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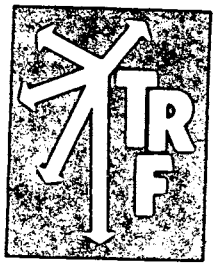

TRANSPORTATION RESEARCH FORUM
In conjunction with

Computer Applications for the Operational Analysis and Management of Urban Bus Routes in India

*By A.K. Gupta and S.S. Jain**

ABSTRACT

Indian cities are characterized by large growth rate in population and an accompanying stress on the conventional 'Public Transport System' particularly the bus transport system owing to its inherent advantages for a developing economy. At present bus routing and scheduling is mostly done on adhoc basis resulting into commuter's dissatisfaction and financial losses to the operating agencies. Much of the uncertainties in traffic operation arise due to the inability to predict the effect of changes in the system variables.

This paper elaborates the application of the computer simulation model developed at the University of Roorkee to rationalize a Delhi Transport Corporation (DTC) route, which represents a typical bus route of Delhi Metropolis. The validation of the above model is checked with respect to certain parameters associated with passenger service as well as the operational efficiency of the route. The applicability of the model to test the efficacy of certain bus route management proposals has been demonstrated here.

I. INTRODUCTION

A. General

The alarming growth of urban centres is a well known global phenomenon and India is no exception. The rate at which urbanization is increasing has caught both the planners and administrators unaware. Table 1 gives the envisaged population projections and Table 2 gives the growth trend in population and transportation demand in urban areas by 2001 A.D. Table 3 gives the population growth of metropolitan cities of India having the population exceeding one million, the decadal increase during 1971-81 on an average is 41%. The remarkable growth in urban population and increase in the number of vehicles in the last decades have imposed a serious threat to physical forms of cities resulting into acute problems of congestion and accidents. Congestion create additional problems to the bus fleet operation such as low speeds, bunching of buses, unreliability in passenger service, large passenger waiting time etc, which further add to the inefficiency of the entire bus system. Irrational location of bus stops, use of unprotected bus stops, inadequate capacity of bus bays etc, also contribute to the system inefficiency. These aspects have created the need of finding ways and means of improving operational efficiency of the urban bus system.

B. Objective

In the absence of any rational tool available for analysis and management of urban bus routes, routing and scheduling of buses in metropolitan cities in India are generally done on adhoc basis. University of Roorkee, (UOR) pioneered research on route management.

Various studies have been done on operational analysis of urban route system to fulfill the existing needs. Knowing the limitations of analytical and experimental techniques, many transportation engineers hope to find in the simulation technique a relatively inexpensive and convenient tool to conduct an operational analysis of the urban bus system.

A computer simulation model to optimize the operational efficiency of a single urban bus route has already been developed at this University and has been used through IBM 360/44 and 370/145 systems. The model incorporates the effects of mixed traffic flow conditions, variations in bus passenger demand and their effects on the operation of the system, spacing and geometric design aspects of bus stops, change in traffic signal etc.

This paper elaborates the application of the above computer simulation model to rationalize a Delhi Transport Corporation (DTC) route, which represents a typical bus route of Delhi Metropolis. The validation of the above model is check with respect to certain parameters associated with passenger service as well as the operational efficiency of the route. The applicability of the model to test the efficacy of certain bus route management proposals has also been demonstrated here.

An interesting and note worthy aspect of this research program is that a long-range national effort, to solve the enormous operational problem of DTC in The National Capital City, has also started and is being coordinated at this centre of transportation research.

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TABLE 1
GROWTH OF POPULATION (PROJECTIONS)

Year	1971	1974	1979	1984	1986
Total Population	546.9	581.2	636.8	685.8	705.2
Rural Population	438.0	461.3	497.3	525.6	536.2
Urban Population	108.9	119.9	139.5	160.2	160.8
% Urban to Total	19.9	20.6	21.9	23.4	23.9

TABLE 2
GROWTH TREND IN POPULATION AND TRANSPORTATION DEMAND IN URBAN AREAS

Year	Total Population (in million)	Urban Population (in million)	No. of passenger Trips in Urban areas per day (in million)
1971	547	109	82
2000	960	260	325
Growth in times	1.76	2.36	3.96

