International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
Available at http://inpressco.com/category/ijcet

Research Article

Demand based Scheduling for Rail Commuter Services

Trivedi Hemant S.[†*]

[†]Production Engg. Department, Shantilal Shah Engg. College, Sidsar, Bhavnagar, India

Accepted 05 Feb 2016, Available online 07 Feb 2016, **Vol.6, No.1 (Feb 2016)**

Abstract

The suburban railway system In Mumbai caters to almost 7.5 million people every day, and this number is steadily increasing. In this paper, the problem of deciding on the levels of service, construction of terminal facilities provision of differentiated services(e g fast trains, slow trains, different classes of travel etc.,) and finally the important issue of drawing up the schedule as a combination of various services has been examined. The perspective given here is one of demand satisfaction at the maximum level subject to the supply constraints, rather than one of supply efficiency maximization at certain acceptable levels of service, With the slowly growing supply of services completely unable to keep up with the fast growing demand, public attention is now being increasingly focused on even the details of schedules Decision, to extend trains, provide reversals at terminals, provide fast services, etc are all now at the cost of some other service factor, as the system is heading towards saturated levels of operation. An integrated method of evaluating various service factors to judge the effectiveness of the schedule has been presented in this paper. The ana1yis considers waiting time at the station, travel times and convenience of travel because of trains starting at particular points, to construct a composite service objective which can be optimized. In effect, It can minimize certain measure of passenger inconvenience. In theoretical terms, the permissible schedules from an operational standpoint form a large feasible set and the complicated nature of the composite objective makes for a difficult optimization problem. Simple heuristics and other solution techniques for this type of problem are discussed in this paper. In fact, the advantage of the proposed method is that since it is an open policy based on well-defined demand criteria, it would lend to increased user participation in defining demands accurately, accepting the constraints of supply and dealing with tradeoffs. To the supply authority, (the railways), this method would help in increasing the operational efficiencies, and identifying operational bottlenecks. These effects would have a long-term impact on public acceptance, involvement and commitment to investing and operating public transport systems

Keywords: *Rail, Commuter, Scheduling, Tactical, Modeling, Headway, Service, Operational Efficiency*

1. Introduction

The Mumbai Suburban Railway is an offshoot of the first railway to be built by the British in India, and is also the oldest railway system in Asia. The suburban railway system in Mumbai caters to almost 7.5 million people every day, and this number is steadily increasing. There is now no doubt that a major bottleneck in the overall development of the city is the transport network, which upto recent years was playing a proactive role in the growth of the city. This has been vindicated by the fact that most of the planned development in the city has been guided by the rail network (and to some extent the bus network) rather than the other way around. This is not the case anymore and substantial capital investments have to be found to upgrade the transport system for the needs of the next many years.

It is also possible that more demand side oriented measures like decongesting the city, proper pricing and incentives for modification of modal choice etc. may play a crucial role in the eventual development of transport services in Mumbai, from now on.

In this paper, the focus is specifically at the suburban railway system and considers the issue of operational efficiency at any given level of investment and facility infrastructure[1]. With the saturation of the services in the existing infrastructure (at least as claimed by the railways), the demands made by various sections of commuters cannot all be met simultaneously and trade-offs are inevitably involved. The process of providing services now needs to be made transparent to fulfill several goals:

1) The interests of various constituencies can be effectively included only if the decision making process is transparent. As the demand for services grows, it is not only the quantity of services that needs to be increased. The number of different

*Corresponding author **Dr.Trivedi Hemant S. is working as Associate Professor**

constituencies whose interests have to be considered also grows. Some issues that need to be considered are spatial extent of demand for services, critical mass of population which demands differentiated services, specific groups of customers (e.g. ladies, market vendors, handicapped, etc.) and so on To claim to have included most if not all such constituencies in planning of services, the process of planning has to be accessible, transparent and lead to accountability of the planners, the representatives of various groups of customers and the regulatory or supervisory authority.

2) The methodology of providing effective services can be more rationally addressed. Once the initial setting up of the system infrastructure is over, simple quantifiable measures of service could be defined, which in turn could lead to a proper allocation of resources. These considerations could be subsequently useful in the strategic planning of network expansion.
3) The public and government participation in a transparent process will lead to greater acceptance of implementation. One of the difficulties faced on the supply side is that since transport planning is not completely integrated with broader phenomena like urban development, the demand for services is sometimes out of proportion to what can be offered reasonably. Keeping in mind that there is an imperfect market mechanism as far as railway services go2, the public conception often needs to be refined, as to what a reasonable level of service

   [2]While the analysis has been motivated by the scenario in Mumbai, the methodology is dearly applicable to other similar situations is, compared to the costs involved Greater understanding of the supply side constraints on the side of demand representatives will lead to more informed efforts on all fronts (feedback, monitoring, long-term planning etc.) rather than treating it as the Railway's problem. In any case, participation in the decisions leading to services will force a more realistic assessment of supply side constraints and will in turn force realistic and responsible demands on the side of the public and government, since along with the authority to participate in decision making comes the responsibility and the accountability for the process. Therefore, even if all interests of all groups will not necessarily be met, there will be greater acceptance of the process of planning and implementation
4) A long term signal for public investment is available even as far as strategic initiatives are concerned, a systematic and publicly monitored operational strategy will contribute towards benefit cost analysis of transport initiatives. Since future investments have also to be costed at their optimal level of operation, a detailed methodology for approaching the issue of proper provision of services at a given level of infrastructure is an important step[3]. Methodologically, this would be a contributing step to a proper network design, considering both design costs and costs incurred by users.

