MANAGEMENT OF TRAFFIC CONTROL

A COMPUTER ORIENTED APPROACH

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This is to certify that the thesis entitled "Management of Traffic Control – A Computer oriented Approach" submitted by Sri G. Manas Nirmal Kumar for the award of degree of Doctor of Philosophy is based on bonafide research work carried out by him under my supervision and guidance in the School of Management Studies, Cochin University of Science and Technology. The results embodied in this thesis have not been included in any other thesis submitted previously for the award of any degree or diploma.

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DECLARATION

This thesis contains no material which had been accepted for the award of any other degree or diploma in any university and to the best of knowledge and belief it contains no material previously published any other person except where due reference is made in the text of the thesis.

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CHAPTER 1

1.0 Introduction

Human mobility has led to the growth and development of civilization through ages from the stage of cave man to the nomadic life, the markets and the capitals of ancient civilization to the present day megapolis. Transport systems have emanated to serve the mobility needs of the people and have shaped the growth and patterns of towns and cities from the beginning. Urban transportation has a very dominant role to play in the urban development per-se. An appropriate urban transport policy is important to any developing country in its economic, social, and environmental terms. It directly influences both the city efficiency and national economy along with the welfare of city population. There are strong linkages between urban development transportation, energy and environmental actions. Major reduction in vehicle operating cost can also be achieved through reducing traffic congestion resulting in major energy savings.

With the unpredictable traffic congestion in many cities the business efficiency is seriously constrained and the daily life of the people in these cities is also degraded. An effective traffic control can generate a large time-saving by reducing average journey time and its unpredictability. The economical cost of accidents both in terms of direct damage, hospitalization and loss of potential production while victims are not able to work are now recognized as of major importance in our country. A major contributor to air pollution is usually road traffic.

In recent years it has become evident that improving traffic flow in urban areas by building new highway facilities is to a certain extent a diminishing return solution. Attention is being shifted to the task of devising strategies that can improve traffic flow on existing facilities. Further more, there is a growing awareness that optimization of vehicular mobility does not necessarily result in maximum benefits for the urban communities. Other factors such as air and noise pollution and conservation of scarce energy resources have now been given great importance.

These circumstances draw attention to the fact that improvement in vehicular flow is not an end but a means of achieving better mobility of people and goods, which in turn is a resource for enhancing the quality of urban life. The understanding of this fact has led to the realization that other methods for improving people and goods mobility such as expanding the role of mass transit and modifying urban configuration are not been given adequate attention.

The concept of traffic control is therefore giving way to border philosophy of traffic management where the purpose is not to move vehicles but to optimize the utilization of the urban resources for improving the movement of people and goods without impairing other community values. The application of traffic management philosophy to real life situations is the subject of the concern.

One of the most important analytical tools of traffic management is computer simulation. If a traffic system is represented on a computer by means of a simulation model, it is possible to predict the impact effects of traffic management strategies. These impact effects can be parameters such as average speed, travel time, energy consumption and vehicle emissions.

Construction of mathematical model of transportation networks plays a central role. The aim of analysis is to assist the selection of practicable and beneficial transportation actions. Mathematical modeling and simulation are very useful to evaluate and forecasting road traffic, traffic signals etc. For such short run problems it would appear that marginal change models would be most appropriate. The usual demand on the model is that it produces evaluations for one or more future years. The mathematical model's division makes it much easier to present our problems to experts on particular techniques-mathematical programming algorithm convergence, statistical estimation.

Planning process involves four phases. Planning in service level, planning vehicles and staff operations, carrying out the plan and controlling it. It essentially covers the determination of line networks and offered trips. The vehicle and duty schedules are determined at operational level. That is detailed instructions for carrying out vehicle and staff operations , controlling the execution of vehicle operation and the deployment of the staff are most important.

Traffic management system actions are intended to increase the capacity and efficiency of the existing transportation system by improving traffic flow, smoothing out peak period loads, or diverting to high occupancy modes. General categories of actions include,

1. Actions to ensure efficient use of road space.
2. Actions to reduce vehicle use in congested areas.
3. Actions to improve transit management efficiency.

This can be achieved by reducing the vehicle-miles of travel or increasing travel speeds in congested areas.

The traffic management problem is a complex interaction between the urban traffic manager and the individual trip-maker reflecting their different objectives and differing perceptions of the performance provided by the transportation system. The traffic manager assesses the situation according to his measures of effectiveness and intervenes in the physical transport system to achieve his desired objectives. The trip makers on the other hand perceive the flows according to their own values, which may be different from those of the traffic manager. The manager's criteria for evaluating his action may include such measures of performance as travel time, energy consumption, noise and pollutant emissions and so on. In a city the coordinated strategic control system might fall within a wider city management that could be known as city traffic protocol. This would incorporate multi- model network which will include road traffic and vehicle for public transport. Important features of the network control framework would be a high co- operation between owners of parts of the network and model choice flexibility.

The hierarchy of city traffic control protocol is given below.

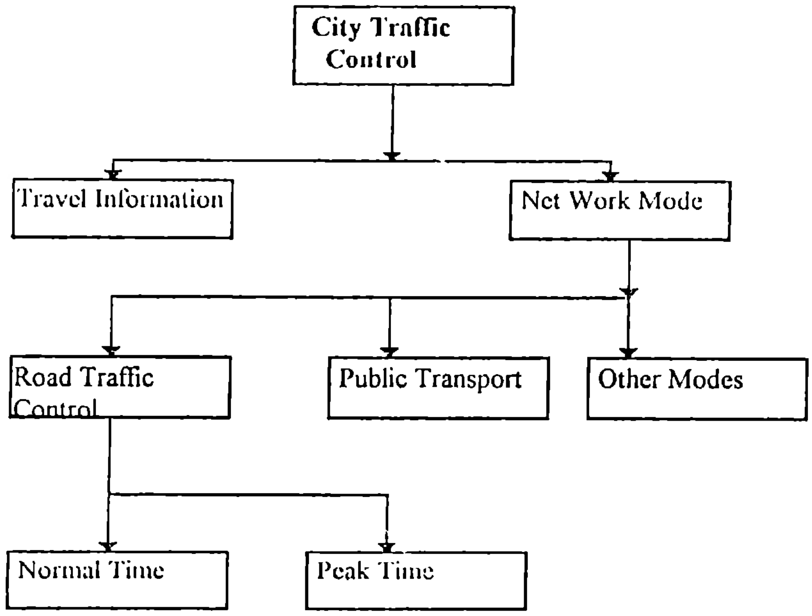


Fig 1.0.1

1.1 Traffic Problems

The urban transportation/traffic problem can be treated as a six sided problem.

1.1.1 Traffic movement and congestion

Congestion may be defined as waiting for other people to be served and is particularly found in service trades like transport where it is not economical to provide sufficient capacity to meet the highest levels of demand. Vehicle congestion is the delay imposed on one vehicle by another, while person congestion characterizes public transport subject to serve demand fluctuations through time. Congestion occurs in all developed cities no matter with their transport provision and is now a long term and apparently immutable fact of life. The effects of congestion are to delay goods movement, frustrate passengers and clog streets with stationary traffic.. When traffic is at 98% of its maximum on road, journey time becomes seven times longer than in light traffic conditions.

1.1.2 Public transport crowding

The person congestion occurring inside public vehicles at such peak times adds insult to injury, some times literally. A very high proportion of the days' journey is made under conditions of peak hour loading during which there will be lengthy queues at stops, crowding at terminals, and ticket offices.

1.1.3 Off-peak inadequacy of public transport

If public transport operators provide sufficient vehicle to meet peak hour demand there will be insufficient patronage off peak to keep them economically employed. If on the other hand they tailor fleet size to the off-peak demand the vehicles would be so overwhelmed during the peak that the service would most likely break down. This disparity of vehicle use is the number of the urban transport for public transport operators.

1.1.4 Difficulties for pedestrians

Pedestrians form the largest category of traffic accident victims. Attempts to increase their safety have usually failed to deal with the source of the problem. (ie traffic speed and volume) and instead have concentrated on restricting movement on foot. Additionally there is obstruction by parked cars and increasing pollution of the urban environment, with traffic noise and exhaust fumes affecting most directly those on foot.

1.1.5 Environmental impact

It is now becoming more widely understood that transport is a major source of air pollution in many urban areas. The main pollutants are outlined below.

1. Carbon monoxide (Co): Can have detrimental health effects particularly in confined spaces and urban areas, but its major impact is its oxidization to Co_2

2. Nitrogen Oxides Nox: is nitrogen based pollutant which have harmful effects on health and global environment, especially when combined with other pollutants.

3. Hydro carbons Hc: including volatile organic components are compounds that result from the incomplete combustion of carbon based fuels. They play an important role in formation of photo chemical oxidants such as ozone, which irritate eyes in smog, damage plants, and contribute to acidification and global warming.

1.1.6 Noise and Vibrations

Noise is any disagreeable sound. Its effects will depend very much on the sensitivity of the individual, on the location, on the time of day and on existing noise levels. It disrupts activity, disturbs sleep, slows the learning process at school, impedes verbal communications. The sources of noise from road vehicles are many and varied, including brake, door slam, loose loads, horns, over amplified music system, and sirens in emergency vehicles. The major sources of noise pollutants are propulsion of vehicle at low speed. One certain way of reducing the nuisance from noise and vibration would be to reduce the amount of traffic in the first place.

There is an intolerable imbalance between expected trends in road based mobility and the capacity of the transport system. This is causing problems to industry, to the environment, and also to the ability of the people to lead comfortable and fulfilling lives. It is not possible to provide sufficient road capacity to meet unrestrained demand for movement. Whatever road construction policy is followed the amount of traffic per unit of road will only increase not decrease. In other words all available road construction policies only differ in speed at which congestion gets worse. It is possible to overcome to all problems provided they are properly harmonized. They will include land use planning, extensive use of traffic management, comfort and cost of public transport and traffic calming schemes.

CHAPTER 2

Existing Traffic Management system

2.0 Introduction

Transport is all embracing in the widest possible sense, incorporating a multitude of different skills, systems, and services. The different modes have their different applications and the common thread is a function of transport, namely to move people or goods from where they are to where their relative values are greater. As communities became larger, so individuals began to specialize in certain crafts and hence division of labour evolved. Specialists worked in a single trade in which they became skilled and thus simulated a demand for their products. People were by this time no longer dependent entirely upon themselves but collectively upon each other; specialization improved workmanship in the form of better clothes, better habitations, better food, and hence an improved quality of life. Such development is synonymous with the development of transport and traffic control and communication and it is necessary only to reflect on our present day economic system to realize the part played by transport/traffic in the fulfillment of the standard of living that we now expect.

People use transport for a variety of reasons. They travel between home and place of work or school and they may travel during the course of their work. This is regarded as essential traffic. The demand for travel is elastic which means that it is more likely to respond to the price and quality of the service. Distance is another characteristic. Works and schools traffic are often local and the journey relatively short. It is unfortunate from the point of view of transport economic, but nevertheless inevitable, that the demand for travel is not easily spread in terms of time and there are periods of heavy traffic concentration. As far as the daily peaks are concerned business and school traffic is likely to clash to create heavy unidirectional flows. Other types of traffic have a more seasonable element,

The characteristics of goods traffic are different from those of passenger traffic. It has been shown that passengers travel for a variety of reasons but their demand and expectations can be accessed accordingly subject only to class of travel. The passengers are standard units. They load and unload themselves. This brings in to focus the term loadability which is a characteristic of goods traffic. Traffic that has good loadability has the property of being able to accommodate itself within the vehicle. The basic characteristic of scheduled service is planned and advertised in advance and will operate regardless of the demand at the time. However that as general freight can sometimes be diverted or delayed due to heavy traffic in a manner that would be unacceptable to passengers.

2.1 Traffic Planning

Major street plans should take into account all types of traffic. Commercial traffic desires might be markedly different from other traffic movements. Peak hour requirements might vary from street to street and so forth. Traffic needs that are measurable through continual traffic studies. The desires and needs of an existing land use pattern can be measured by volume counts and by origin destination surveys. The amount of traffic in the central business district has no basic desire to be there, and that could be better accommodated by new routes around the district could be readily ascertained. The amount of traffic of each type that could be bypassed around the entire city could be measured. The relative importance of each form of transportation should be indicated. When these and other things are known about travel in a community, road way improvements and new roadway developments can be evaluated in terms of aids to existing traffic. Roads and other devices cannot be only for immediate needs, it also serves for future needs like the control of land use, the projection of land development, population shifts and trends and many other planning data.

The street plan might include express ways, major through ways, and local service streets. As the city grows and traffic volumes increase- the new type facility comes into being. Provision should be made for modernization of existing net works when traffic requires accommodation.

Topographic data have major effects upon highway transportation. Rivers, valleys, hills and lake's might impose hardships in planning highways and traffic improvements. A bluff or a hill might pose serious impediments to major flows within a city or a region. While topographic conditions often increase transportation cost , there are many opportunities to take advantage of these conditions.

Population distributions are valuable to traffic controls, since people make traffic. Traffic controls need data on the distribution of populations, income groupings, ages, modes of travel and trends. For simple evaluation of the adequacy of traffic services to the design and location of major routes, these data are valuable.

Vehicle ownership and its data are often used by traffic controllers. These data are related to population and traffic studies to determine travel generation characteristics and potentials. They also serve the traffic authorities in other ways in dealing with general planning matters. Economic factors have the most direct bearing on the capacity of the community undertake highway and traffic improvements. Studies of other transportation media and terminals commonly made by the planner have applications in traffic. The city planning agency will usually develop the information as part of the over all city plan. The traffic and highway agencies often desire to subject it to different analyses and to put it to different uses- uses which integrate all forms of traffic.

Standards for road ways should be reviewed by traffic authorities to ensure safe condition and long range capacity. This applies particularly to the following: corner set backs, subdivision controls, roadside plantings and median plantings, side walks, and drive ways. The planner can well use the knowledge of the traffic authorities in developing and administering these and other standards which affect vehicle operations and pedestrian safety. Location of schools and public buildings involves standards which relate directly to traffic.

2.2 Mathematical Models for Traffic Planning

The main objective of transport model is to predict the number of trips that will take place by different available modes of transport to predict the origin and destination. The accuracy of the traffic forecasting model dictates to the user that can be made of the transport planning process and the scope for evaluation. The transportation planner may observe the situation in an urban area in which journeys are made. The number of trips made is directly proportional to the number of people in the area. If T_i is the number of trips and P_i is the population in the area the relationship may be given as

$T_i = gP_i$ From the model we can predict (calculate)the new number of trips made by new population.

The full transport planning model is more complex. It attempts to describe the travel patterns of large number of people using a series of linked sub models and can be considered a description of the decision-making process the average person might be expected to use when he considers making a journey. He first decides to make a journey(trip generation), he selects destination (trip distribution) and then makes a journey(trip assignment). Generation, distribution, and assignment can together consider as transport planning model.

Trip Generation

The trip generation stage of the transport planning model describes the reason why trips are made and determines the places where trips start and finish. Trips are usually made by people in three ways.

1. Pedestrian movement
2. Journeys by public carrier
3. Other modes(Private carriers)

For example a trip from home to place of work is a home based trip, like the return journey from work to home. The most important factor affecting the trip rate of house hold is the number of cars that the household owns.

Trip Distribution Model

The previous section has looked at trip generation and the development of the models relating trip ends to planning parameters. The outcome of the trip generation stage was the production of trip ends by purpose and perhaps by mode. It is the function of trip distribution to calculate the number of trips between one zone and another given the determined number of trip ends in each zone together with further information on the transport facilities available between these zones. The trip distribution model attempts to explain trips from zone i to zone j Assuming that the trips from i to j are proportional to some attractiveness factor for zone j and inversely proportional to the spatial or temporal separation from zone i and zone j.

The model can be

$$T_{ij} = P_i A_j F_{ij} K_{ij} \,|\, \sum A_j F_{ij} K_{ij} \qquad \forall j$$

where

T_{ij} = trips produced in zone i and attracted to zone j

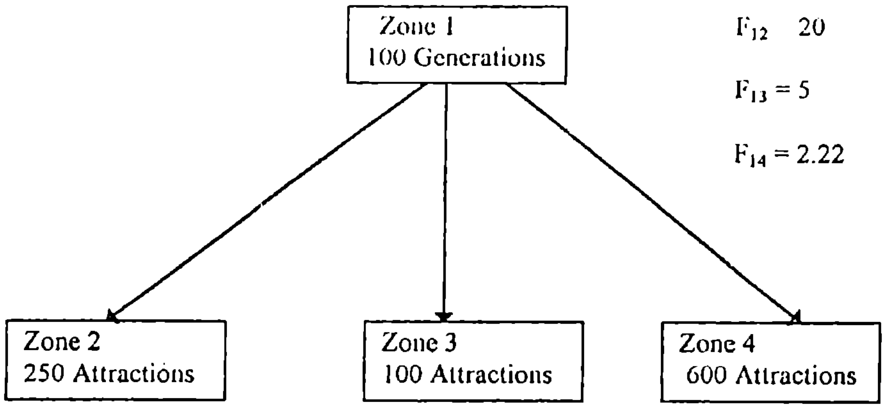
P_i = trips produced in zone i

A_j = trips attracted to zone j

F_{ij} travel time factor which is the function of the spatial separation between zones.

K_{ij}= Specific zone to zone correction factor for special social or economic effects

For example the trip distribution model is consider for the inter zonal interchanges. 100 trip generation at zone1, with 250 attractions at zone2 and 100 attractions at zone3 and 600 attractions at zone4. Assume that 1to 2 is 5 minutes ,1to 3 is 10 minute's 1to 4 is 15 minutes. Assume all K_{ij} factors are unity and that F_{ij} factors are shown below.



Zone	A_i	F_{ij}	$A_j F_{ij}$	$A_j F_{ij} \mid \Sigma A_j F_{ij}$	P_i	T_{ij}
1	0	0	0	0	100	0
2	250	20	5,000	0.732	100	73
3	100	5	500	0,073	100	7
4	600	2.22	1332	0.195	100	20

$\Sigma A_j F_{ij} = 6832$

Table 2.2.1

Trip Assignment Model

In the assignment problem we are given a set of ordered pairs of points on the network that are called (O/D) origin destination pairs. For each O/D pair (x,y) there is a given function $R_{ij}(t)$ $0 \le t \le T$ where $R_{xiyj}(t)$ is the rate at which vehicle leave x_i at time t to go to y_j. The assignment problem is to determine traffic pattern or flows on the links of the network satisfying specified optimality conditions.

Consider a net work G is asset of nodes $\{x\}$ and a set of links $\{x,y\}$connecting pair of nodes. Some of the nodes are origins and others are destinations. By a path P we mean a sequences of links $(x_1,x_2),(x_2,x_3),(x_{n-1},x_n)$where $x_1,x_2,x_3,....x_n$ are distinct nodes, x_1 is an origin and x_n is a destination. Let P denote set of all paths of G , Px the set of all path originating at the origin x, Py set of all paths terminating at the destination y and Pw the set of all paths connecting the origin destination pair w=(x,y)

Traffic flow produced at the origin and traveling along the path of the network terminate at the destination nodes thus generating a flow pattern F={Fp} where Fp denotes the traffic flow on path P. The total no of trips generated in the origin node X(trip production) will be denoted by Ox. The total no of trips terminating at the destination node y (trip attraction) will be denoted by Dy. Finally the travel demand associated with origin -destination pair w will be denoted by dw. , then dw,Ox and Dy must satisfy the flow conservation equation.

$$dw= \sum_{p \in Rw} Fp$$

$$Ox= \sum_{p \in Px} Fp$$

$$Dy= \sum_{p \in Dy} Fp$$

If T denotes the total no of trips produced at all origin nodes (and equal to the total no of trips terminating at all destination nodes). We must also have

$$T = \sum_{orig} Ox = \sum_{dest} Dy = \sum_{p \in P} Fp$$

We assume that each user travelling on a path P incurs a travel cost Cp which depend on flow patterns

$$Cp=Cp(F)$$

The total no. of Ox of trips produced in each origin node X is given. Determine the origin destination travel demand dw and the flow pattern F

Consider the simple net work consisting of a single origin x and three destination's y_1, y_2, y_3. We assume that users travel cost on link i, i= 1,2, ... 6 of the net work is of the form

$$C_i = g_i f_i + h_i$$

where $g_1 = 4$ $g_2 = 1$ $g_3 = 2$, $g_4 = 1$, $g_5 = 4$ $g_6 = 2$

$h_1 = 380$, $h_2 = 400$, $h_3 = 410$, $h_4 = 430$, $h_5 = 440$ $h_6 = 800$.

The total demand produced at origin Ox = 10000. We now add the imaginary destination Ψ and we join y_1, y_2, y_3 with Ψ by the links (y_1,Ψ) , (y_2,Ψ), (y_3,Ψ) with zero travel cost. The problem reduces to single origin-destination pair (x, Ψ) with associated with travel demand Ox. Nodes x and Ψ are connected by six paths which will again be numbered by

1,2,3,........6.where path i is the path containing link i. C_i denotes the flow and users cost both on link i and its corresponding path.

$$\lambda = O_x + \frac{\sum_{i=1}^{k} \frac{h_i}{g_i}}{\sum_{i=1}^{k} \frac{1}{g_i}}$$ and we determine index x for which $h_s < \lambda < h_{s+1}$ then the

solution is

$$f_k = \frac{\lambda_k \quad h_k}{g_k} \qquad k = 1,2,3 \qquad s$$

$$= 0 \qquad k > s+1$$

the Determination of s is given

k	$\sum_{i=1}^{k} \frac{1}{g_i}$	$\sum_{i=1}^{k} \frac{h_i}{g_i}$	λ_k	h_k	h_{k+1}
1	0.21	95	4300	380	400
2	1.25	495	1196	400	410
3	1.75	700	971	410	400
4	2.75	1130	725	430	440
5	3.00	1240	747	440	800

Table 2.2.2

$f_1 = \frac{747 - 380}{4} = 91 \qquad f_2 = \frac{747 - 400}{1} = 347 \qquad f_3 = \frac{747 - 410}{2} = 168$

$f_4 = \frac{747 - 430}{1} = 317 \qquad f_5 = \frac{747 - 440}{4} = 77 \qquad f_6 = 0$

The resulting origin destination travel demand

$d(x,y_1) = f_1 + f_2 = 438$

$d(x,y_2) = f_3 = 168$

$d(x,y_3) = f_4 + f_5 + f_6 = 394$

Land Use Model

The land use model may be formulated as follows.

$$G_i = \frac{\sum_{\forall i} G_i A_i^n v_i}{\sum_{\forall i} A_i^n v_i}$$

where G_i = the fore cast growth for zone i

A_i = accessibility index for zone i

v_i = vacant available land in zone i

$$A_i = \sum_{\forall j} E_j F_{ij}$$

E_j = total employment with in zone j

F_{ij} = fraction factor for travel time between zone i and zone j

2.3 Drawback of the Existing System

The above mentioned models do not yield accurate results and are time consuming , since all the parameters used in various models are not interrelated to one another and have huge volume of datum. Also each models depends on its own functional parameter. The traffic and transportation system in our country is forced to look for new methods to reduce the conflicts between the demands for retention or even expansion of available service. A practical way of escaping from this situation consists in establishing computer aided planning and control systems.

2.4 Proposed Traffic Management System

Present city traffic control management provides poor access to poor quality data. The development and implementation of the effective traffic control requires accurate collection of high quality data. The quality of decision depends on data that are readily available, accurate and relevant to the current problem. The city department of traffic must maintain large amount of related data such as assign, signal and pavement conditions. Though large amount of data is available at present only meagre resources are available to use those data. Consequently city traffic management programs are often inadequate for current and projected management needs. Given the spatial character of these data computer information system technology would greatly simplify the extraction and presentation of data providing a higher degree of user friendliness, better access to data, and the ability to integrate data from many sources

TMS(Traffic Management System) is a computerized database management system. It will be based on a detailed representation of the urban and motor-way road network together with the attributes both static and dynamic required to provide a common network database. This will provide the basis of the net work model that will be used in the urban and motor-way traffic control centers and in the travel and traffic information system. The TMS will also provide a basis for storing and analyzing strategic information relating to traffic and accident statistics ,weather, environmental data and road condition.

The configuration of TMS has been given below

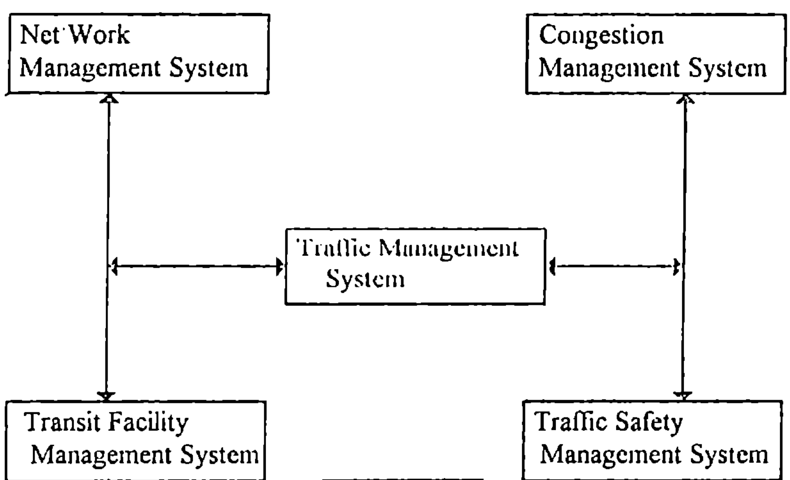


Fig 2.4.1

2.5 Objectives

Creating an user friendly interacting system for Information
Automated computer schedule for bus and crews
Developing Mathematical models and algorithms for traffic flow to predict Traffic
Developing Mathematical models for accident forecast and accident severity

2.6 Scope of the Proposed System

Increase the use of the public transport to gain more revenue
Reducing operating cost for a given timetable or providing increased capacity for given cost
Analyze the consequence of change some of the parameters governing the operation.
Supporting the decision process by simulating different scenarios
Handling time -observing routine work on a computer
Utilizing the savings in labour time for more intensive checking as well as for handling additional time tables in order to adopt the service level to seasonal variations.
Shortening the planning time-scale by applying the optimization technique construct admissible solutions.
Reacting immediately to interruptions in the traffic network and alternations in the service level.
Last but not least economic and political aspects must be considered.
By reducing private transport in favour of public transport it is possible to save energy and air pollution

2.7 Methodology

Mathematical models for speed, travel time, optimization technique for scheduling.
Network methods for Information system and Traffic control.
Computer simulation for the above.

To forecast the traffic volume and density test data has been taken from two centers in Ernakulam where the traffic volume is maximum during peak hours. This has been applied in various statistical distributions

Hardware Configuration

To install TMS for traffic it must have the following hardware requirements

Processor	AMD Duron Processor 1.1 GHZ
Main Memory	128 MB
Total Disc Space	20 GB
Display unit	15" SVGA COLOR

Software support

Operating System	Windows 2000
Software used	Structured Query Language and Pascal

2.8 Literature Survey

The traffic and transportation discipline has been increasingly developed in the world in recent times and can make essential contribution to improved operations of an entire transportation system. The application of existing theoretical models, modifying them and creating new ones can achieve considerable economic effects and improve the level of service. The fundamental developments in computer aided planning originate from the time of World War II and the years which followed. The field of public transport has of course benefited, as the development of computer techniques. The data management system for public transportation in chapter 3 leaves the evaluation of the plans being developed to the experience and perception of the planner. The evaluation programs are introduced to the computer system. This measures various descriptive characteristics of the plans and can be used to evaluate the quality of different plans objectively. The traffic data collection has been widely studied by John B. and Sullivan T. [11] and Date C. [31]. Hunt I.D. and Simmons [45] have discussed the land use model. Wren A. [48], [82],

[51], and [11] have discussed the Computer oriented-planning model. Berg W.D. [87] has introduced the transportation system management idea .

Effective distribution management presents a variety of decision –making problems at all three levels of strategic, tactical and operational planning. Decisions relating to the location of facilities (depots) may be viewed as strategic, while the problem of fleet size and mix determination could be termed as tactical. On the operational level, various decisions concerning the routing and scheduling of vehicles and the staffing of such vehicle with crews require ongoing attention on a day today basis. Clearly the distinction between strategic, tactical and operational planning should not be interpreted too rigidly, especially in view of the close interaction between the decisions involved. Generally, the locations of all facilities are required as input data for planning the local transportation activities. Conversely such decisions rely upon distribution or transportation costs between various geographic locations.

In addition to the location of depots, effective planning of deliveries generally requires inputs concerning a variety of other exogenous decisions, which include

- Fleet size at each depot
- Customer service level

Given the decisions listed above route and schedule its vehicle to perform the assigned functions at minimal cost. This requires an optimum-seeking algorithm to identify the best configuration of route and schedules which brings us to the main focus chapter. Further more, it should be remarked that recent advance in routing and scheduling procedures. In mass transit one must determine the locations of garages to house buses so as to allow for a cost effective servicing of existing bus lines by the fleet vehicles similar issues arise in the location of emergency units. Although cost minimization is the primary objective of most routing and scheduling problems. Other objectives may assume primary importance especially in the context of service operations in the public sector. Safety and convenience are other two objectives.

Many routing and scheduling problems can be formulated as instances of as a special class of zero-one integer programs known as set partitioning or set covering problems.

Basically, a set covering problems involves a given 0 – 1 matrix with cost attached to all columns. The objective is to choose a minimum cost --collection of columns such that the number of 1s appearing in each rov' of selected columns is at least one. If this number is required to be exactly one the set partitioning problem results set covering and the set covering problems have been studied extensively over the last two decades by Balas & Padberg [95] and Garfinkel [97] and Nemhauser[94]. Travelling salesman problem is the basic mathematical programming formulation for routing problems. The multiple travelling salesmen problem is a generalization of the travelling sales problem that comes closer to accommodating real world problems where there is a need to account for more than one sales man (vehicle). Multiple travelling salesmen problems arise in various scheduling and sequencing applications.

In the multiple travelling sales men problem M –salesmen are to visit N given nodes of the network in such a way that the total distance traveled by all M –salesmen is minimum. Each salesman must travel along a sub tour of the nodes, which include a common depot, and exactly one salesman must visit every node except the depot exactly once. The mathematical programming formulation of (MTSP) is a natural extension of the assignment-based formulation of the travelling salesman problem.

$$\text{Min } z \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij}$$

subject to

$$\sum_{i=1}^{n} x_{ij} = b_j \quad m \text{ if } j = 1$$

$$1 \text{ if } j = 2 \qquad n$$

$$\sum_{j=1}^{n} x_{ij} = a_i \quad m \text{ if } i = 1$$

$$1 \text{ if } i = 2 \ldots\ldots n$$

$$x_{ij} \in S$$

$$x_{ij} = 0 \text{ or } 1 \quad (i, j = 1, \ldots. n)$$

The travelling salesman problem requires the Hamiltonian cycle in G of minimal total cost, where G = [N, A, C] is a network be defined with the set of nodes. A the set of branches and C = [c_{ij}] the matrix of costs. That is [C_{ij}] is the cost of moving or the distance from node i to node j This has been discussed by christofides [98] and Nemhauser [6] Karp [99] has shown that the TSP is NP complete. Due to the difficulty of the TSP many heuristic (approximate) procedures have been developed. This heuristic may be compared analytically. Steans and Lewis [100] has studied their worst case behavior. The articles by Stewart [102], Golden [101] is the best source of this topic. In the bus-scheduling problem, which consists of optimally linking trips to form feasible schedules for individual buses operating in an urban area. A large number of short trips are considered and divided into chains of trips so that all trips in the same chain can be connected to form a feasible schedule for a bus. These chains always begin and end at the same bus depot.

The vehicle routing problem consists of designing a set of least cost vehicle routes in such a way that every routes starts and ends at base station or other than the base station. But every city is visited exactly once precisely one vehicle and some other constrains are satisfied. This field has been studied by the authors Sofwat [112], Golden B.L [119], Fadden D.M.L. [122] and Bearley J.E [144]. The Lagrangean based heuristic is one recent approach in vehicle scheduling. The nodes are linked by compatibility arcs. Connections with the depots are explicitly represented by introducing depot souce and sink nodes are connected to all trip nodes. A block corresponds to a path from a source to a sink depot. The idea is to find a set of blocks covering the service such that this set can be partitioned in to feasible vehicle schedules as well as in to crew duties, all complying some global constraints. The idea of converting blocks into duties has recently received much attention by Ball M [146], Gallo G [147], and zloth P. [148] and it is exploited in depth in this work.

Given the timetable for numerous trips one aims to construct bus schedules that minimize the costs incurred by fleet size and dead heading time, while satisfying other operational requirements. This problem is encountered in our country by the public sector operating throughout the state. The assignment of buses to schedules has been dealt with by several researchers, namely Gavish [105] and Hoffstadt [35]. The problem is formulated as a transportation model. The assignment of busses to schedules was first formulated as a transportation problem. Let I = 1,2,3 n denotes an index set of short trips to be operated in a planning interval T. Each trip i ∈ I is characterised by its starting and ending .The depot is also considered as a short trip which is given the index n+1. Hoffstadt formulated the bus-scheduling problem as an assignment model. The linking cost c_{ij} for each feasible pair (i,j)

x_{ij} = 1 if trip i is directly connected to trip j

= 0 otherwise

where the coefficients c_{ij} correspond to the cost relative to the linkage of trip i to trip j. If this is an unfeasible linkage then c_{ij} is taken to D.

Traffic monitoring is probably one of the oldest activities falling under the umbrella of highway planning in our country. The changing uses of traffic data are however requiring significant changes in our traffic-monitoring program. Data is demanded by finer levels of system and geographic. Data users are demanding finer stratification by vehicle type. Management wants data quicker for a number of reasons. Transportation system management has continued but has been enhanced and broadened by the anticipation of the of innovative vehicle, computer and electronic technology. Two closely related challenges are envisioned for the remainder of this century and the beginning of the twenty-first century. A more systematic and comprehensive transportation system management activity and a gradual implementation is the most promising new technologies. Both will be directed towards making maximum use of the existing transportation system. Traffic flow fundamentals will play an important role in meeting these two challenges.