TABLE 3
POPULATION GROWTH OF METROPOLITAN CITIES OF INDIA

Sl. No.	City	Population in Year 1971	Population in Year 1981	Percentage Increase
1.	Calcutta	7031382	9165650	30.35
2.	Greater Bombay	5970575	8227322	37.80
3.	Delhi	3647023	5713581	56.66
4.	Madras	3169930	4276635	34.91
5.	Bangalore	1653779	2913537	76.17
6.	Hyderabad	1796339	2528198	40.74
7.	Ahmedabad	1741522	2515195	44.43
8.	Kanpur	1275242	1688242	32.39
9.	Pune	1135034	1685300	48.48
10.	Nagpur	9304459	1297977	39.50
11.	Lucknow	813982	1006538	23.66
12.	Jaipur	636768	1004669	57.78
	All Metropolitan cities	29802035	42022844	41.01
Other cities and towns		77164499	114641402	48.57
Urban Population (all India) Except Assam, Jammu & Kashmir		106966534	156188507	46.02

II. URBAN BUS ROUTE RATIONALIZATION

A. General

Urban bus route rationalization includes bus routing and scheduling which are the two basic aspects of the problem of assigning a bus fleet to multiple nodes in a city so that a certain level of service is provided which satisfies the urban travel demand.

The issue of route rationalization can be pursued with two approaches.

(i) Rationalizing the route system of the city as a whole
(ii) Rationalizing existing individual routes

A comprehensive approach to rationalizing the route system taking into consideration the entire city as a basis for analysis is highly comprehensive and ambitious. Further, the duration of such a comprehensive study may be so long that by the time the inferences are applied, they may become obsolete. The second approach is an organized disaggregated approach. It refers to rationalizing a particular individual route which needs immediate attention owing to its deficient nature.

B. Analytical Models

The urban bus operation can be studied by mathematical models in terms of the times taken by the passengers and buses in different stages of their journeys. They deal with the analytical formulation of the problems of bus scheduling, passenger loading and unloading characteristics, passenger waiting and walking time and spacing of bus stops etc. Many analytical models have been brought out to optimizing the passenger waiting time, bus passenger service time such as by Newell and Potts, Friedman, Lesley etc. These models are deterministic in nature and do have certain limitations in their application, since most of the bus transport operating characteristics have inherent stochasticity.

C. UOR Simulation Model

A bus simulation model has been developed very recently at UOR for the operational analysis of a given urban route. This model has been tested and validated for Delhi operating environment. For this, DTC route No. 139 was chosen for the study which connects the central area, namely Connaught Place to Mukerjee nagar, a terminal at the north end of the city.

The route to be simulated is divided into a number of links (or blocks). General traffic is simulated macroscopically by a time scanning procedure. At each time interval, the vehicles that constitute the general city traffic are generated according to a Monte Carlo procedure using Poisson distribution. Bus simulation is microscopic and according to an event scanning scheme. Each bus is identified throughout the simulation run and time is recorded whenever a significant bus event takes place. These vents are the arrivals of the buses to stop lines and bus stops and their departures from bus stops. Buses are moved along the link according to the speed density relationship developed for Delhi city for the mixed flow conditions.

D. Computer Simulation Programme

The simulation programme is written in FORTRAN IV language and was initially run on IBM 360/44 and later on IBM 370/145 and DEC-20/50 system. The model consists of the main programme and eight subroutines. The general flow diagram of the simulation model is shown in Figure 1. the validation of the model is done with respect to (a) Time distance relationship of bus service, (b) Irregularity of service and 8c) Passenger waiting time. The result of the validation tests are discussed elsewhere which indicate that the real life situation is well replicated by the simulated model.

III. OPERATIONAL ANALYSIS OF BUS ROUTE—A CAST STUDY FOR A DTC ROUTE IN DELHI

For studying the application of the Simulation Model to urban bus route analysis, DTC route No. 80(3) which starts from Motinagar and ends at Central Secretariat was selected. Field data for the above route was supplied by the delegation of T.R.R.L. (U.K.) stationed at Delhi which carried out research in urban bus transportation in India in collaboration with the Association of State Road Transport Undertakings (ASRTU), New Delhi.

