Transit Network Scheduling for Feeder Bus Operation in Delhi

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Abstract

Transit network (TN) design process involves optimization in two stages. One is transit route network (TRN) design or routing and another is transit network scheduling (TNS). TNS takes care of operating headway or vehicle frequency, fleet size, desire trips, bus schedule tables. This paper deals with the scheduling of the feeder route network of Delhi metro as a part of integrated transit system (ITranS).

Key Words: Transit Scheduling, Optimization, Time table, Integrated Transit System

Introduction

Transit system integration is requirement of urban areas of developing or developed county. Lack of coordination between the modes of transportation leads to longer travel (journey, wait and walk) time, reduced modal share of transit vehicles and finally affect the quality of urban life. TRN and TNS are steps forward of operational integration for ITranS. TSN is attempted here for the Delhi metro feeder network. Feeder routes are generated to increasing the service area coverage and accessibility of metro. Bus service can be used as a feeder to feed the metro. For the optimized feeder bus routes optimal allocation of buses along the routes is important. It can be performed with the evaluation of parameters such as headway, number of trips, fleet size number of buses, trip time and time table or bus schedule tables.

The Careful and detailed scheduling computations and precise presentation of schedules are extremely important aspects of transit system operation. They affect the efficiency and economy of operation, the regularity and reliability of service and the facility with which the public can use system. Good scheduling means spacing transit vehicles at appropriate intervals throughout the day to maintain an adequate level of service. So it minimizes both the waiting time for passenger as well as the transfer time from one route to another. However certain constraints have to be considered to achieve goal of best level of service (minimum of total time).

The resource and service related constraints are:

- Limited fleet size: only a fixed number of buses/trains are available for operating on the different routes.
- Stopping time bounds
    - Minimum stopping time; that is bus/train cannot start as soon as it stops
    - Maximum stopping time; that is bus/train cannot stop for more than a certain period
- Policy headway: on a given route a minimum frequency level needs to be maintained.
- Maximum transfer time; no passenger on the network have to wait too long for a transfer

The factors which will control schedule design are:

- Level of service
    - Service frequency
    - Walking distance
    - Waiting time
    - Travel time
    - Reliability
    - Comfort
- Maximum utilization of the fleet

- Cost
    - Operational cost
    - Travel cost
    - Cost of delay

Research Review

Various attempts have been made to obtain optimal schedule of transit networks. The study reported by Rea (1972) generated a model assuming known transit demand to serve an optimum bus network by adjusting iteratively the frequencies and types of buses. Schedules generated by Sikdar et. al. (1977) for optimal dispatch considered total delay of passenger should be minimum and headway gap at any time of the day should not exceed prescribed maximum interval. The designed schedules are evaluated by indicators like average waiting time, total passenger waiting time, percent occupancy of buses, fleet size. Dubois et. al. (1979) applied set of procedures to the replanning of medium sized town bus routes. Ceder (1984) described and analyzed several appropriate data collection approaches for the bus operator in order to set the bus frequencies/headways efficiently. Out of different methods presented: point check (maximum load) data and ride check (load profile) data, ride check provides more complete information at a greater cost. The heuristic approach for the allocation of buses (frequency) to regional transit bus routes presented by Kalaga et. al. (2001). Yang (2007) presented an optimization model for a bus network design based on the coarse-grain parallel any colony algorithm. The model is objected to maximize the direct travel density based on demand for an entire bus network with minimizing the average trip time between origin and destination without transfer.

Scheduling Model for Optimized Routes

The TN design and scheduling problem corresponds to the first step of the transit planning process (Guihaire and Hao, 2008). Ridership level on the highway network is known as an outcome of the assignment model. Based on the ridership data number of alternative routes for particular set of origin and destination are found out. The optimization process applied to seven metro stations on line 1 of Delhi metro. There are 21 feeder paths are generated by considering the effect of metro and 11 alternatives are found to be optimized. This method describes a mathematical simulation for optimizing bus headway and estimation of bus operation and system characteristics for these 11 routes. For the optimized routes, it is very important to know how optimally allocation of buses along the route can be done. The TNS model estimation is based on the evaluation of different parameters.

Step 1 Passenger Flow on Each Link

First of all, passenger flow on each link is to be calculated with the help of transit assignment model performed for optimized routes. The typical four stage travel demand is performed and validated in GIS based macro simulator TransCAD.