Planners, designers and operators of the transportation system all have a role to play in developing a more systematic and comprehensive transportation system management activity. The skills of planners will be needed to develop and apply improved techniques for evaluating the impacts of land use changes and in developing more precise behavior models of the effects of system changes on spatial and temporal model and total traveler responses. The ingenuity of the designer will be required to identify critical links in the system where capacity increases are urgently needed and to develop design plans that meet the needs, but with serious constraints on available right of way and environmental impacts.

Innovated vehicle, computer and electronic technology are on the threshold of developments that have the potential of making maximum use of the existing transportation system. Technologies with the greatest potential must be identified and a gradual implementation plan developed. New vehicle technologies include in vehicle longitudinal and lateral information warning system, radar brakes and perhaps ultimately fully automatic controlled guidance systems. Computers can play an even greater role in the future in both off-line and on-line operations. Off-line computer packages are becoming faster more flexible and user friendly. The use of the on-line computer systems provides the opportunity of engaging improved control, theory algorithms, such as artificial intelligent expert system, fuzzy sets and the like to make the maximum use of the highway system under normal and unusual traffic conditions. New electronics technologies interact strongly with vehicles and computer technologies. New detectors communication links and control processors are being developed that may lead toward navigation systems and route selection under dynamic traffic conditions.

The highway system today carries a more significant number of vehicles -miles of travel than ever before – greater than that for which it was designed. Demands continue to grow at faster rates than improvements are being made. The movements of persons and goods have gradually deteriorated. Transportation system management and new technologies offer the greatest challenge and hope for improving the quality of movement. The ability to understand and apply traffic fundamentals is an essential ingredient in working toward improving the transportation system.

The general requirements of up to date software systems for computer aided planning and especially realization of plans has become more difficult within the last years. This is not only related to public transport systems. The changed requirements lead to changed tasks for the planner and he sometimes has to come up with inadequate planning tools. Three aspects can be seen as the main reasons of the development.

1. Compared with the past, planning objectives are seen with greater differentiation, at least the objectives are introduced more decisively.
2. Instead of a few alternatives more alternatives must be presented to come to decision today.
3. To let the decision makers participate already in an early stage - this is more and more necessary- the planning process must as far as possible be transparent and understandable also to non-experts.

One way to solve the planner's problem is to use modern computer technology, which offers a variety of chances to improve the planning process. Today the computer capacity of relatively small installations is in a range which some years ago could only be provided by large computer centers. Looking at the software there are some gaps at the movement but this is self evident. Besides the handling of data which is of special interest in the planning process, modern computer technology offers the possibility to evaluate measures in the planning stage by use of models with a model. We try to describe reality as well as possible. The data set coming from the existing situation normally serves as a basis for calibration of model parameters. To find the best solution for a given data set and given objectives optimization methods have been applied to planning in transportation for a long time. The results of optimization methods depend on the quality of the input data set.

Traffic flow fundamentals have been extensively studied by May A.D. [91]. Haight F.A. [17], [16], and [22] have defined the statistical methods for flow theory models. Haight F.A. himself has discussed counting distribution. Sample datum from Ernakulam City have been taken and tested to see whether this is suitable for statistical distributions. Queue estimation and Queuing Theory in traffic has been established Hoose N. [13] and Harris C.M. [106]. Queuing analysis in traffic also been discussed. Net works on traffic has been done by Robertson D.I. [80]. When two or more intersections are close in proximity, some form of linking is necessary to reduce delays in traffic and to prevent frequent stopping. A signal-controlled intersection has a platooning effect on the traffic leaving it, and it is advantageous to have the signals synchronized. The usual procedure for setting signals on arterioles and in networks involves three steps. First is common cycle then splits of green time and finally computer optimization procedure. Several computer programs have been developed for determining offsets in network. Hillier J.A. [103] have extensively worked this on. Gartner N. [10] introduced an idea in Dynamic programming in traffic signal networks. Also the idea of artificial neural network has been introduced to create an expert system in traffic.

2.9 Scheme of the Study

In Chapter 3 we have defined the Net work Configuration. All traffic data has been controlled through Network Database Management in the state. Geo Graphic Information system has been developed with user friendly manner which gives an easy access to the ordinary people. All the required field has been given in this work. Mathematical models for traffic planning and forecasting methods has been discussed. The traffic planner collect the data from Network database management system and the data has been given as an input in the suitable mathematical model for simulation.

Chapter 4 is concerned to meet the public transport demand. That is scheduling the vehicles and their crews in scientific way with minimum number of vehicles. It is the purpose to set appropriate timetables for each transit route to meet the variation in the public demand. Then schedule the vehicle to trips for given timetable. The major objective is to minimize the number of vehicles required. Then assign crew as per the outcome of the vehicle scheduling. The assignment must comply with some constraints regarding starting point, ending point, relief point and so on.

Chapter 5 is devoted to monitor and control the traffic flow with the help of the electronic devices and computer. Statistical count distribution has been discussed to find volume and density of the traffic. The role of artificial neural network and computer vision to control traffic flow has been discussed widely. Queuing analysis and queuing patterns gives a clear idea about level of congestion and the delay in traffic. Mathematical model for area wide traffic network control helps to have a centrally co-ordinate system.

Chapter 6 has been given the importance of the traffic safety. While acceleration of transport activity contributes to economic development and improvement in the quality of human life, it also brings in its wake the problem of traffic risk to the people. To ones dismay , traffic risk on roads has become a common phenomenon in all countries in general and developing countries in particular. India is one among high fatality rates in road accidents. The basic causes of traffic safety problems are those forces or situations that bring about over crowding, a decline in maintenance of roads. The use of fossil fuels, and spillage in the oceans lakes and rivers affect the ecosystem. This work gives a detail description about accident problems and adverse effect of pollution.

Chapter 7 highlights the summary of the work. The importance of the implementation of Traffic Management System has been discussed. The future developments in this field may lead the way to have an effective management in road traffic.

CHAPTER 3

Network Data Management

3.0 Introduction

By means of field studies and the assembly of current data used by various agencies within the area, the planner assembles a complete inventory data of existing highway and transit facilities and a cross section of current travel behavior in the urban area together with the origin destination survey and land use study. The hierarchy of the Network structure is given below.

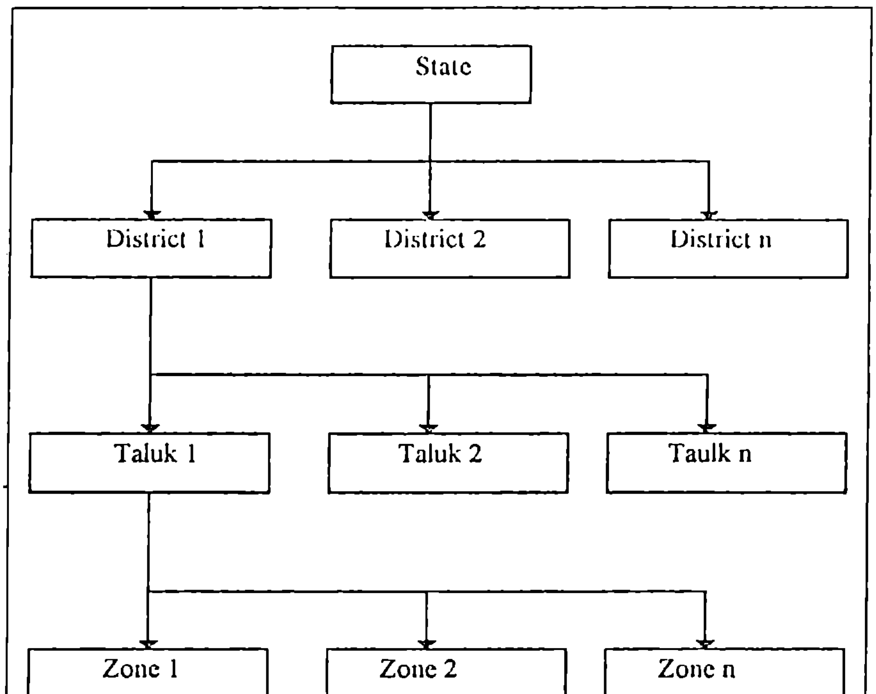


Fig 3.0.1

Street use studies :- The objective of this study is the identification of all streets and highways with significant travel and their classification . Rural highways are classified by their place in the hierarchy of their functional class by their design category by two lanes, multiple lane and so on.

Existing traffic studies:- Those involved in traffic control in the area are required to provide an inventory of traffic service based on the existing facilities under current demand.

Traffic volume count:- Counts are made at carefully selected stations and sample counts on an area wide bases permit a reasonable estimation of traffic volumes throughout the urban area.

Travel time studies:- Measurement of travel time on the major street system enables comparison of the level of service provided by the various road sections comprising the existing network. Travel time studies are conducted at different period of the day to permit this comparison under peak and non peak loading.

Street Capacity:- Based on the geometry of the road way, the type of traffic control, and the vehicular composition of the traffic stream, capacity calculations can be made for all sections of major streets and highways.

Accident study:- Information on vehicular accident is collected and assembled on a comprehensive basis from existing data sources such as the files of the local authorities and public records. Accident information gives a measure of the safety of the street and highway system.

Parking study:-The provision o^c adequate terminal parking facilities is an inherent part of any traffic plan which relies on other mode of vehicles for the movements of goods and people.

Traffic control device study:- Because of the significant effect that control devices exert on the capacity of a street network, the planner carries out a comprehensive study on location, type and functional characteristics of major traffic control devices, area wide parking locations, transit routes and transit loading zones.

Existing transit studies:-In order to determine how well transit meets and stimulates passenger demand for service, it is essential that the planner should have a comprehensive understanding of the existing level of transit service and demand.

Route and coverage study:- The existing route structure is inventoried to determine the relation of the populated areas within the reasonable walking distance of the service. Routes are further examined to determine whether service in general follows the desired lines of travel and whether transit accommodates growing community needs.

Transit route inventory:-A survey is made of the physical characteristics of each transit route.

Passenger load data:- Passenger load data can determine whether the service frequency is adequate to satisfy the existing demand and whether adequate standards of comfort are maintained.

Transit speed and delay studies:- By means of speed and delay studies on actual transit runs identifiable causes and areas of delay can be delineated. Internal and external causes of delay are determined to assist future remedial measures.

Travel and Traffic information:- This is aimed at providing travelers with both strategic information and tactical information. This includes the information of weather and road condition, tourist advice, congested locations and traffic forecasts.

Environmental assessment, Energy and safety:-Reduction of pollution is associated with more efficient traffic, particularly reductions in vehicle stops, delays and congestion. The main traffic parameters likely to affect pollution are flow delay , number of stops and congestion.

Data management:-The purpose of any data management is to provide a mechanism whereby large sets of data can be easily and efficiently stored and then retrieved as desired. The final test is whether the system provides the desired information to the user in a short time. If a data management system is designed by using the actual requirement for information to identify the data needed , the requirement of the total system will be understood and the system will meet the expectations of its user. A basic decision associated with traffic data processing system is to use computers. This will have an impact upon every aspect of the system design time, implementation, cost and maintenance, as well as the operating capabilities of the completed system. Information resources may include storage systems with population data , combinations of traffic factors, statistical data concerning vehicle density, land use pattern and so on. A computerized system can be designed to transform these data into information about traffic flow patterns or congestion models.

Data files:-

Operator identification file:- All information concerning area, population, industrial location, educational institutions, hospitals and so on.

Transit facility file:- All information about depot, vehicles, trip times, Congestion locations, route information, travel places.

Source file:- Information about area, population, congestion, zonal information about industries, institutions, garage information and so on.

Data retrieval Data retrieval procedures are the ultimate aim in the traffic management systems. Its accurate, adequate and timely retrievals can be made from the system to the satisfaction of the users. Both raw data and summary information will be source for retrieval. The summary information may be in the form of reports. Simple examples for retrievals are report about total population, number of educational institutions, industries, hospitals and so on. District wise information about traffic or travel places and traffic flow in particular area. Retrievals from large data sets can be performed by setting codes. A small number of selecting codes will yield comprehensive detailed output data. A large number of selecting codes will yield only few data with very specific information content.

Data summaries:-A summary of data is generally used either to check data for completeness or to obtain information on traffic. Decisions concerning the type of data summaries or analyses required will in turn indicate the raw data to be collected. Each item of data collected should have a definite purpose, as an identity or data value or in the calculation of summaries. Since summaries are atleast one level above from the initial collected data, procedures previously described under data auditing must ensure that the data are complete and accurate. The typical user of the data system may never see the basic data. Data summaries represent very simple types of data retrievals.

Data flow systems:-The handling of traffic data involves various levels of electronic devices like detectors, sensors and optical character readers. The responsibility for gathering and maintaining this data rests with traffic control and information department.

Flow of information:-Once data are entered into the system they are accessible to the personnel responsible for the data. He can have the facility to update, ignore the data according as the situation. Status report and management report may be passed to various administrative and through VDU to people.

3.1 Information System

A good information system yields the useful data about a domain in a short interval of time. If the data size or volume of data is high, then storing of this data in a single place results in the inefficiency of accessing, retrieving and modifying data. Also the database should be updated in periodical intervals so as to reflect the recent pictures. This updation will be much easier if the database is situated very near to the origin of information. i.e. at different geographical locations, local databases are placed, and connect these local information sites together through a high speed communication channel. Such a system will be more useful because local access comes much frequent than remote access in a practical communication system. More over a single system failure will not completely affect the entire information system.

Here, I wish to present an information system for a complete state, keeping in mind that this system should be useful for proper planning in transport and traffic. This information system consists of a group of single site database placed at district head quarters. At a single -site we place six databases to the system. They are

1. Population Database
2. Education Data base
3. Hospital Database
4. Industry Database
5. Transit facility
6. Miscellaneous Database

Implementation

This is implemented as a clien. server model. i.e. At each single site location, there will be a server system which receives individual requests from different systems and hands over the request as the input running in that system. This program will produce the required output information as a packet and send this to the needed place. The request contains the originating address, destination site address and the topics about which the request is made along with a set of parameters needed. The client program at each site will interact with the user. It provides an interactive environment to the user so that the user can easily place his request on the system. The client program transfers the request to the server program which transmits the request to the destination site. In addition to the client and server program there are a number of application programs running in the system. Server program is mainly a communication program. Before sending a request the client program would contain all the required fields in the request. The request type field will determine the database to be opened and the application that is to be invoked at the destination point.

The overall system structure is shown below

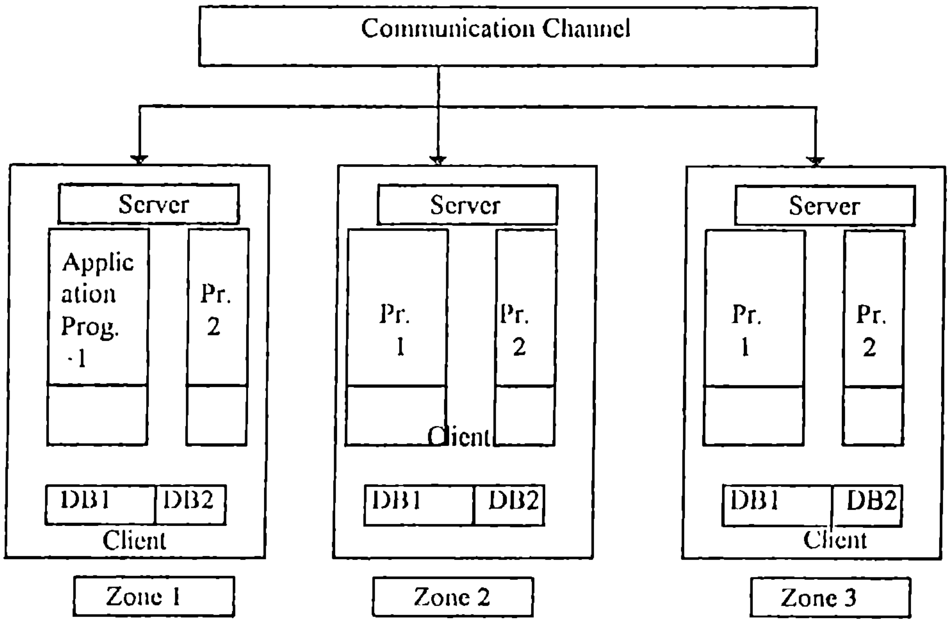


Fig 3.1.1

A database is an ordered collection of information with a number of accessing tools. A database will be assigned to accommodate changes, retrieve information and maintain consistency of information. Data is organized as records. Records are grouped under tables. There may be one or more tables in a database. These tables will contain record information in a specific area. It is possible to connect the records in two different tables so that changes of one record apply to the connected records. A common field is needed to connect the records or tables. Inside a table record can be placed in an order physically or a chain of addresses of records can be made to access the stored records in any needed order. The method of building an address chain for a table is known as indexing. Indexing will be more flexible towards the changes in the database compared to sorting. Also the index method reduces the time needed to access data from a table or database. It is possible to use more than one index to retrieve information from a table. In order to retrieve or manipulate data in the database we use a query language. A menu driven or interactive client program will create a statement in the query language as the user selects options from the menu. Sometimes the user has to type specific value to a field given in a dialogue box to make the query language statements.

Statements in query language searches for finding out a group of records from a table which satisfy some conditions. One of the popular query language is known as Structured Query Language (SQL) which operates on the data in a table. The table manipulation can be done using Data Definition language (DDL). Suppose we want to list the name of all Garages in a district then the query language will be used

```
SELECT Names
FROM GaragedB
WHERE district = "TVM"
```

DDL statements are used to create , alter or delete a table. An example to create a table Garage Employee is

```
CREATE TABLE Employee {
        int Number
        text Name [25]
```

3.2 Creating Databases

In the information system six databases have been created which starts with the population database. Identification of the fields in a record should be in such a way that they give almost full information of the entity with minimum number of fields. Here entity of a person and the fields identified are given below.

Name	Type
Name	text
Identity No.	text
House No.	int
Monthly Income	int
Edu. Quali.	text
Ward no.	int
Panc./Muni.	char
Name p/m/c	text
Zone-code	int
Employee(y/n)	Boolean
Own-vehicle(y/n)	Boolean
Reg. no. of vehicle	text
Trip-line-from	int
Trip-line- to	int

The last two fields will identify the total number of trips(public transport) with the nearest town. This data will be used in the mathematical model for trip generation, population estimation, and traffic forecast. This data is directly used in various models to forecast traffic congestion in a particular place. The public transport facility is rescheduled depending on the fields employed, own vehicle and trip number.

Industry or Institute database

Name	Type
Name of Industry/Inst.	text
Location	text
zone code	text
Type (psc,pvc,cd.i)	char
Environmental safety cond.	text
Pollution parameter	char
Dist. code	char
Bus routes	char
nearest town	char
Phone-no	char
Pin-no	char

There is one more table in the industry database named as tourism. The fields identified are given as follows. This is a very important data for transport planning and traffic also.

Name	type
Name of the place	text
Nearest town	text
Significance	text
No. of Hotels	int
Entertainment facility	text
Bus route	text
Infor. office phone no	int
Airport -Phone	int
Police aid -Phone	int
Hospital -Phone	int
Railway station-phone	int

Education database

District code	text
Name of the institution	char
type (school/college/university)	char
courses	text
location	text
Bus route	char
Nearest town	char
Inst. Phone-no	char
Pin-code	char
No. of students	int
No. of employees	int

In this database name, course list, place, no. of seats are more important. To forecast traffic data total number of intake of the institute is more useful.

Hospital Data

Field Name	type
District code	char
Name of Hospital	char
location	char
Type(pb./pv.)	char
No. of beds	int
Hospital code	char
Hospital phone	char
Hospital-Pin	char
Type of dept.	char
Total no. of employees	char

These are the fields in the General table. Hospital database contains one more table "Specialization" Fields are listed below.

Fields	Type
Hospital code	text
Doctors Name	char
Specialized field	char
Qualification	char
Address	text
Office Phone-no	char
Residence Phone-no	char

Transit facility Database

Four different tables are identified under this database. They are

1. Depot Information
2. Bus Information
3. Employees data
4. Traffic information

The Depot information lists the names of depot in the district. The fields identified are

Field Name	type
District Code	char
Name of the depot	char
Depot Code	char
Location	char
Zone Code	char

The fields identified Bus information table are listed below

Field Name	Type
Depot Code	text
Route No	char
Bus No	char
Time schedule	char

The employees table contains a number of records equal to the total no of employees in the depot. Employee table has fields identified with type of field as follows.

Field Name	type
Depot Code	char
Employee Code	char
Employee Name	char
Department Code	char
Date of Birth	date
sex	char
Salary (Basic Pay)	int
HRA	int
CCA	int
HBA	int
LIC	int
FBS	int
GIP	int
Deductions	int
Allowances	int
Vehicle Loan	int
Over time Pay	int
Net Pay	int

Fields identified in traffic table are listed below

Zone code	char
NH list	char
NH distance	int
State High way	int
Garage information	text
Accident information	text
Congestion information	text

For each zone there will be a record in the traffic table. Miscellaneous database keeps the count of various attributes of other tables. There is one record for each zone. The fields identified are

Field name	Type
Zone code	text
Total Population	int
No. of Hospitals	int
No. Industries	int
No. of schools	int
No. of edu. Institutes	int
No of Garages	int
Tourism places	text

Miscellaneous file is kept for general information. about a zone without attempting other databases. During modifications miscellaneous files will get updated automatically by the application program.

Updation or Modification in the database

Updation and modification are permitted to do only locally at the site itself. This change is recorded to the miscellaneous file also. Passwords are used to prevent unauthorized accessing of the data. Administrators password is needed to add or delete data to the existing database.

3.3 User Interaction

The front end of the system is a menu driven program and the back end is the database. The starting menu leads the user to place a query by a number of selections. Suppose the user wants to know the names of education institute in a district he would select the option available in the menu.

The menu has been given below.

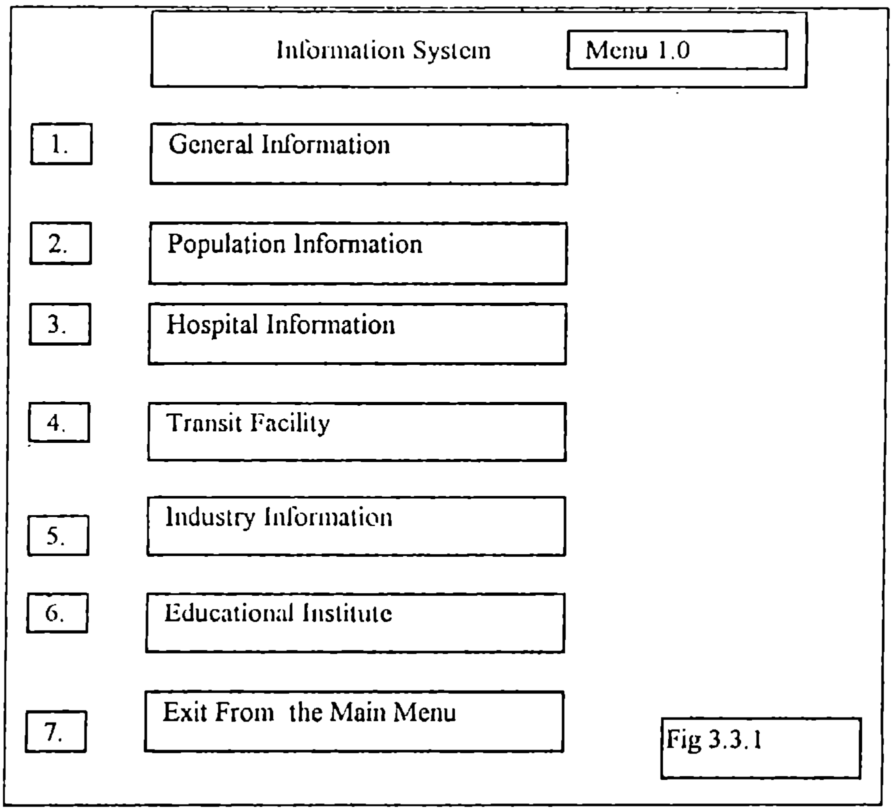


Fig 3.3.1

The pull down menu is displayed for a selection. This pull down menu includes almost all attributes of the selected database. While the user is making the selection the system will be on the process of making the query needed and the required information will be available on the screen.

In the case of entity zone name or zone code is not sure then the user can browse the information and click the essential zone code. The browse operation sends a query to remote/local sites and collect information displayed on the screen

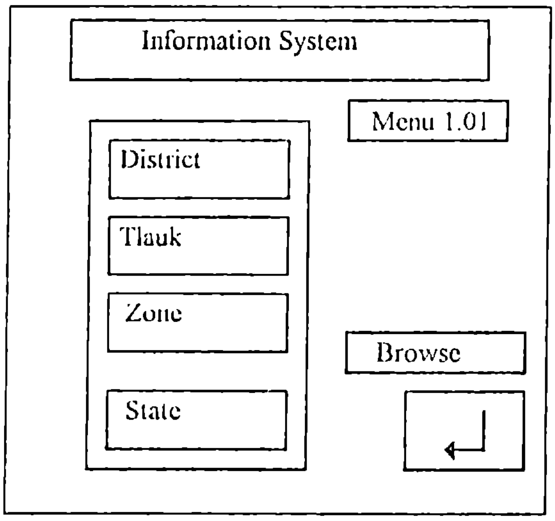


Fig 3.3.2

The Browse operation takes data from a file which is hierarchically starting from the state and going through District, Taluk up to zone name. The names of all district and the underlying taluks are kept to local sites. This file is always referred by a client program.

3.4 Conclusion

Transport is a critical infrastructure needed for the developmental process. In 1990-91 the share of this sector in the total GDP in India was about 4.55%. The growth of the road net work in India has reached beyond the expected rate. India's road net work is one of the worlds largest, stretching for almost 2.1 million km across the country. The main road net work comprising National and state highways has not matched traffic growth. Fifty percent of the villages are still to be connected. The road network increased from 4 lakh km in 1951 to 20 lakh km in 1991, vehicle population rose from 3 to 219 lakh during the corresponding the period. This exposes lack of a high way system to meet the road user demand. The road network has become saturated. Poor quality and maintenance of roads result in wastage of large amount of scarce resources and economic losses. These losses are estimated to be around Rs 200 to 300 billion per annum. Congested sections, existence of railway level crossings leads to abnormal delays in travel and higher fuel cost. A phenomenal growth in personal vehicles and slow growth in road network has resulted in congestion and air pollution. This area is faced by problems such as high accident rate poor road safety and so on.

In this chapter the traffic problems including trip generation, population estimation and traffic forecasting has been discussed. The various mathematical models have been used to solve traffic planning problems. The network management Information system has been developed so as to ease the traffic planning problems. So the traffic manager can access the information easily about current trend and he can predict the future problems arising in traffic.

CHAPTER 4

TRANSIT FACILITY MANAGEMENT

4.0 Mass Transit

Although traffic systems exhibit many of the special characteristic of service industry, it must be increasingly recognised that the fundamental relationships between the generative process and its regulation are similar to those found with many types of production process. The introduction of the modern data processing software has demonstrated the general interdependence of partial systems and elements along the lines of control circuit with its continual exchange condition and instruction data.

However this present day assessment of the situation was not always so obvious and did not become so without difficulty. The path leading to the use of modern data processing in traffic systems began with marked over optimism concerning its possibilities However the basic belief that a modern logistics system could bring about decisive improvements in traffic operations is certainly more than ever warranted today. In general the following two basic principles apply to control of traffic process.

1. The scope of an information system for the control of traffic process must be fixed exclusively by specific process requirements and not by technical possibilities.
2. The organisation of an information system for the control of a traffic process must meet the requirements necessary for optimal human participation

Man and Machine

The generally applicable requirements for optimal potential human participation in control system can be listed as follows.

The structure of an information system for control purposes should be laid out in a hierarchy in which the data manipulation carried out at each individual level always lies within the scope of normal human understanding. It is not sufficient that only the system developer knows and considers as correct the internal set of rules for data conversion.

The personnel relating to the control system must also be able to understand atleast in general what conversion process are going on, since if this is not the case , their interest in collaboration drops or disappears completely.

Information regarding the state of the system provided to a person as the basis of the control decision must in form, content and density correspond to his or her optimum respectively. With regard to form, for example graphically presented information is more easily absorbed than alpha numeric chains of information. Information content should once again reveal the underlying process in as meaningful form as possible. That is, with as little as possible abstraction and with pauses between the individual pieces of information sufficient to enable the process changes which must be deduced from that be grasped.

The choice is to be based on process condition information and should be limited to those specifically useful to the process and presented in a sequence determined by their effect.. One approach which tends to satisfy this requirements is the use of so called **"Menu technique"** Text processing or recording system which leads the operator through the work in a distance sequence of steps each of which offers different alternatives for proceeding.

Adequate time should be allowed to permit the operator to reach each and every decision. This need for distinct reaction time is clearly recognisable .As system interconnections become more complex as the information on conditions becomes more abstract and as the variety of information provided increases, longer reaction time must be allowed. One solution is to offer as far as possible the information on conditions in small modifying steps each of which does not directly require a decision but whose accumulated chronological development makes the direction and importance of the decision to be taken recognisable.

For all traffic operations data manipulations are very important part of the process. Even the smallest transportation service has a mass of incoming and outgoing data to process and disseminate including time-table and service bulletins. This printed output information for customers and company personnel is based on similar voluminous input data such as traffic studies, tables of trip times, regulations concerning periods of duty, company agreements and so on. In the majority of traffic operations, the transformation of input data into output data is considered to be time consuming, difficult to grasp, inflexible and prone to errors.

Analysing the causes of this problem , it is clear that the pure logic of data processing procedure is in no way complicated. The connections between traffic volume, vehicle capacity, time-table fixed cycle, line times and around trip times can all be understood with the help of very basic calculations.

The use of computer in the comprehensive programming of complex planning process and the automation of data processing procedures does offer particular advantages here. In computer systems for the organisation of operations, all the planning process relationships are stored in automatic programs where the transposition of incoming and outgoing data also take place, thus relieving the planner of all purely routine transfer and representation process and leaving him or her free for truly creative planning activities.

The most important function of the new computer data operations system is to store all relevant data so that after a decision is made by the operator at his or her monitor, all task tables or graphics necessary for operations are immediately available without loss of time or errors. In addition the advantage can be taken here of mans inclination to play because the plan from which subsequent data derived can first be worked out. A first trial version can present worthwhile alternatives immediately side by side for comparison. Small changes can be tried out. The interactive nature of the planning process thus permits improved consultation with third parties, which could be an advantage in service planning. The development of the following data operation capabilities seems worth while.

That is programs for the administration of data on services.

line data

run trip data and so on.

In the overall design of data operations systems the entire program package must be developed so that each program can be used independently or in combinations with others. Only through a completely modular package can be the specific needs of a given transportation service be satisfied without burdening it with unnecessary procedures.

4.1 Computer Evaluation Systems

The conversion of data operations programs into decision or evaluation can be of use for two planning problems. First they can provide definite assistance when a choice must be made between numerous planning variations of apparently slight significant difference. In this sense decision and evaluation capabilities which may improve the efficiency of the service include programs for the analysis of transportation demand for uniform periods for a given area, network structure and time(yearly, weekly, and daily)

Programs to establish the readiness for service of vehicles and personnel in each planning period.

Evaluation programs for the disposition of staff and facilities in the event of a deviation from a planned operations(incidental demand, breakdown, and so on)

timetable alternations

vehicle schedule alternations.

Every traffic operation includes far more areas of work than just the actual driving from workshops, provisions of materials to the hiring of external services in all of which new short and long term decisions must be made continuously.

Computer optimisation systems

Some planning process at the level of entire traffic network may require the testing of so many planning variants that processing by way of decision programs based on single characteristic values becomes too costly. For task of this sort optimisation programs can be introduced into an appropriate computer evaluation system In the area of local public transportation the following programs concerned with service efficiency may lead to the application of more effective methods of operational research.

programs for the optimisation of network paths

service network and so on.

Programs for the optimisation of network plans to achieve efficient services

Vehicle schedules personnel duty schedule.

The optimisation models for the solution of traffic problems has shown that it is often insufficient to produce one single solution. Demand requirements and other factors are so varied and subject to so many alternations that uninterrupted adaptation of plans is necessary. The independent use of a computer data operations program obviously cannot guarantee optimisation, but it does ensure much faster and less error-prone planning process. With such a system, the time required for manual planning can be reduced by approximately ninety percent, and procedure become clearer and more flexible.

The field of public transport has of course benefited, as the development of the computer techniques and formalised solution procedures. Mathematical programming approaches include algorithms that are directly based on mathematical model. Dantzig - Ramser formulate vehicle routing problem as a mathematical model in which two interrelated components, one the travelling salesman problem and the other is assignment problem. Christofides discuss Lagrangean relaxation procedure for the routing of vehicles. Christofides also discusses a successful integration of delivery decisions with issues relating to customer service and fleet size determination. Here the method of Optimisation techniques to solve the problems facing by public transport has been discussed.

Vehicle routing and Scheduling

The routing and scheduling of vehicles and their crews is an area important to both operation researchers and transportation planners. Research in this field includes problem formulations and implementation of solution procedures.

The flow chart shows the automatic scheduling process for bus and their crews.