A. Field Data Used

The data supplied by the above team includes the following

(i) Interstand distances in meters
(ii) Interstand travel times taken by the buses in seconds.
(iii) Number of passengers boarding/alighting at each of the bus stops.
(iv) Land use classification of the route No. 80.

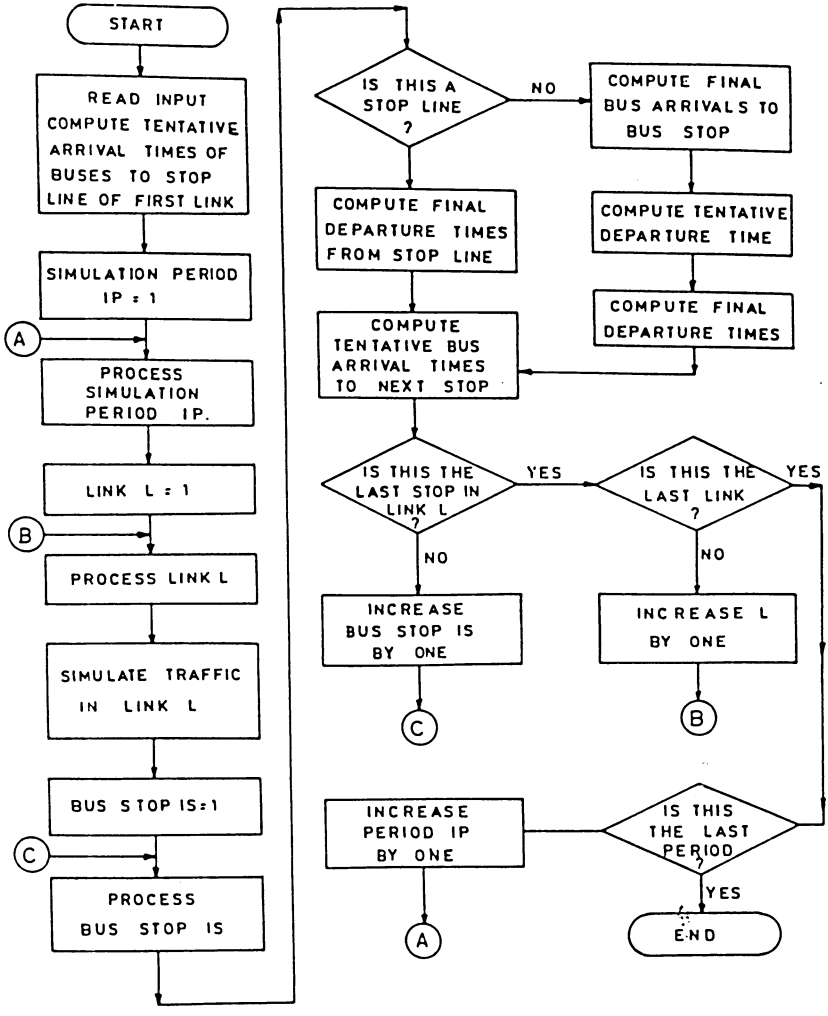
The above data supplied by T.R.R.L. (U.K.) team did not fully satisfy the requirements of the input data needed in the UOR simulation model. This is because, it could not give the following information.

(i) Traffic demand in vehicles per hour at the entry link.
(ii) General traffic volume for each intersection, expected traffic volume coming from mid block sources or attracted by mid block sources, expected traffic volume moving in the opposite direction in each link, turning probabilities at each intersection and expected traffic distribution by lane.
(iii) Mean traffic speed in each link.
(iv) Traffic signal setting at each intersection.

In order to extract the needed input information following assumptions were made for the route studied.

(i) All the intersections are non-signalized.
(ii) The general traffic speed for each link is assumed as the average running speed of the buses at each link.
(iii) The various mathematical relationships with respect to bus speed and density of general traffic, acceleration-deceleration of buses and passenger service time with respect to

Figure 1. General Flow Chart of Simulation Model



loading and unloading characteristics of buses are the same as observed for the D.T.C. bus route No. 139, studied earlier.

B. Model Validation

In this study the validation of UOR Simulation Model is done for peak hour period i.e. 0900 to 1000 hrs with respect to the following.

