuzzy Logic. The first petri net model for traffic signal control was discuused in DiCesare, Kulp, Gile, and List (1994)tunel1 for traffic network in urban areas.in which it was used for

performance analysis and code generation. Another integrated framework on colored petri nets are used to model the signalized traffic network systems in Dotoli and Fanti (2006).tunell1by keeping the phase duration fixed through a deterministic values. In Huang and Chung (2008), the traffic operations are operated by the control system of the coloured petri nets.in Dotoli, Fanti, Mangini, Stecco, and Ukovich (2010), Febbraro and Giglio (2006), Tolba, Lefebvre, Thomas, and Moudnia (2006) represents phase duration by adding fixed ,predetermined interval time. A General-purpose Petri net simulator (GPenSIM, 2009) is a toolbox for the MATLAB software, developed to accommodate easily with the diverse toolboxes present in the MATLAB. Other toolboxes such as Fuzzy Logic Toolbox, Control Systems Toolbox can easily be implemented with models that are programmed and developed in GPenSIM.

The proposed model is easy to understand for its users as it provide mathematical less and simple user interface. The paper proposed a GPenSIM model and a brief study on the tunnels, different parameters involved in road traffic through these, and the potentials of threats acquired with it.

## **1.5 Necessity of tunnels**

- ◁ To avoid taking long, winding roads around a mountain or spur.
- ◁ To prevent open-cut sides from sliding in sifter soils.
- ◁ To connect the two-terminal stations using the shortest route possible.
- ◁ In mountainous terrain, avoid steep declines and keep a fast speed.
- ◁ Tunnels beneath a riverbank are frequently cost-effective.
- ◁ To divert water for the purpose of generating electricity.
- ◁ To stay away from important land or property
- ◁ To save maintenance cost which is generally lesser.

## **CHAPTER 2 TUNNELS**

There are many countries that comes under the list of road tunnels, among them Norway is well known with the highest road tunnel length per capita. The advanced road infrastructure is designed like a web with tunnels to reduce travel time and delays due to jam or heavy traffic. **Table1**(accidents in Norway) shows the increase of number of tunnels for the time of four years upto 13.2%.it is also noted that the length of the tunnels have also increase by 22.9%.However moving towards the advancement in tunnel building, tunnels security is the utmost important element. Research has been done by bringing two major road accidents in Norway by Magne Mo in 1979/80, which was further revised by SINTEF Vegteknikk (Asbjarn Hovd 1981). The study included the data about accidents at the transition zone and mid-zone. It was noted that 72 accidents happened at the transition zone out of 221 accidents, where 100 occurred in the transition area and 49 at the mid-zone. The study reveals some serious facts about the different types of accidents such as

- ◁ Single vehicle accidents were reported 52% of the total.
- ◁ Head-on collisions happened to be 20% of the accidents mostly in the narrower tunnels.
- ◁ Rear-end collisions were reported to be 13% of the accidents, happened mostly in the wider tunnels with thick traffic volume.
- ◁ Miscellaneous ótype accidents were 15%.

It has been seen that the high number of accidents were encounter in the two lane tunnel. While designing tunnels the behavior of the driver and the ratio of the traffic accidents is an important point. Tunnels are easily exposed to accidents and fire

mishaps. In Norway a wholesome department (IDE), has been dedicated to the research and advancement for tunnel safety by iTSRG. iTSRG is a research group and multidisciplinary platform that works exclusively for tunnel safety with the Department of Economy, Planning and Safety (ISØP).

Traffic safety is the most important element for the safety of road tunnel. It depends on three main factors 1) design of the tunnel, (2) tunnel management and (3) emergency response (Burns, 2004)( Burns, D., 2004. Emergency procedures in road tunnels: current practice and future ideas. The Handbook of Tunnel Fire Safety 21, 4376450.) Many safety precautions are needed in a road tunnel to control, manage and mitigate accidents and the release of fire and other dangerous good due to the collision. Lord and Mannering (2010)( Lord, D., Mannering, F., 2010. The statistical analysis of crash-frequency data: a review and assessment of methodological alternatives. Transportation Research Part A 44, 2916305) has presented a strategy in which tunnel safety can be made more potential if we could estimate detailed driving data and crash data. This plan is easily implemented as most of the tunnels are equipped with closed circuit television (CCTV) cameras and an operation control center (OCC). Where the traffic volume and density based on hourly basis can be measure by the time to collision (TTC), for two following vehicles in same lane of road tunnel. (Hayward, 1972) (Hayward, J.C., 1972. Near Miss Determination Through Use of a Scale of Danger (Traffic Records 384). Highway Research Board, Washington, DC).

The tunnels are designed in such a pattern so that if there is a blockage or during any emergency people can evacuate safely from the tunnel. However other road safety measures are equally important which includes the prevention of collisions between

the vehicles and with the infrastructure, to reduce the mechanical impact and fatalities to avoid injuries and reduce the risk of fire.

There are different types of tunnels built with different environment around them, however the characteristics of tunnel plays a vital role in the causes or the effects of the collision. factors such as weather condition, road functionality and its condition, length of tunnels and the amount of traffic volumes has a very serious effect on the type of accidents happened in tunnels and the location in relation with the entrance ,exit and transition area. The summary of the road conditions revealed that wet road surface results in 38% of accidents where 35% of accidents happened in the snowy environment in the transition zone with comparison with county areas.

## **2.1 Tunnel versus open roadway**

following are the number of reasons that makes tunnels different from open roads.

1. Tunnels are design in a way to provide components of additional system which lack in open roadways such as fire safety system, proper ventilation system for gases, a communication system, fire detection and alarming system and so on. These components makes the designing and building of tunnels according to the cross-section of tunnels, the dimensions of tunnels and the length of tunnels.
2. Tunnels should be wide enough to encounter any mishaps such as accidents and fire incidents by providing the accessibility of rescue vehicles, heavy vehicles, ambulances and fire brigades.



3. Here comes the driver ability as an important reason of making tunnels safe for every person .[ PIARC, Human factors and road tunnel safety regarding users, PIARC Technical Committee C3.3, Road Tunnel Operation, Report R17, Paris, 2008 ISBN 2-84060-218-0. (<http://www.piarc.org>) due to the dark and closed cross section area of tunnel [5,6[G. Vashitz, D. Shinar, Y. Blum, In-vehicle information systems to improve traffic safety in road tunnels, Transp. Res. F 11 (2008) 61674.

[6] Guide to Road Tunnels, Part 2: Planning Design and Commissioning, Austroads, 2010]], it becomes difficult for the driver to estimate the length of the tunnel, road alignment specially at the curves and the coming bends due to tunnel wall.[ [7] C. Caliendo, M.L. De Guglielmo, M.A. Guida, Cash prediction model for road tunnels, Accid. Anal. Prev. 55 (2013) 1076115]

4. While designing tunnels it is important to keep in view the tunnel walls and the environment because they are the physical obstacles. Heavy goods vehicles should not be allowed inside the tunnels.
5. Tunnels are costly constructed as compare to open roadways due to the use of huge boring machinery and huge amount of construction material like cement, concrete etc.

## **2.2 COMBINED-USE OF ROAD TUNNELS:**

This chapter explains how complex the structure of tunnels could be when it comes in combinational uses of it. When building a tunnel two elements are the most important

things to be considered,1) cost 2) functionality. That is the reason tunnels are made not only for transportation for vehicles but for other reasons described below:

- 1) Tunnels for road vehicles, bicycle riders, bus stops and foot-travelers (pedestrians). Most of these tunnels are short in length and require special supervision for air ventilation and security.fig4 and fig5 give the clear picture of these tunnels. Bus tunnels are like railway and metro tunnels that have huge number of people traveling through them. These tunnels have space for bus stops
- q p n { " c p f " r g q r n g " e c p p q v " y c n m " c n q p i " v j g "
- longest tunnel in Norway fig5.



Figure 2.1 Tunnel with pedestrian walkways all along



Figure 2.2: Tunnels that accommodate bus stops(Norway)

- 2) In combination with the road vehicles and services such as gas fuel and electric power lines.

These types of tunnels are made across the rivers and connect island and even continents. These tunnels have highway, railway track, a huge network of oil pipelines, and a vast web network of fiber optic cables, hence making these tunnels more prone to the risk of fire so that would need special attention while designing these tunnels.

- 3) In combination with the road vehicles and railway vehicles.

There is a number of examples that comes under the list of this category. fig6. shows a picture of The Hochtief/ Veidekke JV tunnel which is also awarded for the longest tunnel, made between Germany and Norway .some tunnels have separate tube section for road and railway traffic while others have combined tube used for both road and railway track. Other example are the Drogden Tunnel between Copenhagen in Denmark and Malmo in Sweden. This tunnel was completed in 2000 with a length of approximately 4 km (2.5 miles) long .



Figure 2.3: Hochtief/ Veidekke JV Tunnel interior: combined-use for road and railway.

- 4) Another example of tunnels are railway tunnels with railway cars that carry road vehicles. e.g. channel tunnel.

## 2.3 Severe crashes overview in road tunnels including fire

The type of vehicle travelling through the tunnels is also another important topic. the crash risk involve in vehicle is low in road tunnels than it is on open roadways

network , however the catastrophe and disaster related to the tunnel fire is huge[H. Mashimo, State of the road tunnel safety technology in Japan, Tunn. Undergr. Space Technol. 17 (2002) 145-152].It has been study that the number of fatalities in road tunnel fires are more likely to link with HGV. The number associated with HGV is approximately 71% in tunnel fires , 24% is due to the regular vehicles in which trucks are not included and 5% are due to lorries and truck[A.N. Beard, Tunnel safety, risk assessment and decision-making. Technical note, Tunn. Undergr. Space Technol. 25 (2010) 916; 6 \_ 0 " v c d n g " 8 " c t g " D t c p f v summary of annual crash rate in road tunnel due to fire incidents based on Norway and Switzerland database reports. The research of Brandt et al. [R. Brandt, M. Schubert, N.P. Høj, On risk analysis of complex road-tunnel systems, 6th International Conference "Tunnel Safety and Ventilation". Graz. Austria, 2012] shows that the tunnel crash rate is 0.131 per million behicle kilometers. The study also shows that the fire incident rate in tunnel for Norway and Switzerland is 30% of the tunnel crash rate (0.036). It is noted that the rate of fire crash is less frequent but with huge consequences as compare to the traffic crashes.

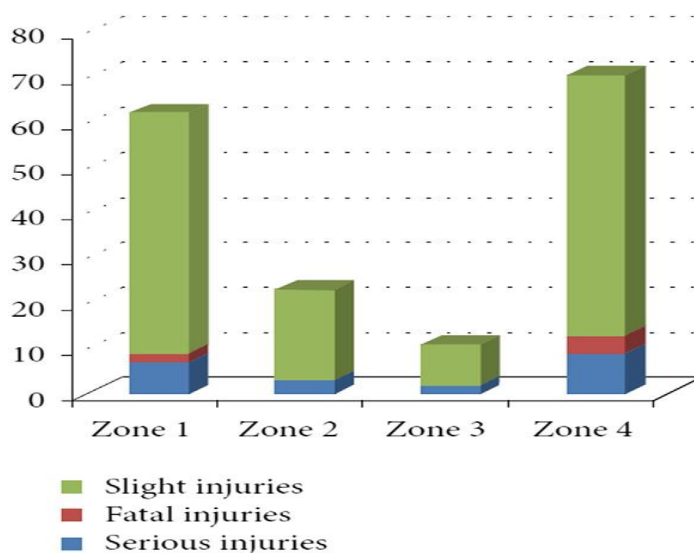


Figure 2.4 . Number of injuries by crash severity and tunnel zone [12]

## **2.4 Vehicle type associated with fire incidents [13]**

In 2001 [F.H. Amundsen, A. Engebretsen, G. Ranes, Car Fires and Breakdowns in Norwegian Road Tunnels 1990-2000, Norwegian Public Roads Administration, Oslo, 2001] A Norwegian study shows that the vehicle fires due to crash in road tunnel were only 10%. The type of vehicle also plays a vital role in the cause and severity of fire incidents [T.O. Nævestad, S. Meyer, A survey of vehicle fires in Norwegian road tunnels, 2008-2011, Tunn. Undergr. Space Technol. 41 (2014) 104-112]. For example, 46.3% of the 135 fires involved one vehicle under 3.5 tons. 38.1% of the 135 fires involve only one heavy vehicle whose weight was above 3.5 tons, where 5.2% was the one with single heavy vehicle and one light vehicle, more than two light vehicles involve 5.9%. Table shows the cause of fire for vehicles over and under 3.5 tons.

In order to characterize road tunnels, researchers have conducted and established a system of classifying tunnels by its types, conditions, classes and different groups. This methodology has been followed according to the technical features, location and design of road tunnels to simplify the construction, technical characteristics, structural standards, and various techniques in the making and designing of road tunnels. Safety tasks such as fire safety, managing risks in designing and construction of tunnels, different operations involved in maintenance of underground tunnels are also brought under the concerned list.