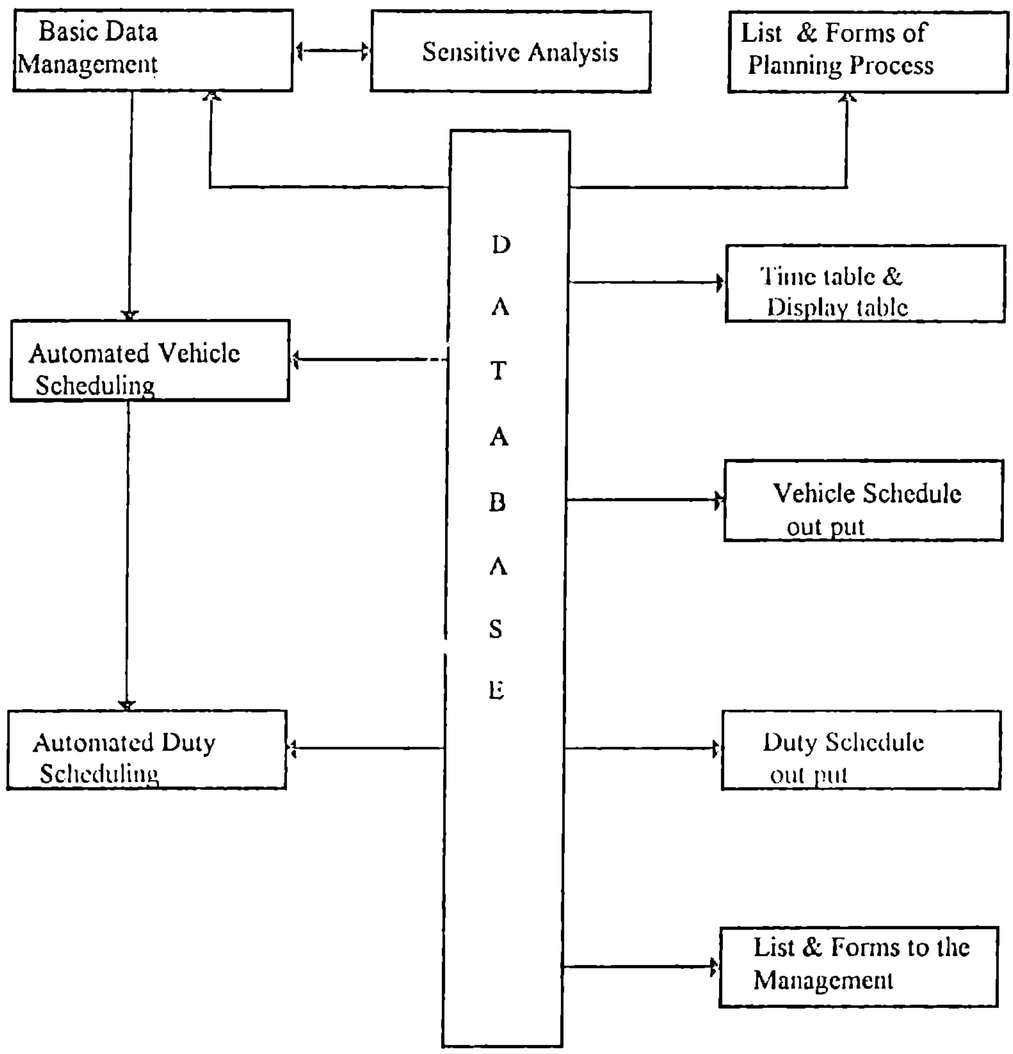


Fig 4.1.1

From a practical standpoint he effective routing and scheduling of vehicles and crews can save government and the industry crores of rupees.

First we define what we mean by routing and scheduling of vehicles. A vehicle route is a sequence of pickup and or delivery points which the vehicle must traverse in the order of starting and at a depot. A vehicle schedule is sequence of pickup and delivery points together with an associated set of arrival and departure times. The vehicle must traverse the points in the designated order at the specified times. When arrival times at nodes and or at arcs are fixed in advance we refer the problem as a scheduling problem. When arrival times are unspecified the problem is a straightforward routing problem.

4.2 Single Garage Multiple vehicle routing problem

Trip is performed by a bus running from one terminal of a bus route to another

block. It is composed of one or several trips normally carried out on a single bus route. Combined block is set a of blocks that can be prompted by the same vehicle

Description of the problem

The transit company has several garages, each characterised by a particular location on the territory and by a specific capacity. Blocks and combined blocks of vehicle must be assigned to each garage in order to minimise the operational cost which are in this case fixed cost of operating the vehicle, the dead head cost (both for crew and vehicle)incurred by each combined block out of this location and garage operating cost related to arrival and departure of vehicles.

Considering the.cost structure of this problem. It is clear that the assignment of blocks to garage is interrelated with vehicle scheduling problem. In fact to minimise number of buses to operate a schedule we may consider the problem of allocating the blocks to a minimum number of vehicles. The result however may generate high dead cost to and from the home garage. On the other hand assigning blocks to garages first to minimise deadhead cost may result in using greater number of buses than necessary. The trade off between these two elements must be considered and may be different from one transit organisation to another depending on the amount of subsides for new buses, the availability of buses and the financing of operating deficits.

The problem of assigning blocks to garages and scheduling vehicle for single garage operation is given below.

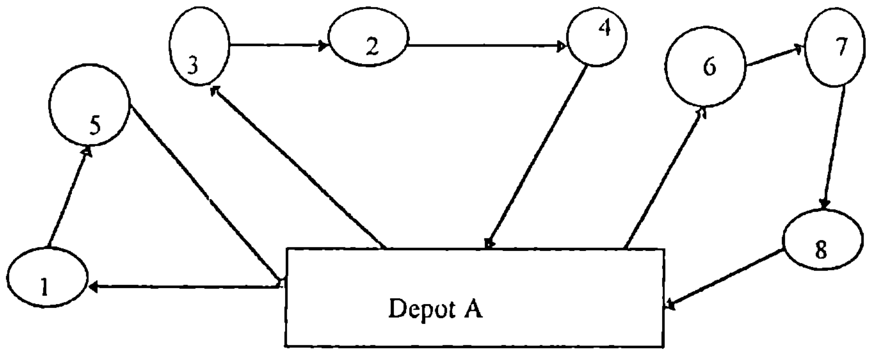


Fig 4.2.1

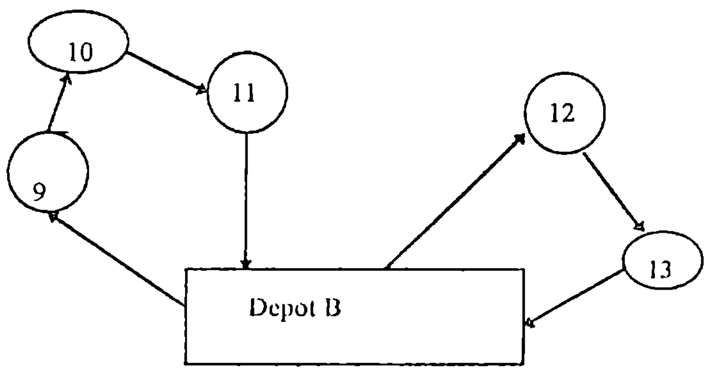


Fig 4.2.2

Route 1 Depot A -1-5- depot A

Route 2 Depot A -3-2-4- Depot A

Route 3 Depot A -6-7-8- Depot A

Route 4 Depot B 9 -10-11-Depot B

Route 5 Depot B -12-13-Depot B

The single garage multiple vehicle routing problem asks for a set of delivery routes for vehicles housed at central garage to minimise the total distance to travel. The demand at each node is assumed to be deterministic and each vehicle has a known capacity.

Mathematical model

$$\text{Minimise } z=\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{v=1}^{nv} c_{ij} x_{ij}$$

Subject to

$$\sum_{i=1}^{n}\sum_{v=1}^{nv} x_{ij} = 1 \qquad j = 2 \quad n \qquad 1.1$$

$$\sum_{j=1}^{n}\sum_{v=1}^{nv} x_{ij} = 1 \qquad i = 1 \quad n \qquad 1.2$$

$$\sum_{i=1}^{n} x_{ip} - \sum_{j=1}^{n} x_{pj} = 0 \qquad v = 1 \ldots\ldots nv \qquad 1.3$$

$$\sum_{i=}^{n} d_i \sum_{j=1}^{n} x_{ij} \leq k_v \qquad v = 1 \ldots\ldots\ldots\ldots nv \qquad 1.4$$

$$\sum_{i=1}^{n} t_i \sum_{j=1}^{n} x_{ij} + \sum_{i=1}^{n} \sum_{j=1}^{n} t_{ij} x_{ij} < T_v \qquad 1.5$$

$$\sum_{i=2}^{n} x_{1j} < 1 \qquad v = 1 \ldots\ldots\ldots\ldots\ldots nv \qquad 1.6$$

$$\sum_{i=2}^{n} x_{i1} < 1 \qquad v = 1 \ldots\ldots\ldots\ldots\ldots nv \qquad 1.7$$

$$x \in s \quad x_{ij} \in \{0,1\} \qquad \forall_{i,j} \in v \qquad 1.8$$

where n = number of nodes .

nv = no of vehicles.

K_v = capacity of vehicle V.

T_v = maximum time allowed for a route of a vehicle V.

d_i = demand at node I.

T_i = time required for a vehicle to cover the node i

t_{ij} = travel time for vehicle from node i to node j

C_{ij} = cost of travel from node i to node j

x_{ij} = 1 if arc i-j is traversed by vehicle v 0 otherwise

The objective function states that the total cost is to be minimized. The equation 1.1 ensure that each demand node i served by exactly by one vehicle. Equation 1.3 represent the capacity of the vehicle. Equation 1.5 and 1.6 guarantee that vehicle availability is not exceeded. We assume that the demand at each node does not exceed the capacity of the system . Now consider there be n nodes to service each demanding v_i (i = 1, 2, n) the transportation of v_i passengers. Vehicles are stationed at the depot B. Assume all vehicles have same capacity v_i and when servicing all must start and finish their trips at point B. Let capacity of any vehicle be greater than demand and each point is serviced by only one vehicle or one vehicle can service several points.

Determine the set of routes to be used by the vehicles when in service so that the total distance covered by the entire fleet of vehicles is at a minimum. Keep the point B as fixed and the n points to be serviced. Let one vehicle service one point at the beginning. This means at the beginning n vehicles leaves point B service n points and return point B. The total distance covered by all n vehicles is

$$2d(B,1)+ 2d(B,2) + 2d(B,3) + \quad +2d(B,n)$$

$$\text{ie } 2\sum_{I=1}^{n} d(B,I)$$

where d(B,i), i=1,2,3, n is the distance between the points B and point i. If one vehicle should service two points instead of one let"s say i and j then there is a saving mode.

$$S(i,j) = 2d(B,i) +2d(B,j) -[d(B,i) + d(i,j) + d(B,j)]$$

$$= d(B,i) + d(B,j) -d(i,j)$$

Quantitatively s(i,j) is obtained by joining points i and j into one route. It is clear that the larger S(i,j) becomes the better it is to join i and j into one route. Points i and j can not be joined into one trip if doing so violates one of the constraints in the problem.

Algorithm

Step 1:- Calculate S(i,j) =d(B,i) + d(B,j) - d(i,j) for every pair (i,j) of points to be serviced

Step 2:- Arrange all S(i,j) in descending order

Step 3:- When examining S(i,j) corresponding branch (i,j) is included in the route if so does not violate one of the given constraints

a. neither point i nor point j has been included in a route
b. either point i or point j is already included in a route if that point is not an internal point on the route.
c. both points i and j are included in different routes and neither one is an internal route point (both are external) in which case the route can be joined together

Step 4:- if the list of S(i,j) (after formation of the first route)is not completely used up return to step 3 and start from the beginning with the largest unsaving. When the list is used up then the algorithm is finished since all the route have been formed

The distance between the nodes are given below.

	1	2	3	4	5	6	7	8	9
1 .	∝	50	45	70	40	65	40	82	70
2	50	∝	55	95	40	90	75	95	50
3	45	55	∝	35	70	60	70	85	85
4	70	95	35	∝	95	45	95	75	85
5	40	40	70	95	∝	90	55	95	95
6	65	90	60	45	90	∝	75	85	60
7	40	75	70	95	55	75	∝	80	55
8	80	95	85	75	95	45	80	∝	90
9	70	50	85	85	95	60	55	90	∝

The vehicle servicing these points have a capacity of V=70. The estimated passengers from each node 2,3,4,5,6,7,8,9 are given below

node i	2	3	4	5	6	7	8	9
quan. Vi	30	10	15	25	40	15	10	20

Calculate the first saving using the formula
s(i,j)=d(1,i)+d(1,j)-d(i,j)
Here s(4,6)=d(1,4)+d(1,6)-d(4,6)=70+65-45=90
Corresponding savings are calculated for all pairs of nodes. The savings are taken in descending order.

Branch (i,j)	S(i,j)
(4,6)	90
(3,4)	80
(6,9)	75
(4,8)	75
(2,9)	70
(6,8)	60
(8,9)	60
(4,9)	55
(7,9)	55
(3,6)	50
(2,5)	50
(7,8)	40
(3,8)	40
(2,3)	40
(2,8)	35
(3,9)	30
(6,7)	30
(5,7)	25
(5,8)	25
(2,4)	25
(2,6)	20
(2,7)	15
(3,5)	15
(3,7)	15
(4,5)	15
(4,7)	15
(5,6)	15
(5,9)	1 5

Here branch (4,6), has the greatest saving as 90. Therefore the first route is(1-6-4-1). The no of passenger in the vehicle will be $V_4 + V_6 = 15+40 = 55 < V$, node 4 &6 can be joined since this does not violate any constraint concerning the vehicle capacity size. The second order of saving is branch (3,4). Node 4 could be included in the route since the node 4 is not an internal point. Check whether node 3 in the route violate the capacity constraint. so we have $V_4+V_6+V_3=65 < V$ and conclude that 6 can be included in the route, so that our route is changed to (1-3-4--6-1). Branch (6,9) is next by order of savings. The node (6&9) can not be joined in the route. Since it violate the capacity constraint. But 6 is the internal point of a route. So we cannot start a new bus route using the node (6 & 9). So ignore it. The next saving is the node (4,8). Here also the capacity constraint of the vehicle is violated for the previous route. We can not start a new route, the point 4 is an internal point of the previous route. So ignore it..

The next highest saving is the node (2,9). Here neither 2 nor 9 is an internal point. So we can start a new route, it the vehicle capacity constraint is satisfied.

$V_2 + V_9 = 30 + 20 = 50 < V$

So the new route is (1-2-9-1). The next saving is (6,8). This cannot be included in the route since 6 is an internal point. The next saving is node (8,9). Here 9 is not an external point. The node (8&9) can be included in the route if the capacity constraint is satisfied. $V_2+V_9+V_8=30+20+10=60 <V$. So the route is (1-2--9-8-1). The next saving is the node (4,9). Here the node 4 is an internal point. So it cannot be included in the route. The next saving is the node (7&9). Here 9 is not an external point But the capacity constraint is violated. ie $V_2+V_9+V_8+V_7=60+15=75 >V$. So it can not be included in the route. Ignore the next highest savings (3,6),(2,5),(7,8),(3,8),(2,3),(2,8),(3,9),(6,7). Since these are the internal points of the previous route. The next highest saving is (5,7). Neither 5 nor 7 is an internal point. So start a new route.

$V_5+V_7=35+15=60<V$. So the route is (1-5-1-7)

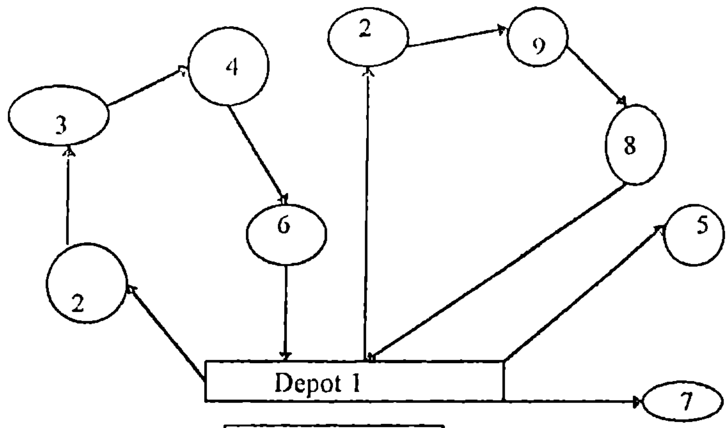


Fig 4.2.3

Pseudo code in Pascal

Read DistMatrix d(i,j) ∀ i,j where i ≠ j and i & j are nodes

Let maxnodes be the total no. of nodes.

Let savings Array [n] stores values in the order node1, node2, savings.

Let k=0

For I = 1 to max nodes-1 do

For j = i+1 to maxnodes do

begin

sij = d(i,j)+d(1,j)-d(i,j)

k = k+1

Savings[k] = Values of (i,j,sij)

end

Let n = k

Sort savings Array[n] in descending order of savings

Read passenger(I) for each node I

Let Route be the set of nodes

Let RouteArray[1to max] be the array of routes

Let I =1,totalP = 0,x = vehicle capacity

```
    Let Routeindex = 1:RouteArray[Routeindex] = {}
    While savingsArray[i].savings <  x and route ≠ {}
    begin
    Route = SavingsArray[i]. Node1 ∪  SavingsArray[i].Node2;
    i = i+1;
end;
While i < index do
begin
Node1 = SavingsArray[i].Node1
Node2 = SavingsArray[i].Node2
If(Node1 ∈ RouteArray(1 to RouteIndex))
                                        and
(Node 2 ∈ RouteArray(1 to Route Index))
then i = i+1
else if (node1 ∈ route array(p)where i < p ≤ route index)
then begin
totalpassenger = Σpassenger[x] | x ∈ routearray[p]
totalpassenger =passenger[node2] + totalpassenger
if total passenger ≤ x then
    routearray[p] = routearray[p] ∪ node2
    i = i+1
    end
else if(node2 ∈ routearray[p] where 1 < p≤ routeindex)
then begin
totalpassenger = Σpassenger[x] | x∈ routearray[p]
totalpassenger = totalpassenger + passenger[node1]
```

```
if totalpassenger ≤ x then
routearray[p]=routearray[p]∪node1
i = i+1
end
elseif(node1 ∉ routearray[p] and node2 ∉ routearray[p]
where 1 < p≤ routeindex)
begin
totalpassenger = Σpassenger[x] | x ∈ routearray[p]
totalpassenger = passenger[node1] + passenger[node2] + totalpassenger
if totalpassenger ≤ x then
routearray[p]  = routearray[p] ∪ node1 ∪ node2
else begin
routearray[routeindex] = routearray[routeindex] ∪ [1]
routeindex = routeiindex+1
routearray[routeindex] = node1∪node2
end
i = i+1
end
end
```

4.3 Multi Garage Vehicle Routing.

Slight modification may be made in the single garage vehicle routing problem. Letting nodes 1,2,3,4.......... M denotes the garage. A straightforward extension of the problem just discussed is to allow vehicles to reside at more than one garage and to seek minimum number of vehicles needed to cover all the task. The problem over the entire network disregarding the depot that would house each vehicle has been discussed .

Mathematical Model

$$\text{Minimise } z=\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{v=1}^{nv} c_{ij}x_{ij}$$

Subject to

$$\sum_{i=1}^{n}\sum_{v=1}^{nv} x_{ij} = 1 \qquad j = m+1, m+2 \qquad n \qquad 2.2.1$$

$$\sum_{j=1}^{n}\sum_{v=1}^{nv} x_{ij} = 1 \qquad i = m+1, m+2 \qquad n \qquad 2.2.2$$

$$\sum_{i=1}^{n} x_{ip} - \sum_{j=1}^{n} x_{pj} = 0 \qquad v = 1 \ldots\ldots\ldots\ldots nv \qquad 2.2.3$$

$$p = 1, 2, \qquad n$$

$$\sum_{i=}^{n} d_i \sum_{j=1}^{n} x_{ij} \le k_v \qquad v = 1 \ldots\ldots\ldots nv \qquad 2.2.4$$

$$\sum_{i=1}^{n} t_i \sum_{j=1}^{n} x_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{n} t_{ij}x_{ij} < T_v \qquad 2.2.5$$

$$\sum_{i=1}^{m}\sum_{j=m+1}^{n} x_{ij} \le 1 \qquad v = 1,2,3 \qquad nv \qquad 2.2.6$$

$$\sum_{p=1}^{m}\sum_{i=m+1}^{n} x_{ip} \le 1 \qquad v = 1,2,3 \ldots\ldots\ldots nv \qquad 2.2.7$$

Algorithm

The problem of routing vehicles when there are several depots is even more complex than the same problem with one depot. When there are several depots the problem appears of joining points which are serviced by individual depots. The problem of vehicle routing on a network with several depots is most often solved in two steps. In the first step individual depots are joined to groups of points to be serviced. The second step solves the problem of vehicles each depot and its corresponding group of points. The method is as follows. First the following relation is calculated for each point i to be serviced $a_i = d_1(i)/d_2(i)$ where $d_1(i)$ and $d_2(i)$ are the distance between point i first closest depot and the second closest depot. The number x is introduced in the process for which $0 < x < 1$. The value of x is arbitrarily chosen and then compared to a_i. If $a_i < x$ then the point is joined to the nearest depot. (A vehicle from the nearest depot will service it.). If $a_i > x$ then the point is left for further consideration. When all the points for which $a_i < x$ are joined to corresponding depots. The points for which $a_i > x$ are taken into consideration. These points are joined to depots as follows. Let there be two points. b &c joined to a depot Bp then we increase the route length starting from depot Bp by

$$d_{bc}a = d_{ba}+d_{ac}-d_{bc}$$

It is clear that we will join the point a to the depot where its addition will cause least increase in the route length starting from this depot. When all the points have been joined to depots in this manner., then the algorithm developed for the case of one depot is applied.

The table represents the distance between the individual nodes.

	1	2	3	4	5	6	7	8	9	10	11	12
1	∝	45	38	70	56	92	37	25	16	75	68	25
2	45	∝	25	67	48	54	16	92	97	36	48	52
3	38	25	∝	25	68	34	92	16	47	72	35	87
4	70	67	25	∝	34	47	28	34	43	66	14	36
5	56	48	68	34	∝	86	45	56	62	55	23	74
6	92	54	34	47	86	∝	54	84	59	93	75	44
7	37	16	92	28	45	54	∝	43	74	25	83	63
8	25	92	16	34	56	84	43	∝	87	37	92	74
9	16	97	47	43	62	59	74	87	∝	18	57	94
10	75	36	72	16	55	93	25	37	18	∝	65	18
11	68	48	35	14	23	75	83	92	57	65	∝	77
12	25	52	87	96	74	44	63	74	94	18	77	∝

Node i	4	5	6	7	8	9	10	11	12
$d_1(i)$	25	48	34	16	16	16	36	35	25
$d_2(i)$	67	56	54	37	25	47	72	48	52

The table represents the ratio of first nearest depot and second nearest depot.

Node i	4	5	6	7	8	9	10	11	12
a_i	.37	.85	.62	.43	.64	.34	.5	.72	.48

Take the arbitrary value for x=0.65. By stated algorithm we will allocate the nodes to the nearest garage.

Node i	depot i
4	3
6	3
7	2
8	3
9	1
10	2
12	1

ie the node 4,6,8 are joined in depot 3, the node 7,10 are joined in depot 2 and the nodes 9,12 are joined in depot 1. The nodes 5 & 11 are not joined in any depot. Since it violates the algorithm variable value x. If the above nodes are joined in any depot causes additional increase in distance In order to minimise the increase in distance we follow the following procedure.

Find out increase in distance if the node is joined in depot 1

$d_5(9,12) = d(9,5) + d(5,12) - d(9,12) = 62 + 74 - 94 = 42$

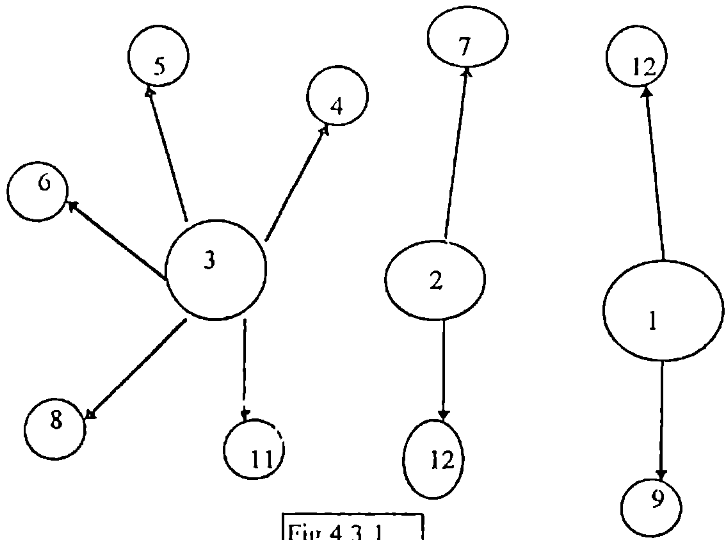


Fig 4.3.1

Pseudo algorithm

let distance [row,col] be the distance matrix

for i = 4 to row

a[i] = distance[1,i]/distance[2,i] assuming 3 depots

let b be the set,keeping some row no.route[1],route[2],route[3]etc.

for i = 4 to row begin

if ar[i] $\leq$ x then

begin

a = distance[1,i]

b = distance[2,i]

c = distance[3,i]

if a < b then

if a < c then route[1] = i $\cup$ route[1]

els if b < c then route[2] = i $\cup$ route [2]

```
    else route[3] = i ∪ route [3]
  end
  else b = b ∪ i
  end
   ∀x,  x ∈ b do begin
  Min distance = max
  ∀route[i]
  begin
  if single(route [i]) then begin
          p1∈ route[i], p2 = i    do step 8
  else ∀p1,p2 | p1 ∈route[i] & p2 ∈ route[i] & p1 ≠ p2
  begin
  distp1p2 = distance[p1,x] + disance[p2,x]- distance[p1,p2]
  if mindist > distp1p2  then  begin
  index = I, mindist = distp1p2, node1= p1,node2 = p2
  end
  end
  end
stop
```

4.4 Bus Scheduling Problem

Formulating the bus scheduling problem as a quasi assignment model. Denote i be the index set of short trips and define the linking cost C_{ij} for each feasible pair (i,j) of trips. The quasi assignment model explicitly represents the depot as a short trip which is given the index n+1. Hence cost relative to linkages from or to the depot are fixed as follows.

$$c_{i,n+1} = d = Dd/2 \qquad i = 1,2,3 \qquad n$$
$$c_{n+1,j} = d = D/2 \qquad j = 1,2,3 \ldots\ldots\ldots\ldots n$$
$$c_{n+1,n+1} = 0$$

The cost relative to unfeasible linkages are made infinite. Therefore if the trips are ordered by increasing value of starting time, the cost matrix becomes

	1	2	3	4	n	n+1
1		c_{12}	c_{13}	c_{14}	c_{1n}	d
2			c_{23}	c_{24}	c_{2n}	d
3				c_{34}	c_{3n}	d
4					c_{4n}	d
n					C_{nn}	d
n+1	d	d	d	d	d	0

The decision variable are defined as follows

x_{ij} = 1 if trip i directly connected to j

0 otherwise

$x_{n+1,j}$ 1 if the depot directly supplies a bus for trip j

0 otherwise

$x_{i,n+1}$ 1 if after trip i the bus immediately returns to the depot

0 otherwise

$x_{n+1,n+1}$ 0 number of buses remaining idle at the depot

The problem becomes

$$\min z = \sum_{i=1}^{n+1} \sum_{j=1}^{n+1} c_{ij} x_{ij}$$

$$\sum_{j=1}^{n+1} x_{ij} = 1 \quad i = 1,2,3,\ldots\ldots\ldots n$$

$$\sum_{i=1}^{n+1} x_{ij} = 1 \quad j \quad 1,2,3,\ldots\ldots\ldots n$$

$$\sum_{j=1}^{n} x_{n+1,j} = n$$

$$\sum_{i=1}^{n} x_{i,n+1} = n$$

$$x_{ij} \geq 0 \text{ and } x_{ij} \in \{0,1\} \quad (i,j = 1,2,3, \ldots\ldots\ldots\ldots\ldots n+1$$

The Graph associated with the problem

A directed graph G = (V,A) associated with the problem can be defined as follows. V=I ∪ {n+1} where n+1 stands for the depot. The arcs in A represent feasible linkages between the depot and trips with a cost c_{ij} on each arc i,j as well as linkages between the depot and trips whose cost are set to the fixed value D/2. The vertices are numbered so that only arcs (i,j) with i <j exist, except for the depot which is connected in both directions to every vertex in i. The bus scheduling problem consists of finding the minimum cost set of hamiltonion circuits passing through the depot and covering every vertex in i. This graph has a very special structure, since no return arcs exist except for the depot. Hence the problem can be approached as quasi assignment model where the typical assignment constraints are valid for all the vertices except one. This vertex corresponding to the depots is such that all the arcs incident to it have identical cost

Algorithm

step1: Reduce the cost matrix in order to obtain at least one null cost entry for each row and column

set $v_i = 0$ for $i = 1,2,3 \quad n+1$

$w_i = 0$ for $j = 1,2,3 \quad n+1$

For every row $i = 1,2,3 \quad n$ set v_i equal to the index of the first column say $j(i)$ such that

$w_{j(i)} = 0$ and $c_{j(ii)} = 0$ then set $w_{j(i)} = i$ if $j(i) \leq n$

For every column $j = 1,2,3 \quad n$ such that $w_j = 0$ and $c_{n+1,j} = 0$ set $w_j = n+1$

step2:-Set $A = 1 \leq \{ i \leq n : v_i = 0\} = \varphi$

$A' = \{1 \leq i \leq n : v_i = n+1\}$

$B' = \{1 \leq j \leq n : w_j = n+1\}$

Compute $nr = |A'|, nc = |B'|$ if $nr \geq nc$ go to 2.b

otherwise goto 2.c

b if $nr = nc$ and $|A| = 0$ goto 3

otherwise do $A = A \cup A' \cup \{n+1\}$

$B = B \cup B' \cup \{n+1\}$ goto 2.c

c Search for a column $j \notin B$ such that $c_{ij} = 0$ and $i \in A$

if such a column does not exist goto 2.d

if a column j is found with $w_j \in \{0,n+1\}$ goto 2.c

otherwise, update $A = A \cup \{wj\}$

$B = B \cup j$

repeat 2.c

d Compute $C_{min} = \min C_{ij}$ where $i \in A, j \notin B$ and update cost matrix as follows

$$C_{ij} = C_{ij} - C_{min} \quad i \in A, \; j \notin B$$

$C_{ij} + C_{min} \quad i \notin A,\ j \in B$

C_{ij} otherwise

goto 2.c

Perform a transfer of assignment $v_{n+1} = w_{n+1} = 0$

Step 3

The optimal assignment which is given either by array v or by array w has been obtained.

Example

To illustrate the algorithm described above, a small example corresponding to six short trip problem with cost matrix is given below. The symbol "-" stands for non admissible linkages and the cost incurred by each bus is 40 d(20)

	1	2	3	4	5	6	7
1			2		4	7	20
2			1			5	20
3				3	2		20
4					2		20
5						1	20
6							20
7	.20	20	20	20	20	20	0

The optimal solution is reached with one transfer of assignment and four updates over the cost matrix. After step 1 an initial assignment is obtained with cost equal to 68.

		1	2	3	4	5	6	7
	w	[7	7	1	3	4	5	0]
	v							
1	3			0*		2	5	18
2	0			0			4	19
3	4				0*	0		18
4	5					0*		18
5	6						0*	19
6	7							0*
7	0	0*	0*	20	19	20	20	0

The 0* position (i,j) means that row i is assigned to column j. $v_i = j$ and $w_j = i$. A null value is inputted to v_{n+1} or w_{n+1}

In step 2.a A = {2} B = Φ nr = 1 and nc = 2. Since nr < nc and rows 1,3,4,5,6,7 are crossed over Proceeding to 2.c the column j = 3 ∉ B is found with $C_{23} = 0$. Since $w_3 = 1 \neq 0$ then A = A ∪ {1} = {2,1}, B = {3}, that is the line over row 1 is removed and column 3 is now covered.

		1	2	3	4	5	6	7
	w	[7	7	1	3	4	5	0]
	v							
1	3			0*		2	5	18
2	0			0			4	19
3	4				0*	0		18
4	5					0*		18
5	6						0*	19
6	7							0*
7	0	0*	0*	20	19	20	20	0

Repeating 2.c no more columns j ∉ B with $C_{ij} = 0$ and i ∈ A are found. Next following 2.d a minimum uncovered value equal to 2 is found at (1,5). After updating the cost matrix and returning to 2.c , the column j = 5 ∉ B with $C_{15} = 0$ and i = 1 ∈ A is selected. Since $w_5 = 4$ update A = A ∪ {4} = {2,1,4} and B = B ∪ {5} = {3,5}

		1	2	3	4	5	6	7
	w	[7	7	1	3	4	5	0]
	v							
1	3			0*		0	3	16
2	0			0			2	17
3	4				0*	0		18
4	5					0*		18
5	6						0*	19
6	7							0*
7	0	0*	0*	22	19	20	20	0

Repeating 2.c&2.d , no more columns j ∉ B with $C_{ij}=0$ and i ∈ A, are found. Next following 2.d a minimum uncovered value equal to 2 is found at position (1,5). After updating the cost matrix and returning to 2.c the column j=5 ∉ B and $C_{15} = 0$ and i = 1 ∈A is selected. Since $w_5 = 4$ update A = A ∪ {4} and B = B ∪ {5} = {3,5}

		1	2	3	4	5	6	7
	w	[7	7	1	3	4	5	0]
	v							
1	3			0*		0	3	16
2	0			0			2	17
3	4				0*	0		18
4	5					0*		18
5	6						0*	19
6	7							0*
7	0	0*	0*	22	19	20	20	0

Repeating 2.c and 2.d no more column $j \notin B$ with $C_{ij}=0$ and $i \in A$ are found and a minimum uncovered entry value is obtained at (2,6). After updating the matrix the set A and B are modified *A={2,1,4,5}, B={3,5,6}*

		1	2	3	4	5	6	7
	w	[7	7	1	3	4	5	0]
	v							
1	3			0*		0	1	14
2	0			0			0	15
3	4				0*	2		18
4	5					0*		16
5	6						0*	19
6	7							0*
7	0	0*	0*	24	19	22	20	0

Following 2.d the minimum uncovered element 14 is found at (1,7). After updating the cost matrix and returning to 2.c the column j = 7 with $C_{17} = 0$ and $1 \in A$ is selected. In this case $w_7 = 0$ and a transfer is assignment is performed in step 2.c

		1	2	3	4	5	6	7
	w	[7	7	1	3	4	5	0]
	v							
1	3			0		0	1	0*
2	0			0*			0	1
3	4				0*	16		18
4	5					0*		2
5	6						0*	5
6	7							0*
7	0	0*	0*	38	19	36	34	0

Returning to 2.a $A = \Phi$, $B = \Phi$ and nr = nc = 2. From 2.b proceeds to step 3 where the algorithm stops with the optimal solution given by v or w having a cost equal to 87.