(i) Time-distance relationship of bus service during peak hour. Typical results of one simulation run are shown in Figure 2.
(ii) Passenger loading and unloading at each bus stop during peak hour.

Comparison of computed and observed data indicated variation from 5 to 20 per cent with respect to travel time of buses. Comparisons of number of passengers loaded and unloaded at various bus stops reveal variance up to 25 per cent. Somewhat larger variance observed in this study in comparison to earlier study for route No. 139(2) may be attributed to assumptions made in the analysis with respect to input data needed as mentioned earlier.

IV. MANAGEMENTS OF URBAN BUS ROUTES

Having developed a comprehensive bus route simulation model for conducting the operational analysis of the bus system, the applicability of the model to practical problems has to be demonstrated to convince the transport managers about the output capability at operational level and to create confi-

dence in its accuracy of predictions. For realizing this objective, several bus route management proposals were evaluated with the simulated model.

A. Removal of some bus stops

From the data supplied by TRRL (U.K.) team, it found that the route No. 80 has 15 bus stops, in which three bus stops via. Railway station, South Patel Nagar and North Avenue II have a very low passenger loading and unloading. These stops are skipped and the loading and unloading of passengers of these three bus stops are distributed equally (50 per cent) to adjacent bus stops.

B. Removal of some buses in peak hours

Route No. 80 has 8 buses in operation during peak hour. In this study only 6 buses are taken and number of the bus stops is kept same as in the existing condition.

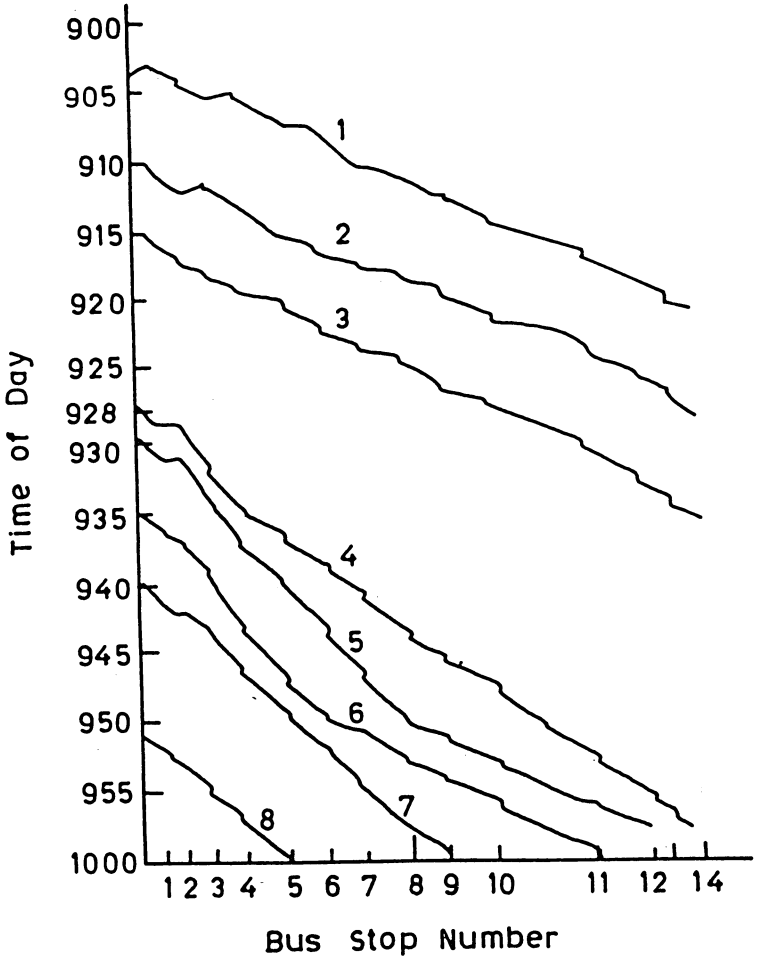
C. Introducing mini-buses

In this study 16 mini-buses are taken in place of 8 single decker buses which are at present in operation. The departure times of buses are refixed to have 50 percent cut in head-way with respect to the existing conditions.