[3]The imperfect market mechanism is a consequence of several factors 1 Centralized budgets and pricing, 2 Not being able to price according to what the market can bear, even if only in some selected categories, 3 Subsidized railway fares, especially the monthly season ticket (pass) which allows for unlimited travel between pairs of stations in the specified time frame and 4 Difficulty of calculating and accounting for opportunity costs.

[4]The design costs reflect the financing costs which are often borne by local or other government authorities and the costs incurred by users include the fares charged, as well as costs to do with congestion and waiting.

2. Operational Decisions & the Timetabling Problem

The major operational decisions in running a suburban train system are as follows:

1. Level of service (i. e. frequency and quantity of service): A major indicator of service available to the commuter is the frequency of provision of the service (within a particular service category). Another quantitative measure of service is the capacity of the rake offered[4]
2. Turnaround of trains: A major demand of commuters is that trains originate from particular stations. In very congested service conditions, the convenience of originating services assumes importance for commuters. The number of services originating at stations and their timings are often strong points of debate between the railway authorities and the various groups of commuters.
3. Provision of differentiated services (e g fast trains, slow trains, different classes of travel etc.). With the growing extent of the metropolitan area, the average lead (distance travelled) of commuters is increasing and commuting time itself is another consideration in evaluation of services from a customer viewpoint[5]

In this paper it is considered the first and part of the third consideration above, to construct the problem of

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drawing up the schedule as a combination of various services. While considering service level, it is assumed that the headway (in terms of trains arriving or leaving the major terminals) is fixed. Similarly, the provision of terminal facilities involves physical infrastructure like platforms, crossovers, signaling etc. The Problem is not considered explicitly here.

[5]Most suburban trains in Mumbai are run with rakes of 9 coaches, but there are a few 12 coachrakes

[6]For historical reasons, there has always been an attempt not to penalize long distance commuters as far as travel time is concerned by providing fast services (the additional money cost is also relatively small because of severe telescoping of fares - some may argue that this is one of the contributors to urban sprawl).

3. Planning Perspective

The perspective focused is one of demand satisfaction at the maximum level subject to the supply constraints, rather than one of supply efficiency maximization at certain acceptable levels of service. This principle is now under some doubt at the strategic level, with the Railways under pressure to run their operations on more commercial lines than they have been doing Such initiatives have to first start with some autonomy in pricing, proper accounting of cross-subsidization, social burden carried by the railways and other factors governing allocation efficiency in the transport economy as a whole. In the absence of such initiatives, the more service oriented philosophy of a government department continues to remain valid at the operational level. This of course has implications in the way the operations are publicly monitored and accounted.

4. Quantification of Schedule Effectiveness

An integrated method of evaluating various service factors to judge the effectiveness of the schedule is proposed. The service measures (from the customer's viewpoint) are split into two parts,

- The first part of the service factor deals with the costs incurred by users, namely the waiting times and the travel times. This is aggregated and eventually minimized, (following the principle of maximum benefit to the maximum number of people). Therefore a composite objective function of customer convenience at the aggregate level. This includes waiting time and travel time during a suitable time period (e g the peak hours, during which the schedule is most constrained).
- The other part consists of parameters specified in terms of bounds (e g at least two trains during a specific time interval should depart from a certain high density origin where terminal facilities are available). The second part is used to construct a number of constraints on schedules. These constraints would be in addition to the ones placed by operational considerations like track/ platform availability, overtaking, turnaround times etc.

5. Characterization of a Schedule

The suburban services are run by electric multiple units (EMUs) in 191 rakes of 9-car, 12-car and 15-car composition. To alleviate the problems of overcrowding, the 9 coach trains are being phased out and replaced with 12-coach trains. 15-coach trains were introduced on 21 November 2009. However, these are few in number. A schedule in its entirety is completely described by the starting times, arrival and departure times at intermediate stations, final destination arrival times and other service information. In the interests of regularity of schedules, it is desirable, at least during peak hours, to have a repeating schedule of some sort, so- that a commuter is assured of some type of service at a reasonable frequency. Such a schedule is considered to illustrate the ideas in this paper. In the subsequent discussion, a-schedule is represented by a pattern of some number of services (say 4 or 5), which are repeated every 20 minutes or so. This pattern represents a block of services, say during the peak hours. The schedule then is specified only by the origin, destination and where the train baits along the way. Given a time when the cyclic or repeating schedule begins, the normal running times, stopping times and acceleration/deceleration times on the section will then determine the precise arrival and departure times at various stations end route.