Pseudo Code

```
    Cost matrix C[n,n]
    Augment one more column & row to the matrix
    All newly added elements have a value d
    C[n+1,n+1] = 0 ie No buses are idle
    For row = 1 to n do begin
    Find k = min C[row,j]  j  varies from 1 to n+1
    Subract k from C[i,j]    for i = row & j = 1 to n+1
end
    For i =  1 to n+1 do begin  v[i] = 0 ; w[i] = 0 end
    For col = 1 to n do begin
    Find k = min[i,col] I varies from 1 to n+1
    subtract  k from C[i,j] for j = col  & i = 1,2,   n+1
end
    For i =1 to n  do begin
    Find the first column say j such that w[j] = 0 , C[i,j] = 0  w[j] = i & v[i] = j
    For j = 1 to n do
    if w[j] = 0 and C[n+1,j] =0 then w[j] = n+1
    Let A,B,a,b be sets
    A = { } B = φ a = { } b = { }
    For i = 1 to n begin
    if v[i] = 0 then include  i in A
    if v[i] = n+1 then include in a
    if w[j] = n+1 then include j in b
    compute nr = no of elements in a
```

```
        nc = no of elements in b
        if nr < nc then goto step 10
        if nr = nc and A = { } then goto 12 (optimal)
        else begin
        A = A ∪ a ∪ {n+1}
        B = B ∪ b ∪ {n+1}
    end
    end
        found = found2 = false
        For j = 1 to n+1 do begin
        if (j ∉ B) and (j ∈ A ) & C[i,j] = 0
        then begin
         found := true;  found2 := true
    end
        if (found2) then
        if w[j] = 0 or w[j] = n+1 goto 11
        else begin
            include w[j] ∈ A
            include j ∈ B
            found2 := false
        end
    end
        if not found begin
        cmin = max
        for i:= 1 to n+1 begin
        for j = 1 to n+1
        if (C[i,j] < max) and (i ∈ A) and (j ∉ B) then
```

C_{min} C[i,j]

end

goto 10

end

"Transform [i,j]

k = v[i]

v[i] = j

w[j] = i

search x such that ($x \notin w$) and C[x,k] = 0

if found w[k] = 0

w[n+1] = v[n+1] = 0

goto 9

Optimal assignment is given by w

4.5 Vehicle and crew scheduling

Vehicle and crew scheduling problems can be thought of as route scheduling problems with additional constraints having to do with the times when various activities may be carried out. In general vehicle and crew scheduling problems interact with one another , the specification of vehicle schedules will set certain constraint on the crew schedules and vice versa. Ideally therefore one would solve the two problems simultaneously. The input to vehicle and crew scheduling problems is a set of tasks. Each task has a specified start time, end time, start location and end location. The cost function consists of components that might include vehicle operating cost and crew operating cost. The fleet of vehicles and the set of crews may be limited and may be housed at one or more depots. The type of scheduling problems that evolves is a function of the constraints imposed upon the formation of schedules the type of tasks being serviced and the locations where these tasks must be carried out.

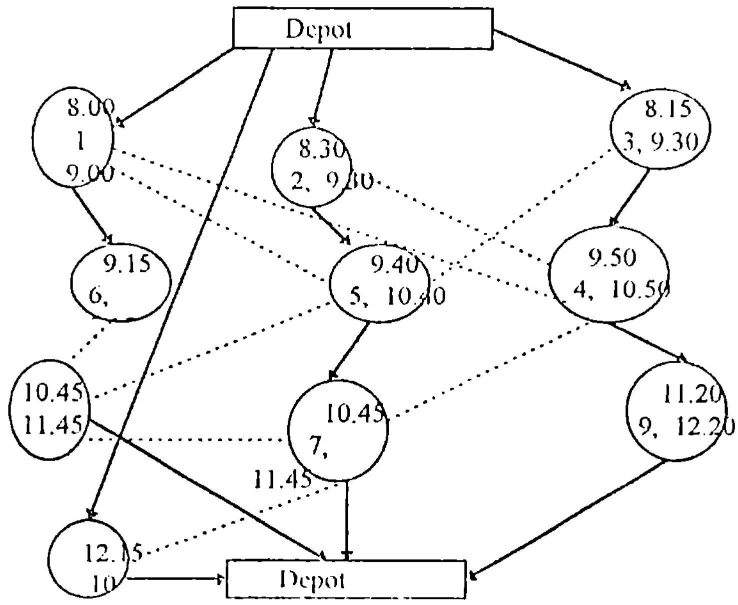


Fig 4.5.1

In the above example each task has same start and end location. (the depot). The start and end times of each task are given within the node representing the task. A solid branch between two nodes indicates that these two nodes are on the same vehicle schedule and that vehicle schedule will follow the orientation of the branch. The dotted branches indicate feasible connections which are not used in the solution. A branch is drawn from node i to j if the start time of the task j is greater than the end time of the task i and if the start time of the task j is less than or equal to end time of the task i plus one hour. There is no branch from node 6 to node 5. Since the start time 5 is less than the end time of node 6 and no branch from node 6 to node 8. Since the start time of node 8 is greater than the end time of node 6 plus one hour. Each vehicle schedule is assumed to be no longer than 8 hours.

We would examine the relationship between crew and vehicle scheduling. Each individual schedule has a set of point where one crew can relieve another. In the mass transit setting , the relief point is a designated stop along a transit line. Each vehicle schedule is split into pieces at one or more relief points. An individual crew scheduling is then obtained by grouping one or more of these pieces together. The feasibility of joining one piece with another depends not only on the end time of the first piece , relative to the start time of the second but also on the end location of the first piece relative to the start location of the second..

Scheduling works at a fixed location.

For this divide the work day into T time intervals and specify a demand for workers dt associated with each time interval $t = 1,2,3.....T$. The worker scheduling problem is to find a set of worker schedules that cover all required works. It is assumed that workers are interchangeable and that any worker can be relieved at the end of any time period and that any worker can start at the beginning of any time period. To define a combined crew or vehicle scheduling problem the nature of the crew movements will be considered. Each line has one or more relief points which are stops along the line where one crew may relieve another. Thus a crew period of work on a single vehicle starts and ends at either a relief point or at the garage.

Mathematical model

The set of tasks with each task i characterised by a start location SL_i a start time ST_i and end of location EL_i and an end time ET_i For ay pair of location $L_1$and L_2 we denote by $TM(L_1,L_2)$ the time to travel from L_1 and L_2 denotes the location of the depot. The node set N consists of a nod representing each task together with a source node s and the link node t. The arc set A is obtained by inserting an arc from the task node i to task node j if it is feasible for a single vehicle to service both task. Further an arc is inserted from s to each task node and from each task node to t. These arcs represents trips to and from the depot. Each (s,t) path through this network represents a possible schedule for a single vehicle. The number of duties generated is equivalent to number of variables. The objective of the set partitioning is to select a subset of duties from all variables so as to minimise the cost of covering work.

Furthermore it is assumed that the total work to be covered in the bus schedule can be expressed as a number of shorter increments of works. An increment of work is defined as work between two adjacent relief on a single block.

$$\min z = \sum_{j=1}^{n} c_j x_j$$

Subject to

$$\sum_{j=1}^{n} a_{ij} x_{ij} = 1 \qquad (i = 1,2,3 \quad ....m)$$

where $x_j = 1$ if duty j is retained in the solution

$= 0$ otherwise

c_j is the cost of duty j taking in to account the time spent on a bus plus any allowances for such thing as over time.

$a_{ij} = 1$ if trip j covers crew I, 0 otherwise

It is clear that unless the problem to be solved are sufficiently small, in terms of number of buses and number of driver duties required or unless steps are taken some how to make them smaller than they were, that set partition would not be feasible because of the enormous number of rows and columns in the mathematical formulation. The original problem can be decomposed to a number of smaller problems, that set partitioning can be used to solve the sub problems and that the resulting solution can then be combined to form a total solution.

The set partitioning problem is defined as

$\min \{cx \mid Ax=e \; x_j = 0 \text{ or } 1 \;\; \forall j \in N\}$

Where A is mn matrix of zeros and ones,

C is an arbitarary n vector

e =(1,1,1,1,1,1,1,1,1) is an m vector

and N = { 1,2,3, n }

If the rows of A are associated with the elements of the set M ={1,2,3, m } and each column a_j of A with the subset Mj of those i ∈ M such that a_{ij} 1.

A partial list of application of set partitioning is crew scheduling, vehicle routing, information retrieval etc.

Algorithm

If R_i is a null vector for any i then no solution exists.

If R_k is a unit vector with a one in column t then xt =1 in every solution and At and all rows

R_i such that a_{it}=1 may be deleted since they are covered by At. Also every column Ap , P≠ t

such that $a_{it} = a_{ip}$ =1 may be deleted, inorder to overcover row Rio

Arrange the columns A_j j∈ P into m lists as described above. Set W = T = ϕ. Z(w)=0, V=Q

and Z = ∞ (Z = value of the best solution)

Let V = Q - T and i = min (i | i ∈v). Set an indicator that tells us to begin at the top of list i .

Begin at the indicated position in list I and examine , in order of increasing cost the columns of

the list. If we find a column j such that $T \cap S_j = \phi$ and $Z(w) + C_j \leq Z$ goto 7

There are no optimal solutions containing the columns in the current partial solution. If w ≠ ϕ

terminate. If W = ϕ let k be the last element included in w. Set w = w - {k}. Z(w) - C_k and

T= T - S_k. Let I = number of the list in which column k is stored. and set an indicator at the position below column k in list i. Goto step 5.

Set $w=w \cup j$, $Z(w) = Z(w) + C_j$ and $T = T \cup S_j$. If T = Q goto 8. otherwise goto 4

A new best solution is found. Set Z =Z(w) and save w. Goto step 6.

The given data are

	1	2	3	4	5	6	7	8	9	10
1	0	0	1	0	1	0	0	0	0	0
2	0	0	0	1	1	1	0	0	0	0
3	0	1	0	1	0	0	0	1	1	0
4	0	0	1	1	0	0	0	1	0	1
5	1	1	0	0	0	0	1	0	1	0
6	1	1	0	1	0	1	0	1	0	0
c[j]	18	22	14	36	17	14	8	24	11	7

The data are organised as shown in the table

Column	Sj	Cj	Field in list
1	(5,6)	18	5
2	(3,5,6)	22	3
3	(1,4)	14	1
4	(2,3,4,6)	36	1
5	(1,2)	17	1
6	(2,6)	14	2
7	(5)	8	5
8	(3,4,6)	24	3
9	(3,5)	14	3
10	(4)	7	4

Let P1 = ϕ, Q = (1,2,3,4,5,6) , P = (1,2,3,4,5,6,7,8,9,10)

w=T= ϕ, Z = ∞

step 2 V = (1,2,3,4,5,6) i = 1

step 3 S_j=S3 = (1,4)

step 4 w= 3 Z(w) =14, T =(1,4)

step 2 V = (2,3,5,6) i = 2

step 3 S_j = S6 = (2,6)

step 4 w = (3,6) Z(w) =28 T = (1,2,4,6)

step 2 V = (3,5) i =3

step 3 S_j = S9 =(3,5)

step 5 w = (3,6,9) Z(w) = 42 T = (1,2,3,4,5,6) = Q step 6 w (3,6,9) Z =42

step 4 w = (3,6) Z(w) = 28, T (1,2,4,6), i = 3

step 3 No S_j found

step 4 w = (3), Z(w) = 14, T = (1,4), i 2

step 3 No S_j found

step 4 w = ϕ, Z(w) = 0, T = ϕ, i = 1

step 3 $S_j = S_5$ = (1,2)

step 5 w = (5), Z(w) = 17, T = (1,2)

step 2 V = (3,4,5,6) , i = 3

step 3 $S_j = S_9$ = (3,5)

step 5 w = (5,9), Z(w) = 31, T = (1,2,3,5)

step 2 v = (4,6), i = 4

step 3 $S_j = S_{10}$ = 4

step 2 V = 6, i = 6

step 3 No S_j found

step 4 w = (5,9), Z(w) = 31, T = (1,2,3,6), i = 4

step 3 No S_j found

step 4 w = (5), Z(w) = 17, T = (1,2), i = 3

step 3 $S_j = S_2$ = (3,5,6)

step 5 w = (5,2), Z(w) = 39, T= (1,2,3,5,6)

step 2 V = 4, i = 4

step 3 No S_j found

step 4 w =(5), Z(w) = 17, T = (1,2), i = 3

step 3 $S_j = S_8$ = (3,4,6)

step 5 w = (5,8), Z(w) = 41, T = (1,2,3,4,6)

step 2 V = (5) i = 5

step 3 No S_j found

step 4 w = (5), Z(w) = 17, T = (1,2) i = 3

step 3 No S_j found

step 4 $w = \phi$ $Z(w) = 0$, $T = \phi$, $i = 1$

step 3 No S_j found

Step 4 Terminate. the only optimal solution is $x_3 = x_6 = x_9 = 1$, all other $x_j = 0$, $z = 42$

4.6 Optimizing Program Modules and software Tool

In our country planning and operational management of public transport has become increasingly complex , the ability to respond to changing demand for travel. The planning and scheduling problems faced by public transport is unimaginable. At the strategic level routing and frequency decisions are made in response to changing trends in demand. Clearly these decisions cannot be altered too often because of inconvenience to the travelling public. However it is undesirable for routes and frequencies to remain unchanged over a long periods. Manual scheduling is a skilled and time consuming job. To tackle the complexities of these problems at all levels a computer based decision support system has been developed to assist public transport authority. The computer based support system for vehicle scheduling and crew scheduling has been discussed.

Once the desired frequencies of service that should operate along each route through the day have been determined a set of time-tables be constructed and vehicles are scheduled to these time-tables. The main objective is to meet the desired service levels at minimum cost which is often interpreted as using the minimum number of vehicles. These are mainly concerned with providing a reliable service and avoiding an excessive amount of dead running.

The problem of crew scheduling may be stated as one of finding the set of crew duties of least total cost that states a given bus schedule. In practice, however the scheduler usually knows or has a good idea of the number of duties he is prepared to use in order to cover a bus schedule. In these cases it may be impossible to cover every trip of the bus schedule without minor adjustments being made to some of the times at which the trips are made. Such adjustments are usually preferable to and more cost effective than using extra crew. Thus a better formulation is to obtain as near to a complete crew schedule as possible using a specified number of duties for a given bus schedule. A duty schedule is to be acceptable to both traffic management and crews. It must possess other characteristics such as minimum work time of a duty and times at which meal breaks may be taken. Thus in determining the validity of a duty it is often required to take the following factors into account.

Start time
length of work portions
finish time of work potion
duty spread
finish time
length of work for the whole duty

In the area of transportation planning and traffic control , development in Information Technology have presented great opportunities. Current developments in Computer Technology in relation to software systems making the computers easier to use and providing the user with greater access to relevant computer held data in the form of databases. The computer linked via a "local area network" in which user has to access to the data stored on the work station as well as his own data. In this case a distributed database is involved in which the relevant data for the application is distributed over a number of computers rather than residing in just one computer. The workstations of the type described above are being common. Such systems enable decision makers to obtain computer assistance in many of the decision areas in which they are involved. Thus greater case of access to direct computing power and different databases together with software systems that recognise that the managers problem are inter linked, offers integrated support to decision making

Data required for the system

Garages:- This simply gives a correspondence between a two digit code for a garage and its name, for brevity in describing other items related to garages.

Places:- This gives a correspondence between a three character code and the actual place name for certain points within the urban area which are frequently referred by a code rather than by full description. Such points are start point, terminal point, crew change point, fuel filling point and so on.

Route itinerary:- This contains a list of the streets down which the bus must travel in order to make the outbound journey, together with a separate list for the return journey. It also contains information regarding which garages serve the route and crew change points

Time table data:- A route schedule is the kernel of a set of timetables, all of which have been created using same route itinerary and garage route instructions. It contains the timing details relating to a specific route itinerary. In particular it gives the times of the first and the last service to be run, and trip times in each direction for specified time phases for each time phase it also contains target figures for average headway, layover time at each terminus which are necessary for automatic creation of time tables.

Time table:- A time table is a collection of running boards which go together to make up a complete service on a specific route for particular days. Each running board refers back to the relevant set of base data from which it was created. Time-tables for different routes are grouped together when crews swap from one route to another.

Running Board:- A running board is a description of the work to be done by a specific bus. It shows the time that is required for the bus to leave and finally return to the garage and the departure and the arrival times at each of the termini served throughout the day.

Function of the system

Automatic time-table creation and crewing is handled by mathematical models. It takes a set of requirements and produces its best result within those requirements.

Interactive time table creation or amendment

The system provides interactive screens for the creation and amendment of all of the base data associated with the time-table. Most of this base data will be used across a wide range of time-tables. The creation of a time-table can also be done interactively using the base data within the system

Using the time-table editor, new time-tables can be drawn up or existing one be modified. The program allows graphic representation of the input data in the form of a time-table. The user is provided with tools to select any options available on the screen.

1. Delete a journey
2. Insert a journey
3. Re time a journey
4. Break a link between two Journeys
5. Form a link between two journeys
6. Create a new route variant
7. Create a new bus
8. Alter a garage allocation of a bus
9. Link a journey to garage
10. List all unlinked journeys
11. Alter a bus number
12. Display running board
13. Exit

Output:-A series of time-table analysis can be produced for any time-table or crew schedule

Duty list:-Shows the details of each duty in the time-table which includes the service time, paid time, and split duties.

Scheduling list:-Which lists each of the running boards in the timetable in bus number order and their departure time from the terminus.

Employees or Garage :-It will give all details about the crew pay particulars/ Garage information and so on.

4.7 Transit Management Behaviour Model

Transit management usually has relatively little information on the demand curve which faces for its services. It has information on the actual flow on its various routes. Information is available on the actual origin and destination pattern of traffic or in the other demand characteristics such as trip length distribution. It will be assumed that transit management has no control over the running time of buses from one end of the route to other. This time being determined by the transit vehicles acceleration and speed capabilities and the prevailing speed of traffic on the roads comprising the route. In this context, the only decision variable open to management is to plan how frequently to operate buses. First, buses would be operated with a frequency at least equal to the frequency considered acceptable for the transit service.

$f \geq F = 1/H$ where

where f= frequency of bus departures in one direction, buses per hour

F= maximum acceptable frequency

H= maximum acceptable headway hour per bus

since the volume of passenger could exceed that which can be accommodated in buses operated at the minimum frequency, the frequency also has to be greater than or equal to that which is required to accommodate the passenger flow during any particular period

$f \geq p/q$

where p = passenger flow point peak load point on route , passenger per hour

q = capacity of bus

Assuming that management operates the minimum number of buses in order to meet these two service related criteria, the frequency of the buses are

$f = \max(F, p/q)$ that minimises the cost of operating the service, since the number of buses, operators and vehicle -miles would be minimised for the given route conditions.

A further complication is that the rate of passenger flow may vary within any period. This would lead to non uniform headway if more than the minimum frequency service is required. If management policy permitted non uniform head-ways and if a constant headway is required , the headway would be adjusted for the peak passenger flow with in each schedule period. This would lead to an average load , less than the vehicle capacity and could be incorporated in the model by appropriate selection of the value of q. It also should be noted that the number of bus trips made over the entire day must be an integer, there by possibly requiring a slight adjustment in the frequency of operation in each period. Similarly variations in the passenger flow during any one period will be ignored.

One important aspect of the supply of service would be the travel time from Origin to Destination for any particular traveller including the waiting time as well as one vehicle time. Assuming uniform or random passenger arrivals at the origin stop and the constant head-ways the average waiting time would be one-half the head way

$w = (1/2)h = 60/(2f)$

where h = bus headway minutes per bus

As the passenger traffic increases above that amount required to fill the minimum frequency of buses, travellers waiting time would decrease. Assume that the volume of traffic is sufficient to fill all the vehicles at the minimum frequency the average number of passenger past the peak load point will be independent of the traffic volume. Assuming the Origin-Destination pattern of traffic does not vary with volume, the same number of passengers will board each vehicle regardless of volume. Therefore it may be assumed that the number of stops and the dwell time is independent of volume and hence the travel time will be independent of volume. In this case travel time between any points i and j equals

which may not be made. Such an adjustment will not be considered $t_{ij} = v_{ij} + ½ h$ where

v_{ij} = vehicle running time between stops i and j plus one-half the dwell time required for alighting at j minutes

t_{ij} = total travel time between stops i and j minutes

Two points regarding the v_{ij} term should be made. First in the case where the passenger traffic is less than sufficient to fill the minimum number of vehicle trips operated. (the minimum frequency), then the travel time presumably will be slightly less, reflecting a diminished value of v_j, due to fewer stops and dwell time for loading and unloading. Of course this assumes a timetable adjustment by the management which may not be made. Such an adjustment will not be considered further. The position of v_{ij} due to the time required for unloading at stop j is also likely to be very small. The perceived average travel time for any traveller between stop i and j will be

$$t_{ij} = v_{ij} + w\ 60/(2f) + 30\ w/\max(F, p/q)$$

where

t_{ij} = total perceived travel time between i and j

w = relative weight of waiting to on board vehicle time

v_{ij} = vehicle running time from i to j

4.8 Design, Analysis and Decision - Making in Vehicle routing & Scheduling

The Concept of Mobility Accessibility and Land use

Mobility means the possibility to move from one place to another constituting a freedom sought by all citizen, enabling them to maintain or expand choices in everyday life. It permits them to choose an employer or a work place not located in the vicinity of their home, to go to shopping where they want and where the prices are the best. The private car meets this concern perfectly well and this is the reason for its wide popularity.

Accessibility means ease of access, is a concern more closely related to the production and distribution of products or services. In trade and non trade sectors, players try to place their establishment in such a place to minimise transportation cost or to minimise the amount of time their clients spend travelling At a time when the public transport was the main answer to the mobility demand of the people, the competition was responsible for the success of the town center for commercial and office establishments. More recently, the development of automobile mobility has re-oriented the search for accessibility by distributors of goods and services to more peripheral locations.

The combination of consumer's mobility in private cars and the search for accessibility on the producers side therefore induced a process of de-localization of housing as well as the production and commercial functions which contributes to strengthening the dependence on cars for satisfying the need for mobility.

The effects of this behaviour of a greater search for mobility by the consumers and for a better accessibility by the producers combine to multiply themselves and lead to the congestion of road infrastructure.

4.8.1 URBAN MOBILITY AT DEAD LOCKS

Inhabitants of cities, particularly those in metropolitan cities, its surroundings and to a lesser extent , those of the rest of the country, feels that the transportation system which is at their disposal in order to travel around the city or to get the city imposes higher and higher restrictions on their mobility. These restrictions vary according to the case concerned.

Some have seen the time it took them to travel to work by car doubled in less than ten years due to the congestion. Moreover once they arrive close to their destination they cannot find a place to park their car.

Children of some people do not have effective public transport at their disposal to reach their school, and their parents are thus obliged to drive them to school and back. Finally people who do not have. a car because of their age, a physical disability or insufficient revenues, which means those who are called "captive" users of public transport are more and more limited in their possibility to travel where they want and when they want because of their suppressor of services due to increased scarcity of public transport users.

THREATS TO PROSPERITY

The case of contracts and exchange of goods and services are the basis of the urban society prosperity. Any hindrance to these contracts and exchanges has a negative effect on this prosperity. At the same time the comparative advantages of housing in the cities are decreasing, which reinforces the tendency of better off inhabitants to look for a place to live in the surrounding area of the city where as the poorest inhabitants tend to accept being left in the centers. The rise in population also the cause of increase of private cars in road.

Restoring mobility by healing symptom of road traffic congestion, that is, trying to suppress the traffic bottlenecks, increasing the capacity of the main road networks and creating new parking lots is no longer realistic in the long term. Experience has shown that in any city where measures were taken to increase the fluidity of traffic, the initial problem reappear after some years later in an even or more acute form. The two main dangers of the current trends are

1) The deterioration of the general accessibility of the city because this is an immediate danger for the source of its economic prosperity
2) The excess of automobile mobility in the city because the problem it creates for the land and environment is threat to the population.

With regard to these two dangers, the reactions that can be considered by the regional public authorities must be selective; these are

The selective improvement of accessibility in the public transport and the selective restriction of accessibility by private cars. The total geo-graphical area of the state is 38.85 lakh ha. The increase in population and the vehicle growth tend to grab the area utilised for agriculture. Land under non-agricultural use was 8.6% in 1998 –1999 and has increased to 9.1% in 1999-2000. The following table shows that the land status and vehicle growth in Kerala

Land use pattern in Kerala (Area in ha.)

Sl.no	classification	1998-99		1999-00	
		Actual	%	Actual	%
1	Total Area	3885497		3885497	
2	Forest	1081509	27.80	1081509	27.80
3	Non-agricultural uses	333822	8.6	354390	9.1
4	Barren and un-cultivated	28341	0.70	28341	0.70
5	Grazing land	682	0.02	253	0.007
6	Land under miscellaneous	20200	0.50	18515	0.50
7	Cultivable waste	62710	1.60	58279	1.50
8	Fallow other than current	31537	0.80	32138	0.80
9	Current fallow	68022	1.80	72166	1.90
10	Net area sown	2258674	58.10	2239363	57.60
11	Area sown more than once	657831	16.90	762341	19.60
12	Total cropped area	2916505	75.10	3001704	77.20
13	Cropping intensities	129		134	

Table 4.8.1.1 (source:- Economic Review 2001- SPB, Pattom)

Category –wise growth of Motor vehicles in Kerala since 1980

	Type of vehicle	1980	1985	1990	1995	2000	2001
1	Goods vehicle						
a	Four Wheeler	20128	36699	51530	88180	135058	142168
b	Three wheeler	993	4170	9576	12072	28385	31688
2	Buses						
a	Stage carriages	8705	12910	15056	19988	23537	25161
b	Contract carriages	842	2324	5234	14874	35351	40520
3	Cars & wagons						
a	Cars	54381	75731	116676	155150	257796	282996
b	Station Wagons	196	507	849	--	--	--
c	Taxi cars	17780	28189	37638	54681	71581	75628
d	Jeeps	7023	12972	24351	37774	67497	69261
4	Three wheeler						
a	Auto-rickshaws	7397	24383	58165	103465	227895	248350
b	Motorised cycle rickshaws	38	34	62	77	58	58
5	Two wheelers						
a	Motorised cycle	58	73	70	63	1124	1124
b	Scooter/bike	50493	11629	248374	496873	1020797	1151735
6	Tractor Trailer	1864	2104	2661	3388		
7	Tractors	1892	3089	4115	5045	7782	8177
8	Tillers	469	1118	1927	4626	4763	4763
9	Trailers	260	416	580	763	1506	1576
10	others	1735	2891	4190	8903	27107	28680
	Total	174254	319259	581054	1005922	1910237	2111885

Table 4.8.1.2 (Source:- Economic Review -2001, SPB, Pattom)

From the tables [4.8.1.1 & 4.8.1.2] we can deduce that, to house the 2,111,885 vehicles needed an area of 42,237 ha.. The state has the road network of 1.141 lakh km. Further growth level poses a threat to grab the agricultural area. The agricultural area declined year by year for inhabitation. All these parameters will affect prosperity. The following suggestion have been made to overcome the land problem

1) Improve the accessibility of the periphery by developing suburban services of the national railway.
2) Reduce parking possibilities on streets in the city centre.
3) Implement an effective system of restricting parking along roads to residents living in housing areas without garages.
4) Promote combined " Bicycle- public transport travel "
5) Restrictions for private cars in a limited level

4.8.2 Vehicle Routing and Scheduling problem on Networks

Designing vehicle routes is a problem which is often encountered. Often vehicle must call at a certain number of nodes in the transportation network, or must go through specifically determined by branches in the networks. Collecting garbage, mail, cleaning streets, distributing news papers, scheduling plane crew and bus drivers for certain jobs are daily problems encountered by traffic and transportation experts.

Depending on whether vehicles must go along certain branches or call at certain nodes in the network, problems are differentiated into edge covering problems or node covering problems respectively. These problems have been greatly studied in recent years and one example " travelling sales man "(the best- known node covering problem) has been the subject of hundreds of papers throughout the world.]

In order to solve different variations of vehicle routing problems or crew scheduling problems, diverse techniques are applied, including dynamic programming and combinatorial programming (the branch and bound method). The heuristic-procedure is also used to solve many problems of this type. In the majority of cases, the application of classical mathematical programming methods required a great deal of computer work which rapidly increases with the increase in the number of nodes on the transportation. For this reason many combinatorial problems are solved with heuristic - procedures.

Problem concerning vehicle routing, determining the optional position for the vehicle depot within transportation system crew planning belong to the class of so called combinatorial problems, can be those dealing with sequences, assignments, choice making or any combination of these problems.

For sequencing problems, there is usually a series of n elements whose objective functions reach an extreme value. This can be used to distribute n drivers onto n buses as well.

Classification of Vehicle routing and Scheduling on Transportation Network

Different versions of vehicle routing and scheduling problems on transportation network appear in all fields of transportation, depending on specific problem at hand. Well-organised vehicle routing or a well designed schedule can markedly contribute towards a decrease in transportation costs and increase the quality of transportation services.

Vehicle routing problems do not have time constraints as to when services in different nodes should start or finish contrary to this scheduling problems contain time fixed in advance within which service in each node must be completed.

In cases when a certain time interval is planned for performing services in each node, we usually speak of a combination vehicle routing and scheduling problem starting with specific characteristics which describe certain types of routing or scheduling problems.

1. Time to service in a specific node or on a specific branch.
   a) time to carry out service fixed in advance (scheduling problem).
   b)service in certain nodes must be carried out within a specific time interval(combined routing and scheduling problems)
   c)There are no specific demands regarding service in each node(vehicle routing problem).
2. Number of vehicle depots in the network
   a) there is only one depot in the network
   b) the network contains several depots
3. Size of vehicle fleet available
   a) the fleet contains only one vehicle
   b) the fleet contains several vehicles
4. Type of vehicles in the fleet
   a) all vehicles in the fleet are the same
   b) the fleet contains several vehicles

5. Nature of service demands

a) deterministic demands appear in the network

b) stochastic demands for service appear.

6. Location of service demands

a) service demands appear in the networks' needs

b) service demands appear in the networks' branches

c) service demands appear in nodes and branches

7. Maximum allowed vehicle route length

a) all vehicles in the fleet have the same maximum allowed route length

b) some vehicles have different maximum allowed route length

c) there are no constraints regarding the maximum allowed vehicle route length

8. Costs

a) variable

b) fixed

9. 9. Operations carried out

a) picking up

b) delivering

c) picking up and delivering

10. Objective functions on which optimisation is based

a) minimising route costs

b) minimising total fixed and variable costs

c) minimising the number of vehicles needed to carry out transportation operation

4.8.3 Vehicles on Network and Graph Theory

Consider the graph G(N,A) whose set of nodes N can be divided into two subsets S and T so that $s \cup t = N$ and $S \cap t = \emptyset$. Decompose the acylic oriented graph in to chains. That is divide the set of nodes into sub set of nodes which do not have common element. The given graph can always be decomposed |N | number of chains each one made up of only one node. The fig [4.8.3.1] shows an acylic oriented graph whose set of node contains nodes x_1, x_2, x_3, ...,x_{20}.