In the modern era of tunnel world , new methods are introduce for the calculation and design of constructing tunnels, use of modern tools and mechanism, introducing effective methods with materials and high-performing machinery[L.V. Makovskiy, S.V. Chebotarev, N.A. Sula, Innovative constructional-technological decisions in transport tunnels construction.Background information, highways and bridges. 4 (2005) 3 104]. Newly huge attention has been paid in the field of transport tunneling for investigation and design of tunnels.[ 2-4]/[2] State Standard 33154-2014, Automobile roads of general use, Finding of tunnels, The general requirements, Standartinform Publ., Moscow,2015. (In Russian).

[3] State Standard 33153-2014, Automobile roads of the general use, Projection of tunnels, The general requirements, Standartinform Publ., Moscow, 2015. (In Russian).

[4] E.A. Shemshura, R.V. Kargin, A.A. Domnitskiy, Development of regulatory requirements for road tunnels, Internet-magazine Naukovedenie. 5 (2014)][Formalization of Requirements to Road Tunnels]

## **CHAPTER 3 CLASSIFICATION OF ROAD TUNNELS**





A research with its various versions, strategies and designs, features of tunnels has been made it easier to classify tunnels for the normative document having the national status [5]. The purpose of the effort was to come up with work divided into different classes of tunnels depending upon the classification of tunnels, symbols and standard constructive and technological decisions. [6].

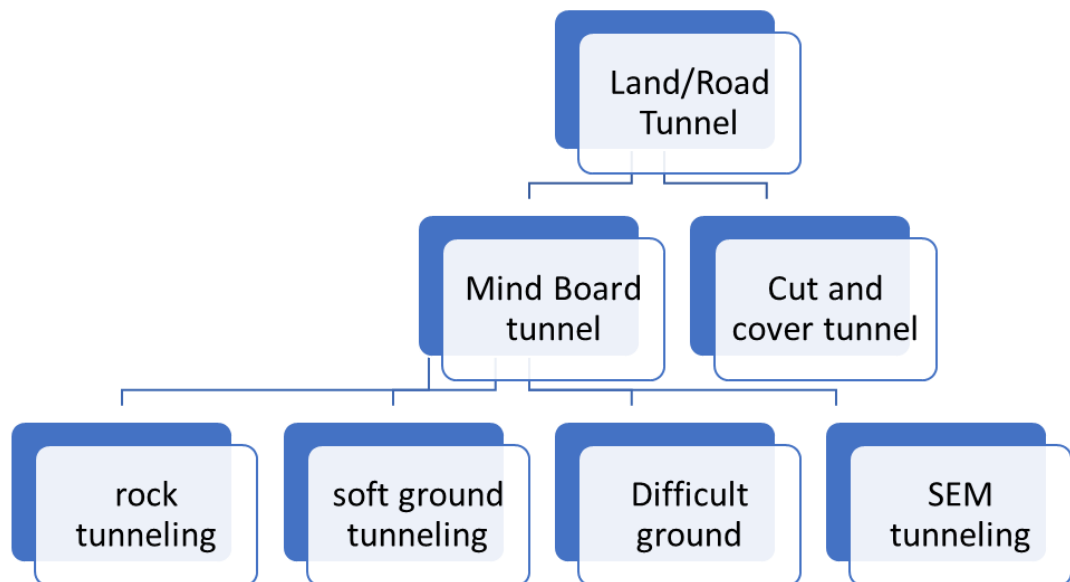


Figure 3.1 General Classification of Tunnels

**In [7-16]** [7] R.B. Garibov, Road transport works (roadways, bridges, tunnels, culverts), SGTU, Saratov, 2009.

[8] P.M. Salamahin, Engineering works in transport construction, Academy, Moscow, 2007.

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### **3.1 Indicators based Tunnel classification**

The analysis shows that road tunnels can be distinguish according to overall indicators or ideally known as general indicators, technical indicator and design indicators.

#### **3.1.1 General indicators:**

it includes the seismological area of construction, occurrence depth, technique involved in the construction, pattern of traffic organization and the Locality in relation to the assistance of the earth's surface.

#### **3.1.2 Technical indicator:**

it includes the size of cross section area of tunnel, length profile, profile in the tender, total number of strips in road tunnel and the traffic lane width.

### **3.1.3 Design indicators:**

it includes the quantity of tiers and flights, different form of cross section, type of padding and tunnel portal.

## **3.2 Public Highway tunnels**

On public highway tunnels are classified into construction, constructive and technical characteristics groups. The classification is further divided into four sub classes described below

### **3.2.1 X type :**

It includes the arrangement in relation to the relief of global surface such as mountain, underwater and plain areas.

### **3.2.2 X class :**

according to the occurrence or frequency of earthquakes in a region of construction e.g. tunnels in the zone of seismicity or out of the seismic zone or tunnels in other dangerous areas whose seismicity is upto 7; 8; 9 and 10 points.

### **3.2.3 x condition :**

Depending upon the depth i.e. how shallow and deep the occurrence is

### **3.2.4 x group :**

according to the design depending upon the quantity of tiers and flights. Typical size of tunnels are determined by parameters of technical characteristic which includes the length and width. With respect to this tunnels are also subdivided depending upon the material of construction and lining used in making of tunnels. [[5]

State Standard 33152-2014, Automobile roads of the general use, Classification of tunnels, Standartinform Publ., Moscow, 2015. (In Russian)].

### **3.3 Design of Road Tunnels.**

In [17-20] analysis of research has been proposed and various experience in constructing tunnels has been studied and presented briefly. The study shows brief technological solutions for road tunnels and systematized requirements for deciding space planning, construction, design and establishing engineering structures of tunnels.

The design of the tunnel depends upon the form of cross section which is demarcated by designing line.

The design of lining is find out by the relief and the frequency of earthquakes in a region of the area of construction, engineering and geological conditions, occurrence depth, loads expected to be applied and the rate of production technology of installation and construction works. The main goal of tunnel lining is to provide resistance to fire, operational reliability, toughness, wearability and resistance to different types of destructive effect of external environment. Talking about the cross section of tunnels they could be circular, vaulted, elliptic (oval) or rectangular outline.

Normally tunnels design lining are divided into groups, depending upon the technological structures of the way road tunnels are constructed. Nowadays , modern construction of road tunnels are subdivided into open, underground and special groups.

Open methods are used in construction of tunnels where there is shallow occurence.

These methods provide construction of tunnels in underground designs which were dug previously from the Earth's surface or in the creation of walls in trenches.

Where Underground methods, are used without the opening of the Earth's surface. These methods are applicable to construction of tunnels of both shallow and deep occurrence. E.g. are the mining, panel board and breakdown methods . for digging deep tunnels , methods such as mining and panel board are used where shallows tunnels are built by breakdown methods. Other special techniques are used for sinking, tunnels- caissons and for chemical fixing of unstable rocks , freezing methods and dewatering all belongs to the special methods.

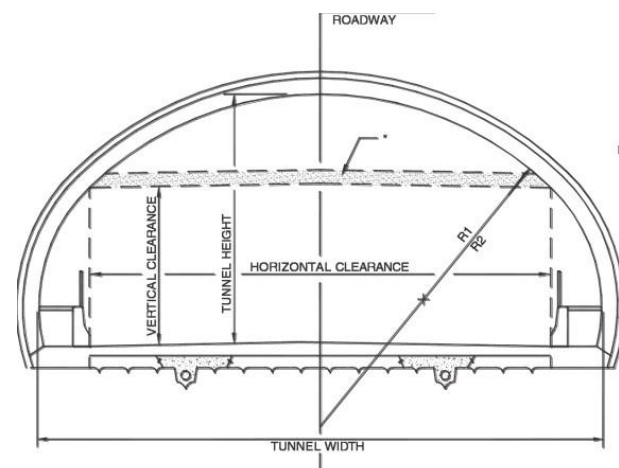
### 3.4 Shape based Tunnel Classification

The nature and kind of ground through which a tunnel goes, as well as whether it is built to carry a single or double lane, determine the tunnel's size and shape. A tunnel's shape should allow the lining to withstand the forces imposed by the tunnel excavation's unsupported walls. Based on the shape of tunnels, the highway traffic tunnels are divided into four types, namely;

- 1) Oval or Egg shaped Tunnel
- 2) Horseshoe shaped Tunnel
- 3) Circular or Round Tunnel
- 4) Rectangular Tunnels

The details of these tunnels are described below;

#### 3.4.1 Oval/Egg shaped tunnel



There are a multitude of centres and radius lengths in this tunnel shape. These can be used as sewer tunnels to transport sewage water. However, a lot of base is required to make it practical for the Traffic and Transport system.

### 3.4.2 Horseshoe Shaped tunnel

The shape of a horseshoe tunnel is a hybrid of arches and a circular tunnel. The shape of these tunnels is very common.

### 3.4.3 Circular

Water is transported under pressure through circular tunnels. Because additional filling is required to make the base flat, these are not suitable for traffic tunnels. The best course of action is to oppose the external or internal force. It has the largest cross-sectional area while having the smallest perimeter. To build a flat base for building a road or railway track,

further filling is required. Also Lining work in circular tubes is quite challenging. Regardless of the reason for

which the tunnel is built, a circular tunnel is ideally suited for resisting both internal and external forces. Theoretically, the highest cross-sectional area for the lowest diameter is provided by a circular section, which gives higher resistance to external pressure.

Figure 3.2 Oval/Egg tunnel with two lanes

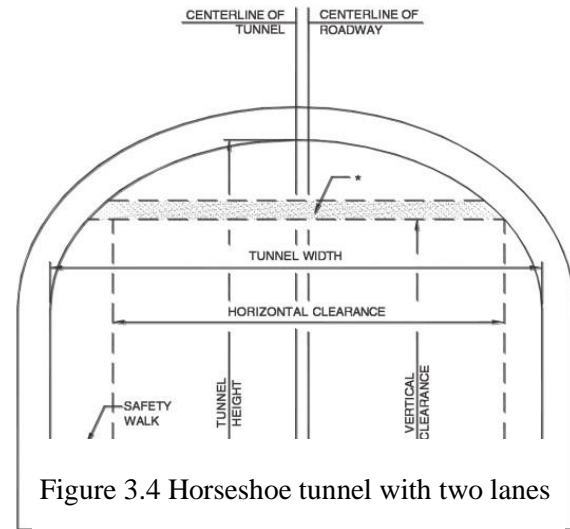


Figure 3.4 Horseshoe tunnel with two lanes

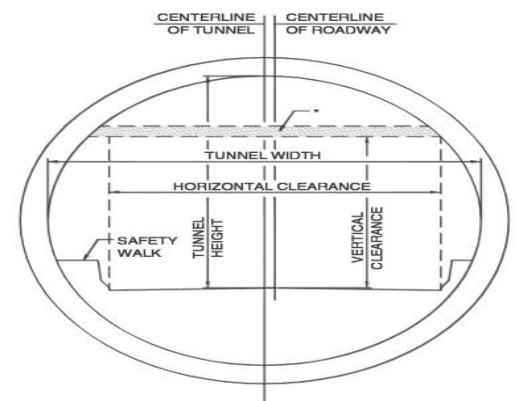


Figure 3.3 Circular Tunnel with two lanes

### 3.4.4 Rectangular

Tunnels with rectangular form are best for pedestrian traffic. If pre-fabricated R.C.C caissons are utilised, these tunnels are occasionally allowed. Due to their rectangular design, these tunnels are not suited to withstand external pressure and are no longer in service.

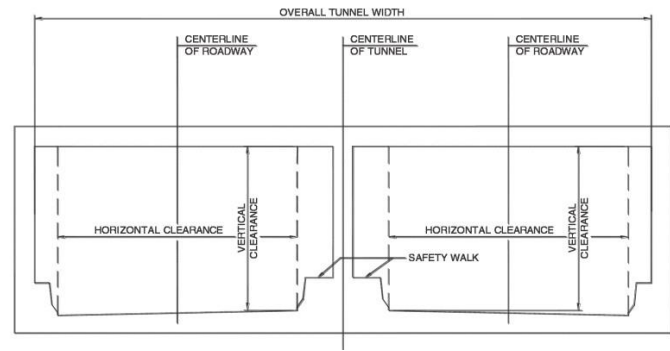


Figure 3.5 Rectangular tunnel with two lanes

## 3.5 Purpose based Classification

Tunnels are passages beneath the ground that are utilised for transportation. They might be used to transport freight and passengers, as well as water and sewage. Beyond a certain depth, tunnels are more cost-effective than open cuttings. During construction, tunnels avoid disturbing or interfering with surface life and traffic. Based on Purpose the tunnels can be classified into two categories; namely;

- 1) Traffic Based Tunnels
- 2) Conveyence Based Tunnels

The requirements for tunnels to be built change depending on the tunnel's intended use.

### 3.5.1 Traffic

The goal of traffic tunnels is to move commodities and people, and their requirements can be divided into four categories: operational, structural, constructional, and maintenance.

### **3.5.2 Conveyence**

Materials, water, and sewage can all be transported through the conveyance tunnels. The ones for transporting materials are usually restricted to industry or smaller areas, and their requirements are mostly structural, constructional, and maintenance-related.