D. Introducing exclusive bus lane system

In this study it is assumed that the curb lane is reserved for buses, so that the vehicle from general traffic (which includes vehicles coming from left and right sides and vehicles coming from mid block sources) are allowed up to a maximum of 5 percent of exclusive bus lane traffic and rest of the vehicles

Figure 2. Computed Relationship of Bus Service During Peak Hour from One Simulation Run



are assumed to use the next lane adjacent to curb lane. In this study 8 buses and 15 bus stops are taken in operation as in the existing conditions.

Figure 3 shows the comparison of mean overall speed of buses operative in the above mentioned proposals vis-a-vis the existing condition. It is observed that the mean overall speed is the highest in case of exclusive bus lane system and lowest in the third proposal i.e. in case of introduction of mini-buses. The mean passenger waiting time is also the least in case of exclusive bus lane system as compared to other systems as shown in Figure 4. If the running cost of a bus is assumed as rupees 50/- per hour of running, the saving in terms of bus running cost would vary from Rs.0.33 to 12.01 per bus for the above mentioned route rationalization proposals. The saving is the highest in case of exclusive bus lane system. There would be a loss in operational cost in case of proposal i.e. introduction of mini buses in place of single decker buses which would amount to rupees 9.40 per bus. The UOR Simulation Model thus assists bus operators to perform

Figure 3. Comparison of Mean Overall Bus Speed for Each System

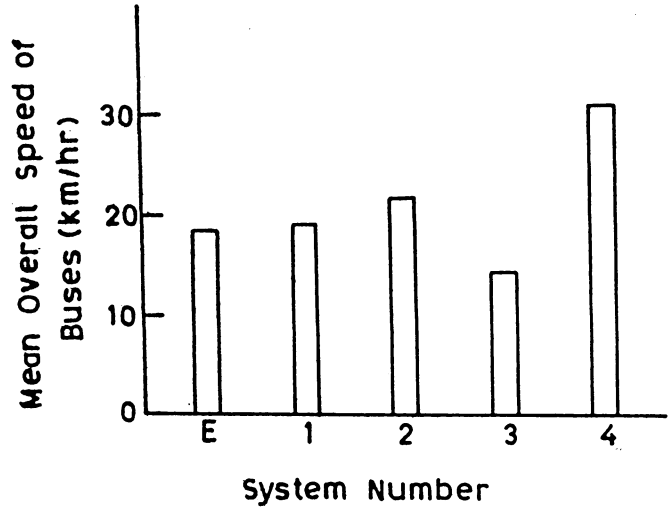
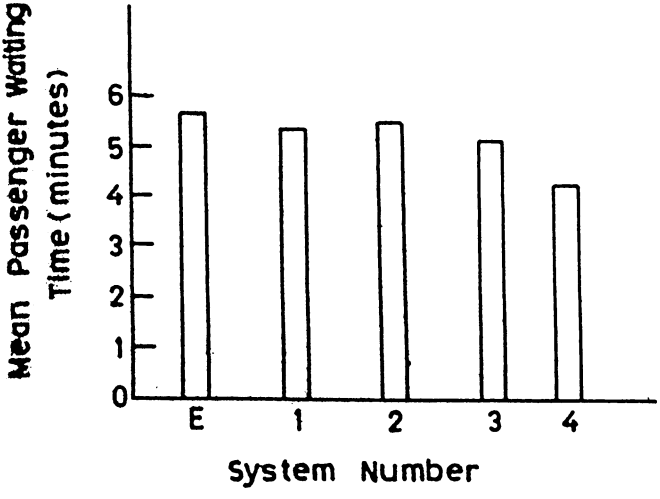


Figure 4. Comparison of Mean Passenger Waiting Time for Each System



quantitative evaluation of various alternative schemes of improvement in the operation of the urban system.

E. Bus System Efficiency

The efficiency of a bus system should be rated from the view point of management as well as commuters. A reduction in the average travel time results in an accumulated saving in bus minute which can either be considered as saving for the management or can be pooled back into the system. A reduction in the wasting time is a measure of effectiveness of the service offered to commuters. In order to combine these two aspects and to bring out the effectiveness of the various alternative systems, a term called efficiency index (EI) is used which is defined as the ratio of average speed of travel per bus to average waiting time per passenger. The index is adjusted by a factor so that the existing system with no improvements has an EI of 1.0. By knowing the increase in efficiency that can be expected from various improvements in transit service, it is possible to test in advance, alternative management proposals that would be needed to cater for the anticipated future demands for planned expansion of an urban bus system. This prior knowledge about the impact of the various bus management proposals on the system efficiency is a basic necessity.