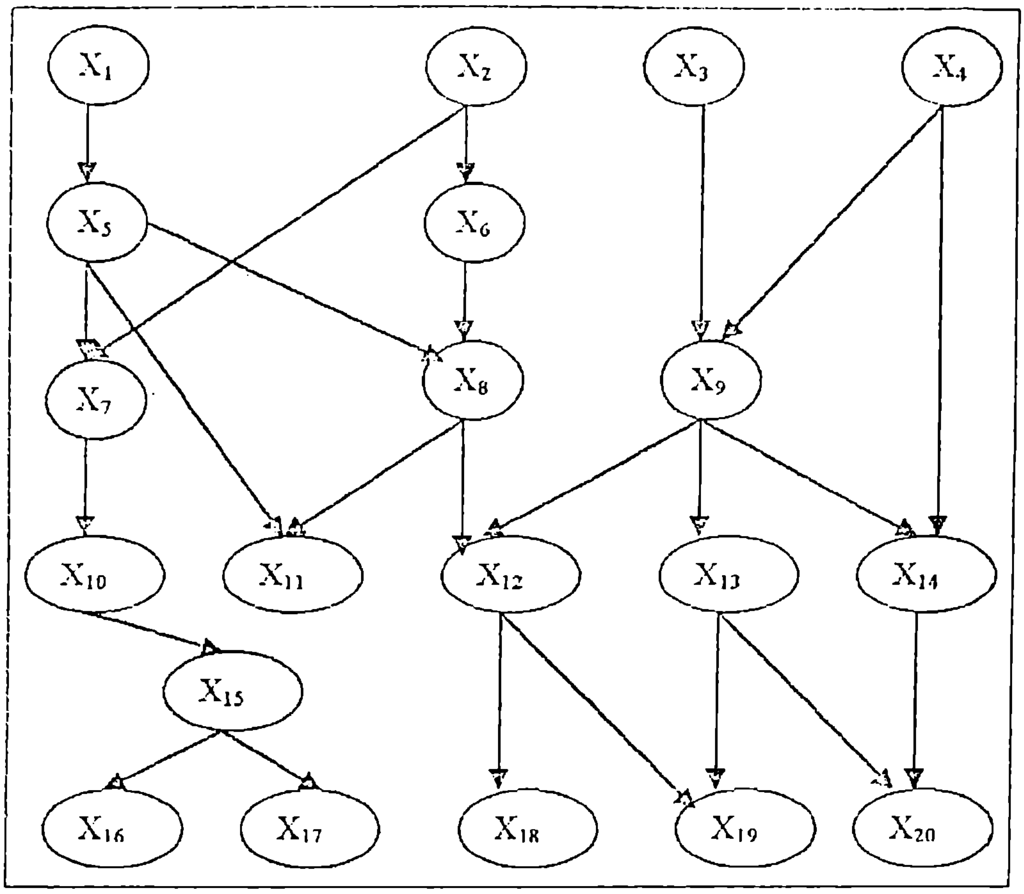


Fig. 4.8.3.1

The decomposition of the graph is in fig [4.8.3.2]. The graph is decomposed in to chains. Three chains are made up off only one node. (chain x_6, chain x_{17}, chain x_{19}). An acylic oriented graph can be decomposed into chains in several ways. It is clear that the larger the number the nodes included into the individual chains, the smaller the number of chains into which the graph is decomposed. The connection between determining the minimum number of vehicles needed to service of a given schedule on

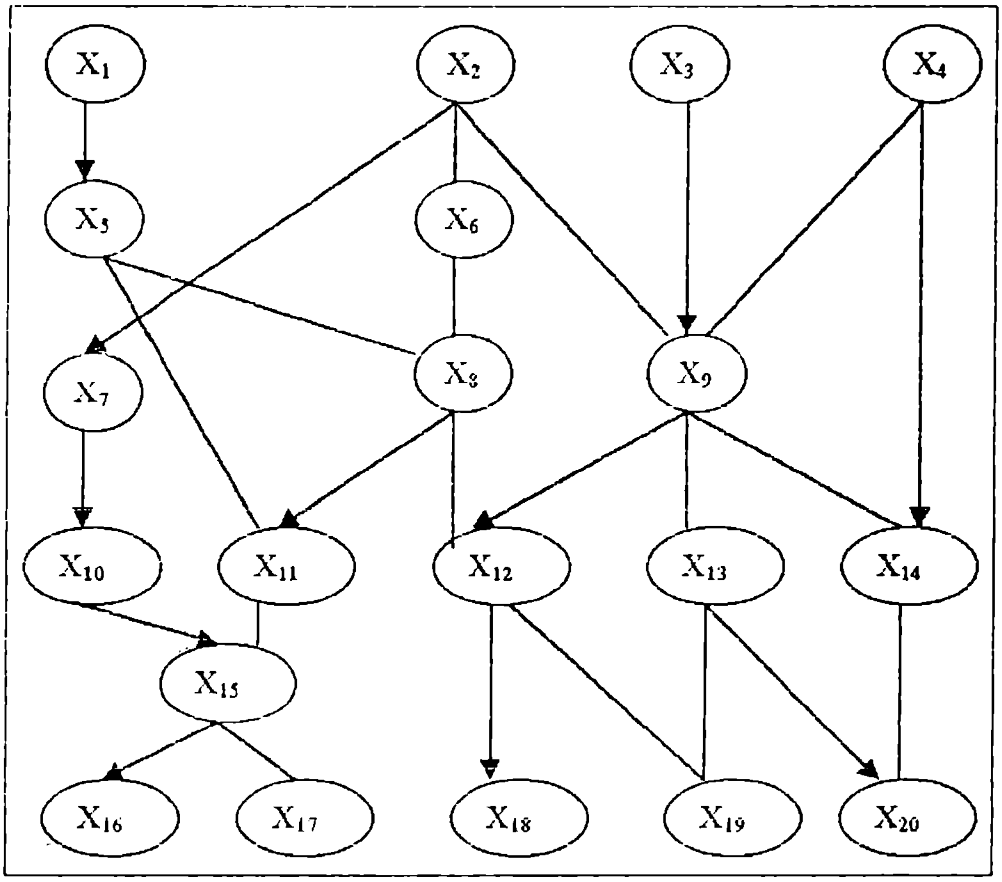


Fig. 4.8.3.2

the transportation network is determining the minimum number of chains into which an acyclic oriented graph ca be de composed. The fig [4.8.3.3] shows a space – time diagram with

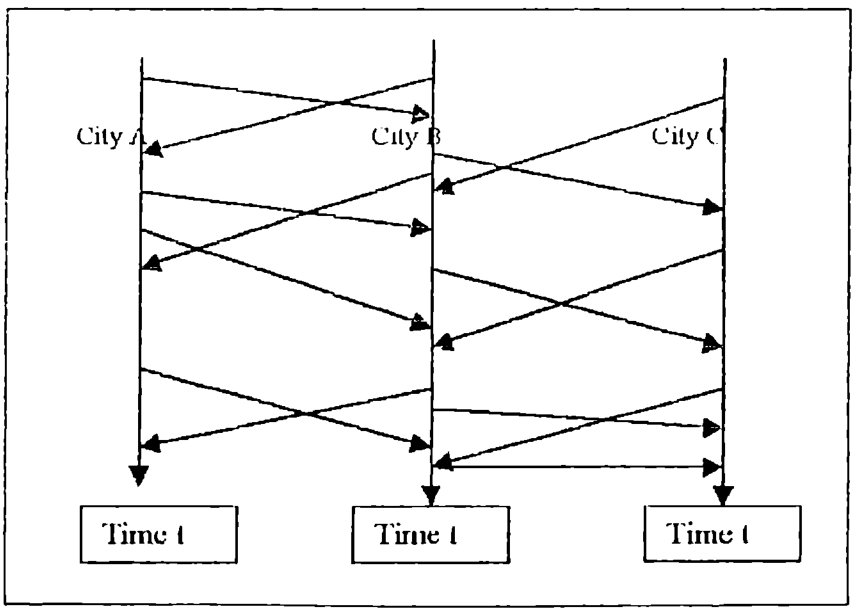


Fig 4.8.3.3

14 trips to be carried out between cities A & B and cities B & C and Cities C & B and cities B & A. We can distribute the vehicles to carry out 14 trips in different ways. A vehicle can take trip1 then trip 5 then trip 7 and finally trip 10.

In the network a branch is directed from node x_I towards node x_j only if trip x_j can be made after trip x_I. x_j can be made after trip x_I if trip x_j starts in the city where trip x_I finishes and if the planned time trip x_j is after the finishing time of the trip x_i. Since chains represent vehicle routes the minimum number of vehicles needed to service a given schedule on the transportation network equals the minimum number of chains into which the acyclic oriented graph can be decomposed with each node where the trips to be made.

Let us examine acyclic oriented graph G(N,A). The number of chains into which the graph is decomposed with |c| . The chains are denoted respectively by k =1,2,3, |c|. The number of nodes belonging to the k^{th} chain is denoted n_k. The total number nodes in graph G is denoted by |N| . Since every node belongs to only one chain.

We have $n_1 + n_2 + n_3 \quad + n_k = |N|$ and further

$$|N| = \sum_{k=1}^{|c|} n_k = \sum_{k=1}^{|c|} n_k + (c - c)$$

$$|N| = \sum_{k=1}^{|c|} n_k - 1 + |c|$$

The number of branches in every chain is 1 less than the number of nodes in the chain. Therefore if n_k is the number of nodes in the chain k then $n_k - 1$ is the number of branches in chain k. It is clear that $\sum_{k=1}^{|c|} n_k - 1$ is the number of branches belonging to the chains in to which the graph G is decomposed. We denote this number with |D|. This means $|D| = \sum_{k=1}^{|c|} n_k - 1$ or $|N| = |D| + |c|$. Since the number of nodes |N| of the graph G is fixed we can minimise the number of chains |c| into which the graph G is decomposed by maximising the number of the branches |D| which belong to the chains. We construct bipartite graph $G(S,T,A^*)$ which corresponds the graph G(N,A) as shown in the figure [4.8.3.4].

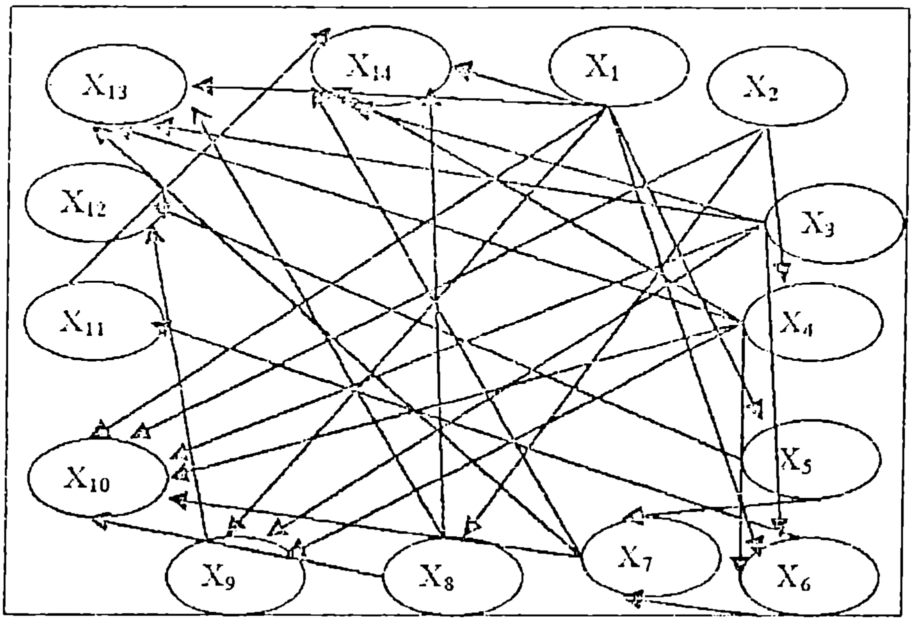


Fig..4.8.3.4 Nodes represents planned Trips

The corresponding bipartite graph is given in the fig [4.8.3.5].

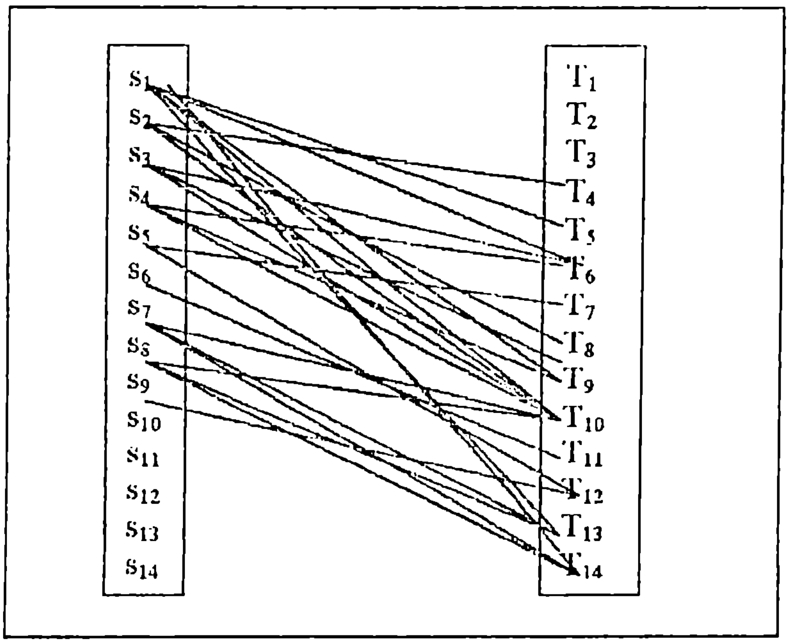


Fig. 4.8.3.5 Bipartite graph G(S,T;A*)

For example trip x_5 can be made after trip $x_1$there is a branch in the corresponding bipartite graph G(S,T,A*) which joins node S_1 with t_5. We assume that the capacity of every branch in the bipartite graph $(s_i, t_j) \in A^*$ equals 1. If branch (x_i, x_j) from starting graph G belongs to one of the chains into which the graph G has been decomposed then we note that the flow with a value 1 goes through the corresponding branch on the bipartite graph. If branch (x_i,x_j) is not part of any of graph G'^{s} chains then we note that there is no flow through the corresponding branch (s_i,t_j) on the bipartite graph or that the flow value equals 0.

If the bipartite graph $G(S,T,A^*)$ contains a flow along branch (s_i,t_j) then branch (x_i, x_j) of graph $G(N,A)$ is part of a chain into which graph G has been decomposed. This means that the total number of branches belonging to graph G's chains |D| equals the total number of flows going through the bipartite graph. By minimising |c| or maximising |D| we maximise the total flow through the bipartite graph $G(S,T,A^*)$ keeping in mind that a flow with a maximum value of 1 can appear from every source s_i and a flow with a maximum value of 1 can arrive at every sink t_j.

4.8.4 MULTI CRITERIA ANALYSIS

Many decision problems specially those arising in the infrastructure development of the transport sector today are complicated by the need to consider a range of uses, such on those relating to environment, quality of life substainability of development, and by the participation of divergent interest groups. To reflect this majority of the transport infrastructure development problems has to deal with multiple objectives and methods which are designed to assist groups of decision makers. The evaluation process have to integrate the quantitative and qualitative aspects of transport infrastructure development. The general frame of the multi criteria analysis consists of the following steps.

Identification of

- The policy maker(s)
- Public elected officials
- Private sector agencies rep.
- Appointed government officials
- Experts of financial institutions
- The decision levels
  - Government (national)
  - Regional (local)
  - local (company level)
- The time horizon of decision
  - Operative

Strategic

Political

The purpose of decisions

To find best solution

Resource allocation

Identification of the alternative courses of action

(variants for development)

land use

community and neighbourhood for proximity to city centre

proportion of mixed land use

proportion of undeveloped land area.

Density of population

location of social institutions

location of neighbourhood boundaries

economic impacts

employment

income

business activity

residential activity

effects on property

regional and community plans

resource consumption

social impact

displacement of people

accessibility of facility and services

effects of terminals on neighbourhoods

special user groups

physical impacts

aesthetics and historic value

infrastructure

impact on the ecosystems

air quality (Co, H2, No, sulphur oxides, particles)

noise

vibration

used land

public safety

dead

seriously injured

slightly injured

energy

assignment of value for each attribute to measure the performance of the alternatives on that attribute

determination of a weight for each attribute

taking a weighted average values assigned to that alternative

making a provisional decision

performing sensitivity analysis to see how robust the decision is changes in the figures supplied by the decision maker.

Over viewing the multi-criteria decision process it is also useful to describe a few basic definition and theoretical considerations.

In the analysis we implicitly make a number of assumptions about the decision makers preferences. These assumptions can be regarded as the axioms of the procedure, in that they represent a set of postulates which may be regarded as reasonable. If the decision maker accepts the axioms and if he or she is rational the he or she should accept the preference rankings. The generally considered axioms are

Decideability

: Ability to decide which of two options is to be preferred.

Transitivity means if a>b and b>c then a>c.

Summation if a>b and b>c then the strength of preference of a over c must be greater than the strength of a over b. Finite upper and lower bounds for value in assessing values we assume that the best option and the worst are not infinite.

In the multi-criteria evaluation model the decision making problem can be described as follows. There are n alternatives with m criteria. This type of decision situation contains (one or) more decision makers who are to evaluate and rank a finite number of alternatives with respect to a finite number of criteria

Let A_1 A_2, -------------A_n denote the alternatives and C_1, C_2, -----------C_m the criteria. Assume that the data related to the alternative are known. Let $a_{ij} >= 0$, C= 1-----------------m, j=1-------------n denote the value of j^{th} alternative with respect to c^{th} criterion. Any assessment of transport infrastructure to be developed calls for a whole range of criteria. The multi model transport systems comprise a set of basic elements like

Infrastructure network (mode specific)

Interface (stations, ports)

Auxiliary (for operation and maintenance)

Rolling stock, vehicles, fuels

Human capital

Information (information system and telematics including passenger information, booking, reservation, scheduling)

Finance(availability revenue, subsidisation)

Given five different development alternatives A_1, A_2, A_3, A_4, A_5 evaluated according to four different criteria C_1, C_2, C_3, C_4. The weight of the criteria i is w_i, where $\sum_{i=1}^{n} w_i = 1$ $w_i \geq 0$ $\forall i$ The scores fo. a five categories evaluation process are given in the tables 4.8.4.1 and 4.8.4.2

	C_1	C_2	C_3	C4
Very good	90	80	70	60
Good	70	65	60	55
Medium	50	50	50	50
satisfactory	30	35	40	45
Bad	10	20	30	40

Table 4.8.4.1

	C_1		C_2		C_3		C_4	
A_1	vg	90	m	50	G	60	m	50
A_2	m	50	v	80	S	40	v	60
A_3	s	30	g	65	V	70	m	40
A_4	g	70	s	35	M	50	m	50
A_5	b	10	b	30	G	60	m	50

Table 4.8.4.2

Where max| h_j – hi | is the maximal difference of scores between the alternatives j and i considering all criteria and H = 90 – 10 = 80 = constant. Their values are given in the table 4.8.4.3

	A_1	A_2	A_3	A_4	A_5
A_1		C_{12}=60% d_{12}=37.5%	C_{13}=50% d_{13}=18.7%	C_{14}=100% d_{14}=0%	C_{15}=100% d_{15}=0%
A_2	C_{21}=40% d_{21}=50%		C_{23}=80% d_{23}=37.5%	C_{24}=40% d_{24}=25%	C_{25}=80% d_{25}=25%
A_3	C_{31}=50% d_{31}=75%	C_{32}=20% d_{32}=25%		C_{34}=50% d_{34}=50%	C_{35}=90% d_{35}=12.5%
A_4	C_{41}=10% d_{41}=25%	C_{42}=60% d_{42}=54.2%	C_{43}=50% d_{43}=37.5%		C_{45}=50% d_{45}=18.7%
A_5	C_{51}=60% d_{51}=100%	C_{52}=20% d_{52}=50%	C_{53}=10% d_{53}=25%	C_{54}=60% d_{54}=75%	

Table 4.8.4.3

The assortation graph for ranking the alternatives can be calculated starting from 100% value of preference(P) and 0% value of disqualification (Q)

P=100% / C_{14}=C_{15}=100% Q=0% / d_{14}=d_{15}=0%

At this level the order of the alternatives can be identified between A_1-A_4 and $A_1 \rightarrow A_5$

Decreasing the level of preference to the next discrete value of Cij (P=90%) and increasing the level of disqualification to the next discrete level of dij (Q=12.5%) gives

P=90% / C_{35}=90% Q=12.5% / d =12.5%

And the order of alternatives can be identified between A3-A15. The next level of P & Q can be chosen like below

P=80% / C_{23}=80% Q=37.5% / d_{23}= 37.5%

The order of the alternatives can be identified between A_2-A_3. To stop the ranking procedure at preference level of 100% and disqualification level of 40%

P>−100% / C_{12}−100% Q<−40% / d_{12}−37.5%

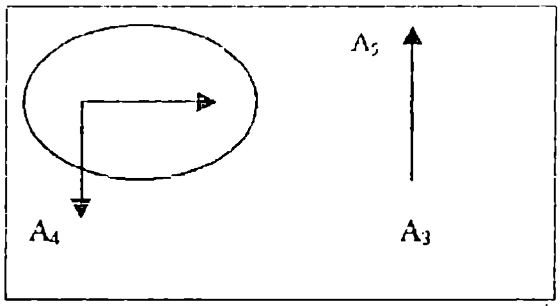


Fig 4.8.4.1

The order of alternatives can be identified between A_1-A_2. The final assortation graph is given in fig 4.8.4.1.The graph means that only A_1 and A_4 alternatives are included in the final rank with the order ,first is A_1, the second is A_2 others cannot be ranked at this level of preference and disqualification.

4.8.5 MATHEMATICAL MODEL

The weight $W_2 >= 0$ be assigned to k^{th} decision maker to the c^{th} criterion by $A_1, A_2 \ldots\ldots An$, the n alternatives by $C_1, C_2 \ldots\ldots Cm$, the m criteria and by $D_1, D_2, \ldots\ldots D_l$, the l group members .ie. decision makers. The procedure then includes the following steps.

The value a_{ij} given by the k^{th} decision maker D_k for alternative Aj the criteria C_i is determined. The normalized linear combination is calculated at each simple sub tree N'

$$\mu^k{}_j = \frac{\Sigma i\ t\ N^{il}\ Wi^k\, aij^k}{\Sigma i\ t\ N^l\ Wi^k} \qquad j = 1\ldots.n\ , k = 1\ldots l$$

Proceeding on the tree towards the roots weight on the higher level criteria are combined with values obtained from one level below.

To find individual score by the K th decision maker D_k for A_j will be the value assigned to the root and the alternative will be ranked in descending order.

Group ranking can be considered, let denote by $V(w)i^k$ the voting power assigned to D_k, for his or her .weighing on any criterion Ci and by $V(q)c^k$ the voting powers assign to D_k for his or her criteria $C_{ij} = 1 \ldots.n$, $k = 1\ldots..l$.For calculating the group utility from the alternative A_j the preference weight will be aggregated into group weights W_i at each criteria by

$$\Sigma k{=}1^l\ V(W)c^k\ Wc^k$$

$$W_i = \frac{\Sigma_{k=1}^{l} V(W)c^k \, Wc^k}{\Sigma_{k=1}^{l} V(W)c^k} \qquad c = 1 \ldots m$$

The group qualification Q_{ij} at each leaf criterion C_{ij} for each alternative A_j is given by

$$Q_{ij} = \frac{\Sigma_{k=1}^{l} V(q)c^k \, aij^k}{\Sigma_{k=1}^{l} V(q)c^k} \qquad i \in N^l \; j = 1 \ldots\ldots n$$

4.8.5 Rail traffic control

Within rail traffic system (inter city, high speed rail networks), the real time control problems are essentially related to surveillance and safety issues. On the other hand for off line planning and scheduling problems (allocation of locomotives to trains, crew scheduling, time plan) combinatorial optimisation problems are mostly involved in the optimal utilisation of available infrastructure like bus crew scheduling.

An important safety related task within rail traffic systems is collision avoidance (on a line or at node). To this end, traditional measures that are based on robust Electro-mechanical devices implementing simple but efficient logical (boolean) functions are quite broadly utilised. Within modern systems the implementation of electronic devices (micro computers) with high redundancy architectures (to satisfy high reliability requirements) become increasingly common .

For surveillance of rail traffic from a central operation room, advanced telematic evices (radio transmission, satellite communications,) tools are increasingly employed. Major surveillance task include

Monitoring of the movement of each train in the network

Verification of the proper functioning with respect to the time schedule

Intervention in case of severe disturbances so as to re normalise the traffic

The task of re-normalisation of traffic is fairly complex and largely manually executed as yet. Involved real time sub tasks include

prediction of the duration of an occurred incident that blocks a line.

Routing of affected trains in the network, if necessary

Suitable time schedule modification to address current abnormal situation.

The main goal of these actions is the traffic normalisation. ie the quick and smooth return to the initial time schedule. Automatic control and artificial intelligence methods may be adopted for a partial automation.

4.8 Conclusion:

The program first generates all the trips specified in the headway files and sorts them by terminal point and time Arrival at terminal point are linked to subsequent departure from the same point, if the idle time between these two events does not exceed the time given in the run file for maximum durable lay over. Not all the arrivals and departures can be linked in this way; those remaining after this stage are examined to see whether buses can be moved between terminals to form links.

Preference is given to moving a bus to another terminal in the same point group to make a link. If this can not be done the program finds an unmatched arrival and an unmatched departure and looks for a route which either extends the arrival journey forward to the departure point or extends the departure journey backwards to the arrival point.

Failing this the program searches for a route which contains both the arrival and departure points. If such a route exists and there is a sufficient time then a new journey in service is inserted by the program. There may be several departures which could be linked in one of these ways to a particular arrival. If this is the case a departure is chosen according to the above order of priority, giving preference to an earlier departure at the same level of priority. The linking of an arrival and a departure by this set of rules does not take place and if there is a time for the bus to return to the garage and remains there for the specified minimum break period.

Following the matching of arrivals and departures, blocks of journeys have been formed. If there is more than one garage each block is examined to see whether it starts and finishes near the same garage. The blocks are linked to that garage which minimise the total running time from the garage to the start of the block, and from the end of the block to the garage. The garage linking journey are inserted live or dead according to the instructions in the run file. The schedule is now complete and the time tables have been created together with running boards, the crew relief time for each bus, and the other output documents requested by the user.

CHAPTER 5

CONGESTION MANAGEMENT SYSTEM

5.0 Introduction

Digital computers may be used to control urban road traffic in the modern day. The computers may be connected by data transmission lines to the traffic signal controllers at street junctions to form what are now called TMS. Thus it becomes possible to centrally co-ordinate the traffic signal timings over a wide area to check if the signals operate. Thus traffic may be diverted towards the free space and away from congested areas. It seems probable that in the foreseeable future, increases in the real cost of vehicle fuels, lost causes by accident, environmental impact and decreases in the cost of computer equipment will add further impetus to the development and use of TMS.

At present area coordinated signals are being set in fixed time cycles. A set of time determines when the signal should turn green and red within a cycle time, that is common to all signals in one area of a town. Typically the cycle time is between 40 and 120 seconds and any one set is operated for at least 15 minutes and up to several hours. Fixed time plans are pre calculated to suit the average conditions that the traffic controller expects to occur at different times of the day and days of the week. In most areas separate fixed time cycles are calculated for the morning and evening peak conditions and for the period between these peaks. Now it sense that fixed time cycles may not give the best standard of the control if the information on average flow is seriously erroneous, if there are large , random variations in flow or if unexpected events, such as an accident occurs by chance.

In practice, the costs of collecting and analyzing traffic data are such that, in many towns the information on average flows within junctions is sparse and frequently many months or years out of date and is thus of low quality. Even if the traffic information is accurate a poor standard of control may still result if the method of calculating fixed time is defective. Now a days in our country fixed time cycles are calculated by manual means for example by drawing time distance diagrams that depict the progression of a group of vehicles through several adjacent signals. Because of the complexity of the traffic movements, in most cases it is preferable to use computers to search in a systematic way for signal timings that minimize total traffic delay, stops, fuel consumption. Also it is a heavy burden for the traffic control staff who must periodically collect traffic data and check their operation.

Furthermore, unless vehicle detectors are installed throughout the street net work, the computer has no information on the current traffic situation and so can not be programmed automatically to perform traffic management functions such as restricting the number of vehicles that can enter the congested areas. Vehicle detectors may be located on the approaches to all signalized junctions to collect data on traffic behaviour. It is possible to use other types of vehicle detectors that provide similar information on vehicle presence. The detectors may be located as for upstream as possible from the signal stop line. The data from detectors on vehicle flow and occupancy are stored in the computer in the form of cyclic profiles for each approach to a signal. The accuracy of the profile depends upon the values assumed for turning flows, discharge from queues, and effective green time and so on. On each section of street, cyclic profiles are stored and the traffic model makes a prediction of current value of the queue of vehicles. The computer controls the red and green signal time according to the queue.

Widespread congestion in a town can occur where the queues, which may start from just one bottleneck, grow in length and extend backwards in to up stream junctions. There may then be a loss of capacity at the upstream junctions which causes further congestion on other streets. Eventually, it is possible for the congestion to spread over large areas of a town. To reduce the possibility of this happening it is desirable to control traffic signals so that their associated queues do not extend into adjacent junctions. The traffic model measures the proportion of the cycle time that the detector is occupied by a queue. This information is used by the computer to alter the signal timings so as to reduce the likelihood of the queue blocking the upstream junctions.

The queues, number of stops and level of congestion depend upon many factors but of the particular importance is the number of vehicles that are attempting to travel through the area under control. In this chapter various mathematical models for traffic flow, area network control, and queuing analysis have been discussed with proper computer algorithm for calculating, estimating and predicting the queues and traffic flow. The control of traffic by using Neural Network and Artificial Intelligent support systems have been discussed.

The study of traffic flow was established only after motorized road vehicles began to appear in huge numbers. The fact that traffic volumes were about to reach the capacity of road infrastructure was the initiating factor for the scientific analysis of traffic flow. As early as 1934 Mr. Green Shields published a work named " A study of traffic capacity". It is remarkable how very early it was established that traffic flow must be a stochastic process. A historic document revealing this early cognition is a paper by Mr. Adams in 1936 en titled "Road traffic considered as a random series"

It was a considerably more significant approach to base the deterministic description of traffic flow in dense traffic on the movement of single vehicle. This idea , first published in 1950 by Reuschel, was initiated by an American team. They carried out a multitude of experiments with car drivers, looked at the distance behaviour between following vehicles and tried to model the observed behaviour using the so-called car following - equations. A significant new development was undertaken in Germany a wide manner in 1974, who developed an approach to simulate car following behaviour in a more realistic way.

In whatever way traffic flow will be modeled or described, the fundamental relation ship between traffic volume, traffic density and mean speed will always be valid. Vehicular traffic theory can be broadly separated into two branches. Traffic Flow Theory and Car Following Theory. Traffic flow theory is concerned with finding relations between three fundamental variables of traffic flow which are velocity v, density ρ and flow q. Only two of these variables are independent since they are related through $q = \rho v$

6.1 Traffic studies

The basic traffic studies are necessary to gather facts on traffic conditions. They must be set up and carried out so that the information is timely, reasonably accurate and unbiased. Studies may be classified as administrative which is the assembly of data already available in office which involves existing condition.

Inventories

An inventory is the accounting, tabulation, listing information, and describing existing the conditions. Some inventories such as traffic, parking facilities and transit route may require frequent updating.

Traffic Generators

Schools
Parks
stadium
Shopping centres
office complex

The use of automated data processing systems will facilitate accessibility to most inventories and data files especially in larger agencies. The details of intersections or street and high way sections should be readily available.

Volume studies

Many traffic analysis such as those relating to capacity, design, channelizion and delay are most specifically involved with peak hour conditions. Many situations can be adequately described by counts that are taken during the single heaviest hour of morning traffic and of evening traffic. Hourly variation graphics show the present daily traffic.

Statistical distribution of traffic characteristics

Statistical distributions are useful in predicting events where events occur randomly. An event is said to occur randomly when each small increment of time or space is equally likely to contain an event. The event may be the arrival of vehicle at a left turn lane in a rural intersection. As long as the flow rate q is constant each half second interval is as likely as every other half second interval to contain a vehicle arrival. As a further example, consider the distribution of occupied parking spaces in a parking garage. The event (a parked vehicle) would be random if every space had the same opportunity of being occupied. This would probably not be a random event because the spaces near the pedestrian exit and on the lower levels are more likely to be occupied than spaces more distant from the pedestrian exist. Statistical distribution can be classified into two general categories.

1. Counting or discrete distribution
2. Interval or gap distribution

Counting Distribution

Counting of the number of events that occur in a given time period is relatively easy and has been a use useful tool of the traffic controller. Four counting distributions are discussed below.

1. Poisson distribution
2. Binomial Distribution
3. Negative Binomial distribution
4. Generalized Poisson distribution

Poisson Distribution

Poisson distribution is used to describe discrete events that are truly random and was the first distribution to be applied to an analysis of vehicle flow. The distribution is stated as

$$P(x) = \frac{m^x \ e^{-m}}{x\,!} \qquad \text{where } x = 1,2,3,4,$$

$$P(x) = \frac{(\lambda t)^x \ e^{-\lambda t}}{x\,!} \qquad \text{for traffic counting}$$

where P(x) = probability that x vehicles will arrive during a counting interval t

λ = average rate of arrival veh/s = flow rate

t = duration of each counting interval

m = λt average no. of vehicles during a period of duration t

e = natural base of log.

The only parameter that must be estimated is the arrival rate λ. Consider the 1 hour flow of 120 vehicles. The average minutes count in this case is 2 vehicle per minute since t = 1. Substitute 2 for λ and t =1. The equation becomes

$$P(x) = \frac{2^x \ e^{-2}}{x\,!} \quad \text{since x is varying from } 0,1,2,3$$

For each value of x a P(x) is determined. Knowing the number of counts per study period the P(x) value can be used to calculate the f(x) value, which is the number of minutes expected to have a flow of exactly x vehicles. The procedures are followed and the results are tabulated in the table.

The test data has been taken from Ernakulam city.

x	Observed frequency	P(x)	Theoretical frequency	fx
1	3	0.0035479	.86	3
2	5	0.001427	3.48	10
3	10	0.348779	8.51	30
4	16	0.6696	16.33	64
5	30	0.11549	28.17	150
6	35	0.13165	32.12	210
7	30	0.14449	35.24	210
8	30	0.13867	33.83	240
9	25	0.11833	28.83	225
10	23	0.09087	22.17	230
11	14	0.06345	15.48	151
12	11	0.0406	9.90	131
13	7	0.02399	5.85	94
14	2	0.1316	3.21	28
15	3	0.067380	1.67	45

If the number of vehicles (x) counted in intervals of time (t = 1 minute) and the observed frequency of each interval is taken, the values of P(x) are determined , the theoretical frequency is $\sum f(x) . P(x)$.

The above equation can be rewritten with x values of 0,1,2,3,

$$P(0) = \frac{(\lambda t)^0 \; e^{-\lambda t}}{0} = e^{-\lambda t}$$

$$P(1) = \frac{(\lambda t)^1 \; e^{-\lambda t}}{1\,!} = \frac{\lambda t}{1}[P(x = 1)]$$

$$P(2) = \frac{(\lambda t)^2 \; e^{-\lambda t}}{2\,!} = \frac{m^2 \; e^{-m}}{2} = \frac{m}{2}[P(x = 2)]$$

$$P(3) = \frac{(\lambda t)^3 \; e^{-\lambda t}}{3\,!} = \frac{m^3 \; e^{-m}}{3} = \frac{m}{3}[P(x = 3)]$$

So P(x) can be calculated as follows

$$P(x) = \frac{m}{x}[P(x - 1)]$$

Generalized Poisson Distribution

The generalized Poisson Distribution is given by

$$P(x) = \sum_{j=xk}^{(x+1)k-1} \frac{e^{-\lambda t} \lambda t^{j}}{j\,!}$$

x	f	fx	fx^2	p(x)	Theoretical frequency
1	3	3	3	0.0055	2
2	5	10	20	0.0187	5
3	10	30	90	0.043	11
4	16	64	256	0.756	18
5	30	150	750	0.1079	27
6	35	210	1260	0.1302	32
7	30	210	1470	0.1365	33
8	30	240	1920	0.1270	31
9	25	225	2025	0.1065	26
10	23	230	2300	0.0814	20
11	14	154	1694	0.0573	14
12	11	132	1584	0.0375	10
13	7	91	1183	0.0229	6
14	2	28	392	0.0131	3
15	3	45	675	0.0071	2
Σ	244	1822	15622		

$\bar{x} = 7.46$ $s^2 = 8.299$ $k = 66$ $p = 0.0898$ $q = 0.102$

$p(0) = p^k = 0.898^{66} = 0.00082$

5.2 Interval Distributions

If the vehicles arrive in some pattern by the counting distribution it follows that there is also a distribution of intervals or gaps between the arrivals of successive vehicles. These intervals will be in time units and are continuous variables as opposed to discrete variables obtained from counting distributions.