## **3.6 Construction based Classification**

Tunnels are classified based on the material through;

- 1) Hard rock; soft rock, such as shale, chalk
- 2) Soft ground, consisting of soil and very weak rock
- 3) Water bearing soil

These four major types of ground conditions necessitate extremely distinct excavation and ground support techniques. Despite this, almost all tunnelling operations follow the same fundamental procedures: investigation, excavation, and material transportation, ground support, and environmental management.

### **3.6.1 Hard Rock**

The weight of loosened rock underneath the ground arch is the most typical loading on the support of a tunnel in hard rock. The term "hard rock" refers to rock with a uniaxial compressive strength (UCS) of greater than 100 MPa. Hard rocks are geologically old and have well-developed and worn joints; consequently, if left unsupported, these joints may cause major problems with rock falls and seepage in tunnels.

### **3.6.2 Soft Materials**



Soft ground tunnels are found in sensitive metropolitan areas where tunneling-related settlement is a major concern. To ensure successful tunnelling in soft ground, protective procedures such as dewatering, ground improvement, compensatory grouting, and positive pre-support might be implemented. On comparison to hard rock, a tunnel built in soft ground ó such as clay, silt, sand, gravel, or mud ó need particular techniques to compensate for the fluctuating nature of the terrain.

### **3.6.3 Water bearing soil Tunnel**

Tunneling in water-bearing ground can cause undesired groundwater input into the excavated region, resulting in groundwater drawdown.

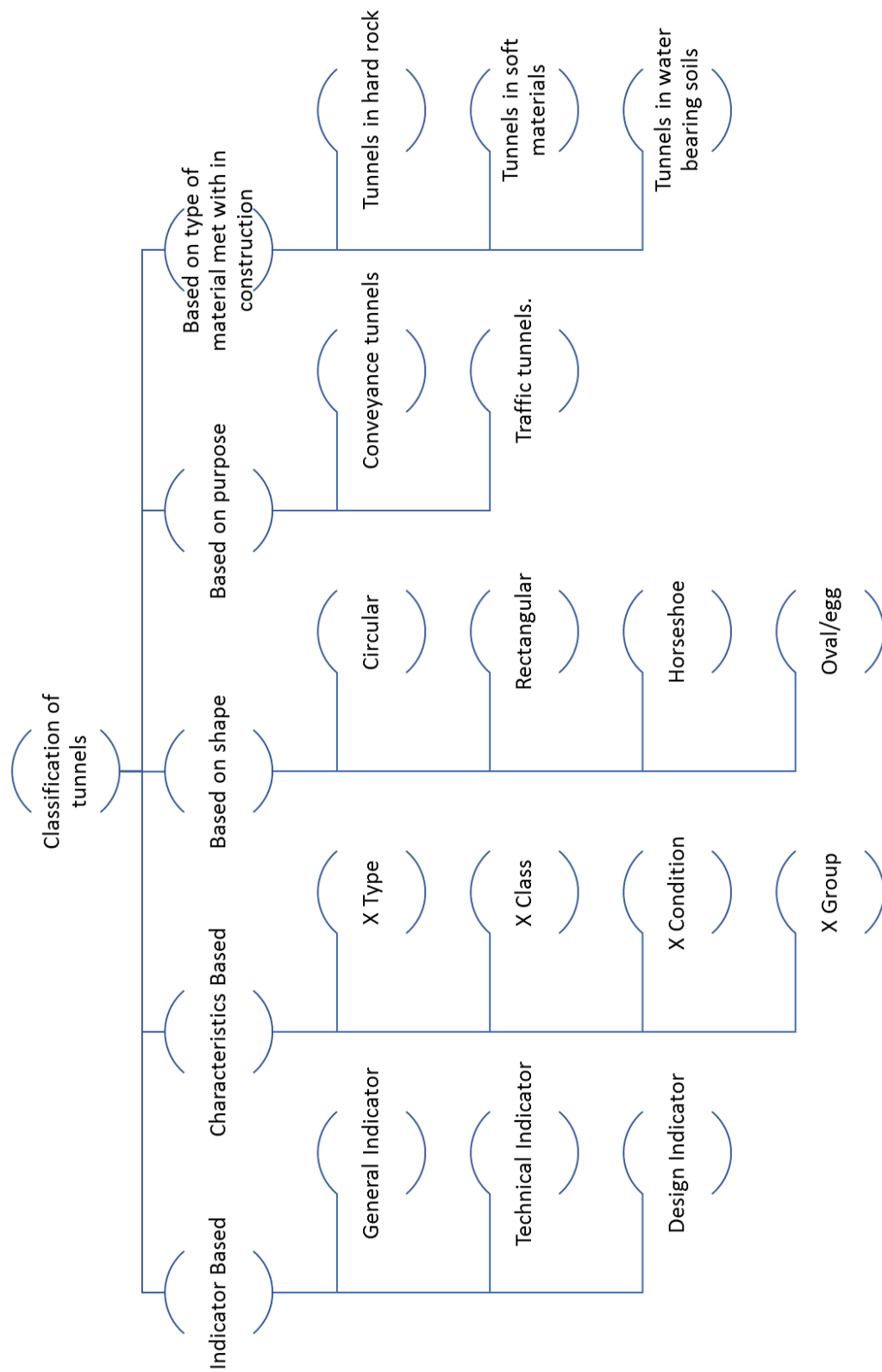


Figure 3.6 Taxonomy of Tunnels

### 3.7 Accident types

In the National Road Data Bank all the accidents are recorded by its type. Table2 shows different road tunnel accidents happened within and outside tunnels by its type. Clearly the number of pedestrian and turning vehicle accidents is less as most of the tunnels do not facilitate pedestrian traffic through them. The table shows that the head on collision accidents , single vehicle and miscellaneous accidents in tunnels are common to those occurred on road . the collision at the rear- end are noticeably twice the open road. Fig(1) shows different accidents by its type in tunnel.it has been notice that at the tunnel entrance, the ratio of frontal accidents is high. Crossing and turning accidents are more frequent at 50m beyond the tunnel opening and outside it. Pedestrian accidents occur in those tunnels where pedestrian are allowed to walk specifically in short length tunnels.

The study compare the accident type for one and two-way tunnels.

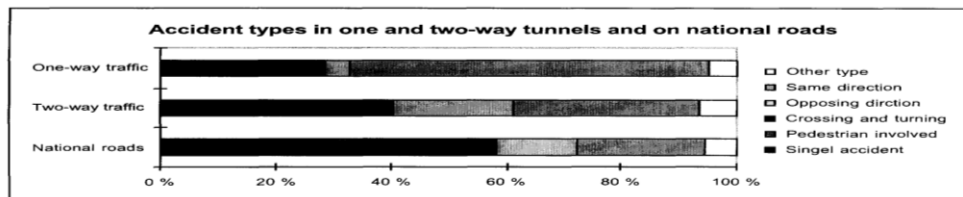


Figure 3.7: Accident types in one-way and two-way tunnels NRN.Bars, from left to right:

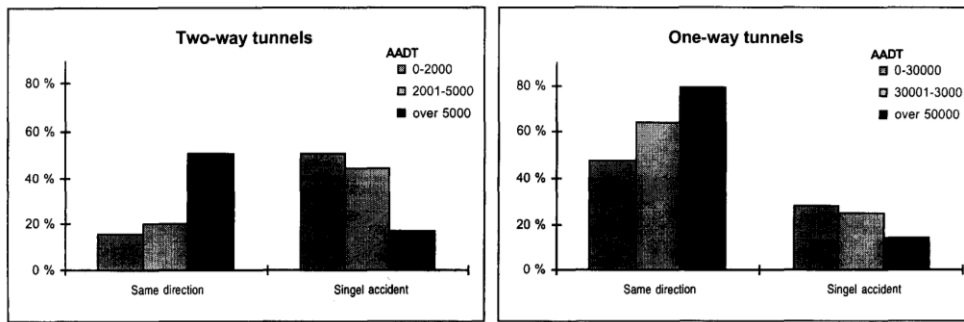


Figure 3.8: Relationship between AADT and single-vehicle accidents and accidents with vehicles moving in the same direction.

Tunnels with twoólane in one way have 62% of the total number of accidents, Where single vehicle had 23%. Tunnels with two way traffic in same direction for single vehicle are 34%, with head on collision 21%. The data on the national road network shows that for single, crossing or turning and accidents that happened to be in same-direction are of alike magnitude: 26%,24% and 22%.fig1.

Whether the tunnel is single way or two way the amount of accidents rises with traffic volume. In Two way traffic, the increases is from 16% with traffic below 2000 AADT to 50% with traffic exceeding 5000 AADT. The share with one-way traffic increases from 48% with an AADT below 30 000 to 79% for an AADT above 50 000. Fig2 shows the decline upto 50% in single accidents for two way traffic with an AADT below 2000 to 17% with an AADT above 5000. One way traffic have 28% and 14% for AADTs below 30 000 and above 50 000, respectively.

### 3.8 Accidents in sub-sea road tunnels

the study shows that there are in total 13 sub-sea tunnels in Norway. Whose average length is 3400 m, with an average AADT of 1800. Among these nine of the tunnels

encountered accidents with a total of 14 for the period of five year. The average rate of accident estimated was 0.07 annual person injury accidents per million vehicle km. which is a very low accident rate in comparison with all tunnels.

### 3.9 Accidents in dual tube tunnels

There are around 28 dual tube tunnels in one way traffic with estimated length of 20km. the collective data shows that the accident rate in these tunnels is around 0.12 which is expected to be higher. This higher number is because of the reason that one-way tunnels are short with heavy traffic volumes. Which increase the risk of congestion causing rear-end collision most frequently fig.2. for one-way tunnel the rate of accidents at the inward are illustrated in fig3, which shows the accident volume thickness outside the tunnel opening that could be due to rare-end collision or by blinding sunlight.

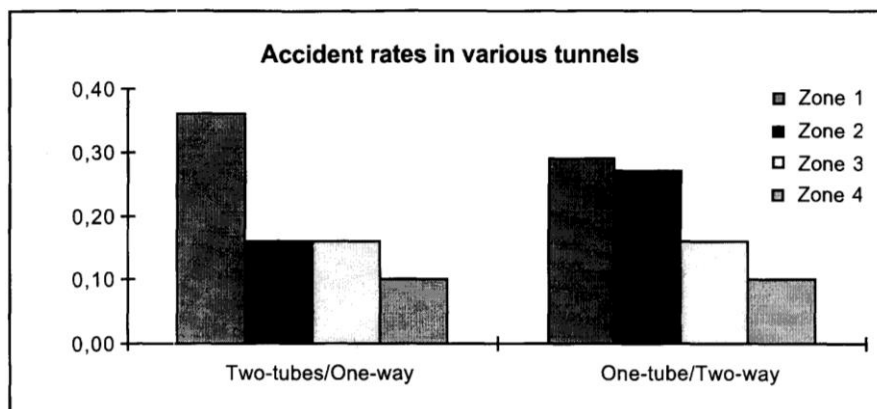


Figure 3.9: Accident rate for one-way and two-way tunnels

# **CHAPTER 4**

## **EXPERIMENTAL ANALYSIS AND RESULTS**

This chapter shows the simulation results done for the modelling of the traffic in tunnel. Petri net model has been shown in brief with figures explaining the types of traffic and lane followed for one way traffic and two way traffic in tunnels. For a good number of years the, petri net has being used for the modeling, analysis and control of different types of traffic at different locations. Whether its urban traffic, sky traffic that is airplanes traffic or sea traffic, petri net comes into the play. Various studies have been discussed in the literature review about the work done on Petri net. The results gained from the research shows the potential of using Petri net model for the control of traffic, predict different traffic scenarios, analyze difficult logics and control capabilities and improve the traffic performance in dense traffic areas with closed environment. our discussion has proposed a model for one to two lane traffic with simulation results showing that a safe a secure traffic system can be adopted by using petri net model.

The simulation is performed by loading a file khantestunnelwaq.m in matlab. Fig (8) shows the output of the code with the option of the one lane traffic and two lane traffic inside the tunnel.