The stepwise improvement programme by which the EI of the bus system for the selected route can be increased from 1 to 2.1 is clearly brought out by the model and is summarized in Table 4.

V. PRESENT EFFORTS IN THE ANALYSIS AND MANAGEMENT OF URBAN BUS ROUTES OF DTC IN DELHI

At present bus routing and scheduling is mostly done on adhoc basis resulting into commuters dissatisfaction and financial losses to the operating agencies. Much of the uncertainties in traffic operation arise due to inability to predict the effect of changes in the system variables. Field experimentation of traffic management techniques is expensive and time consuming when conducted in well developed metropolitan cities. An overall analysis of the urban bus system involves the description of all the bus routes through network analysis which is very expensive. Alternatively, it is thought desirable to conduct operational analysis of each route separately. The object of the present research is to develop a computer simulation model of urban transport for mixed traffic conditions in Indian environment so as to be able to forsee the results of introducing certain policy and engineering changes in the bus routes and traffic management. To achieve the above objective, some typical bus routes of DTC have been selected. The route details as collected from the records of DTC are given in Table 5.

The route details as given in Table 5 shows the route length, range of frequencies, earning per kilometer (E.P.K.) and fleet size etc. that are most commonly found in existing DTC bus routes. There are routes even longer than 25 kms. The ten routes selected are the representative of route passing through various nodal points as planned in the overall system of routes in Delhi. The routes chosen at present are shown in the Figure 5. The data collection work on the above routes is in progress.

It is hoped that the results of the above study will be useful in development of a suitable methodology for the operational analysis and management of urban bus routes in a metropolitan city of Delhi. This would be further useful in the improvement of the existing routes in Delhi as well as planning of new routes for the developed and under developed cities of India.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

Due to large number of variables involved in the urban bus route operational analysis and the inherent stochasticity of the problem, simulation technique is generally adopted to arrive at the optimal proposal for route rationalization. One such computer simula-

TABLE 4
EVALUATION OF VARIOUS BUS MANAGEMENT PROPOSALS

Management Proposal	Bus System Efficiency Index
1. As Existing	1.00
2. Increase in Bus Stop Spacing	1.45
3. Provision of Bus-Bays for two Buses	1.70
4. Introduction of Exclusive Bus Lanes	1.84
5. Introduction of Grade Separated Bus Lanes	1.95
6. Grace Separated Bus Lanes with Bus Bays for Four Lanes	2.10

TABLE 5
DETAILS OF SELECTED ROUTES

Route Number and Name	Route Length (km)	Route Details		
		No. of Buses	Frequency (Minutes)	E.P.K. (Rs.)
Ring Road				
952, Punjabi Bagh Extn. Kamla Market	15.3	8	20/40	1.64
503, ISBT-Malviya Nagar	18.6	10	6/12/24	1.45
207, ISBT-Chanakyapuri	15.2	5	20/40	1.32
440, Regal-Kalkaji	16.1	7	8/15/30	1.58
208, Raja Garden-ISBT	12.5	4	20/40	1.30
300, Noida-Central Secretariat	25.1	5	18/36/72	1.60
116, Red Fort-Azadpur (T)	14.8	5	20/40	0.99
680, Central Secretariat-Manadgir	22.4	10	7/14/28	1.55
216. Seema Puri-Laxmi Narain Temple	19.3	15	5/10/20	2.10

tion model has been developed at the University of Roorkee to optimize the passenger service level and urban bus operational efficiency of the given service route. The application of the model to route rationalization is demonstrated herein for D.T.C. route No. 80. The effectiveness of four route rationalization proposals via. (1) Removal of some bus stops (2) Removal of some buses in peak hours (3) Introducing mini buses (4) Introducing exclusive bus lane system have been evaluated in terms of changes in mean overall speed of buses and mean passenger waiting time. The results exhibit adequate sensitivity of the model to various changes in the system variables.