Negative Binomial Distribution

If the mean flow changes during the counting period, giving a mean / variance ratio which is substantially less than 1.0 we use negative binomial distribution. The negative binomial distribution follows from the binomial distribution and gives the probability that x failures occur in n trials before getting k events. Consider a traffic stream made up of a mixture of cars and trucks. The passage of each vehicle is a trial. The passage of the passenger car is will be considered a successful event. The negative binomial distribution may be used to give a probability that six passenger cars will be observed (x = 6) before the third truck arrives (k = 3). The total no of trials n = x + k, (6+3) =9

$$P(x) = \frac{(x+k-1)!}{x!(k-1)!} p^k q^x \qquad x = 0, 1, 2, 3$$

calculations may be simplified by noting that

$$P(0) = p^k \text{ and } P(x) = \frac{x+k-1}{x} q\, P(x-1)$$

The mean value of x is

$$\bar{x} = kq/p \text{ and the variance of x is } kq/p^2$$

Assume that 10% of the vehicles in a traffic stream are trucks (p = 0.10, q = 0.90). Then the probability that six passenger cars (x = 6) will be observed before the third truck (k = 3) is observed can be derived by the equation

$$P(6) = \frac{6+3-1}{6!(3-1)!}(0.1)^3 (0.9)^6 = 0.0149$$

The values of p and k are estimated as follows.

$$p = \frac{\bar{x}}{s^2} \qquad k = \frac{\bar{x}}{s^2 - \bar{x}^2}$$

Binomial Distribution

As traffic flow becomes congested, the flow becomes more uniform, so that the variance of the number of vehicles per interval is decreased and the ratio of mean/ variance is greater than one. Binomial distribution is fit for the case.

$P(x) = n_{cx} p^x q^{n-x}$

The two parameters of the binomial distribution are estimated as follows

$$p = \frac{\bar{x} - s^2}{\bar{x}} \quad \text{and } n = \frac{\bar{x}}{\bar{x} - s^2}$$

where $\bar{x}$ = mean number of events per n second

s^2 = variance in the no. of events

x	frequency	f x	f x^2	p(x)	Theoretical frequency
1	3	3	3	0.000938	
2	5	10	20	0.000449	2
3	4	12	36	0.0142	4
4	6	24	96	0.03335	8
5	10	50	250	0.062	16
6	20	120	750	0.095	24
7	30	210	1470	0.123	32
8	33	264	2112	0.138	36
9	32	288	2592	0.136	36
10	35	350	3500	0.1197	32
11	30	330	3630	0.0947	25
12	30	360	4320	0.0679	17
13	15	195	2535	0.0444	12
14	8	112	1568	0.0266	7
15	1	15	225	0.0147	3
Σ	262	2343	23077		

$x = 8.94$ $s^2 = 8.13$ $n = 98$ $p = 0.09$ $q = 0.91$

$p(0) = q^n = 0.91^{98} = 0.0000968$

The interval distributions are

1. Negative exponential Distribution.
2. Shifted Exponential Distribution
3. Erlang Distribution

Negative Exponential Distribution

Negative exponential distribution is the interval distribution directly from the Poisson distribution. If there is no vehicle arrived n a time interval t there will be a head way h of at least t seconds between the last previous arrival and the next arrival.

$P(0) = P(h \geq t) = e^{-\lambda t}$

But $\lambda = \frac{1}{\bar{t}}$ where $\bar{t}$ is the mean head way. So we may express in $p(h \geq t) = e^{-t/\bar{t}}$ The cumulative distribution function of the negative exponential may be written as

$P(h \leq t) = 1 - e^{-\lambda t} = 1 - e^{-t/\bar{t}}$

The probability density function of the negative exponential distribution is

$f(t) = \lambda e^{-\lambda t}$ with mean and variance $\bar{t} = 1/\lambda$ $s^2 = \frac{1}{\lambda^2}$

$\lambda t = 7.46$

$\lambda = 0.1243$

$p(h \leq 0s) = 1-e^{-\lambda t} = 1 - e^{-1243(0)} = 0.000$

$p(h \leq 1s) = 1-e^{-\lambda t} = 1 - e^{-1243(1)} = 0.1168$

$p(h \leq 2s) = 1-e^{-\lambda t} = 1 - e^{-1243(2)} = 0.2201$

$p(h \leq 3s) = 1-e^{-\lambda t} = 1 - e^{-1243(3)} = 0.3112$

$p(h \leq 4s) = 1-e^{-\lambda t} = 1 - e^{-1243(4)} = 0.3917$

$p(h \leq 5s) = 1-e^{-\lambda t} = 1 - e^{-1243(5)} = 0.4628$

$p(h \leq 6s) = 1-e^{-\lambda t} = 1 - e^{-1243(6)} = 0.5256$

$p(h \leq 7s) = 1-e^{-\lambda t} = 1 - e^{-1243(7)} = 0.5810$

$p(h \leq 8s) = 1-e^{-\lambda t} = 1 - e^{-1243(8)} = 0.6300$

$p(h \leq 9s) = 1-e^{-\lambda t} = 1 - e^{-1243(9)} = 0.6733$

$p(h \leq 10s) = 1 - e^{-\lambda t} = 1 - e^{-1243(10)} = 0.7115$

and so on. The probability between the head way interval is

(0 & 1) is 0.1168

(1 & 2) is 0.2201 - 0.1168 0.1033

(2 & 3) is 0.3112 - 0.2201 = 0.0911

(3 & 4) is 0.3917 - 0.3112 = 0.0805

(4 & 5) is 0.4628 - 0.3917 = 0.0711

(5 & 6) is 0.5256 - 0.4628 = 0.0628

(6 & 7) is 0.5810 - 0.5256 = 0.0554

(7 & 8) is 0.6300 - 0.5810 = 0.0490

(8 & 9) is 0.6733 - 0.6300 = 0.0433

(9 & 10) is 0.7115 - 0.6733 0.0382

The corresponding graph is plotted below to compare the probability for various distributions.

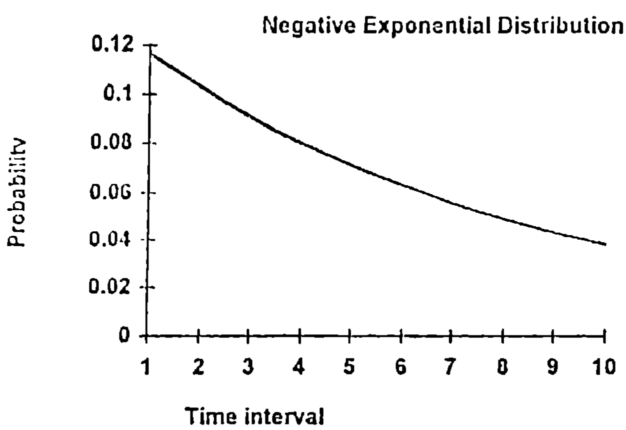


Fig. 5.2.1

Shifted Negative exponential Distribution

Small time head ways are very unlikely to occur in vehicles observed in a single traffic lane, but the negative exponential distribution predicts the highest probabilities for short time head ways. One approach is to introduce a minimum allowable headway. A region in which head ways are prohibited. This can be accomplished by shifting the negative exponential distribution to the right to a distance c. For the shifted negative exponential function the cumulative distribution is

$$P(h \le t) = 1 - e^{-[t-c/\bar{t}-c]} \text{ for } t \ge c$$

The probability density function is

$$f(t) = \begin{cases} 0 & \text{for } t < c \\ \dfrac{1}{\bar{t} - c} e^{-\frac{t-c}{\bar{t}-c}} & \text{for } t \ge c \end{cases}$$

mean and variance $\bar{t} = \dfrac{1}{\lambda}$, $s^2 = (\bar{t} - c)^2$

The mean headway $\bar{t}$ can be calculated from observed frequency and the shifted parameter c is assumed.

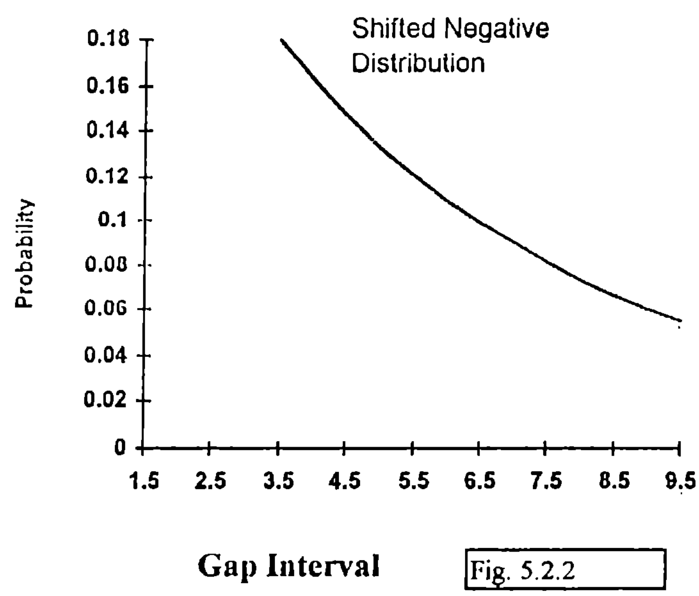


Fig. 5.2.2

Erlang Distribution

The shifted negative exponential distribution makes a probability of a head way less than c equal to zero. A more desirable distribution, one that would have a very low but not zero, probability of a small headway is the Erlang Distribution

$$f(t) = \lambda e^{-\lambda t} \frac{\lambda t^{k-1}}{k-1\,!}$$

The mean and variance are

$$t = \frac{k}{\lambda} \qquad s^2 \quad \frac{k}{\lambda^2}$$

The cumulative distribution function of Erlang distribution is

$$P(h \le t) \; 1 - e^{-\lambda t}\sum_{n=0}^{k-1}\frac{(\lambda t)^n}{n!}$$

For k = 1 this reduces to

$1 - e^{-\lambda t}$ the negative exponential distribution.

For k = 2 $\qquad P(h \le t) = 1 - e^{-\lambda t}[1 + \lambda]$

For k 3 $\qquad P(h \le t) \quad 1 - e^{-\lambda t}[1 + \lambda t + \lambda t^2 /2]$

For k = 4 $\qquad P(h \le t) = 1 - e^{-\lambda t}[1 + \lambda t + \lambda t^2 /2 + \lambda t^3 /3!]$ and so on

5.3 Vehicular Speed

Speed is a fundamental measurement of the traffic performance on the high way system. Most analytical and simulation model models of traffic predict speed as the measure of performance given the design, demand, and control of the highway system. Speed is also used as an indication of level of service, accident analysis and traffic noise and so on. The wide spread availability of radar, nearly all speed checks may be conducted with such an electronic equipment. The radar meter operates on the principle that a radio wave reflected from a moving target undergoes a frequency change proportional to the speed of the target. Graphic records may be available to provide a permanent record.

Speed Characteristic under Uninterrupted flow conditions

Consider standing at a point along a highway facility during a relatively short period of time under uninterrupted flow conditions that is a location away from intersections. The speeds of the individual vehicles are measured and recorded. The sample mean and sample variance of these un-grouped speed observation would be

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n - 1}$$

where $\bar{x}$ = sample mean speed

x_i = speed of the i^{th} vehicle

s^2 = sample variance

In most cases the speed observations are grouped. The frequencies of each speed level or speed interval are determined from the series of individual vehicular speeds. Observed spot data has been collected from various stations of Ernakulam city and calculations are given below.

$$\bar{x} = \frac{\sum_{i=1}^{g} f_i x_i}{n} \qquad s^2 = \frac{\sum_{i=1}^{g} f_i x_i^2 \quad 1/n[\sum_{i=1}^{g} f_i x_i]^2}{n-1}$$

where g = no. of speed groups

i = speed group i

f_i = no. of observation in speed group i

x_i = mid point speed group i

N = total no. of speed observations

x	f	cum	%	fx	fx^2
20-22	6	6	1.63	126	2646
22-24	0	6	1.63	0	0
24-26	15	21	5.706	375	9375
26-28	7	28	7.608	189	5103
28-30	84	112	30.43	2436	70644
30-32	36	148	40.21	1116	34596
32-34	9	157	42.66	297	9801
34-36	36	193	52.44	1260	44100
36-38	10	203	55.16	370	13690
38-40	64	267	72.55	2496	97344
40-42	80	347	94.29	3280	134480
42-44	0	347	94.29	0	0
44-46	7	354	96.19	315	14175
46-48	14	368	100	658	30926
48-50	0	368	100	0	0
Σ	368			12918	466880

$\bar{x} = 35.10$ $s^2 = 36.55$

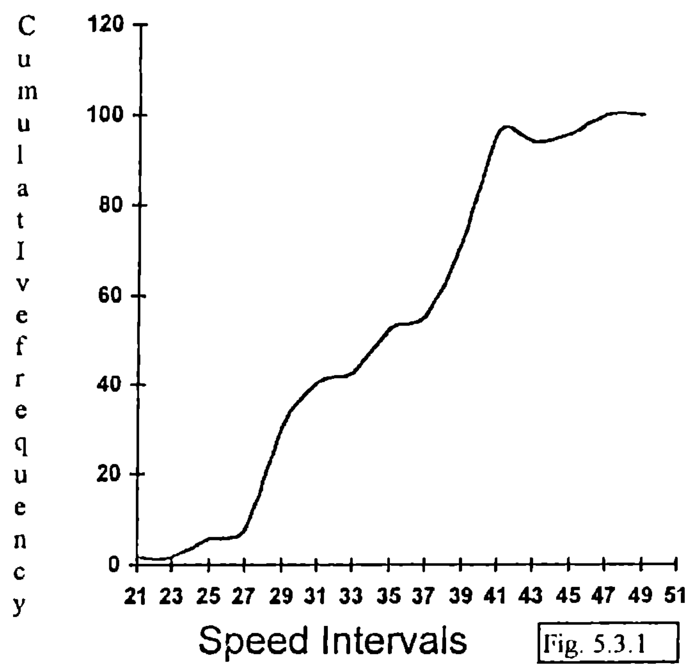


Fig. 5.3.1

The graph is a cumulative percentile distribution in which the vertical scale represent the percent of vehicles travelling at or less than the indicated speed group and the horizontal scale is speed in miles per hour. From the graph it is very clear that, it is fairly bell shaped distribution which is a normal distribution. The probability density function of normal distribution is

$$f(x_i) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x_i - \bar{x})^2}{2\sigma^2}}$$

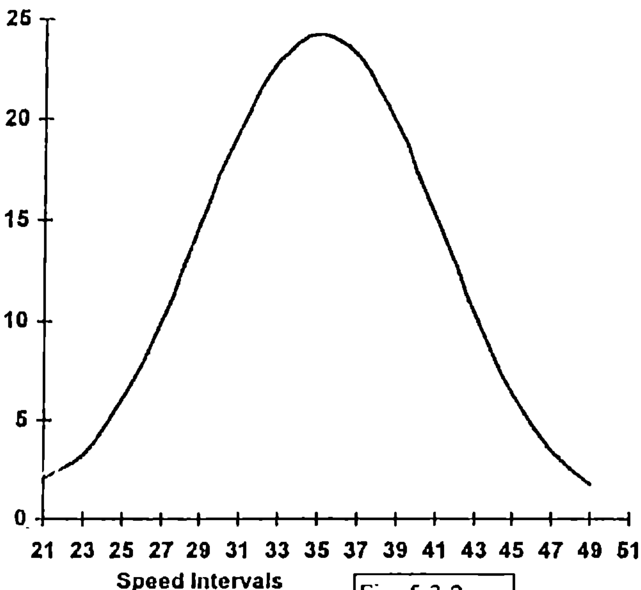


Fig. 5.3.2

5.4 Mathematical models On Flow density Speed

In this we shall establish the relationships between speed density, flow and travel time for uninterrupted and interrupted traffic flows. The difference between arrival flows measured upstream of queuing section and the departure flows measured at a reference point along the road is emphasized. The former is related to demand while the latter is related to capacity. The difference is of particular importance in over-saturated (congested) conditions where demand exceeds the capacity. The speed measured at a reference point along the road under congested condition is known as moving queue speed. This speed is associated with departure flow which cannot exceed the capacity flow. On the other hand, the average speed based on travel time through a road section including the travel distance upstream of the queuing section is associated with demand flow rate exceed the capacity.

As a starting point three basic variables describing the movement of a vehicle as observed at a reference point along the road are headway, spacing, speed. Headway (h) is the time between the passage of the frond ends of two successive vehicles. Spacing (L_h) is the distance corresponding to the headway. ie the distance between the front end of the leading vehicle and the front end of the following vehicle. Speed (v) is the distance travelled per unit time.

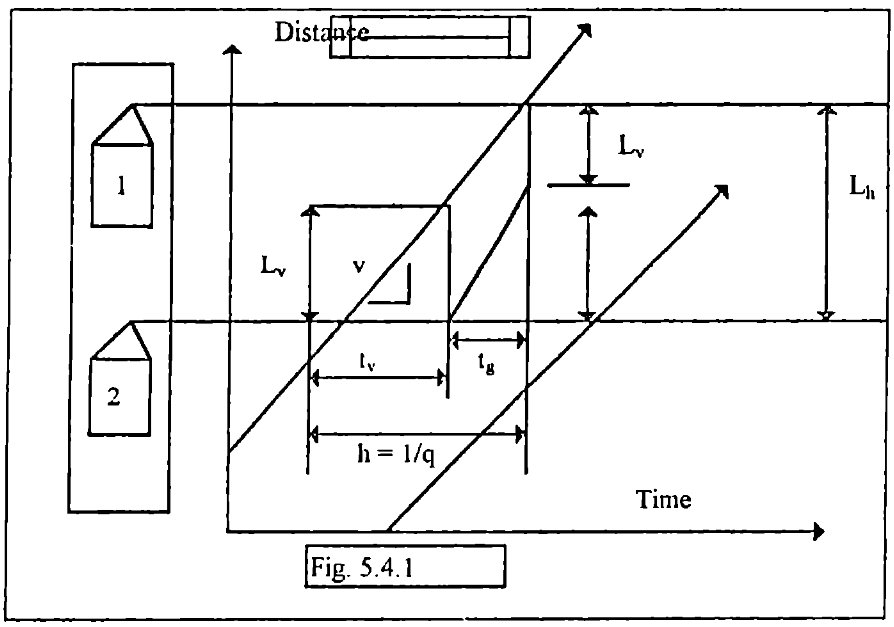


Fig. 5.4.1

The relationship between the headway, spacing and speed is

$$v = L_h / h$$

where

h = headway (sec)

L_h = spacing (m/veh)

v = vehicle speed (m/sec)

Other variables shown are the vehicle length, space(gap) length and the corresponding vehicle passage time and gap time. The space (gap) length L_s, is the distance between two successive vehicles as measured between the back end of the leading vehicle and the front end of the following vehicle, and is equivalent to spacing less vehicle length.

Vehicle passage time t_v corresponds to vehicle length and is the time between the passage of the front and back ends of a vehicle. Gap time t_g is the time between the passage of the back end of the leading vehicle and the front end of following vehicle and equivalent to headway time minus vehicle passage time. Thus

$$L_s = L_h - L_v$$

$$t_v = L_v / v\ ,\quad t_g = h - t_v = h - L_v / v = L_s / v$$

where

h = head way

t_v = vehicle passage time (sec)

t_g = gap time (sec)

L_s = vehicle length (m/veh)

In the calculations relating to average traffic conditions the vehicle length should represent the actual traffic composition where the traffic stream is represented as a mixture of light vehicles (LVs) and heavy vehicles (HVs), the average vehicle length can be calculated as

$$L_v = (1-P_{hv})\, L_{vm} + P_{hv}\, L_{vHv}$$

P_{hv} = proposition of heavy vehicles in the traffic stream

L_{vm} = average vehicle length for light vehicles / passage car units

L_{vHv} = average vehicle length for heavy vehicles

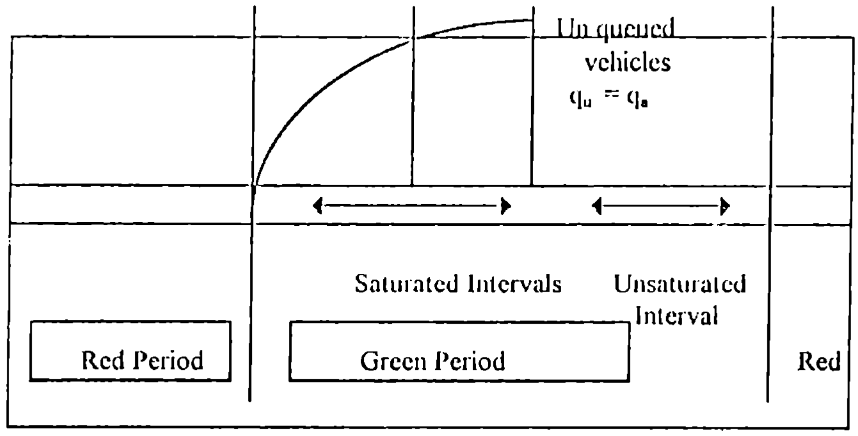


Fig. 5.4.2

Flow rate

Flow rate (veh/sec) is the number of vehicles per unit passing (arriving or departing) a given reference point and can be related to a headway.

$$h = 1/q$$

Considering the difference between congested and not congested traffic operations it is important to distinguish between the arrival (demand) flow rate and the departure flow rate for a given traffic facility. For example, at a signalized intersection approach lane, the departure flow rate measured at the stop line is the queue discharge flow rate during the saturated portion of the green period, $q = q_s$ (departure from queue) and the arrival flow rate after queue has cleared, $q = q_u$ (not queued vehicles). The departure flow rate after queue clearance corresponds to the arrival flow rate measured under uninterrupted conditions at a point upstream of the back of the queue $q_u = q_u$

Density

Density is the number of vehicles per unit distance and is related to average spacing through

$k=1/L_h$ where L_h is in meters and k is in veh/m Since $L_h = v/q$, the density is related to flow rate and speed as $k = q/v$. The average spacing in a stationary queue L_{hj}(jam spacing) is the sum of the vehicle length L_v and the jam space length L_{sj}.

$L_{hj} = L_v + L_{sj}$

L_v = vehicle length (m / veh)

L_{sj} = average space length in a stationary queue measured from the back of the leading vehicle to the front of the following vehicle

The jam density, ie the number of vehicles per unit distance in a stationary queue, can be calculated from the average spacing in queue.

$k_j = 1000/Lhj$ where L_{hj} is in m/veh and k_j is veh / km

Typical jam space length of 2m. Hence jam spacing of L_{hj} = 6m per car and 12 m per heavy vehicle. So L_v = 4.3m the jam spacing L_{hj} = 4.3 + 2.0 = 6.3 m / veh and the corresponding jam density is k_j = 1000/6.3 =159 veh/km. Similarly density at maximum flow is k_n = 1000 / L_{hm} where the spacing at maximum flow L_{hm} = 1000 v_n /q_n there fore k_n = q_n / v_n where L_{hm} = m / veh, q_n is veh / h, v_n is km / h in veh / km

Speed - Density - flow relationship

As the vehicles speed up from a stationary queue, the space length between vehicles increases gradually and therefore the spacing increases and the density decreases. The corresponding flow rate increases to a maximum flow (q_n) and then decreases as the speed increases towards the free flow speed (v_f). The relationship between speed, density and flow is known as the fundamental relation in traffic flow theory.

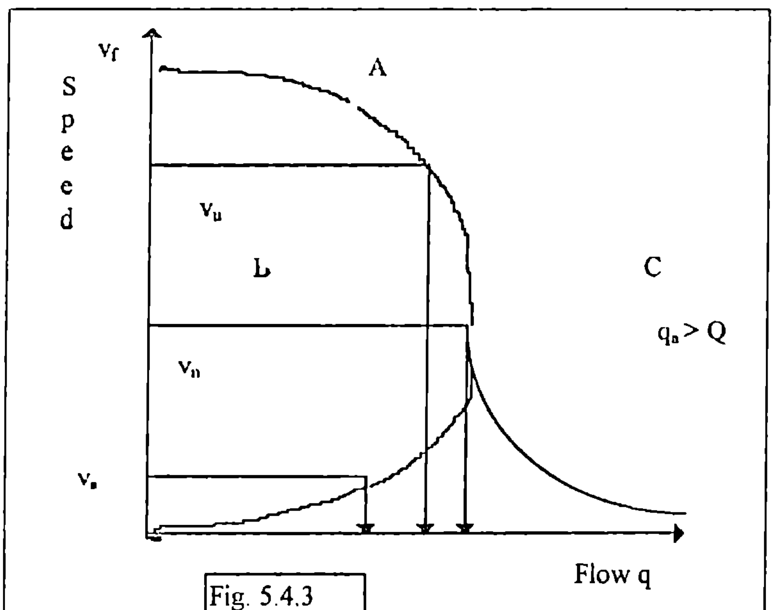


Fig. 5.4.3

$q = vk$ where q is the flow rate (veh/h or veh/sec) v is the speed km/h, m/sec and k is the density (veh/km or veh/m). For uninterrupted traffic [Fig 5.4.3] the maximum flow rate q_n is the capacity (Q

$=q_n$). Region A represent under saturated conditions with arrival flows below capacity ($q = q_a \leq Q$) which are associated with uninterrupted speeds ($v_f \geq v_u \geq v_n$) where v_f is the free flow speed v_n is the speed at maximum flow. Region B as observed at a reference point along the road represents over saturated (congested) conditions with flow rates below the maximum flow ($q = q_s \leq q_n$) which are associated with reduced speeds ($v_s \leq v_n$).

Changes in condition from region A to region B through the maximum flow point represents queue formation (eg. due to two lanes of traffic merging into one lane, or traffic stopping at traffic signals). On the other hand, changes in conditions from region B to region A through the maximum flow points represents queue discharge (eg. one lane of traffic diverging into two lanes, or traffic departing from a queue at traffic signals)

Region C for uninterrupted flow represents arrival flows above capacity ($q_a > q_n$) associated with average speeds based on travel time through the section. In this case the flow represents the demand flow rate which can exceed the capacity value.

For interrupted traffic [Fig. 5.4.4] capacity is given by Q = sg/c where s is the average queue discharge (saturation) flow rate, g is the effective green time and c is the cycle time. The average saturation flow rate is smaller than the maximum queue discharge rate ($s < q_n$) because of lower discharge rate at the start of the green period and the capacity is the average saturation flow reduced by the available green time ratio g/c.

The flow rate for the congested flow region (B) eg. at a signalized intersection stop line is the rate departure from the queue. This corresponds to the instantaneous queue discharge flow rate during the green period (q_s) that increases from zero to steady maximum queue discharge flow rate (q_n) while the queue discharge speed increases from zero to steady queue speed (v_u) corresponding to the maximum flow.

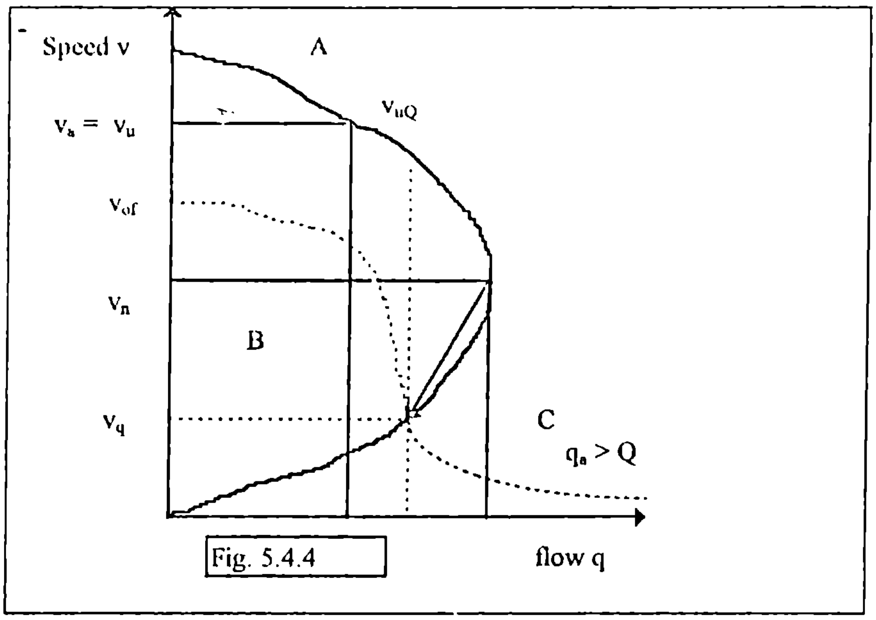


Fig. 5.4.4

The free flow speed for uninterrupted flow (v_f) is the average speed that occurs under zero flow conditions. The corresponding zero flow speed for interrupted flow (v_f) includes the free flow travel time for uninterrupted flow plus total minimum (zero flow) delay at traffic interruptions.

A speed flow model can be used as a starting point. For region B the following model from derived using exponential queue discharge flow and speed models can be used.

$$v_s = v_n [\, 1 - (1 - q_s/q_n)\, k_n / k_j]$$

where v_s, q_s = speed (km/h) and flow rate (veh/h) in region B

v_n = speed at maximum flow (km/h)

q_n = maximum flow rate (veh/h)

k_n = density at maximum flow (veh/km)

k_j = jam density

if the speed v_s is known the flow rate in region B (q_s) can be estimated from

$$q_s = q_n [\, 1 - (1 - q_s/q_n)\, k_n / k_j \,]$$

The time dependent travel time function model for the region A & C of the speed flow relationship for uninterrupted or interrupted flow condition is

$$v = v_{of} / [1 + 0.25 v_{of} T_p [z + \sqrt{z^2 + m_{cx} / Qt_p} \,]$$

where v = travel speed in km/h ($v = v_u$ for uninterrupted flow, $v = v_d$ for interrupted flow

v_{of} = zero flow travel speed in km/h ($v_{of} = v_f$ for uninterrupted flow)

T_p = peak flow (analysis) period in hours

Q = capacity in vehicle per hour

z = x - 1

x = q_a/ Q (q_a is the demand flow rate)

m_c = a delay parameter

The slope of the speed- flow curve in region A and C is determined by the delay parameter m_c. This slope indicates the rate of change of delay. ie the difference between the zero flow travel and travel time at a given flow rate. For interrupted conditions this delay is due to vehicle interactions with in the traffic stream. A speed flow function for interrupted traffic flow can be constructed from uninterrupted speed flow function by calculating the zero flow and speed at capacity (v_{of}, v_Q) from

$v_{of} = v_f / [1 + d_m v_f /3600]$ $v_Q = v_{uQ} / [1 + d_Q v_{uQ} / 3600]$

where v_f = uninterrupted zero flow speed

v_{uQ} = uninterrupted traffic speed when the demand flow equals traffic capacity

d_m = minimum delay per unit distance

d_Q = delay per unit distance at capacity (q_a = Q)

5.5 Queuing Process in traffic flow

Queuing theory which was originally developed by A. K Erlang in 1909 has found wide spread application in the problems of high way traffic flow. In any high way traffic situation it is necessary to know the distribution of vehicles arrival into the queuing system; whether the source of vehicles arrival is finite or infinite. The application of queuing theory to traffic control has been mainly developed around the regular and random distributions. When vehicles arrive at random the number of vehicles arriving in successive intervals of time can be represented by Poisson distribution and depart with an exponentially distributed service rate.

Consider a traffic queue where P(n, t+dt) is the probability that the queue contains n vehicles (n>0) at time t+dt. There are three ways in which the system could have reached this state if it is assumed that dt is so small that only one vehicle could have arrived or departed.