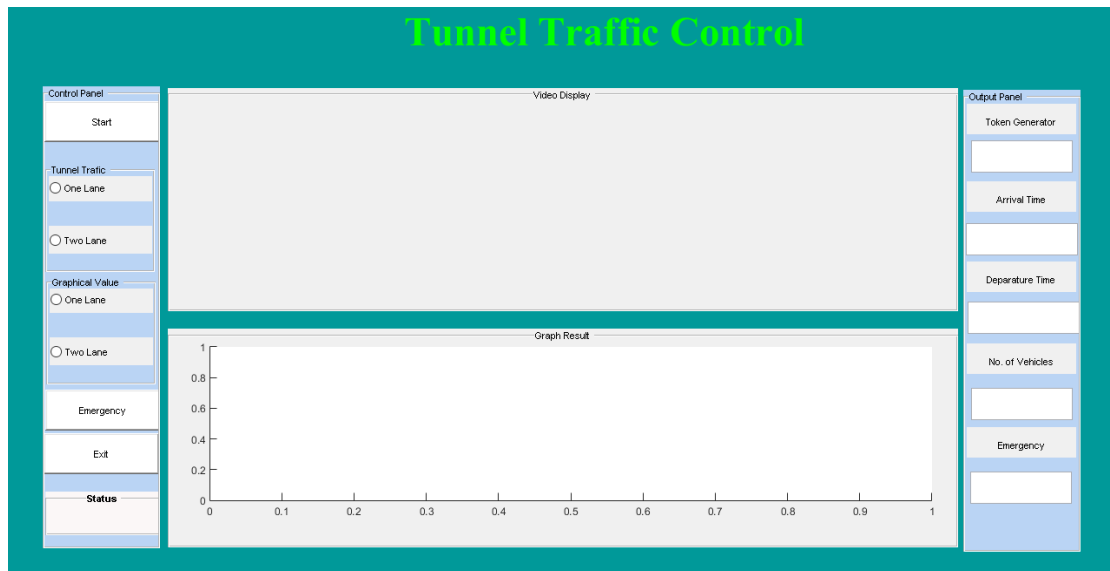


Figure 4.1 Tunnel traffic control

There is a token generator which shows the primitive idea for petri net with respect to transitions and places. Tokens are responsible to show that the condition related with the place could be true or false if they are absent or present. the arrival time is the time for the vehicles entering the tunnel whereas the departure time is the leaving time of the corresponding vehicle from the tunnel. For understanding of the code in the matlab the time of the arrival of the vehicle and departure time of the vehicle could be selected simultaneously. The block showing the no. of vehicles shows that how many vehicles can enter or leave the tunnel in a particular period of time. The emergency button shows that when there is emergency such as fire , accident or tunnel collapsed the emergency alarm can be activated with which no further vehicle is allowed to enter the tunnel . with the activation of the emergency alarm another secured way out could be adopted. Fig(9) shows that when the matlab code is run we get the tunnel traffic control window showing how one lane traffic and two lane traffic travels.



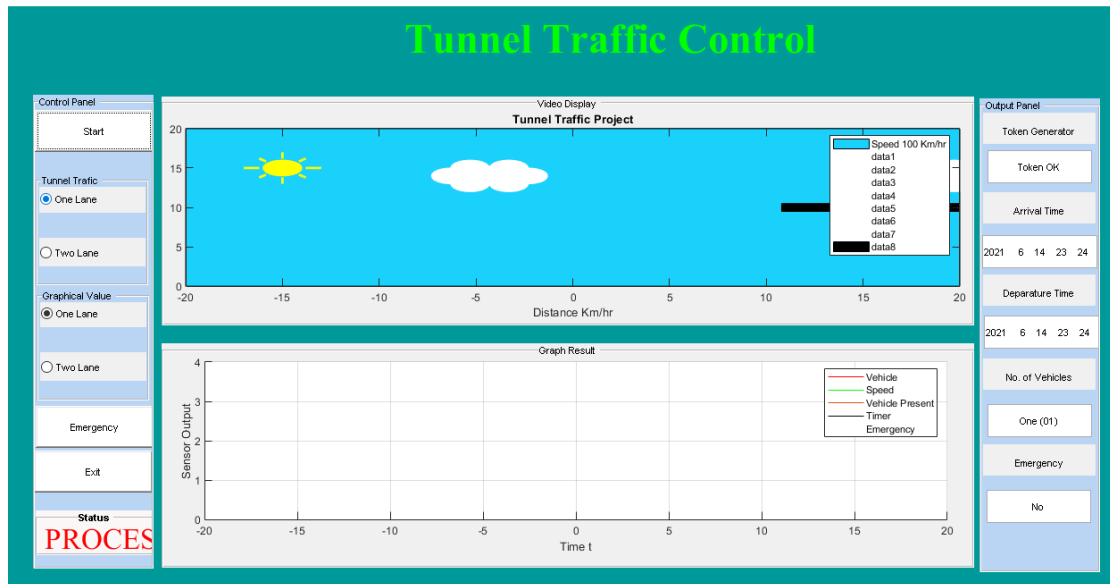


Figure 4.2 Tunnel Traffic control for one lane and two lane

When the start button is pressed with selecting option one lane we get a graph also showing how traffic follows a straight path without any blockage or crossing over. In the graph section different color bands are designated to show the number of vehicles, speed, time and emergency. We can engage the traffic by selecting the type of traffic whether its one lane traffic or two lane traffic and see how the graph changes with time. The arrival time comes with the date and sec and hours to exactly capture the vehicle entry time and leaving time from the tunnel. To keep the simulation understandable and easy we have considered the number of vehicles to one in both the lane which can be increase.

#### 4.1 Implication

For over a decade, applications of PNs in modeling, analysis, and control of urban v t c h L e " u { u v g o u " j c x w r k s d n s u g h p N - b a s e d a p p l i c a t i o n s h a v e X c t k q w u been reported in the literature

Figure (10 ) shows two way traffic in a tunnel in matlab window. showing how two cars cross each other in closed tunnel environment.

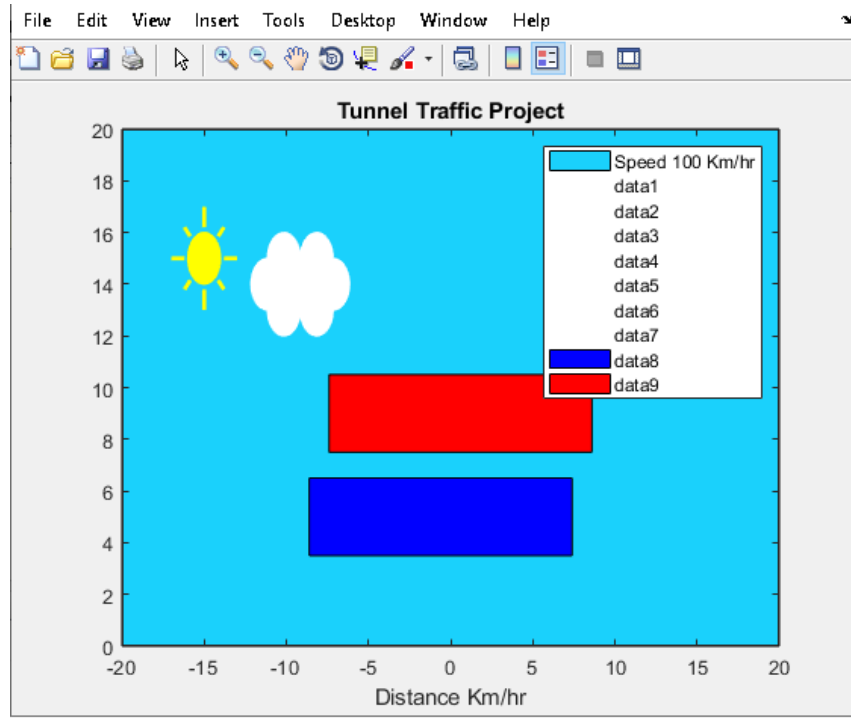


Figure 4.3 Tunnel Traffic Project

A Microscopic model theory has been adopted in the research to capture every single parameter of the vehicle such as speed, time , acceleration etc. moving in the traffic tunnel. Petri net follows a stochastic distribution function to measure real time traffic which is the demand and requirement of today. In the research as the number of roads and the number of lanes are defined and the amount of physical space that could be availed by the traffic when moving from one point to another of a tunnel. To understand the one lane traffic in a tunnel consider fig 11. By loading the file (khanwaqtestmodelpetri) in matlab we could easily understand how the proposed model runs for one lane traffic in bi direction without collision in the tunnel.

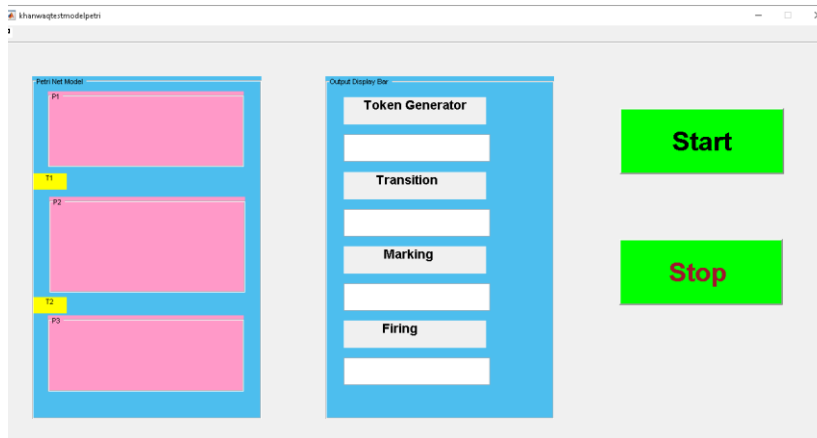


Figure 4.4 One Lane Traffic Window

Figure shows a window with different section showing a petri net model for the one lane traffic with two lane. P1 shows the vehicles moving inside the tunnel where T shows the transition from one lane to another. Token generator option is given which is already explained in the previous section. Marking show the assignment of tokens to different places of a petri net model. After running the petri net code in Simulink it is shown in fig 12 that the tokens are generated and marking is also shown with M1, O 4 " c p f " O 5 0 " U v q r " u j q y u " v j g " r t q e g u u " e c p " d simulation in the matlab program.

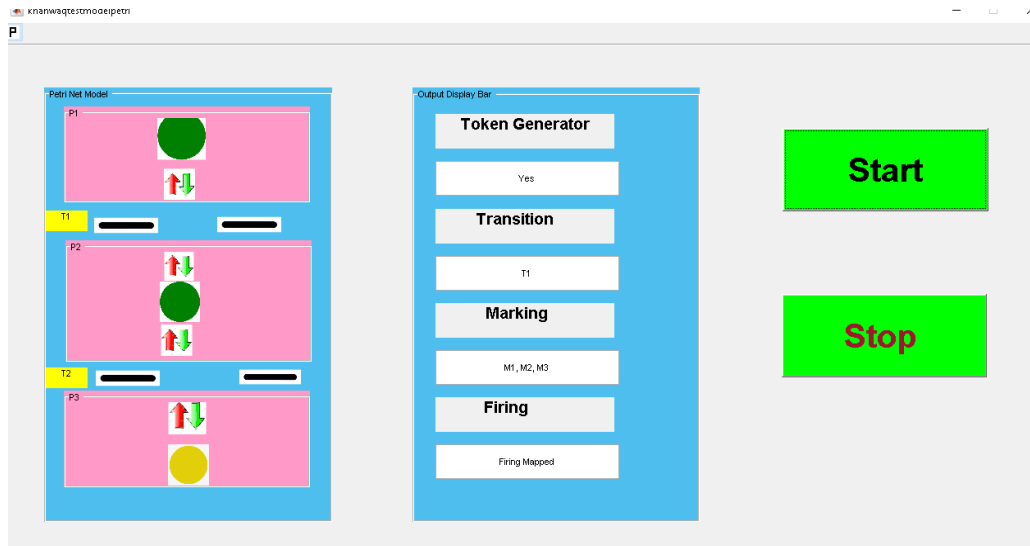


Figure 4.5 Petri net model for one lane traffic

Figure 13 shows the layout behind the working of the fig12 coding .

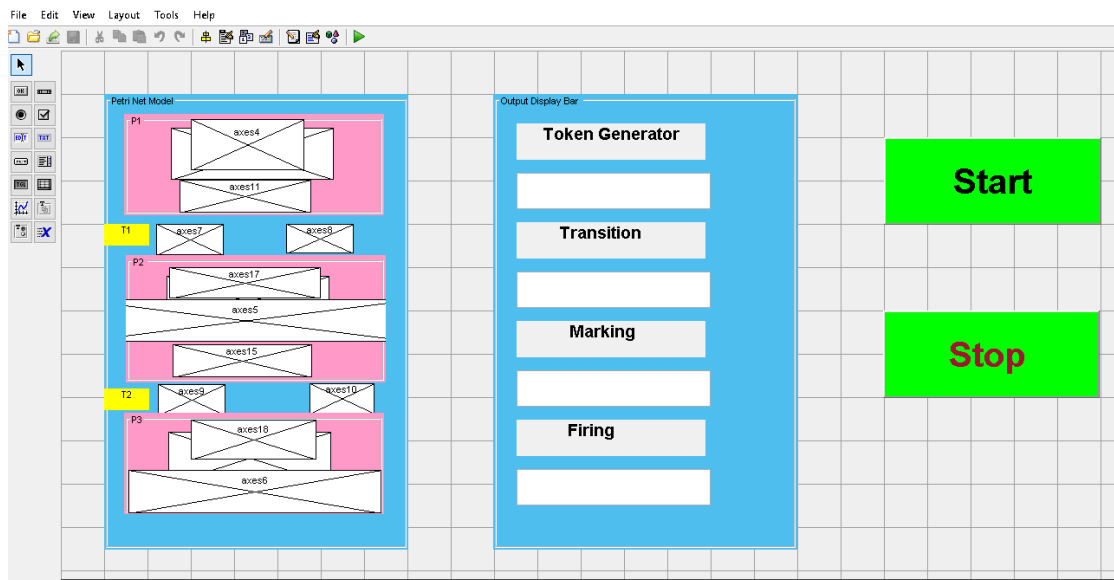


Figure 4.6 Layout of single lane petri net model

To more understand how the proposed model work for two lane process we defined a model with more lanes in petri net. Fig 14 shows the direct layout of petri net model which shows how the vehicles shows transition from one lane to another.