The approach as discussed in this paper for analysis of urban bus routes would be helpful for the traffic engineer and planner in decisionmaking to arrive at the optimal traffic management schemes. The research efforts are in progress to include more number of the routes on systematic basis for further insight and larger applicability.

B. Recommendations

(i) Further studies can be made to extend this work for the effects of interaction of overlapping routes on the routing and scheduling which have been neglected so far to a large extent.

(ii) The data base for analysis in such a system normally, requires the use of a high speed computer system. The use of computer aided analysis and design is very useful in the management of such complex problems, having a multitude of interacting variables. This problem is being usefully studied at University of Roorkee aided by a DEC-20/50 computer system, in succession to earlier works on relatively slower computer systems.

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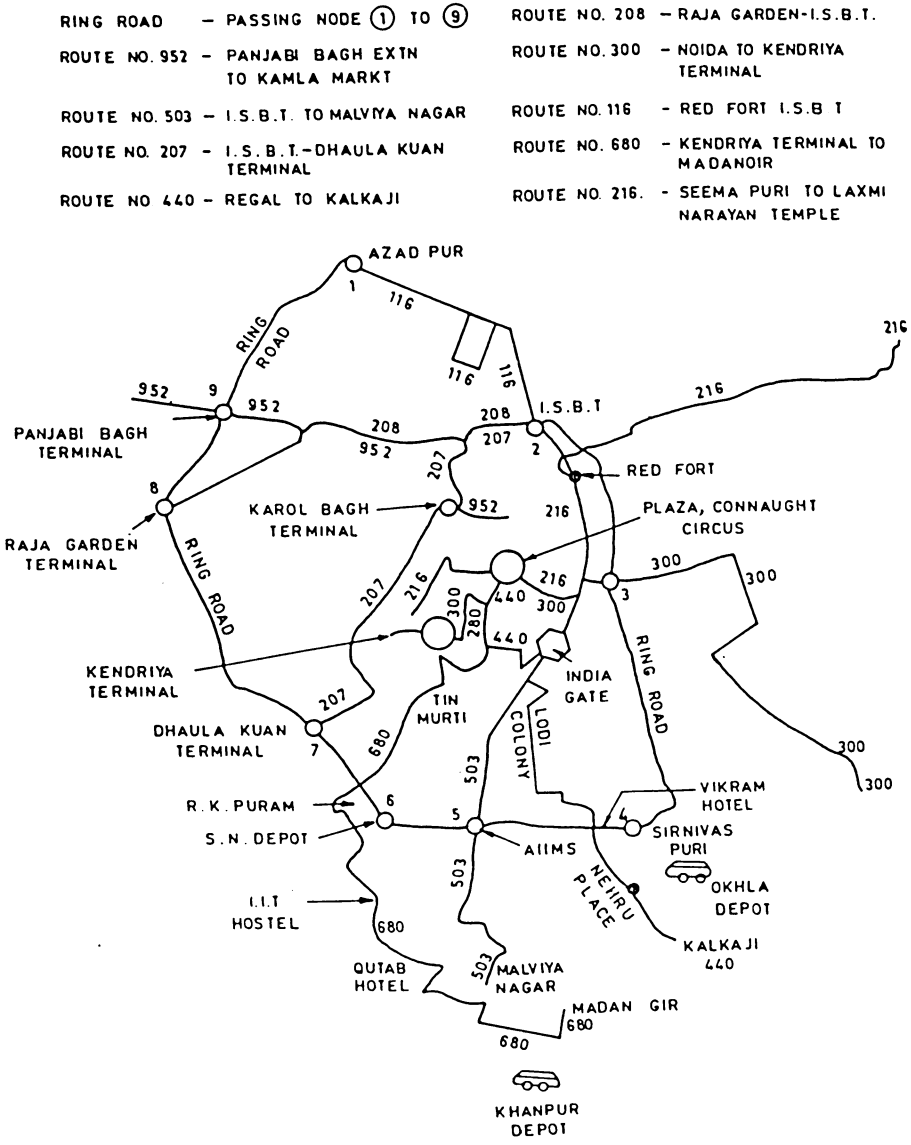
Figure 5. D T C Routes Chosen for Detailed Study



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