1. A vehicle did not arrive or depart in time t to t+dt
2. The queue contained n-1 vehicles at time t and one arrived in dt
3. The queue contained n+1 vehicles at time t and one departed in time dt

Now with Poisson distributed arrivals

$$P(n) = (\lambda t)^n e^{-\lambda t} / n!$$

where P(n) is the probability of n vehicles arriving in time t when the mean rate of vehicle arrival is λ.

$$P(0) = (\lambda dt)^0 e^{-\lambda dt} / 0! = e^{-\lambda dt}$$

where P(0) is the probability of zero arrivals in t to t+dt

$$P(1) = (\lambda dt)^1 e^{-\lambda dt} / 1! = \lambda dt\, e^{-\lambda dt}$$

where P(1) is the probability of one arrival in t to t+dt

$$P(0) = (1 - \lambda dt + \lambda^2 dt^2 / 2! - \lambda^3 dt^3/3! \ldots\ldots\ldots\ldots)$$

$$P(1) = \lambda dt(1 - \lambda dt + \lambda^2 dt^2 / 2! - \lambda^3 dt^3/3! \ldots\ldots\ldots\ldots)$$

Since dt is too small. So ignore the higher powers we have

$$P(0) = 1 - \lambda dt, \quad P(1) = \lambda dt$$

Similarly the probability of 0 and 1 departure from the queue are

$$P(0) = 1 - \mu dt, \quad P(1) = \mu dt$$

where μ is the mean rate of departure from the queue where ($n > 0$) the system can reach a state of n vehicles at time t+dt

$$\begin{aligned} P(n,t+dt) &= P(Nat)\, P(\text{a vehicle does not arrive or depart}) + \\ &\quad P(n-1,t)\, P(\text{a vehicle arrives}) + \\ &\quad P(n+1,t)\, P(\text{a vehicle departs}) \\ &= P(n,t)(1-\lambda dt)(1-\mu dt) + \\ &\quad P(n-1,t)\, \lambda dt + P(n+1,t)\, \mu dt \end{aligned}$$

Ignoring second and higher powers of dt

$$P(n,t+dt) = P(n,t)[1 - \lambda dt - \mu dt] + P(n-1,t)\, \lambda dt + P(n+1,t)\, \mu dt$$

$P(n,t+dt) - P(n,t) /dt = -P(n,t)[\lambda + \mu] + P(n-1,t) \lambda + P(n+1,t) \mu$

In the limit for steady state solution the rate of change is zero. Hence

$P(n)[1 + \lambda /\mu] = \lambda /\mu P(n-1) + p(n+1)$

Similarly when (n =0) there are two ways in which the queue can contain n vehicles at time t +dt

$P(0,t+dt) = P(0,t)(1-\lambda dt) + P(1,t) \mu dt$

$P(0,t+dt) - P(0,t) /dt = P(1,t) \mu dt - P(0,t) \lambda dt$

As before the steady state of the queue probability of n vehicles in the system is

when $n = 1 \quad P(1) = \lambda /\mu \; P(0)$

$n=2 \quad P(2) = [\lambda /\mu]^2 P(0)$

$n=3 \quad P(3) = [\lambda /\mu]^3 P(0)$

$n=n \quad P(n) = [\lambda /\mu]^n P(0)$

when the queue size may be infinite

$P(0) + P(1) + P(2) + P(3)\ldots\ldots\ldots\ldots\ldots \; P(\infty) = 1$

$P(0) + [\lambda /\mu] P(0) + [\lambda /\mu]^2 P(0) + [\lambda /\mu]^3 P(0) + \ldots\ldots\ldots\ldots\ldots = 1$

$P(0) = 1- \lambda/\mu$

Also $P(n) = [\lambda /\mu]^n [1- \lambda /\mu]$

The expected number in the queue is

$E_n = nP(n)$

$= 0 P(0) + 1 P(1) + 2 P(2) + 3 P(3) \qquad + n P(n)$

$= [\lambda /\mu] P(0) +2 [\lambda /\mu]^2 P(0) + 3 [\lambda /\mu]^3 P(0) + n [\lambda /\mu]^n P(0)$

$= [\lambda /\mu] P(0)[1 + 2 [\lambda/\mu] + 3 [\lambda/\mu]^2 + \ldots\ldots\ldots\ldots + n [\lambda/\mu]^{n-1}$

$= [\lambda /\mu] P(0)/[1- [\lambda /\mu]]^2$

Because there is a probability that the queue will be zero the mean queue length

$E_m = (n-1)P(n)$

$= nP(n) - P(n) + P(0)$

$E_n - \lambda/\mu$

The expected number in the queue as well as the mean queue length, the waiting time w before being taken into service and total time in the queue are of considerable importance in the field of traffic. The waiting time distribution may be considered as two parts.

First there is the probability that the waiting time will be zero.

$$P(0) = 1-\lambda/\mu \text{ ie } n = 0$$

Secondly there is the probability that the waiting time for a vehicle is between time w and w + dw

$P(w < \text{wait} < w+dw) = f(w)dw$

Such a delay is possible as long as there is a vehicle in service which may be expressed as

$$P(n \geq 1) = \quad P(n)$$

For the waiting time for a vehicle to be exactly between w and w+dw all the vehicles in the queue ahead of one being consider.

$$P(n-1,w) = [\mu w]^{n-1} e^{-\mu w}/n-1\,!$$

$$P(1,w) = \mu dw$$

$$f(w)dw = P(n)\,P(n-1,w)\,P(1,dw)$$

$$= [\lambda/\mu]^n\,[1-\lambda/\mu]\,[\mu w]^{n-1}[e^{-\mu w}/n-1!\,]\,\mu dw$$

$$= \lambda\,[1-\lambda/\mu]\,dw\,e^{-\mu w} \qquad [\mu w]^{n-1}/\,n-1!$$

$$f(w) = -[\lambda/\mu]\,[\mu-\lambda]\,e^{-w[\mu-\lambda]}$$

For more generalized cases when service time can no longer be described by a negative exponential distribution, the expected number in the queue when the arrivals are at random is given as

$$E_n = \lambda/\mu + [\lambda/\mu]^2\,[1+c^2\,]\,/\,2[1-\lambda/\mu]$$

where c is the coefficient of variation of the service time distribution that is the ratio of the standard deviation to the mean. If the service is exponential then $c^2 = 1$

$$= \lambda/[\mu-\lambda]$$

If the service is regular $c^2 = 0$ and

$$E_n = [\lambda/\mu][1 - \lambda/2\mu]/[1 - \lambda/\mu]$$

In this case it has been shown that the average time a vehicle spends in queuing is given by

$$E_w = \lambda/2\lambda\,[\mu - \lambda]$$

The vehicles arrive at random. The number of vehicles arriving in successive time intervals may be represented by the Poisson distribution. The probability of n vehicles arriving in a given interval of time may be calculated from

$$Pn = (\lambda t)^n e^{-\lambda t} / n!$$

This distribution is often referred to as the counting distribution because it describes the number of vehicles arriving at a given point on the highway.

5.6 Queuing Analysis

Queuing process occur in all transportation models and in everyday situations include freeway bottlenecks, parking facilities and so on. The input requirements for queuing analysis include the following five elements.

1. Mean arrival value
2. Arrival distribution
3. Mean service value
4. Service distribution
5. Queue discipline

The mean arrival value is expressed as a flow rate such as vehicle per hour. The arrival distribution can be specified as a deterministic distribution. The input is substituted for the term arrival. The mean service value is expressed as a flow rate such as vehicle per hour. The service distribution can also be specified as a deterministic distribution. The term departure is mean for service. The most common queue discipline encountered is referred to as first in first out. That is vehicles are served in the order in which they arrive. The arrival rate (λ) is specified in vehicle per hour and is constant for the study period. The service rate (μ) has two states. Zero when the signal is effectively red and up to saturation flow rate (s) when the signal is effectively green. The service rate can be equivalent to the saturation flow only when a queue is present. Otherwise the service rate is equal to the arrival rate if the signal is green. Thus the arrival rate goes through the origin and slopes up to the right with a slope equal to the arrival rate. During the red period the service rate is zero. At the start of the green period a queue is present and the service rate is equal to the saturation flow rate (s). The cumulating arrival line intersects the cumulating service line during the green period. At this point in time the queue is dissipated and the cumulative service line overlays the cumulative arrival line until the end of the green period. Then the pattern repeats itself with the service rate varying again from zero to saturation flow rate and to arrival flow rate.

A series of identical triangles are formed with the cumulative arrival line forming the top side of the triangles and the cumulating service line forming the other two sides of the triangle. Each triangle represents one cycle length and can be analyzed to calculate the set of five measures of performance. Let us take time duration of queue (t_Q), no. of

$\lambda t_Q = \mu(t_Q - r)$

$$t_Q(\mu - \lambda) = \mu r$$

$$t_Q = \mu r/(\mu - \lambda)$$

$$Pt_Q = 100\, t_Q / C$$

The number of vehicles experiencing queue is represented by the vertical projection of the queuing triangle. The first vehicle experiencing the queue is the vehicle that arrives just after the signal turns red. All vehicles arriving during the red as well as the vehicle arriving during the green but before the queue is dissipated experience the queuing process and are forced to stop or slowdown considerably. Its value varies between λr and λc and is expressed in number of vehicles.

$$N_Q = \lambda t_Q/3600$$

$$N = \lambda c/3600 \quad PN_Q = 100\, t_Q / C$$

where N_Q = number of vehicles queued

N = number of vehicles per cycle

PN_Q = percent of vehicles queued.

The queue length is represented by the vertical distance through the triangle. At the beginning of the red period the queue length is zero and increases to its maximum value at the end of the red period. Then the queue length remains equal to zero until the end of the green period when the pattern repeats itself.

$Q_m = \lambda r / 3600 \quad Q^*_Q = Q^+_m / 2 = \lambda r/7200$

$Q^* = Q_m t_Q / 2C$

where Qm = maximum queue length

Qq = average queue length while queue is present

Q = average queue length

Individual delay is represented by the horizontal distance across the triangle. The first vehicle to arrive after the beginning of the red encounters the largest individual delay. Each vehicle arriving there after experiences a smaller and smaller individual delay until the queue is dissipated. Vehicles arriving thereafter until the beginning the next red encounters no individual delay

$d_M = r$

$D_Q = r / 2 \quad D = rt_Q / 2C$

where d_M = maximum individual delay

D_Q = average individual delay while queue is present

D =. average individual delay

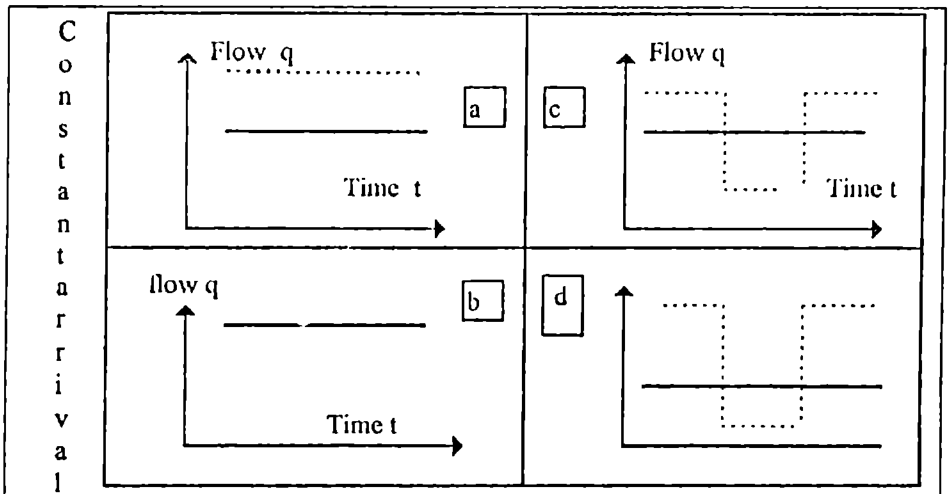
The total delay per cycle is represented by the cross sectional area of the queuing diagram triangle and is expressed in vehicle seconds.

The total delay per cycle is represented by the cross sectional area of the queuing diagram triangle and is expressed in vehicle seconds.

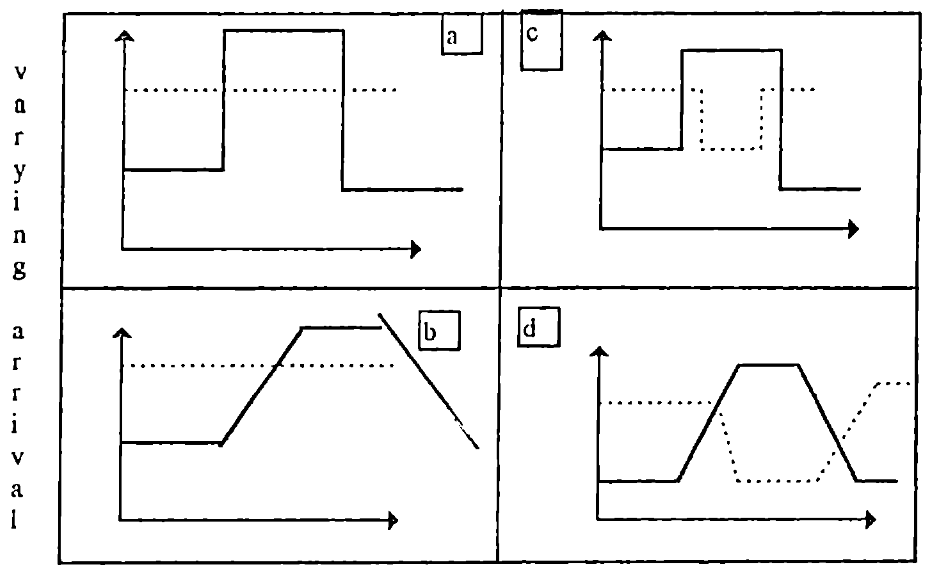
$TD = N_q r / 2$ where TD is the total delay in vehicle seconds

Queuing Patterns:_

A variety of queuing patterns can be encountered. The classification scheme is based on how the arrival and service rate vary over time. Consider the pattern of a constant arrival rate. If the arrival rate is less than the service rate, no queue is encountered. If on the other hand the arrival rate is greater than the service rate the queue has a never ending growth with the queue length equal to the product of time and the difference between arrival and service rates.



Constant service [------ Fig. 5.6. varying service [-------]



Constant Service Fig. 5.6.2 varying service

Consider the graph. In [Fig 5.6.1.a] the arrival rate is less than the service rate, no queuing is ever encountered. On the other hand, the arrival rate is greater than service rate the queue has a never ending growth with a queue length equal to the product of the time and the difference between the arrival and service rates as in [Fig 5.6.1.b]. If the arrival rate is constant, but the service rate is less than the arrival rate for some periods of time, greater than the arrival rate for other periods of time, the service rate does not have to be in the form of a square wave. That is several changes in service rates of different amounts can be encountered which has been in [Fig 5.6.1.c,d]. In [Fig 5.6.2.a,b] the arrival rate varies over time, while the service rate constant over time. For queuing to occur and then be dissipated, the arrival rate must be greater than the service rate for some periods of time and less than the service rate during the other periods of time. The graph [Fig 5.6.2,c,d] shows that complex situation where both arrival and service rate vary over time. For queuing to occur and then be dissipated the arrival rate must exceed the service rate and later be less than the service rates. This indicates a square wave type of arrival rate and inverted square wave type of service rate.

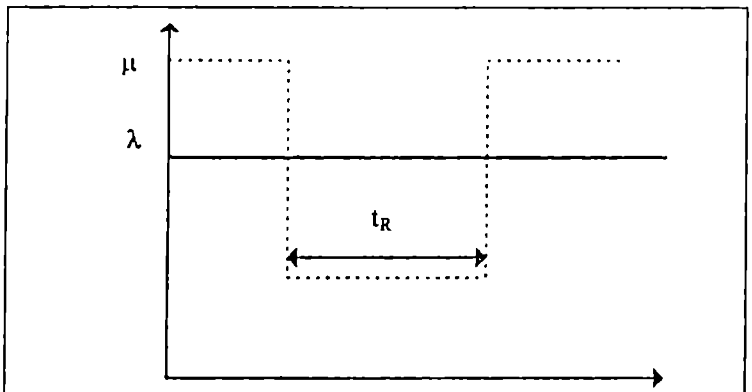


Fig 5.6.3

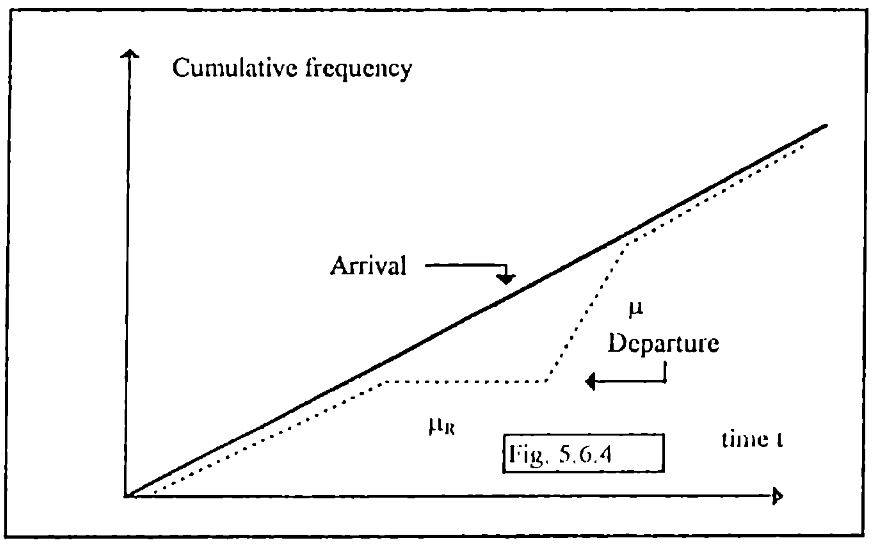


Fig. 5.6.4

The queuing diagram for the incident situation is given in the graph. The arrival rate (λ) is specified in vehicle per hour and is constant for the period. The normal service rate (with out an incident) is indicated in the diagram as (μ) and since it exceeds the arrival rate, no queuing would normally exist. However an incident occurs that reduces the service rate to μ_R which is below the arrival rate, and this lower service rate is maintained for t_R hours. The cumulative vehicles versus time graph shows the arrivals as a straight line passing through the origin with a slope up and to the right equivalent to the arrival rate(λ). For the first period of time the service line follows the arrival line until the incident occurs. At that point in time the service rate becomes equivalent to μ_R and maintains a flatter slope until the incident is removed. This continues until the arrival line and the service line intercept at which the service line once again overlays the arrival line.

Varying arrival rate

Assume service rate is constant vehicles per hour rate for the entire period. The arrival rate (λ) takes on the form of a typical peak period demand pattern, with a gradual increase in arrival rates in the early portion of the peak period and a gradual decrease in arrival rates in the latter portion of the peak period. The arrival rate begins at a constant rate of λ_0 during time period T_0 which is less than the service rate (μ). During the time period (T_1) the arrival rate (λ_1) increases linearly from λ_0 to λ_1 and some time during this period of time the arrival rate (λ_1) begins to exceed the service rate. During the time period (T_2) the arrival rate remains constant at (λ_2). Then the arrival rate begins to decrease linearly from (λ_2) to (λ_3) and some time during this period the arrival rate (λ_3) becomes less than the service rate. After the time period (T_3) the arrival rate (λ_3) remains at constant rate ((λ_4). If (T_1) & (T_3) are set equal to zero the arrival pattern will be rectangular. On the other hand if (T_2) is set equal to zero a triangle shaped arrival pattern will result.

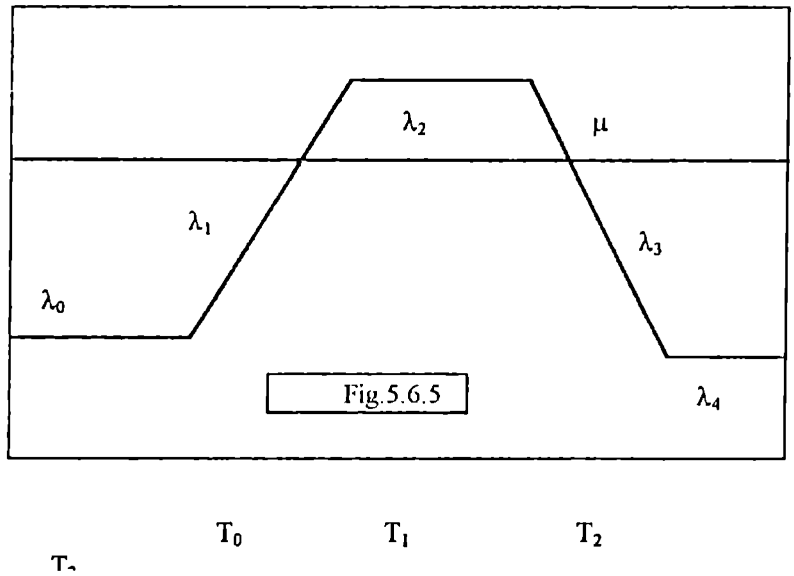


Fig.5.6.5

The exact time that the arrival rate begins to exceed the service rate is

$$ET = T_0 + T_1 (\mu - \lambda_0) / (\lambda_2 - \lambda_0)$$

The exact time at which the arrival rate becomes less than the service rate is

$$T = T_1 (\lambda_2 - \mu) / (\lambda_2 - \lambda_0) + T_2 + T_3 (\mu - \lambda_2) / (\lambda_4 - \lambda_2)$$

The duration of the queuing process (QP) can be determined by investigating two cases. If the queue is dissipated during time (T_3)

$$Qpp = T + [(\lambda_2 - \mu) / (\mu - \lambda_4) (T + T_2)]^{1/2}$$

On the other hand, if the queue is dissipated after the time period (T_3), the equation

$$Qpn = T/2 [(\lambda_2 - \mu) / (\mu - \lambda_4) + 2] + T_2/2 [(\lambda_2 - \mu) / (\mu - \lambda_4)] + T_3 [(\lambda_4 - \mu) / /(\lambda_4 - \lambda_2)$$

The no. of vehicles adversely affected by the bottleneck can be expressed

$$N_Q = \mu Q_p$$

The total delay in vehicle hours is

$$TD = \int_0^{TQ} [\lambda(T) - \mu(T)]dt$$

The solution of the integral gives the total delay as a function of the flow rates.

5.7 Network and area traffic control

Area traffic control system plays important role in determining the equilibrium between demand and supply in an urban highway Network. The system provides the additional capability of monitoring the traffic flow, keeping track of its time varying dynamics in great details via - vehicle detectors, signals and computer altogether.

The basic paradigm of equilibrium in a transportation network is

L = level of service (such as trip time) on a particular facility

V = volume of flow on this facility

T = specification of the transportation system (including its control measures)

A= specification of the activity system

Then the supply function

L = S(T,V) shows an increase in the level of service as volume increases and the demand function V = D(A,L) a decrease in volume as the level of service increases (in the negative sense). The resulting equilibrium point $E(L_0,V_0)$ occurs at the intersection of the two curves. Computing the traffic equilibrium in a signal control-led high way network the sampling assumption is made that demand is an inelastic function fixed at a flow pattern Fo. The equilibrium value in this case $E(L_o,F_0)$, represents the level of service at which the given demand is serviced. The most important element determining the level of service of traffic in an urban area is at grade control intersection. The effect of traffic flow on travel time between intersections is usually minor compared to its effect on the delay time incurred at the intersection itself. Therefore, the primary determinant of the level of service variable L becomes the delay time.

Let us consider first one approach to a signaled intersection. assuming that arriving traffic is not modulated by any nearby controlling device, the average delay per vehicle on the approach d can be regarded as the sum of two components.

$$d = d_s + d_d$$

where d_d is the delay that would result if the flow were uniform and d_s is the additional delay caused by nature of traffic flow. The average delay per vehicle on the approach can be approximated from the formulae

$$d = k[c(1-g)^2/2(1-q/s)] + [x^2/2q(1-x)]$$

where c = the signal cycle time (sec)

G = effective green time for the approach

g = G/c proportion of cycle which is effectively green

q = arrival flow on approach

s = saturation flow at the signal stop line (veh/sec)

x = q/gs degree of saturation

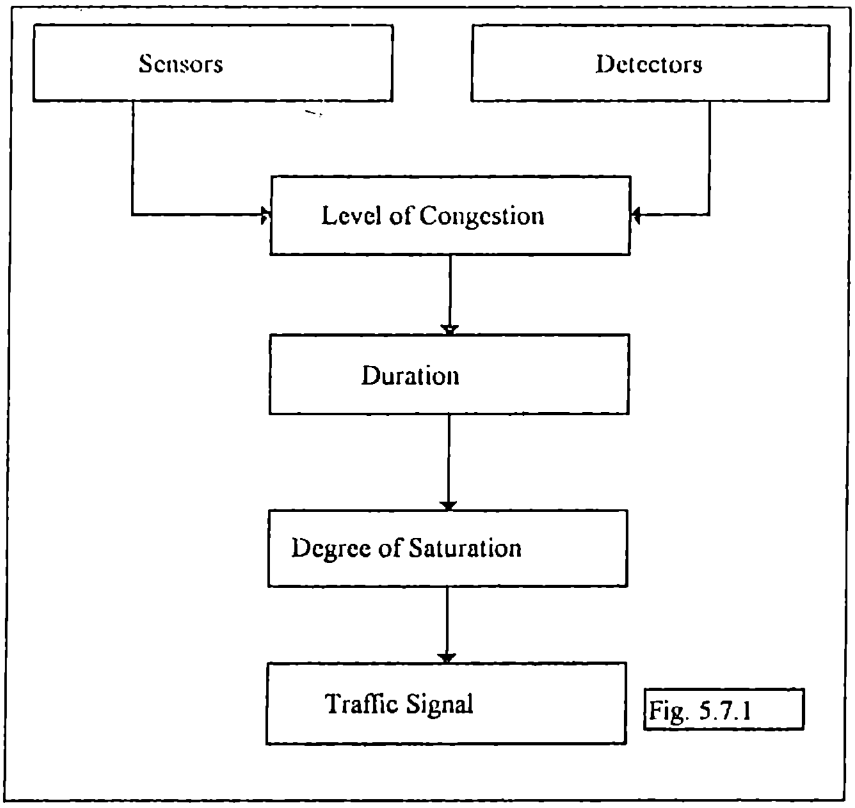


Fig. 5.7.1

It is seen that at higher degree of saturation the delay rises steeply. Theoretically the delay increases to infinity as the flow approaches capacity. But in practice the flow does not sustain a high value for a long period. It falls off at the end of the peak period and the queue does not reach a length required to cause excessive long delays.

To derive the level of service at which traffic through the intersection will be served both the green time G and the cycle time c have to be determined and all flows must be considered. The signal has two phases corresponding to the two possibilities of movement, N - S and E - W. The sum of the effective green times for the phase is $G_{EW} + G_{NS} = C - L$ where L in this case is the total lost time for the intersection. To calculate the average delay per vehicle on each approach

We have to obtain the rate of delay

$$D_{EW} = [q_E + q_W]d_{EW}$$

$$D_{NS} = [q_N + q_S]d_{NS}$$

The rate of total delay D considering all flows through the intersection is

$$D = D_{EW} + D_{NS}$$

G_{min} is the minimum effective green time that still can accommodate the demand on the approach though at a very high rate of delay and is given by $G_{min} = qc/s$. The apportioning of green time among the conflicting streams at the intersection can be formulated as the following optimization program

$$\text{Min } D = D_j \text{ subject to}$$

$$G_j = c - L$$

The optimal solution is obtained at an equilibrium point where the marginal rate of delay for the conflicting phases is equalized. The approximate rule for determining the optimal splits of green time

$G^{*}_{j} = [c - L]y_j / Y$ where y_j is the maximum ratio of flow to saturation flow for the different approaches having simultaneous right of way during phase j and $Y = y_j$

To determine optimum cycle time c for the intersection, capacity consideration play an important role. For each approach i we must have $q_i c \leq G_j / c$. Summation over all phases at the intersection yields

$$y_j = g_j$$

The minimum cycle time

$c_{min} = L/(1-y)$ such a cycle will use an intolerable amount of delay.

When two or more intersections are in close proximity, some form of linking is necessary to reduce delays to traffic and prevent frequent stopping. A signal controlled intersection has a platooning effect on the traffic leaving it, and it is advantageous to have a signals synchronized. That is operating with a common cycle time. It also becomes necessary to co-ordinate the signals, that is to establish an offset between the signals, so that loss to traffic is minimized. The usual procedure for setting signals on arterial and in networks involves three steps. A common cycle time is determined according to the requirements of the most heavily loaded intersection. The split of green time are apportioned at each intersection according to the interacting flow or capacity ratios. A computer optimization procedure is used to determine a set of offsets throughout the network.

The signal controlled traffic network consists of a set of links (i,j) connecting to the adjacent signals S_i and S_j. Let

G_{ij} (R_{ij}) = effective green (red) time at S_j facing link (i,j)

L_{ij} lost time at signal phase serving link (i,j)

ϕ_{ij} = offset time between S_i and S_j along (i,j)

q_{ij} (s_{ij}) = average flow (saturation flow) on link (i,j)

The link performance function is composed of a deterministic delay. The deterministic component

Z_{ij} (ϕ_{ij}, R_{ij}, c) is given by average delay incurred per vehicle in a periodic flow through S_j. The stochastic component which arises from variations in driving speeds, marginal friction and turns is expressed by the occurrence of an over flow. Queue is a non homogeneous poisson process with a periodic intensity function represented by the flow pattern on the link. Therefore it can be considered the total delay in the network D to be composed of two components.

$$D = D_d + D_s$$

where $D_d = q_{ij} Z_{ij} (\phi_{ij}, R_{ij}, c)$

$D_s = Q_{ij} (R_{ij}, c)$

A number of constraint equations involving the decision variables are necessary to model the network. First the algebraic sum of offsets around any loop of the network must equal an integral multiple of the cycle time

ie $Q_{ij} = n_l c$ where n_l is an integer number associated with loop l. Effective green and effective red are related by

$$G_{ij} + R_{ij} = c$$

In order for the network to be able to handle the given flow we must have for each link the capacity constraint as $q_{ij}c \le S_{ij} G_{ij}$

For practical consideration including pedestrian crossing times and driver behaviour are prescribed as

$$R_{ij} \ge R_{ij\,min}$$

$$C_{min} \le c \le C_{max}$$

Assuming for simplicity two phase intersections we have

$$R_{ij} - l_{ij} = G_{kj} + l_{kj}$$

where (i,j) and (k,j) are assigned conflicting phases at S_j

Thus the net work signal setting problem can be stated in a general form as the following non-linear optimization program

$$\text{Min } D = D_D + D_s$$

subject to

$$\phi_{ij} = n_l c$$

$$G_{ij} + R_{ij} = c$$

$$R_{ij} - l_{ij} = G_{kj} + l_{kj}$$

$$q_{ij} \le S_{ij} G_{ij}$$

$$R_{ij} \ge R_{ij\,min}$$

$$C_{min} \le c \le C_{max}$$

$$G_{ij}, R_{ij} \ge 0,\ n_l \text{ is an integer}$$

This can be solved by mixed integer programming.

5.8 Computer vision and Neural Net work for traffic monitoring

The ever increasing use of video cameras for a range of traffic surveillance and control task together with a steady fall in computer provides a clear opportunity for the introduction of reliable automatic video image analysis systems. Over the past decade scientist have developed a number of image processing systems for traffic analysis. It would be better to analyze the traffic representation by Artificial Neural Network System and Vision Technology. This is the first advanced hybrid neural network based computer vision system to be applied to monitor traffic current video image processing system for traffic analysis. It falls in to three categories.; First straightforward detection and counting system capable of providing traffic data such as vehicle count, speed and headway measurements; Second congestion monitoring and incident detection systems for assessing traffic conditions based on spatial and temporal analysis of the traffic scene without measuring individual vehicle statistics and third vehicle identification, classification and tracking systems.

Systems in the first category generally employ algorithms which maximize processing speed to detect in real time, changes in image intensity, representing moving objects along the road. Systems in the second category more effective use of spatial information contained within video image to provide some description of traffic movements. Systems belonging to the third category demand most system resources as well as algorithm complexity. However it is evident that there is a need for low cost yet reliable traffic detection and analysis systems which are

Adaptive to changes in real world environment

Capable of operating independently of human operators

Capable of intelligent decision

Capable of monitoring multiple cameras

Capable of continuous operation

When considering the design of more intelligent systems there are two general classes of adaptive decision making systems

Expert systems

Learning systems

Expert systems are based on explicit encoding of the knowledge of a human expert and are generally considered as alternatives to learning systems. In order to develop an expert system an articulate human expert must define all the rules and knowledge to be incorporated into the expert system. In many real world situations human expertise and experience may be scarce or to expensive to acquire, thus making expert systems unattainable.

A learning system is one which is able to make correct decisions based on criteria extracted from examples of successfully solved cases and examples of different traffic conditions or different classes of vehicle exist in abundance, learning systems begin to be much more attractive. Furthermore a learning system is still capable of capturing "Expert" knowledge by opting a process in which the expert chooses the most appropriate information to be presented to the system during its training phase. A learning system has in theory the potential to discover new relationship from the input pattern and improve performance by searching through the data in successfully solved cases.

Individually expert system and learning system have their own strengths and weaknesses. Neural Networks excel in pattern matching and classification but are not very well suited for precise numerical computations. In addition to that although a neural network may correctly identify a given situation there may be no explanation of how or why the system has come to that conclusion. In real world situations there will be limitations on what can be learnt from examples and hence an expert system may be used to reinforce a decision. By combining appropriate elements of both systems improved performance may be achieved.

Neural Net work Classification

Neural network is a parallel distributed information processing system. It consists of a large number of highly interconnected, very simple processing elements known as neurons. Each neuron has a number of inputs and one output which branches out to inputs of other neurons. There may be one or more layers of neurons in a network. The output of a neuron is a function usually non-linear sum of all inputs through weighted links. The knowledge of a network is therefore distributed throughout out weighted links. The weights are modified during the learning process by repeatedly showing an input pattern than adjusting the weights to produce the desired target output pattern.

The Biological Neurons

The human brain is an extremely complex interconnected neural network of over 10^{11} processing elements known as neurons. Each neuron is connected to 10^{4} other neurons which suggest approximately 10^{15} interconnections. A biological neuron consists of a cell body around the dendrites. The connecting points between neurons are called synapses. A single neuron receives stimulus from other neurons by its dendrites at the synapses, sums the stimulus at its cell body and based on the sum of the stimulus sends an output to other neurons through its axon.

Artificial Neural Net work

Artificial neural network are computing techniques which are able to imitate activities of the human brain. A neural network is trained so that an application of a set of inputs produce the desired set of outputs. Training is accomplished by sequentially applying input vectors, while adjusting network weights according to a predetermined procedure. During training, the network gradually converge to values such that each input vector produces the desired output vector. Training is of three different types.

a. Supervised training
b. Unsupervised training
c. Graded training

The most popular one is the supervised training. It requires the pairing of each input vector with a target vector representing the desired output. The two vectors together is referred to as a training pair. An input vector is applied, the output of the network is calculated and compared to the corresponding target vector. The difference (error) feed back through the network and weights are changed according to an algorithm that tends to minimize the error. The vectors of the training set are applied sequentially, errors calculated, and weights adjusted for each vector, until the error for the entire training set is an acceptably low level; in terms of the error criterion chosen.