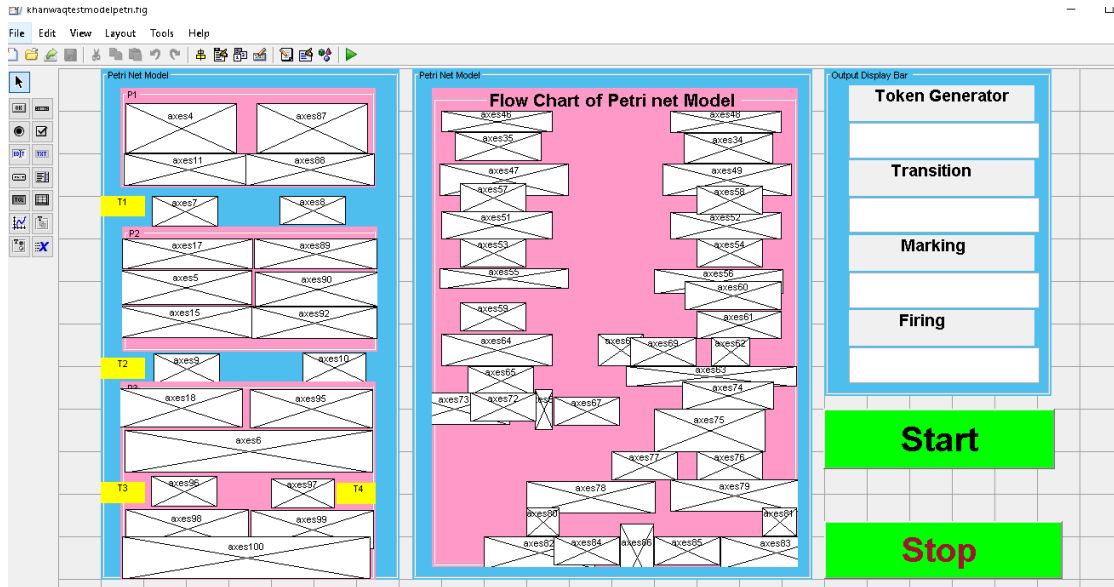


Figure 4.7 Two lane petri net model

In order to be operative, we need to implement and install advanced signal control system based on exact current picture of the traffic flow inside the tunnel. As there are majorly, no traffic signals system present inside the tunnels to control over flow of traffic and to avoid jam traffic, therefore a sensitive methodology is needed to be adopt to avoid any type of accidents or mishaps in the tunnels.

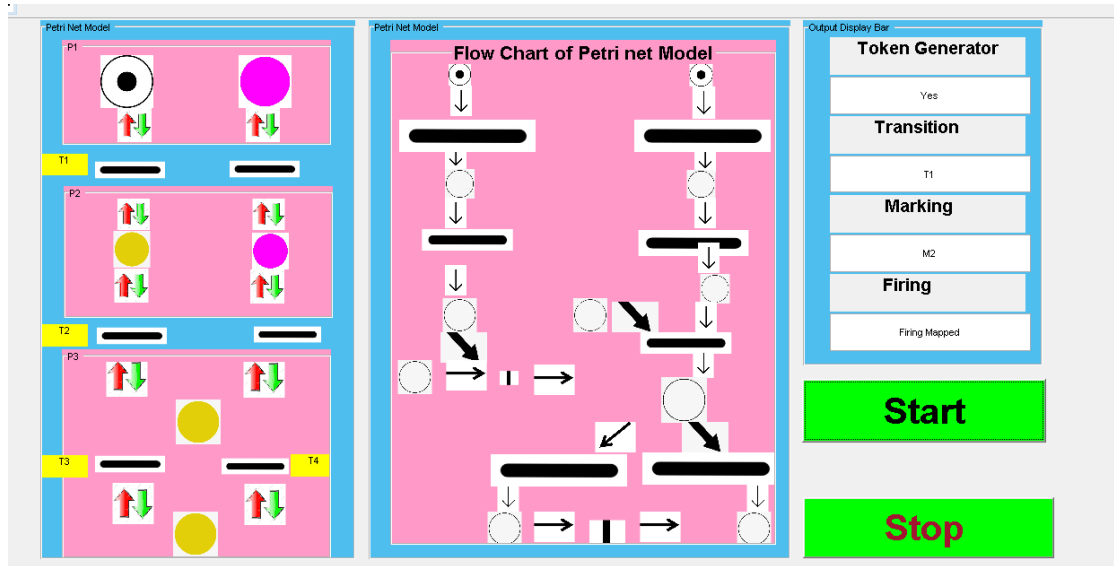


Figure 4.8 Flow of traffic with sensors and petri net model

## 4.2 Control Traffic Signal communication

Fig 15 shows a flow of traffic between different transition points in two lane traffic. The proposed work has used actuated control system which uses information about present information obtained from sensors about different rate of traffic flow. {Roess, R. P., Prassas, E. S., & McShane, W. R. (2004). Traffic Engineering (3rd Edition). Upper Saddle River, New Jersey, USA: Pearson Prentice Hall}. Actuated traffic control system has advantage over pre-timed traffic signal control due to their responsive behavior. Collectively the behavior of the controller and the sensors are specified within the petri net model fig 16.

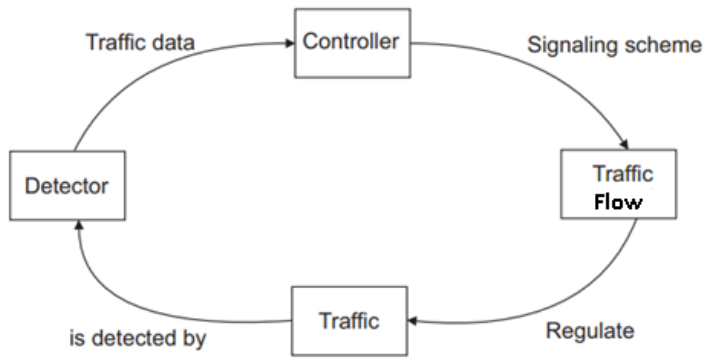


Figure 4.9 Traffic Scheme

It has been noted that as the tunnels lack traffic signals the ratio of vehicles collisions are intense in tunnels. The purpose of introducing sensors and control system in petri net model is to ensure that the traffic flow is smooth without any over flow and jam traffic inside the tunnel. Sensors and control system is embedded inside the tunnel from start to end so that every vehicle entering the tunnel must be encounter and kept under supervision. Fig 17a and fig 18 shows the flow of traffic inside the tunnel at position zero and at peak time . it is noted that when there is peak hours of traffic the graph shows dense traffic values which alter the sensors and controllers to become active.

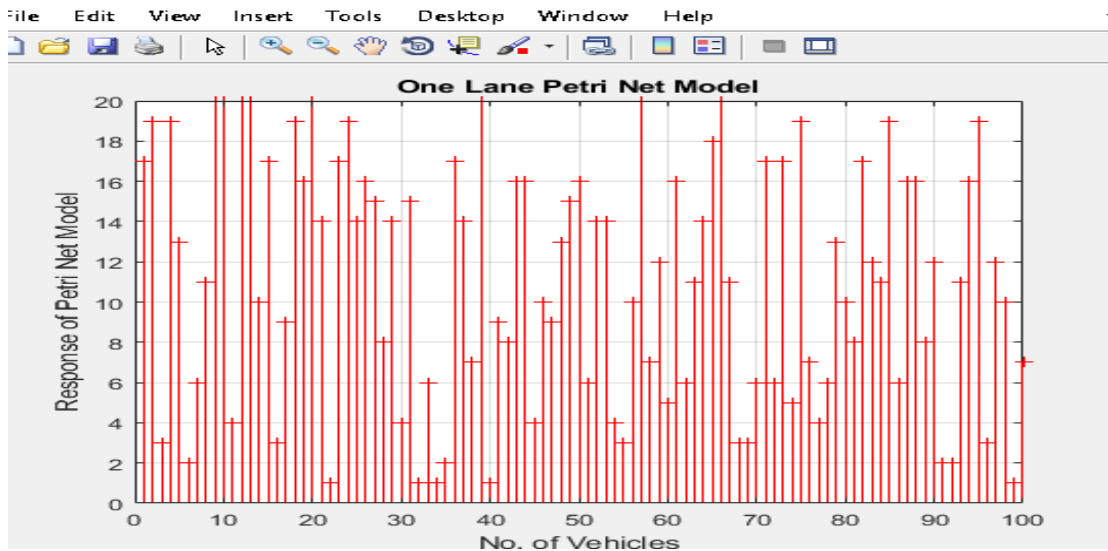


Figure 4.10 One lane Petri net model in peak hours

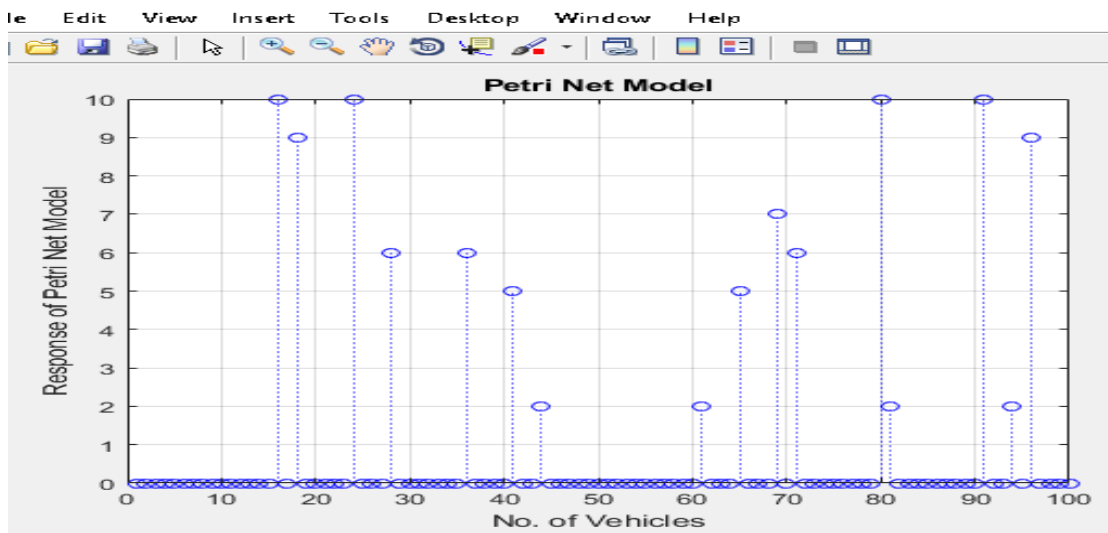


Figure 4.11 Petri net model of one lane traffic in normal hours

Whereas the ratio of traffic flow inside the tunnel fig 19 has been changed when we consider two lane traffic flow that also under different traffic hours. In the peak traffic hours the number of vehicles entering the tunnel has been seen increasing.



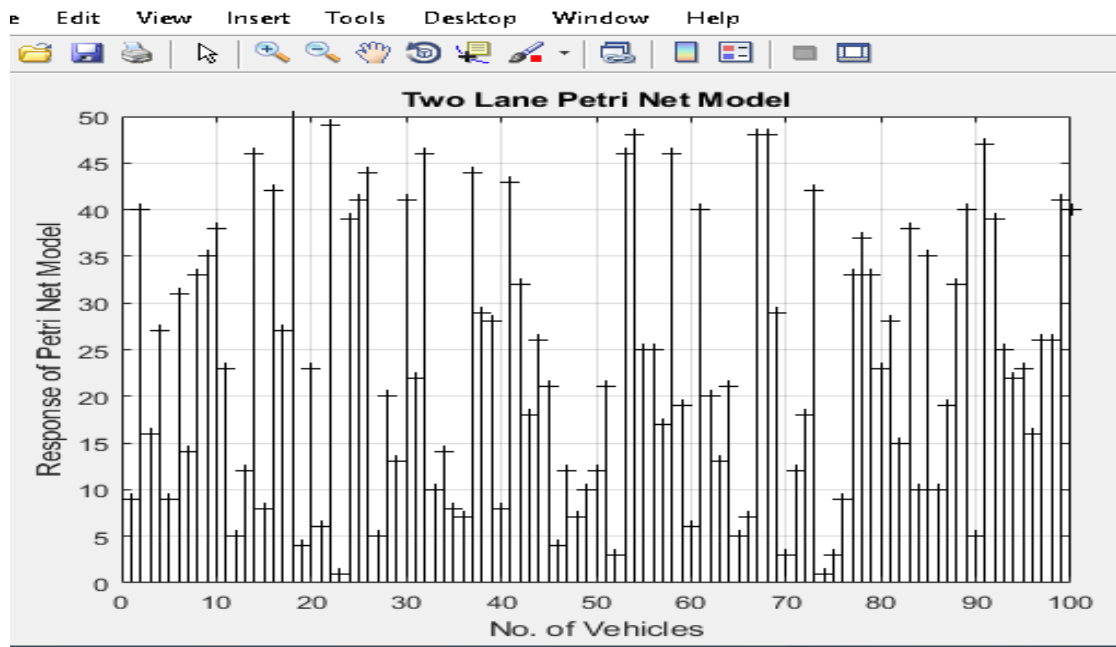


Figure 4.12 Two Lane Petri net model

Fig19 graph shows how traffic flow occurs in two lane. The control phase where the controller and the sensors come into play depends upon the vehicle and the detector. Every data detected by the detectors due to the existence of the vehicle are sent to the controllers. Now the controllers activate their signals by a scheme of signals to inform about the traffic density inside the tunnel. It is compulsory to implement the safety rules and the performance rules which should not be violated at any cost. fig 20