Step 2 Identification of Bus stops

For identifying location of the bus stops on the route, node buffer layer of 150 meter is prepared over the route system in the simulator as per convenient walking distance. There should not be more than 50% overlapping among two neighbor nodes influence area for selection as stop. The maximum and minimum number of stops are also given as constrain. Constrain is decided based on the maximum route length allowed based on the optimum length. The minimum numbers of stops are two per kilometer route length and maximum is fifteen. Any node within half a kilometer of metro station is not considered as bus stop and excluded from demand and halt time. Passengers are not expected to use feeder bus as 500 meter is considered to be a reasonable walking distance.

Step 3 Bus Trips for Route

Desired bus trips can be calculated based on passenger link flow 'L_f' and desire average bus load for a specified level of service (LOS) '$avgBL_D(LOS)$'. The desire average bus load considered for LOS I is 35, LOS II is 40, LOS III is 45 and LOS IV is 50. In this study LOS II is assumed and route wise desire bus trips are calculated. It also required to find out minimum trips for the route by knowing weighted equivalent peak hours 'PH_{weq}' and policy headway 'H_P'.

It is also required to decide the type of bus as number of trips also depends on it. Ideally standard bus with the capacity of 50 passengers is operated but if the congestion on the feeder links is high or the category of the link is lower than double lane divided (narrow link) then mini bus may be operated.

$$Desire\ Bus\ Trips\ on\ Route = BT_D = L_f / avgBL_D(LOS) \quad (1)$$

$$Minimum\ Trips\ on\ Route = Assigned\ Bus\ Trips = BT_A = PH_{weq} / H_P \quad (2)$$

Step 4 Estimation of bus operation and system characteristics

Following characteristics of scheduling policy are also calculated for analysis of system. The estimated parameters for each route are given in table 1. Three different time components are considered for calculation of round trip travel time. Travel time component is ride time or IVTT. For IVTT calculation the average speed of the bus is considered 20 km per hour. The halt time is dependent on number of passengers boarding and alighting per stop. OVTT is represented as halt time and assumed average value of 0.5 minute per stop as it varies with time (peak or off-peak). The last component is layover time and the value assumed is 5 minutes.

For the estimation of operating headway schedule time period is consider as operating hours of feeder in a day and assumed to be 18 hours (5-30 hr to 23-30hr). The operating headway found here is an average headway throughout the day. Due to higher demand in peak hours and lower in off peak, the headway cannot be constant. A number of travel demand analyses have shown that while the average wait for local, often irregularly scheduled bus service can be adequately described for travel estimation purposes as one-half the headway, the average wait for commuter rail service cannot (TSF, 2004). Number of buses is counted per route as the minimum requirement and to have an idea of total fleet size. Number of parking lots is also decided based on layover time and operating headway. Kilometer operated per bus defines the utilization of the buses along the route.

$$Round\ Trip\ Time = TT_R = 2(Travel\ Time + Halt\ Time + Layover\ Time) \quad (3)$$

$$Operating\ Headway = H_o = Scheduling\ Time\ Period / BT_D \quad (4)$$

$$Number\ of\ Buses = N_B = TT_R / H_O \quad (5)$$

$$Number\ of\ Parking\ Lots = N_{PL} = \frac{Layover\ Time}{H_O} + 1 \quad (6)$$

$$Average\ Wait\ Time = WT_{avg} = 0.5 * H_O \quad (7)$$

$$Fleet\ Size = F_Z = \sum N_B \quad (8)$$

$Total\ km\ Operated = T_{kO} = 2 * L_r * T_O$, L_r is route length and T_O is operating trips (9)