The perceptron training algorithm employs the square difference criterion expressed as

$$E = 1/2 \sum_{\rho} \sum_{j} (T_{pj} - O_{pj})^2$$

where T = target activation

O = actual output activation

j = output unit

ρ = input vector pattern

The Perceptron Training Algorithm

Weight Initialization: Set all weights and node thresh hold to small random no s.

Calculation of activation: Activation level of an input unit is determined by the instant presented to the network Activation level of an output unit is determined by

$$O_j = F\left(\sum W_{ij} x_i - \theta_j \right)$$

Weight training:

Adjust the weight by

$$W_{ij}(t+1) = W_{ij}(t) + \Delta W_{ij}$$

The weight change ΔW_{ij}

may be computed using the delta rule which states that

$$\Delta W_{ij} = \eta \delta_j O_i$$

where η = learning rate coefficient

$\delta_j = T_j - O_j$ (the difference between the target output & actual output of unit j) O_i = activation level of unit I

Repeat the iterations until convergence

ANN Paradigms

Adaline network and Back Propagation network are two of the widely used ANN paradigms in solving traffic monitoring problems.

Adaline Network

As a branch of artificial intelligence, the most remarkable achievements of neural net works have been made in pattern recognition. The range of ANN has however quickly become wider in recent years. A considerable number of potential applications of neural networks are in traffic.

In ANN the transfer function generally executes a thresh hold logic. In adaline the thresh hold logic is ignored and instead weighted sum is used as the output of the processing unit directly. Then the output is compared as

$$out = \sum_{i=0}^{n} w_i x_i$$

where

out = output of the processing unit

x_i = i^{th} input

w_i = weight of the connection between i^{th} input and adaline

x_o is a bias input and it is always set to 1. w_o is the weight corresponding to x_o. The learning of the adaline network is implemented with an error correcting strategy which adjusts the weights according to the difference between actual out put and the desired output. The weights are adjusted step by step through many iterations with the formula

$$w^{new} = w^{old} + \delta w$$

where

w^{new} = updated weight

w^{old} = the weight being updated

δw = weight adjusting rate

The weight adjusting rate is determined by the following formula.

$$\delta w_{ij} = x_i [out_j - t_j] \ ln$$

where out_j = output of processing unit j

t_j = desired output of processing unit j

ln = learning parameter

Trip generation prediction is a major process in traffic planning. The number of trips generated from a specific geo-graphical zone is considered as an effect of the socioeconomic activities taking in that zone based on this consideration. Zonal socioeconomic indexes such as income population employment and the number of vehicles owned in the zone are generally used to infer the zonal trip rate generated.

To model a relationship between the trip rate and socio-economic indexes the most common existing approach is regression analysis. Linear regression analysis constructs a mathematical in the following form

$$Y = c + b_1x_1 + b_2x_2 + \ldots\ldots\ldots\ldots + b_nx_n$$

where

Y = dependent variable (trip rate)

x_i = independent variable (socio-economic index)

b_i = regression coefficient

c = constant i= 1,2,................n

The constant and coefficient are determined with the least square error method . Such regression analysis is generally based on the following assumptions

The variance of the Y values about the regression line must be the same for all magnitudes of the independent variabies

The deviations of Y values about the regression line must be independent of each other and normally distributed.

The x values are measured without error.

The regression analysis requires an error free database. The assumptions would not be one hundred percent true in an actual situation. Such a shortcoming affects the prediction accuracy of the model.

The Back Propagation network

The back propagation network employs a generalized form of the delta rule which enables the training of multi-layered network.

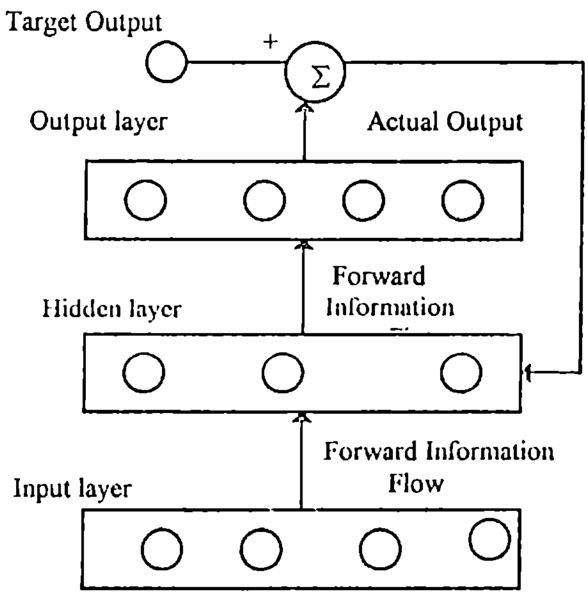


Fig. 5.8.1

Principle

Like a single layer perceptron a BP. network typically starts out a random weight initialization. The network adjusts its weights, each time, a training pair is applied. The training take place in two stages.

Forward Pass

This involves presenting a sample input to the network and letting activation flow until they reach the output layer. The equation O = F(X,W) is applied to each layer from the input to the output.

Backward Pass

During this stage the networks actual output from the forward pass is compared with the target output and error estimates are computed for the output units. The weights connected to the output units can be adjusted to reduce the errors. The error estimates for the hidden layers are derived from those of the output layer. Thus the errors propagate back to the connections stemming from the input units. Thus the reverse pass consists of two main steps.

1. Adjusting the weights of the output layer

The delta rule is modified due to the presence of the non linear activation function.

$$OUT = F(NET) = 1/[1+e^{-(NET)}]$$

$$F^{|}(NET) = OUT(1 - OUT)$$

$\delta_k,k \rightarrow \delta$ for the neuron q in the output layer k is expressed as

$$\delta_k,k = OUT(1-OUT)(Target - OUT)$$

$\Delta W_{pq},k \rightarrow$ change in the weight connecting a neuron p in the hidden layer j, to a neuron q in the output k is expressed as

$$\Delta W_{pq},k = \eta\, O_{pj}\, \delta_q,k$$

therefore $$W_{pq}, k(t+1) = W_{pq}, k(t) + \Delta W_{pq},k$$

2. Adjusting the weights of a hidden layer

δ for the hidden layers must be generated with out the benefit of a target vector.

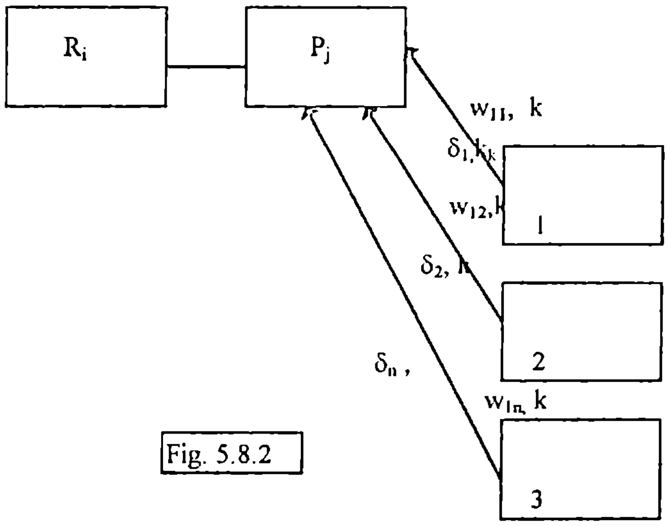


Fig. 5.8.2

During the forward pass, a neuron p in the hidden layer j propagates its OUT to neurons 1,2,3,4,......... n in the output in the output layer through the interconnecting weights W_{11}, W_{12}, W_{1n}. During the reverse pass, the same weights pass the δ value from the output layer to the hidden layer. Each weight is multiplied by the δ value of the output neuron to which it is connected

$$\delta_1,k\ W_{11},k + \delta_2,k\ W_{12},k + \delta_3,k\ W_{13},k + \delta_4,k\ W_{14},k \ldots\ldots\ldots\ldots\ldots \delta_n,k\ W_{1n},k$$

$$= \sum_{q=1}^{n} \delta_q,k\ W_{pq},k$$

This sum of products is multiplied by the derivation of the squashing function. (non linear activation function) to get δ of the hidden layer neuron.

$$\delta_{pj} = OUT_{pj}(1 - OUT_{pj}) \sum_{q} \delta_q,k\ W_{pq},k$$

If r is a neuron in the previous hidden layer i then

$$W_{rpj(t+1)} = W_{rpj(t)} + \Delta W_{rpj}$$

$$\Delta W_{rpj} = \eta \delta_{pj}\ OUT_{r,i}$$

Optical character recognition

Neural network architecture appears to lend itself well to optical character recognition. (Example vehicle number plate recognition). The aim of this is to further investigate the learning and classification capability. To improve the accuracy, it may be trained with more than one character font type while at the same time shifting and rotating the position slightly to reduce position dependency.

5.7 Knowledge based system for traffic monitoring

The development of an Automatic Incident Detection system based on the application computer vision techniques. Computer vision involves the automatic digitizing, processing and interpretation of pictures from the road side CCTV cameras. The AID system is based on the analysis of video images from CCTV cameras installed in strategic sites along the road carried out in processing models which produces the meaningful real time spatial data. These data are further processed at central level to produce the spatial and temporal trailing of the received data to detect and follow up incidents and congestion along the road network.

Local Sensors Modules

The LSM performs the image processing and computer vision procedures. Each LSM has been connected to a single fixed camera. It primarily aims at detecting incidents that occur within or near by the camera field of view (usually several hundred meters). The LSM acts as a traffic sensor that calculates as a set of traffic measurements such as volume, velocity and concentration. With this data it also calculates the current level of service of the road.

Communication interface

It provides the link between the CS and all installed LSM. It is prepared to support most of the standard communication services, while the application protocols ensure the appropriate session management and data formats translation. The incoming information of this module is collected in cycle blocks and transformed into the normalized definition of traffic state.

Decision support module

Every cycle the data coming from sensors are pushed into traffic data bases which in turn is linked to other static databases that maintain the other information of systems

Decision Evaluation model

Gives the temporal consistency of the successive "cycle states" creating the linkage between alarms and the pattern of evolution (spatial & temporal) of such incident and congestion situations. This process is of key importance for the filtering out of the false alarms. The level of confidence is a parameter related to the accuracy of the data used for the system to detect an incident and set an alarm. The LSM will issue the level of confidence of detection but this may be modified by the CS according to rules that take in to account a number of additional data.

Traffic information database

This will include an increased number of sensors in urban areas and an exchange of traffic information between the metropolitan and urban areas. Additional equipment includes information boards and road side communication facilities for more reliable information concerning. Congestion levels together with predictions of current traffic conditions such as journey time, accidents, restrictions and car parking space will be available to meet the increasing needs of travelers.

Configuration of the system

The basic concepts of the overall advanced traffic control and management system consists of three basic types of supervisions. The first one is the implementation of the real time control. It collects changing traffic information from the network and according to this information it optimizes vehicle flow by adjusting signals and providing appropriate traveller information.

The second one is daily traffic supervision. This monitors traffic flow and intervenes with control in response to incidents such as accidents, traffic restrictions and so forth.

The third one is the long term traffic management. It gathers information on static variations of traffic situations to establish overall traffic policies to execute large scale traffic regulations.

Traffic Management systems

The lowest control level is the terminal system consisting of several computers. Each computer directly controls the signals and detectors in each region.

At the intermediate level of control, the main function of the system is to develop the traffic information database and provide signal control strategies and management information. The level of control is handled by each of the dedicated computers sharing functions in the decentralised way.

The upper level is the administration component of the system and consists of large-scale information boards, multi function consoles and a group of computers. It is at this level that the so called man machine interface functions such as inquiries for information reference and checks of traffic policies take place.

Traffic control centre

The traffic control centre has large scale information boards, consoles and TV monitoring. All the information related to traffic condition in the whole area is presented to the operator, so that appropriate countermeasures may be taken. The large scale information boards are planned to give an overall picture of the general traffic situations. The consoles house the latest electronic work station as their CPUs and are capable of indicating traffic information on appropriate maps or diagrams. They can also indicate the statistical information about the traffic.

Collection of traffic information

Various types of traffic information are collected using vehicle sensors, registration plate readers and so forth installed at intersections and at road sides. They are used for measurement of present traffic condition and also for forecasting. Traffic characteristics continuously monitored include journey time, traffic flow, congestion, automatic vehicle flow classification and speed. The traffic information thus obtained is used to meet the needs of the new traffic control system, to adjust signal timings and provide information to the operator. Terminals collect information from existing sensors (Example image processing, ultrasonic and microwave detectors. They measure driving speed and classify vehicles.

Signal controls

Signal controls are the key measures to realize comfortable driving conditions by reducing and dispersing congestion and executing various traffic supervision measures. Often at junction of trunk or semi trunk at roads traffic demand exceeds the capacity. It is at critical intersections that traffic flows need to be dealt with to avoid the build up of congestion throughout the network. The traffic situations at these critical intersections are categorized into three types each with an approximate control strategy. In under-saturated conditions safe and comfortable driving may be achieved by choice of signal cycles with coordinated signal control. Those who choose to drive at an excess speed are compelled to stop at signals Whilst those who drive at the design speed may pass through the network with minimum delay. Such coordinated signal control strategies will be designed by the use of off-line simulation models.

Control of nearly saturated traffic

In a close to saturated condition one of the cross roads may be congested while another may be less crowded. Under such circumstances the new system employs a control of green split in accordance with the degree of saturation. It improves the green split to balance queues. In this method the splits are allocated using saturation rates and due consideration for number of cars in the queue. This method can also be applied to under as well as over saturated junctions and is very effective for multi phase intersections, where signal control is critical.

Control of over saturated traffic

Over saturation occurs when traffic demand exceeds the traffic handling capacity of an intersection. This results in congestion at each of the lanes. The control of splits will improve the efficiency of critical intersections. Also for a measure of the level of congestion on particular roads travel time ratio control will be applied, with the latter constraint signal control is defined so that the travel time for a vehicle at each of the inflow lanes comes as close as possible to a target value. On the other hand when more cars are entering congested roads from narrow streets vehicle flows may be suppressed by applying offsets.

Traffic management supporting functions

The supporting function includes traffic surveillance, data analysis, investigation, intervention and evaluation of the various counter measures. The congestion simulation uses a time series analysis of traffic volumes.

5.9 Conclusion

In this chapter various counting distributions have been discussed to analyze the current traffic situation in terms of traffic flow, volume and density. It is suggested that sensors and detectors may be used for counting purpose and the datum may be directly fed to the computers connected through communication channels. These datum automatically uses the mathematical models (statistical distributions) and the computers will give the information on current situation. In this work, most of the counting distributions, the theoretical frequency, and the observed frequency are compared and found fit to each other.

The speed -flow - density relation model gives ample space to control the flow. Queuing theory and Queuing analysis helps the computer to estimate the level of congestion and predict the queues. Area traffic control network model helps the traffic planner and Controller to have a centrally coordinated system. The use of artificial neural network and computer vision in traffic have been discussed.

In the light of the above terminology, it may inspire our people to have a centrally coordinated system with the help of computers to control traffic and avoid congestion.

CHAPTER 6

SAFETY MANAGEMENT SYSTEM

6.0 Introduction

As population increases traffic activity, economical restraints and potential and actual conflicts all increase but at the same time technical or procedural improvements do not take place. The crisis conditions associated with transportation are in operation and maintenance, environmental impact, and fuel availability. Each of these conditions affects personnel safety. Increase in transportation operations expose operators, passengers, pedestrians and by standees to greater risks of injury and death. Decline in the quantity and quality of maintenance produce greater risk and incidence of failure. The use of fossil fuels, and spillage's in the oceans, lake and rivers, affect ecosystems and eventually human health and well being.

Causes and problem areas

In general, traffic accidents are caused by failure of one of the three major elements of transportation system the human being (driver), the vehicle, and the road condition. Improvements in each of these areas can be expected to improve the general safety and to reduce the potential for failure. The basic causes of traffic safety problems are those forces or situations which bring about over crowding, a decline in maintenance of road ways, lacks of attention to clear and apparent hazards. The study of accident is a preventive point of view, that

is lessons learnt from the occurrence of a specific accident or a specific type of accident is applied towards the prevention of future accident, however in all modes the accident study approach and the preventive approach have developed separately.

Traffic accident studies:

Accident data, tabulated and analysed may be used by traffic safety personnel in the following ways

To define and identify high accident locations

To justify action on public request for installation of traffic control devices

To aid in evaluating different geometric designs and in determining and developing Proper designs of streets, intersections, drive ways, and traffic control devises Accommodate local conditions.

To establish ranking, programming and scheduling of improvements at high accident locations as based on numbers of accident types preventable by traffic measures

To identify the need to for improving police traffic, parking restrictions, improved road way lighting.

With electronic data processing, a number of tabulations may be available including periodic print out listing of accidents by location, periodic listing of high accident locations, accident frequency rates to highway type, geometric features, pavement conditions, etc. In many cases, the coding is only for accidents on the numbered state route system and accident data may not be readily available for secondary routes and city streets.

6.1 Inventory

Inventories are listings of accidents, keyed to general location such as intersections, individual blocks of a city or sections of rural highway. When developing inventory sections it is important to realise that data from short links can readily be added together whereas subdivision of data from sections of excessive length is much more difficult.

The problem of traffic accident is more serious in India. Nearly 22% of accidental death are due to heavy traffic. It is stated that the accident ratios have increased faster than the population. One of the major adverse effects of traffic problem in urban area apart from traffic congestion and deterioration in environmental quality is decline in road safety levels. Circulation of pedestrians is of prime importance for the substance of the cities. The share of the pedestrian trips in the total trips is of the order of 40% in many cities in India. This share is not likely to diminish in the near future in view of the increasing migration of rural population to urban areas. The pedestrian safety is a vital concern deserving immediate attention. The major measures to improve pedestrian safety includes side walk and crossing facilities. The main thrust of the measures should be to avoid pedestrian conflicting with vehicular traffic. Pedestrians crossing at signalised intersections are found to be very effective. However it is necessary to provide sufficient green time for a crossing pedestrian. Pedestrian underpasses are useful facilities to avoid conflict with vehicular traffic.

Cyclists

Bicycle is known as poor mans transport means. Comprehensive data on bicycle traffic and its characteristics are lacking for most of the urban areas due to its unregulated character and under representation in urban and traffic planning studies. In our country the existing database of road accident continues to be poor. An important implication for the design of new format of accident recording information is that it can be easily fed into the computer. Analysis also can be done on computer. The variables included in the form should be used on the kind of analysis which analysts expect to do later.

Accident rate calculations

There are three basic types of comparisons,

1. Parallel study (between different locations or areas for the same period of time)
2. Before and after study (between different time periods at the same location or in the same area.
3. Condition study (between physical features of the road way, regardless of the location or time)

In making comparisons, a measure of any change in exposure should be incorporated. The standard equation for calculation of accident rate is

rate = number of accident X basis / exposure

6.2 Mathematical Models

Speed and Accident severity:- In the case of road accident the kinetic energy is dissipated mainly in the form of damage to the vehicle and their occupants leading to fatalities and injuries in the case of high energy level. The dissipated kinetic energy during traffic conflict between two vehicles can be calculated on the basis of an inelastic impact as follows

$$\Delta E = 1/2g[G_1V_1^2 + G_2V_2^{\ 2} -(G_1 + G_2)V^2]$$

where $V = 1/(G_1 + G_2)[\sqrt{(G_1V_1)^2 + (G_2V_2)^2 + 2G_1G_2V_1V_2 \cos\alpha}$

ΔE = dissipated energy during impact

G_1, G_2 = weights of first and second vehicle respectively

V_1, V_2 = Velocity of first and second vehicle before impact

g = acceleration due to gravity

α = crossing angle

For the case that $G_1 = G_2 = G$. It can be reduced from the equation

$$\Delta E = G/4g [V_1^2 + V_2^2 - 2V_1V_2 \cos\alpha]$$

$$= G/4gV^2rel$$

where $V_{rel} = \sqrt{[V_1^2 + V_2^2 - 2V_1V_2 \cos\alpha]}$

if the speeds are equal

$$V^{rel} = V\sqrt{2(1-\cos\alpha)}$$

Thus accident potential of a highway increases significantly as the speed range increases. This increase becomes more and more pronounced as the conflict angle α increases from 0 to 180.

Accident forecasting

It is possible to predict the number of deaths likely on Indian roads in the year 2010 based on past trend fatality rate and vehicle ownership rate. Vehicle ownership rate in the year 2010 is

$$[(N/P) \times 10^4)]_{2010}$$

where

N = motor vehicle population per 10,000 people

P = people population

The vehicle owner ship rate $N/P \times 10^4$ has generally at the rate of 8.46% per annum

$$(N/P) \times 10^4 = 13.719(1 + 0.0846)^n$$

where n is the number of the year since 1960

$$= 13.719(1.0846)^{2010-1960}$$

$$= 13.719(1.0846)^{50}$$

$$= 505.5$$

There will be 795.7 vehicles for every 10,000 persons in the year 2010. Various agencies have projected Indian population to the year 2010 roughly it will be around 1020 million. Thus there will be 81 million vehicles in 2010.

The fatality rate in the year 2010 is

$$(D/N) \times 10^4 = 86.285(1-0.0241)^n$$

where $(D/N) \times 10^4$ death rate per 10,000 vehicle in the nth year.

$$[(D/N) \times 10^4]_{2010} = 86.285(1-0.0241)^{2010-1960}$$

$$= 86.285 \times 0.9759^{50}$$

$$= 26$$

Thus 26 will be killed per 10,000 vehicles. In 2010 AD we have estimated that 81.2 million vehicles on road. Thus all probability 2,11,120 persons will die out of road accidents.

Model for Comparing crash & Casualty rates

The crash occurrence results from a confluence of driver characteristics, vehicle characteristic and the people's environment

Crash = f(Driver, vehicle, people, environment)

Causalities(or fatalities) = crashes x severity

Severity can be defined as either fatalities or casualties per crash, depending upon the focus of the analysis. In developing countries, crash severity is impacted by a variety of factors including availability of emergency of medical service, vehicle type, and vehicle loading. Factors relating to crash involvement include road user characteristic such as driver age, years of driving experience, weather conditions or alcohol use.

6.3 Air Pollution

Environment has gained great importance in the world particularly during the last few decades. The Stockholm conference of 1972 that led to the declaration of the united nation's conference on the human environment awakened international community to the need for a common outlook and for common principles necessary to be observed for the preservation and enhancement of the human environment. The Rio Declaration on environment and development 1992 was another epic event in the preservation of the environment so important for the survival of mankind. Today more than ever before nations become environment- conscious and people have begun to realise the disastrous consequences of reckless industrialisation and technological invasion of nature. Multinational corporations bent on profit making at any cost from any where often ignores environmental guards and victimises humankind.

Air is a clean free life sustaining substance found in abundance. It is only after 50 years of independence, urban citizens are facing the risk of being gassed out their urban habitats. Particularly the metros are filled with smoke belching vehicles and a large number of polluting industrial units. The result is poisoned urban air. Recent survey indicates that one out 10 of Delhi school children suffers from asthma, Worsening air pollution caused by motor vehicles affects 8,80,000 in Delhi. About 40,000 are dying early every year - 7,500 in Delhi, 5,700 in Mumbai, 4,500 in Calcutta because of air pollution. Indians spend Rs 4,550 crore annually to make up for health damages caused by air pollution. In most of the 23 Indian cities with million plus populations air pollution levels are dangerously higher than World Health Organisation limits. The levels of suspended particulate matter (SPM)- dust and carbon particles coated with toxic gasses are at least three times higher than WHO standards. The main culprit is vehicle exhaust. It accounts for 65% air pollution in Delhi, 52% in Calcutta and 30% in Mumbai (Source:- centre for science & environment studies)

Vehicle exhaust contains harmful gases such as nitrogen oxides Nox , Sulphur dioxide So_2, Hydrocarbons Hc, Carbon monoxide Co, lead pb,. Vehicles also emit spm less than 10 micrometers in diameter (PM_{10}) which can be inhaled. About 80% of this are deposited in respiratory system. Ozone another poison form when exhaust reacts with sun light.

Many effects of vehicle exhaust are hidden and the damage is visible only very late. Study shows that air pollution causes serious health problems even when the levels are much lower than WHO limits.

Respiratory problem

There is mounting evidence that air pollution is related to numerous respiratory problems and even deaths from such illnesses. The pollutants that are mainly responsible for this are So_2, Nox, Ozone, PM_{10}. The rise in PM_{10} levels by 10 μg/m3 (micrograms per cubic meter) rise causes bronchitis, a chronic cough.

Cancer

Cancer is believed to be caused by alternations in our cell structure (mutation) which results in abnormal and uncontrolled growth of more cells. Scientists have estimated that at least 60% of cancers are preventable through control of environmental factors such as breathing polluted air. Cell mutations are caused by exposure to PA and SPUME. The diesel exhaust that has a high fraction of both causes 10 times more mutations than leaded petrol. The unleaded petrol contains a high level of benzene widely known to cause lung cancer and leukaemia.

Heart Problem

Pollutants such as So_2 , PM_{10}, Ozone and Nox , cause death from heart problems. Congestive heart failures can be linked to Co that presumably binds to the haemoglobin and decreases oxygen transport to the blood.

Brain damage

Lead is present in huge quantities in the petrol used in most vehicles in India. It is well-known cause of encephalopathy (a disease of the brain)in children that often results permanent brain damage. When children breathe in lead it can permanently lower IQ. In India leaded petrol is used in 90% of vehicles.

The ever increasing proliferation of the automobiles indicate that gaseous exhaust products would increase without limit. It is estimated that each vehicle annually emits on an uncontrolled basis, 0.15 tons of hydrocarbon, 1.06 tons of carbon monoxide, 0.053 tons of Nitrogen oxides, 0.005 tons of sulphur oxides and 0.004 tons of particulate. The later containing lead compounds. The total uncontrolled pollution emission for that year would be 0.15 x totals no of vehicles in that area etc. A variable source of air pollution that is strongly dependent on traffic flow patterns and more directly on automobile commuting activities. In the design of highways no special recognition has been given to difference in vehicle size or speed range. Thus the bus & other type of vehicles with its different speed, different pollution emission characteristic travel along the same highway during the same time interval increase emissions more. The restriction of standard automobile entry to major traffic arteries might be accomplished by computer control method pave the way to reduce emissions.

6.4 Planning and Development

In our country most of the highways are unplanned that encourage proliferation of automobiles and travel mileage adds their own contribution to the air pollution problem. New approaches should be made to the planning, design and operation of the transportation systems and urban development to illustrate the relationship of air pollution, emission etc. With respect to operations the improvement of traffic flow and the encouragement of the use of mass transit systems reduce the pollution levels.

The evaluation of the air pollution which has an impact on a large urban area from vehicle emission is a cause for concern in the major cities of India. The problem of pollution emission as well as pollution transport towards it has been tackled in two ways. Experimentally by evaluating the input and output mass flow by remote - sensing technique. Measurements have been performed along the motorways around the city.

Remote sensing Measurements

For experimental evaluation of pollution transport over the city, surveys were made along the motorways around the urban area with a mobile laboratory equipped with remote sensors. The measurements were performed while the van moved along the motorways. On board simultaneous information about the time and location were stored together with the measured data in a computer. For the modeltic approach, the emission inventory has been assembled not only for urban sources but also for isolated sources located inside and outside the area under investigation.

Optimal air quality control strategies

Let us assume we have chosen a certain control strategy depending on L control parameter's x_i (i= 1,2,3, L) with which concentration patterns of N pollutants can be influenced. If γ denotes the total cost due to a given set of the L parameters x_1, x_2, x_3, x_L, the general optimisation problem can be stated as follows

$$\text{minimise } z = \sum_{k=1}^{n} E_k C_k$$

subjected to

$$\sum_{k=1}^{n} E_k C_k \leq ET$$

$$\sum_{k=1}^{n} (1 - E_k) Pk(x,y) \leq P^* \qquad \forall x,y$$

where $p_k(x,y)$ is a pollutant concentration at (x,y) due to emissions within S_k , k=1,2,3, n be the non intersecting sub regions of the urban area, which can be potentially supplied with heat E_k, the thermal heat that is needed to supply S_k. ET is the total amount of the thermal energy available C_k, the cost for supplying sub region S_k with thermal energy.

$$E_k = \begin{cases} 1 \text{ if } S_k \text{ is supplied} \\ 0 \text{ otherwise} \end{cases}$$

In our country Centre for Science and Environmental studies proposes three variations for calculating environmental excise duty that will be in addition to the existing excise duty.

Slab:- For 2 and 3 wheelers, vehicles with emissions greater than 2.0 gm/km of carbon monoxide (CO) and 1.5gm/km of hydro carbons (Hc) and nitrogen oxides (Nox) Rs 550 /gm/km of (co + Hc + Nox)

Slab 2:- For vehicles with emissions up to 2.0 gm/km of co and 1.5 gm/km of Hc + Nox Rs 55/gm/km

Slab1:- For 4 wheelers' vehicles with emissions greater than 2.72 gm/km of carbon monoxide (co) and 0.97gm/km of hydro carbons (Hc) and nitrogen oxides (Nox) Rs 650/gm/km of (co + Hc + Nox)

Slab 2:-For vehicles with emissions up to 2.72 gm/km of co and 0.97 gm/km of Hc Nox Rs 65/gm/km.

Though zero emission vehicles are unlikely to hit the market in the very near future, an extra incentive will be needed for their production keeping in mind that the vehicle population in India is growing rapidly, while traffic and road infrastructure are not keeping pace, leading to congestion and enormous pollution. This means that our standards have to be more stringent than the rest of the world.

6.5 Noise Pollution

Noise levels generated by highway traffic can be measured. It is however the reaction of human beings to noise, levels which is of importance in attempting to determine the impact of the noise. Different people have different reactions to the same noise level and it is to determine the distribution to noise by the use of attitude surveys. Social surveys may be conducted in which respondents were assessed to give their reactions to traffic noise levels experienced at home. The range of sound pressure levels are given below.

Sound	Approximate sound pressure dB
Normal conversation	60
Library	40
Quite conversation	30

when sound pressure levels are measured adjacent to a highway, a meter measuring in dB might indicate the same value when a fast moving motor cycle with high frequency note and when a slow moving vehicle passes with lower frequency note. The major factors which influence the generation of road traffic noise are

a. The traffic flow

b. The traffic speed

c. The proportion of heavy vehicle

d. The gradient of the road

e The nature of the road surface

Noise reduction techniques can be applied to buildings themselves, such as double glazing and noise absorbing insulation. One certain way of reducing the nuisance from noise and vibration would be to reduce the amount of traffic in the first place, a strategy which would of course mitigate transports other environmental impacts too.

6.6 Conclusion

The chapter deals with the importance of the safety of passengers and the environment. The amount of degradation of environment due to traffic pollution has been analysed, and the methods for the reduction of pollution with the help of mathematical models has been discussed.

Further many models haven been developed to forecast traffic accident rates. The role of noise pollution due to heavy traffic has also been discussed.

CHAPTER 7

Conclusion and Scope for Future Research

7.0 Summary of the work

Traffic Management system (TMS) comprises four major sub systems: The Network Database Management system for information to the passengers, Transit Facility Management System for service, planning, and scheduling vehicle and crews, Congestion Management System for traffic forecasting and planning, Safety Management System concerned with safety aspects of passengers and Environment.

The Network Database Management system provides the bases of the network models that will be used in the urban motorway control centres and in the travel and traffic information systems. It will also provide a basis for storing and analysing the strategic information related to traffic. It provides wide spectrum of data which can be used by various government agencies.

The Transit Facility management describes the philosophy underlying the design of the system and the broad outlines of the intelligent interactive scheduling methods for administrative purpose. The best results are obtained with the power of mathematical techniques and computer technology, which permits a kind of higher level interaction between man and machine as an intelligent - interactive system.

The Congestion Management System deals with traffic flow. Statistical count distributions are used to estimate flow condition. Artificial neural network methods were established to create intelligent support systems for traffic monitoring and pattern recognition. Queuing analysis and centrally co-ordinated signal control system models have been discussed to estimate the severity of the congestion

The Safety Management system highlights the importance safety of the passengers. Mathematical models for pollution control and forecast accident fatality rate have been developed.

This work has opened a rather wide frame work of model structures for application on traffic. The facets of these theories are so wide that it seems impossible to present all necessary models in this work. However it could be deduced from the study that the best Traffic Management System is that which

is realistic in all aspects

is easy to understand

is easy to apply

As it is practically difficult to device an ideal fool-proof model, the attempt here has been to make some progress in that direction.

7.1 Future Development

Further developments in hardware will yield no fundamental alternation in the not - too- distance future, while the cost to performance ratio will become ever more profitable. Out of this an increasing use of computers will result. Most emphasis will be on user friendly interfaces, data management systems and computer networks. Certainly, conceptual improvements will be established in the software field. One main factor will be the complete inclusion of relational database systems. Not only does this consideration relate to the application and further development of isolated program systems, but the database system will acquire great importance as a connecting link between different packages for computer aided planning. However the data model may produce structures which will cause performance problems in certain planning phases.

Another essential aspect will be the further development of operational research and management science algorithms. This will be true for discrete as well as for probabilistic solution procedures.

Artificial intelligence, although not highly developed at present will be used in practice for different applications in the near future. Nevertheless the exceptions from the techniques should not be set too highly, certainly artificial intelligence systems will remain only as helpful devices used by the planning staff. Probably artificial intelligence procedures will be used mainly in two fields.

Computer - aided analysis and decision support systems.

Modelling processes

However, these techniques will not be able to replace the advantages of optimisation techniques.

7.2 Conclusion

Looking at the present situation further developments in computer- aided systems need no longer be the subject of financial restrictions in procuring hardware. In many cases lack of information among potential users prevents computer aided systems from being applied. At the same time there are tendencies to reject such systems for ideological reasons.

Therefore practical applications have to be prepared very care fully. This involves training of the planning staff as well as the acquisition of information and further education of different management levels. Further more there are financial burdens which result from parallel working during the transition from manual working to Traffic Management system.

In spite of additional expenditure, which will be limited to a specific time period, no mass transit company will be able to reject Traffic Management System in the medium or long term.

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