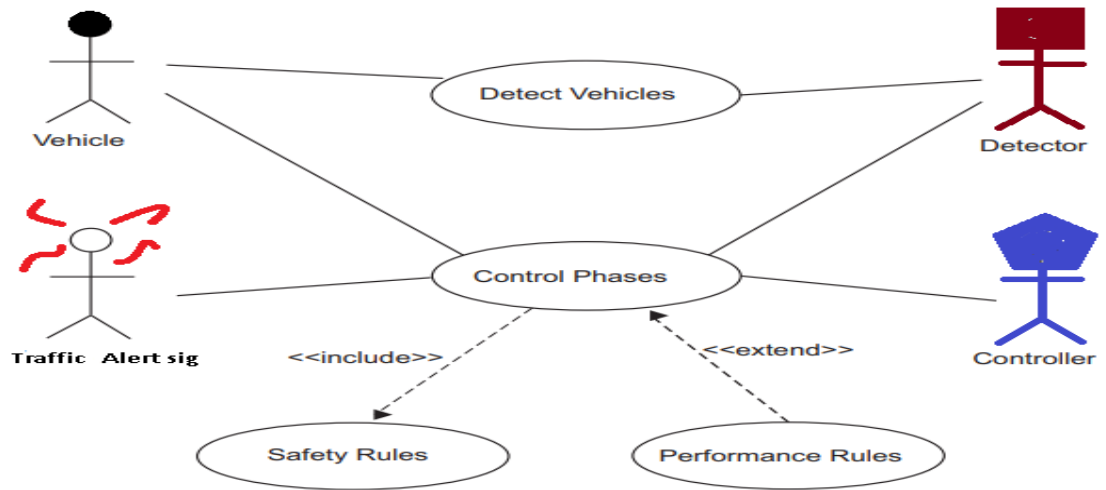


Figure 4.13 Control Phase diagram

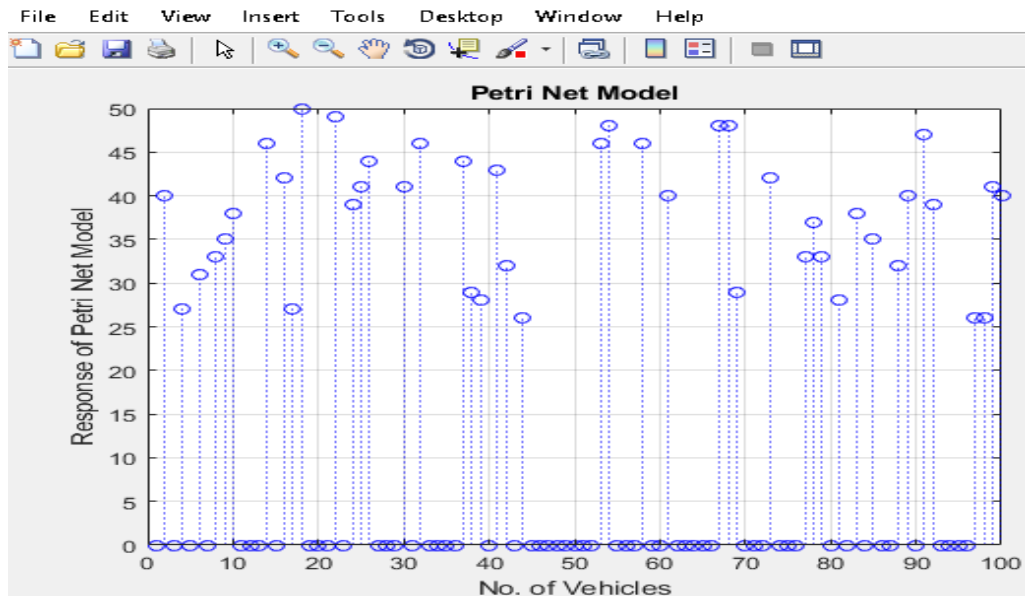


Figure 4.14 Control Petri net model for one lane traffic tunnel

Fig 21 shows the control petri net model for one lane traffic inside the tunnel. Where

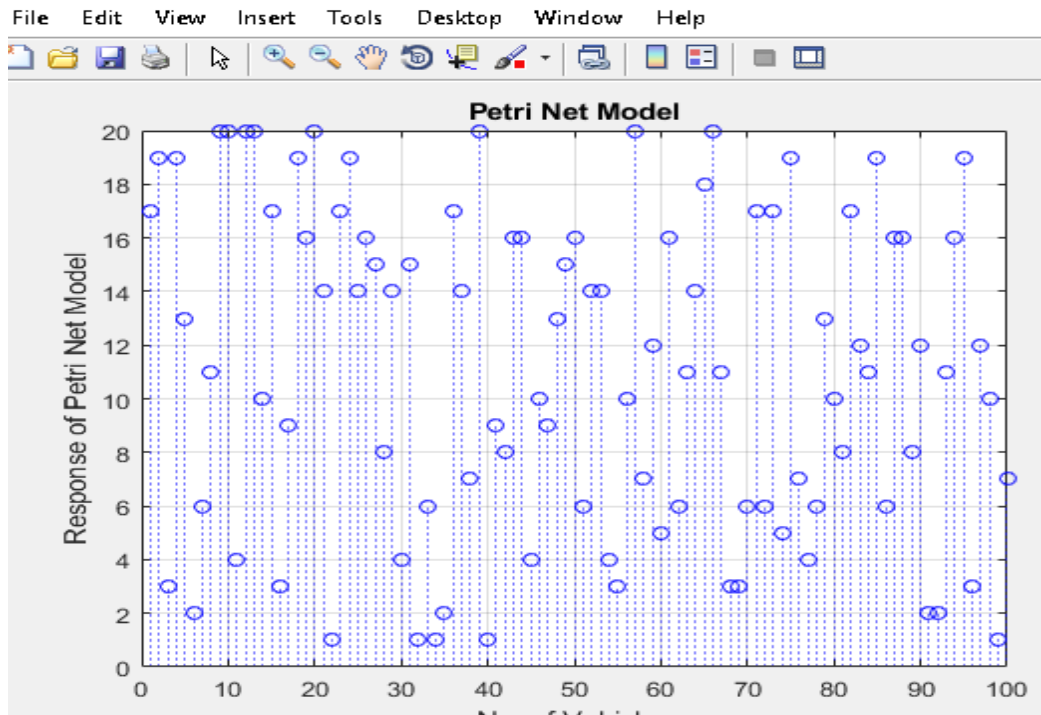


Figure 4.15 Control Petri net model for two lane traffic inside tunnel

## **CHAPTER 5 CONCUSSIONS AND FUTURE WORK**

In this paper, application for Petri nets has been proposed with extension in the design and analysis of traffic control system with sensors and control strategies. From a single lane road network in tunnels to two and more lane road tunnel are considered under different scenarios and different traffic timing such as normal and peak traffic hours. Due to the versatility of Petri net model, in this thesis it is used in association with the sensors and controllers allowing tunnel traffic phase durations to be quantified from a lowest to an extreme peak values. The simulation are done on the common token algorithm where the analysis is performed by invariant theory of Petri net model.

## **5.1 Future Work and Recommendation**

However the scope of this work is limited to road tunnel traffic system, this does not limit the scope of Petri net model in further discipline of transportation. The results obtained from the simulation shows that there is a huge amount of potential of using Petri net models to regulate and predict different traffic situations, control and analyze and improve traffic performances. This dissertation focuses on Petri net model for road tunnel traffic under different traffic hours that provide possibility for code implementation and an analysis platform for safe and control. However future work should be needed to focus on the modularity of the Petri net model for large underground road tunnels and for other tunnel transportation. It should also be noted and brought under consideration on how to focus on the accuracy of the traffic states. More specifically the arrival and the departure time of every vehicle. Petri net used as an extension with artificial intelligence methods will definitely enhance its ability and improves the performance of traffic control schemes in providing prediction and regulation of traffic dynamic.

## **CHAPTER 6 REFERENCES**

## APPENDIX B (MATLAB CODE)

## Petri-Net Model (petrinetmodel.m)

[illegible]







```

for ii=1:1:N111
if (TA11(ii)'<=10)
    aa11(ii)=TA11(ii)';
else
    bb11(ii)=TA11(ii)';
end
end

figure (7);
stem(N11,TA11,'-+r');
title('Two Lane Petri Net Model');
grid on;
xlabel('No. of Vehicles');
ylabel('Response of Petri Net Model')

```

```

figure (8);
stem(N11,aa11,'b');
title('Petri Net Model');
grid on;
xlabel('No. of Vehicles');
ylabel('Response of Petri Net Model')

```

```

figure (9);

stem(N11,bb11,'-^y');
title('Petri Net Model');
grid on;
xlabel('No. of Vehicles');
ylabel('Response of Petri Net Model')

```

```

c1109=clock;a109=fix(c1109);X1109 = sprintf('Departure Time');disp(X1109);
X1209 = sprintf(' %d',a109(1,4),':',a109(1,5),a109(1,6));disp(X1209)

```

## **Code for one lane and two lane tunnel traffic** **khantesttunnelwaq.m**

```

function varargout = khantesttunnelwaq(varargin)
% KHANTESTTUNNELWAQ MATLAB code for khantesttunnelwaq.fig
%   KHANTESTTUNNELWAQ, by itself, creates a new KHANTESTTUNNELWAQ or raises the
existing
%   singleton*.
%
%   H = KHANTESTTUNNELWAQ returns the handle to a new KHANTESTTUNNELWAQ or the
handle to
%   the existing singleton*.
%
%   KHANTESTTUNNELWAQ('CALLBACK',hObject,eventData,handles,...) calls the local
%   function named CALLBACK in KHANTESTTUNNELWAQ.M with the given input arguments.
%
%   KHANTESTTUNNELWAQ('Property','Value',...) creates a new KHANTESTTUNNELWAQ or
raises the
%   existing singleton*. Starting from the left, property value pairs are
%   applied to the GUI before khantesttunnelwaq_OpeningFcn gets called. An
%   unrecognized property name or invalid value makes property application
%   stop. All inputs are passed to khantesttunnelwaq_OpeningFcn via varargin.
%
%   *See GUI Options on GUIDE's Tools menu. Choose "GUI allows only one

```

```

% instance to run (singleton)".
%
% See also: GUIDE, GUIDATA, GUIHANDLES

% Edit the above text to modify the response to help khantesttunnelwaq

% Last Modified by GUIDE v2.5 25-May-2021 17:37:25

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                  'gui_Singleton',   gui_Singleton, ...
                  'gui_OpeningFcn', @khantesttunnelwaq_OpeningFcn, ...
                  'gui_OutputFcn',  @khantesttunnelwaq_OutputFcn, ...
                  'gui_LayoutFcn',  [], ...
                  'gui_Callback',    []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT

% --- Executes just before khantesttunnelwaq is made visible.
function khantesttunnelwaq_OpeningFcn(hObject, eventdata, handles, varargin)
% This function has no output args, see OutputFcn.
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% varargin   command line arguments to khantesttunnelwaq (see VARARGIN)

% Choose default command line output for khantesttunnelwaq
handles.output = hObject;
axes(handles.axes1);
t = text(-30.5,30.5,'Tunnel Traffic Control','color',[0 1 0],'FontSize', 35,'FontName',
'Times','FontWeight', 'bold');
axis([-100 100 -100 100]);
for blinks=1:10
    set(t,'Visible','off')
    pause(0.5)
    set(t,'Visible','on')
    pause(0.5)
end
% Update handles structure
guidata(hObject, handles);

% UIWAIT makes khantesttunnelwaq wait for user response (see UIRESUME)
% uiwait(handles.figure1);

% --- Outputs from this function are returned to the command line.