$$km\ Operated\ per\ Bus = T_{kO} / N_B \quad (10)$$

Table 1 Estimated Scheduling Policy Parameters

Route No.	Metro Station	Direction	IVTT (min)	No. of Stops	OVTT (min)	Total Travel Time (min)	Total Length	Desire Bus Trips	Operating Headway (min)	Round Trip Time (min)	No. of Buses	No. of Parking Lots	Avg. Waiting Time (min)
1	Jhilmil	N	15.3	12	6.0	21.3	5.11	85	12.71	31.3	2.47	1.39	6.35
2	Mansarovar	N	16.0	14	7.0	23.0	5.32	62	17.42	33.0	1.89	1.29	8.71
3	Welcome	N	15.3	11	5.5	20.8	5.10	88	12.27	30.8	2.51	1.41	6.14
4	Silampur	N	13.1	11	5.5	18.6	4.38	75	14.40	28.6	1.99	1.35	7.20
5	Shastri Park	N	15.8	11	5.5	21.3	5.28	80	13.50	31.3	2.32	1.37	6.75
6	Silampur	S	13.2	11	5.5	18.7	4.39	65	16.62	28.7	1.73	1.30	8.31
7	Shastri Park	S	12.5	10	5.0	17.5	4.17	87	12.41	27.5	2.22	1.40	6.21
8	Shahdara	S	10.1	8	4.0	14.1	3.36	91	11.87	24.1	2.03	1.42	5.93
9	Dilshad Garden	S	8.3	6	3.0	11.3	2.77	85	12.71	21.3	1.68	1.39	6.35
10	Jhilmil	S	12.6	10	5.0	17.6	4.21	70	15.43	27.6	1.79	1.32	7.71
11	Mansarovar	S	9.0	7	3.5	12.5	2.99	58	18.62	22.5	1.21	1.27	9.31

Feeder Bus Schedules

For time tabling first total hours of bus operation system must be decide by keeping in view of demand and travel characteristics. Bus service as a feeder to metro takes consideration of operating times of metro (main mode). The demand varies depending on the peak and off peak hours of a day. Since the peak hour has higher load than the lean hours, the frequency of the service will be higher. Headway of feeder routes should not be less than the operating headway of metro which is 4 minutes.

Trips required in peak and off peak hours are found out by multiplying the weighted hour fraction to the total desire trips. By knowing the actual operated trips and scheduled hours, operating or actual headway can be determined. The actual headway and round trip time gives no of buses required. The example calculation for the bus schedule for the feeder route number 1 is explained here. The weighted distribution of the hours in to peak and off peak for the study area is mentioned in table 2.

Table 2 Distribution of Trips

Time of a Day	5.30 to 7.30	7.30 to 11.30	11.30 to 17.30`	17.30 to 21.30	21.30 to 23.30
Hour	Off Peak	Peak	Off Peak	Peak	Off Peak
Weighted Distribution	0.071	0.357	0.167	0.309	0.095
Duration (hrs.)	2	4	6	4	2
Desire Bus Trips (ex. Total 85)	6	30	12	28	9
Headway (min)	20	8	30	8.5	13

For feeder bus service of Delhi metro operating hours (5.30 to 23.30) are decided half an hour before and after the operating hours of metro (6.00 to 23.00). The gap of half an hour is decided based on trip time with an average value of 28 minutes. The operating hours again divided in the peak an off peak range. From the field data, weighted distribution of the trips throughout the day is work out. Suppose 85 desire trips are there for route number 1 then total trips are multiplied with the weighted distribution to get the number of trips for particular duration of peak and off peak. Duration in minutes is divided by trips to get the operating headway in minutes. With the help of this operating headway schedule of the bus in terms of time table is prepared. The time table is prepared for first three durations and similarly it can be done for rest two durations.

Time		Schedule
5.30 to 7.30	→	5.30, 5.50, 6.10, 6.30, 6.50, 7.10, 7.30
7.30 to 11.30	→	7.38, 7.46, 7.54, 8.02, 8.10, 8.18, 8.26, 8.34, 8.50, 8.58, 9.06, 9.14, 9.22, 9.30, 9.38, 9.46, 9.54, 10.02, 10.10, 10.18, 10.26, 10.34, 10.42, 10.50, 10.58, 11.06, 11.14, 11.22, 11.30
11.30 to 17.30`	→	12.00, 12.30, 13.00, 13.30, 14.00, 14.30, 15.00, 15.30, 16.00, 16.30, 17.00, 17.30

Conclusions

For optimized route, selection of destinations and bus stops is very important. The potential destinations and bus stop locations are identified by the following procedure.

- Based on the passenger flow on highway network traffic assignment performed through TransCAD, demand per node is identified.

- The buffer of 150 meter is created for node layer of integrated network and the stops are assigned with less than 50% overlap between two consecutive nodes.

Coordination between modes cannot be achieved without scheduling model. It is also important to allocate buses along the route optimally. Before deciding scheduling policy the transit assignment model is run and passenger flow is assigned on route using TransCAD. The estimated operating parameters for the selected 11 routes are desire bus trips, operating headway, number of buses and number of parking lots.

Finally, bus operating schedule is prepared and explained in detail for an optimized route. Schedules are necessary to increase regularity and reliability of service.

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