```



```
guidata(hObject, handles);
```

```
% --- Executes on button press in pushbutton3.  
function pushbutton3_Callback(hObject, eventdata, handles)  
% hObject    handle to pushbutton3 (see GCBO)  
% eventdata  reserved - to be defined in a future version of MATLAB  
% handles    structure with handles and user data (see GUIDATA)  
axes(handles.axes2);  
set(handles.edit5, 'String', 'Yes') ;  
t = text(-90.5,30.5,'Emergency','color',[0.6350 0.0780 0.1840],'FontSize', 20,'FontName',  
'Times','FontWeight', 'bold');  
axis([-100 100 -100 100]);  
for blinks=1:10  
    set(t,'Visible','off')  
    pause(0.5)  
    set(t,'Visible','on')  
    pause(0.5)
```

```
end
```

```
axes(handles.axes5);
```

```
x = -1;  
y = 0;  
Name = ('Emergency');  
TH = text(x,y,Name,'Color', '[0.6350 0.0780 0.1840]','FontSize',20,'FontName', 'Times');  
axis([-1 3 -5 5]);  
grid on;  
for kk=1:1  
for i = 1:100  
    x = x +0.01;  
    % y= y + 0.01  
    set(TH,'Position', [x y 0]);  
    pause(0.1);
```

```
end
```

```
for ii = 1:100  
    x = x -0.01;  
    % y= y + 0.01  
    set(TH,'Position', [x y 0]);  
    pause(0.1);
```

```
end
```

```
end
```

```
guidata(hObject, handles);
```

```
% --- Executes on button press in pushbutton4.  
function pushbutton4_Callback(hObject, eventdata, handles)  
% hObject    handle to pushbutton4 (see GCBO)  
% eventdata  reserved - to be defined in a future version of MATLAB  
% handles    structure with handles and user data (see GUIDATA)
```

```
clc;
```



```

y=15+sin(t);
xy=fill(x,y,'y');
xy.EdgeColor='y';
hold on;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
t=0:pi/2:2*pi;
x1=-15+2*cos(t);
y1=15+2*sin(t);
x2=-15+1.2*cos(t);
y2=15+1.2*sin(t);
for k=1:length(t)
    plot([x1(k) x2(k)], [y1(k) y2(k)], 'y', 'linewidth', 2);
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% RAY
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
t=pi/4:pi/2:2*pi+pi/4;

x1=-15+1.7*cos(t);
y1=15+1.7*sin(t);
x2=-15+1.2*cos(t);
y2=15+1.2*sin(t);
for kk=1:length(t)
    plot([x1(kk) x2(kk)], [y1(kk) y2(kk)], 'y', 'linewidth', 2);
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

T1=linspace(0,(pi));T2=linspace(pi/2,3*pi/2);T3=linspace(pi,2*pi);T4=linspace(3*pi/2,pi/2);
hold on;
x1=cos(T1);
y1=sin(T1);
x2=cos(T2);
y2=sin(T2);
x3=cos(T3);
y3=sin(T3);
x4=cos(T4);
y4=sin(T4);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
z7=fill(-10+2+x1+jj(i)/4,y1+15,'w');
z7.EdgeColor='w';
hold on;
z1=fill(-10+x1+jj(i)/4,y1+15,'w');
z1.EdgeColor='w';
hold on;
z2=fill(-10-1+x2+jj(i)/4,-1+y2+15,'w');
z2.EdgeColor='w';
hold on;
z3=fill(-10+x3+jj(i)/4,-2+y3+15,'w');
z3.EdgeColor='w';
hold on;
z4=fill(-10+2+x3+jj(i)/4,-2+y3+15,'w');
z4.EdgeColor='w';
hold on;

```

```

z5=fill(-10+3-x4+jj(i)/4,-1+y4+15,'w');
z5.EdgeColor='w';
hold on;
z6=fill([-10-1+jj(i)/4,-10-1+jj(i)/4,-10+3+jj(i)/4,-10+3+jj(i)/4,-10-1+jj(i)/4],[15,13,13,15,15],'w');
z6.EdgeColor='w';
hold on;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
x=linspace(-20,20);
plot(x,'Color',uint8([105 105 105]),'LineWidth',200);
axis([-20 20 0 20]);
legend('Speed 100 Km/hr');

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

z7=fill(13+x1+jj(i)/4,y1+15,'w');
z7.EdgeColor='w';
hold on;
z1=fill(13+2+x1+jj(i)/4,y1+15,'w');
z1.EdgeColor='w';
hold on;
z2=fill(10+2+x2+jj(i)/4,-1+y2+15,'w');
z2.EdgeColor='w';
hold on;
z3=fill(10+3+x3+jj(i)/4,-2+y3+15,'w');
z3.EdgeColor='w';
hold on;
z4=fill(10+5+x3+jj(i)/4,-2+y3+15,'w');
z4.EdgeColor='w';
hold on;
z5=fill(10+6-x4+jj(i)/4,-1+y4+15,'w')
z5.EdgeColor='w';
hold on;
z6=fill([10+6+jj(i)/4,10+6+jj(i)/4,10+2+jj(i)/4,10+2+jj(i)/4,20-5+jj(i)/4],[15,13,13,15,15],'w');
z6.EdgeColor='w';
hold on;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

fill([-8+jj(i) -8+jj(i) 8+jj(i) 8+jj(i) .3+jj(i)],[9.5 10.5 10.5 9.5 9.5],'k');%grid on;axis([0 30 0 100]);
% fill([3+jj(i) -8+jj(i) -8+jj(i) -6+jj(i) .01+jj(i)],[9.5 9.5 9.5 9.5 9.5],'k')
grid on;

pause(0.001);
% clf
title('Tunnel Traffic Project');
xlabel('Distance Km/hr');

end

```





```

y1=15+2*sin(t);
x2=-15+1.2*cos(t);
y2=15+1.2*sin(t);
for k=1:length(t)
    plot([x1(k) x2(k)], [y1(k) y2(k)], 'y', 'linewidth', 2);
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% RAY
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
t=pi/4:pi/2:2*pi+pi/4;

x1=-15+1.7*cos(t);
y1=15+1.7*sin(t);
x2=-15+1.2*cos(t);
y2=15+1.2*sin(t);
for kk=1:length(t)
    plot([x1(kk) x2(kk)], [y1(kk) y2(kk)], 'y', 'linewidth', 2);
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

T1=linspace(0,(pi));T2=linspace(pi/2,3*pi/2);T3=linspace(pi,2*pi);T4=linspace(3*pi/2,pi/2);
hold on;
x1=cos(T1);
y1=sin(T1);
x2=cos(T2);
y2=sin(T2);
x3=cos(T3);
y3=sin(T3);
x4=cos(T4);
y4=sin(T4);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
z7=fill(-10+2+x1+jj(i)/4,y1+15,'w');
z7.EdgeColor='w';
hold on;
z1=fill(-10+x1+jj(i)/4,y1+15,'w');
z1.EdgeColor='w';
hold on;
z2=fill(-10-1+x2+jj(i)/4,-1+y2+15,'w');
z2.EdgeColor='w';
hold on;
z3=fill(-10+x3+jj(i)/4,-2+y3+15,'w');
z3.EdgeColor='w';
hold on;
z4=fill(-10+2+x3+jj(i)/4,-2+y3+15,'w');
z4.EdgeColor='w';
hold on;
z5=fill(-10+3-x4+jj(i)/4,-1+y4+15,'w');
z5.EdgeColor='w';
hold on;
z6=fill([-10-1+jj(i)/4,-10-1+jj(i)/4,-10+3+jj(i)/4,-10+3+jj(i)/4,-10-1+jj(i)/4],[15,13,13,15,15],'w');
z6.EdgeColor='w';
hold on;

```

```

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
x=linspace(-20,20);
plot(x,'Color',uint8([105 105 105]),'LineWidth',200);
axis([-20 20 0 20]);
legend('Speed 100 Km/hr');

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

z7=fill(13+x1+jj(i)/4,y1+15,'w');
z7.EdgeColor='w';
hold on;
z1=fill(13+2+x1+jj(i)/4,y1+15,'w');
z1.EdgeColor='w';
hold on;
z2=fill(10+2+x2+jj(i)/4,-1+y2+15,'w');
z2.EdgeColor='w';
hold on;
z3=fill(10+3+x3+jj(i)/4,-2+y3+15,'w');
z3.EdgeColor='w';
hold on;
z4=fill(10+5+x3+jj(i)/4,-2+y3+15,'w');
z4.EdgeColor='w';
hold on;
z5=fill(10+6-x4+jj(i)/4,-1+y4+15,'w')
z5.EdgeColor='w';
hold on;
z6=fill([10+6+jj(i)/4,10+6+jj(i)/4,10+2+jj(i)/4,10+2+jj(i)/4,20-5+jj(i)/4],[15,13,13,15,15],'w');
z6.EdgeColor='w';
hold on;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

fill([-8+jj(i) -8+jj(i) 8+jj(i) 8+jj(i) 1+jj(i)], [6.5 3.5 3.5 6.5 6.5], 'b');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fill([-8-jj(i) -8-jj(i) 8-jj(i) 8-jj(i) -8-jj(i)], [10.5 7.5 7.5 10.5 10.5], 'r');
grid on;

pause(0.001);
% clf
title('Tunnel Traffic Project');
xlabel('Distance Km/hr');

end
c1=clock;a1=fix(c1);
set(handles.edit1, 'String', num2str(a1));

guidata(hObject, handles);
% Hint: get(hObject,'Value') returns toggle state of radiobutton2

```

```

% --- Executes on button press in radiobutton4.
function radiobutton4_Callback(hObject, eventdata, handles)
% hObject    handle to radiobutton4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
set(handles.edit3,'String','Token OK');
% t = datetime('now')
c=clock;a=fix(c);
set(handles.edit2, 'String',num2str(a)) ;
% set(handles.edit4,'String',sprintf('%d',t))

% set(handles.edit1, 'String','00:20') ;
set(handles.edit4, 'String','One (01)') ;
% set(handles.edit4,'String',sprintf('%d',t));

```

```

axes(handles.axes6);
x=-20:5/pi:20;
y=2;y1=linspace(0,10,2000);y2=2;y3=1.1;y4=0;
Vehicle=animatedline('Color',[0 .44 .71]);
Speed=animatedline('Color',[.85 .39 .09]);
InsideVehicle =animatedline('Color',[.30 .74 .09]);
Timer=animatedline('Color',[.85 .32 .09]);
Emergency=animatedline('Color','w');
% set(gca,'Xlim',[-20 20],'Ylim',[0 4]);
axis([-20 20 -20 20]);
grid on;
legend('Vehicle','Speed','Vehicle Present','Timer','Emergency');
xlabel('Time t');
ylabel('Sensor Output');
for kk=1:length(x)
    addpoints(Vehicle,x(kk),y);
    addpoints(Speed,x(kk),y1(kk));
    addpoints(InsideVehicle,x(kk),y2);
    addpoints(Timer,x(kk),y3);
    addpoints(Emergency,x(kk),y4);
drawnow
% legend('curve')
% pause(.1);
end
c1=clock;a1=fix(c1);
set(handles.edit1, 'String',num2str(a1));
% Hint: get(hObject,'Value') returns toggle state of radiobutton4

```

```

% --- Executes on button press in radiobutton3.
function radiobutton3_Callback(hObject, eventdata, handles)
% hObject    handle to radiobutton3 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hint: get(hObject,'Value') returns toggle state of radiobutton3
set(handles.edit3,'String','Token OK');
% t = datetime('now')

```

```

c=clock;a=fix(c);
set(handles.edit2, 'String',num2str(a)) ;
% set(handles.edit4,'String',sprintf('%d',t))

% set(handles.edit1, 'String','00:20') ;
set(handles.edit4, 'String','One (01)' ) ;
% set(handles.edit4,'String',sprintf('%d',t));

axes(handles.axes6);
x=-20:.15/pi:20;
y=1;y1=linspace(0,20,2000);y2=2;y3=sin(1.3*pi);y4=0;
Vehicle=animatedline('Color','r');
Speed=animatedline('Color','g');
InsideVehicle =animatedline('Color','[.85 .32 .09]');
Timer=animatedline('Color','k');
Emergency=animatedline('Color','w');
% set(gca,'Xlim',[-20 20],'Ylim',[0 4]);
axis([-20 20 0 4]);
grid on;
legend('Vehicle','Speed','Vehicle Present','Timer','Emergency');
xlabel('Time t');
ylabel('Sensor Output');
for kk=1:length(x)
    addpoints(Vehicle,x(kk),y);
    addpoints(Speed,x(kk),y1(kk));
    addpoints(InsideVehicle,x(kk),y2);
    addpoints(Timer,x(kk),y3);
    addpoints(Emergency,x(kk),y4);
    drawnow
%    legend('curve')
%    pause(.1);
end
c1=clock;a1=fix(c1);
set(handles.edit1, 'String',num2str(a1));

function edit1_Callback(hObject, eventdata, handles)
% hObject    handle to edit1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit1 as text
%        str2double(get(hObject,'String')) returns contents of edit1 as a double

% --- Executes during object creation, after setting all properties.
function edit1_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

```

end

```
function edit2_Callback(hObject, eventdata, handles)
% hObject    handle to edit2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit2 as text
%        str2double(get(hObject,'String')) returns contents of edit2 as a double
```

```
% --- Executes during object creation, after setting all properties.
function edit2_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

```
function edit3_Callback(hObject, eventdata, handles)
% hObject    handle to edit3 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit3 as text
%        str2double(get(hObject,'String')) returns contents of edit3 as a double
```

```
% --- Executes during object creation, after setting all properties.
function edit3_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit3 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

```
function edit4_Callback(hObject, eventdata, handles)
% hObject    handle to edit4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

```

% Hints: get(hObject,'String') returns contents of edit4 as text
%       str2double(get(hObject,'String')) returns contents of edit4 as a double

% --- Executes during object creation, after setting all properties.
function edit4_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit5_Callback(hObject, eventdata, handles)
% hObject    handle to edit5 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit5 as text
%       str2double(get(hObject,'String')) returns contents of edit5 as a double

% --- Executes during object creation, after setting all properties.
function edit5_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit5 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

```

---

## Petri net model for two lane traffic with controllers and sensors

### khanwaqtestmodelpetri.m

```

function varargout = khanwaqtestmodelpetri(varargin)
% KHANWAQTESTMODELPETRI MATLAB code for khanwaqtestmodelpetri.fig
%   KHANWAQTESTMODELPETRI, by itself, creates a new KHANWAQTESTMODELPETRI or
%   raises the existing
%   singleton*.
%

```

```

% H = KHANWAQTESTMODELPETRI returns the handle to a new
KHANWAQTESTMODELPETRI or the handle to
% the existing singleton*.
%
% KHANWAQTESTMODELPETRI('CALLBACK',hObject,eventData,handles,...) calls the local
% function named CALLBACK in KHANWAQTESTMODELPETRI.M with the given input
arguments.
%
% KHANWAQTESTMODELPETRI('Property','Value',...) creates a new
KHANWAQTESTMODELPETRI or raises the
% existing singleton*. Starting from the left, property value pairs are
% applied to the GUI before khanwaqtestmodelpetri_OpeningFcn gets called. An
% unrecognized property name or invalid value makes property application
% stop. All inputs are passed to khanwaqtestmodelpetri_OpeningFcn via varargin.
%
% *See GUI Options on GUIDE's Tools menu. Choose "GUI allows only one
% instance to run (singleton)".
%
% See also: GUIDE, GUIDATA, GUIHANDLES

```

```

% Edit the above text to modify the response to help khanwaqtestmodelpetri

```

```

% Last Modified by GUIDE v2.5 13-Jun-2021 23:20:23

```

```

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',    mfilename, ...
                  'gui_Singleton', gui_Singleton, ...
                  'gui_OpeningFcn', @khanwaqtestmodelpetri_OpeningFcn, ...
                  'gui_OutputFcn', @khanwaqtestmodelpetri_OutputFcn, ...
                  'gui_LayoutFcn', [], ...
                  'gui_Callback', []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT

```

```

% --- Executes just before khanwaqtestmodelpetri is made visible.
function khanwaqtestmodelpetri_OpeningFcn(hObject,eventdata, handles, varargin)
% This function has no output args, see OutputFcn.
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles     structure with handles and user data (see GUIDATA)
% varargin    command line arguments to khanwaqtestmodelpetri (see VARARGIN)

```

```

% Choose default command line output for khanwaqtestmodelpetri
handles.output = hObject;

```

```

% Update handles structure
guidata(hObject, handles);

```



```

% UIWAIT makes khanwaqtestmodelpetri wait for user response (see UIRESUME)
% uiwait(handles.figure1);

% --- Outputs from this function are returned to the command line.
function varargout = khanwaqtestmodelpetri_OutputFcn(hObject, eventdata, handles)
% varargout cell array for returning output args (see VARARGOUT);
% hObject handle to figure
% eventdata reserved - to be defined in a future version of MATLAB
% handles structure with handles and user data (see GUIDATA)

% Get default command line output from handles structure
varargout{1} = handles.output;

% --- Executes on button press in pushbutton1.
function pushbutton1_Callback(hObject, eventdata, handles)
% hObject handle to pushbutton1 (see GCBO)
% eventdata reserved - to be defined in a future version of MATLAB
% handles structure with handles and user data (see GUIDATA)
axes(handles.axes48);
aaB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\1A.jpg');
imshow(aaB);
axes(handles.axes46);
aaB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\1A.jpg');
imshow(aaB);
axes(handles.axes34);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A.png');
imshow(aaC);
axes(handles.axes35);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A.png');
imshow(aaC);
axes(handles.axes80);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A.png');
imshow(aaC);
axes(handles.axes81);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A.png');
imshow(aaC);
axes(handles.axes58);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A.png');
imshow(aaC);
axes(handles.axes57);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A.png');
imshow(aaC);
axes(handles.axes49);
aaD=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(aaD);
axes(handles.axes78);
aaD=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(aaD);
axes(handles.axes79);
aaD=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(aaD);
axes(handles.axes47);
aaD=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(aaD);
axes(handles.axes52);

```

```

aaE=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3A.png');
imshow(aaE);
axes(handles.axes51);
aaE=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3A.png');
imshow(aaE);
axes(handles.axes82);
aaE=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3A.png');
imshow(aaE);
axes(handles.axes83);
aaE=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3A.png');
imshow(aaE);
axes(handles.axes54);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A.png');
imshow(aaC);
axes(handles.axes53);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A.png');
imshow(aaC);
axes(handles.axes56);
aaD=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(aaD);
axes(handles.axes55);
aaD=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(aaD);
axes(handles.axes60);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A.png');
imshow(aaC);
axes(handles.axes59);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A.png');
imshow(aaC);
axes(handles.axes61);
aaE=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3A.png');
imshow(aaE);
axes(handles.axes64);
aaE=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3A.png');
imshow(aaE);
axes(handles.axes62);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A.png');
imshow(aaC);
axes(handles.axes65);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A1.png');
imshow(aaC);
axes(handles.axes63);
aaD=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(aaD);
axes(handles.axes66);
aaD1=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4A.jpg');
imshow(aaD1);
axes(handles.axes86);
aaD1=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4A.jpg');
imshow(aaD1);
axes(handles.axes67);
aaD=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2AR.png');
imshow(aaD);
axes(handles.axes84);
aaD=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2AR.png');
imshow(aaD);
axes(handles.axes85);
aaD=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2AR.png');
imshow(aaD);

```

```

axes(handles.axes68);
aaE=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3A.png');
imshow(aaE);
axes(handles.axes69);
aaD=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A1.png');
imshow(aaD);
axes(handles.axes73);
aaE=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3A.png');
imshow(aaE);
axes(handles.axes72);
aaD=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2AR.png');
imshow(aaD);
axes(handles.axes74);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A.png');
imshow(aaC);
axes(handles.axes75);
aaE=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3A.png');
imshow(aaE);
axes(handles.axes76);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A1.png');
imshow(aaC);
axes(handles.axes77);
aaC=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2A2.png');
imshow(aaC);
for ii=1:5
axes(handles.axes4);
aa=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\1.jpg');
imshow(aa);
axes(handles.axes87);
aa=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\6.png');
imshow(aa);

axes(handles.axes11);
bb=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bb);
axes(handles.axes88);
bb=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bb);

axes(handles.axes7);
bb1=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb1);
axes(handles.axes8);
bb2=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb2);

axes(handles.axes15);
bb3=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bb3);
axes(handles.axes92);
bb3=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bb3);

set(handles.edit1, 'String','Yes') ;
set(handles.edit2, 'String','T1') ;

```

```
set(handles.edit3, 'String','M1, M2, M3') ;
set(handles.edit4, 'String','Firing Mapped') ;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
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```

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```

```
axes(handles.axes5);
aaA=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\2.jpg');
imshow(aaA);
axes(handles.axes90);
aaA=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\7.png');
imshow(aaA);
```

```
axes(handles.axes17);
bbA=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbA);
axes(handles.axes89);
bbA=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbA);
```

```
axes(handles.axes9);
bb1A=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb1A);
axes(handles.axes10);
bb2A=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb2A);
axes(handles.axes96);
bb2A=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb2A);
axes(handles.axes97);
bb2A=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb2A);
```

```
axes(handles.axes15);
bb3=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bb3);
```

```
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```

```
axes(handles.axes18);
bbB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbB);
axes(handles.axes95);
bbB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbB);
axes(handles.axes98);
bbB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
```

```

imshow(bbB);
axes(handles.axes99);
bbB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbB);
axes(handles.axes6);
bbB1=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\5.png');
imshow(bbB1);
axes(handles.axes100);
bbB1=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\5.png');
imshow(bbB1);

pause (0.01);

for kk=1:1
axes(handles.axes4);
aa=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\1A.jpg');
imshow(aa);
axes(handles.axes87);
aa=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\8.png');
imshow(aa);

axes(handles.axes11);
bb=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bb);
axes(handles.axes88);
bb=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bb);

axes(handles.axes7);
bb1=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb1);
axes(handles.axes8);
bb2=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb2);

axes(handles.axes15);
bb3=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bb3);
axes(handles.axes92);
bb3=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bb3);

set(handles.edit1, 'String','Yes') ;
set(handles.edit2, 'String','T1') ;
set(handles.edit3, 'String','M1, M2, M3') ;
set(handles.edit4, 'String','Firing Mapped') ;
%%%%%%%%%%%%%%
%%%%%%%%%%%%%%

%%%%%%%%%%%%%%
%%%%%%%%%%%%%%
%%%%%%%%%%%%%%
%%%%%%%%%%%%%%

```

```

axes(handles.axes5);
aaA=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\5.png');
imshow(aaA);
axes(handles.axes90);
aaA=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\8.png');
imshow(aaA);

axes(handles.axes17);
bbA=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbA);
axes(handles.axes89);
bbA=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbA);
set(handles.edit2, 'String', 'T1') ;
set(handles.edit3, 'String', 'M2') ;
axes(handles.axes9);
bb1A=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb1A);
axes(handles.axes10);
bb2A=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb2A);
axes(handles.axes96);
bb2A=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb2A);
axes(handles.axes97);
bb2A=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb2A);

set(handles.edit2, 'String', 'T4') ;
set(handles.edit3, 'String', 'M1, M3') ;
axes(handles.axes15);
bb3=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bb3);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
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axes(handles.axes18);
bbB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbB);
axes(handles.axes95);
bbB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbB);
axes(handles.axes98);
bbB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbB);
axes(handles.axes99);
bbB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbB);
axes(handles.axes6);
bbB1=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\6.png');
imshow(bbB1);
axes(handles.axes100);

```

```
bbB1=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\8.png');  
imshow(bbB1);
```

```
pause (.01);
```

```
for kk=1:1  
axes(handles.axes4);  
aa=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\7.png');  
imshow(aa);  
axes(handles.axes87);  
aa=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\8.png');  
imshow(aa);
```

```
axes(handles.axes11);  
bb=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');  
imshow(bb);  
axes(handles.axes88);  
bb=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');  
imshow(bb);
```

```
axes(handles.axes7);  
bb1=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');  
imshow(bb1);  
axes(handles.axes8);  
bb2=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');  
imshow(bb2);
```

```
axes(handles.axes15);  
bb3=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');  
imshow(bb3);  
axes(handles.axes92);  
bb3=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');  
imshow(bb3);
```

```
set(handles.edit1, 'String','Yes') ;  
set(handles.edit2, 'String','T2') ;  
set(handles.edit3, 'String','M1, M2') ;  
set(handles.edit4, 'String','Firing Mapped') ;  
%%%%%%%%%%%%%%  
%%%%%%%%%%%%%%
```

```
%%%%%%%%%%%%%%  
%%%%%%%%%%%%%%  
%%%%%%%%%%%%%%  
%%%%%%%%%%%%%%
```

```
axes(handles.axes5);  
aaA=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\1.jpg');  
imshow(aaA);  
axes(handles.axes90);  
aaA=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\1A.jpg');  
imshow(aaA);
```

```

axes(handles.axes17);
bbA=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbA);
axes(handles.axes89);
bbA=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbA);
set(handles.edit2, 'String','T1') ;
set(handles.edit3, 'String','M3, M2') ;
axes(handles.axes9);
bb1A=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb1A);
axes(handles.axes10);
bb2A=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb2A);
axes(handles.axes96);
bb2A=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb2A);
axes(handles.axes97);
bb2A=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\4.jpg');
imshow(bb2A);

```

```

axes(handles.axes15);
bb3=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bb3);

```

```

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
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```

```

axes(handles.axes18);
bbB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbB);
axes(handles.axes95);
bbB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbB);
axes(handles.axes98);
bbB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbB);
axes(handles.axes99);
bbB=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\3.jpg');
imshow(bbB);
axes(handles.axes6);
bbB1=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\6.png');
imshow(bbB1);
axes(handles.axes100);
bbB1=imread('E:\BIT Course Folder\Tayyaba Gul\Data 12 june 2021\7.png');
imshow(bbB1);

```

end

end



end

```
% --- Executes on button press in pushbutton2.
function pushbutton2_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
exit;
quit;

function edit1_Callback(hObject, eventdata, handles)
% hObject    handle to edit1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit1 as text
%        str2double(get(hObject,'String')) returns contents of edit1 as a double
```

```
% --- Executes during object creation, after setting all properties.
function edit1_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%        See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

```
function edit2_Callback(hObject, eventdata, handles)
% hObject    handle to edit2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit2 as text
%        str2double(get(hObject,'String')) returns contents of edit2 as a double
```

```
% --- Executes during object creation, after setting all properties.
function edit2_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%        See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

```

function edit3_Callback(hObject, eventdata, handles)
% hObject    handle to edit3 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit3 as text
%        str2double(get(hObject,'String')) returns contents of edit3 as a double

% --- Executes during object creation, after setting all properties.
function edit3_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit3 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit4_Callback(hObject, eventdata, handles)
% hObject    handle to edit4 (see GCBO)

% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit4 as text
%        str2double(get(hObject,'String')) returns contents of edit4 as a double

% --- Executes during object creation, after setting all properties.
function edit4_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

```

## Chapter 6

### References

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