5.1 Representation of a Schedule

For purposes of analysis, a schedule for a block of 20 minutes has been taken, which is represented by a string of 0's and l's denoting whether a train halts at a particular station or not. For example, on the Western Railway suburban section, consisting of 28 stations, the schedule for 4 trains consists of a long string of 4 times 28 entries the first 28 entries referring to the first service in the block of 4 and so on.

5.2 Assumptions of the Model

The following assumptions has made under which the model is meaningful. Many of the assumptions are for convenience and there is considerable flexibility in the way the model can be actually used in practice.

- The headway is fixed at a certain value depending on the operating conditions.
- The arrival pattern of passengers at various origins and their desired destinations are known. It is

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assumed that a certain uniform arrival rate, which is reasonable during the peak periods. Other arrival patterns based on a more detailed knowledge of the schedule on the part of commuters can be incorporated.

- It is assumed that passengers wait for the first train that both (a) stops at their point of entraining and (b) stops at the point they wish to detrain. In this form the model precludes passengers who are willing to change trains, but this can be easily incorporated. The other possibility that all passengers who wish to enter a train may not be able to do so, can also be incorporated.
- Some nominal values are used for value of time, both waiting and travelling. Again for convenience, it is assumed that these are the same.

6. Mathematical model

It is convenient to represent the schedule using the following variables

x_{ij}=1 if train *i* halts at station *j* and x_{ij}=0 otherwise.
Here, train *i* refer to the i^{th} train in the recurring block of trains in time period (say 20 minutes) under consideration. The definition of x_{ij} can be made a little more precise, and suitable constraints imposed, if we want to take the variable terminating point of a train into account.[7]

[7]For example, the case of a train not passing through a station *j* would also come under the case x_{ij} = 0, and x_{ik} = 0 for all $k > j$ would indicate that the train does not even pass through *j*

6.1 Objective function

Using these variables, the composite objective function of the total travel and waiting time is constructed as follows.

Give the entire schedule for the block, every pair of stations is considered, one by one. For, each pair of stations the average time T between two trains in the block catering to that pair of stations (i.e. stopping at both the stations) is calculated. If only one train in the block stops at both the stations, then the average time is the block time. The number of passengers arriving per minute during the period under consideration is known and the average waiting time (half the average time T above) multiplied by this gives the total waiting time for passengers between that pair of stations.

Similarly, the total travel time is calculated (using assumption 3 in Section 5.2 above) by multiplying for each train in the block and for each pair of stations served by that train, the travel time between the pair of stations and the number of people who have been waiting since the last train to have served those stations.

[7]For example, the case of a train not passing through a station *j* would also come under the case x_{ij} = 0, and x_{ik} = 0 for all $k > j$ would indicate that the train does not even pass through *j*

6.2 Constraints

The constraints of the model are of several types. Few of them are discussed here, which seem particularly useful. A block refers to the scheduling period chosen for the recurring pattern, in what follows.

- At least one train in the block halts at station *j*. This is modeled as

$$\sum_i x_{ij} \geq 1, \ \forall j$$

- All trains must halt at station *k*. This is simply done by forcing x_{ik} =1 for all *i*.
- If a train halts at station *k*, then it halts at station *l*. This is achieved by $x_{ij} < x_{il}$.
- More complicated constraints can also be modeled, such as the specification that at least one train in a block must start from a particular station.

6.3 Features of the model

The model has the features that

1. The value placed on the convenience of a starting train is not explicitly considered in the objective but included in the constraints.
2. The physical operational constraints are aggregated to give simple bounds on certain variables. For example, the minimum turnaround time at terminal is addressed by a bound constraint on departures. If required, more detailed modeling and variable definition can even handle track access and platform availability constraints. The former is especially useful when constructing schedules which combine features of services (e.g. in Mumbai there are semi-fast services which operate on the fast lines up to a point and then move over to the slow track).
3. Different methods are permitted in the calculation of the values of the bound constraints. Considerable sophistication is possible in the way the terminals are decided, the minimum levels of service and other parameters of the model.

7. Analysis and Solution Techniques

In theoretical terms, the permissible schedules (from an operational standpoint) form a large feasible set and the complicated nature of the composite objective makes for a difficult optimization problem. The simplified representation of the schedule that has been discussed allows at least two possible methods of analysis:

1) Since the set of feasible schedules is described by linear constraints with integer (0-1) restrictions on some variables, one can use linear programming and integer programming based techniques for optimization.

2) By simply considering the different discrete possibilities, the representation still permits some idea of what schedules are close to each other, how to generate a better schedule by modifying a given schedule and so on This forms the basis for some of the heuristits and some modern techniques that can be attempted on the problem.

8. Heuristics based on Interchange

Often, a reasonable schedule is available, for example the currently operated one. The first question to ask is whether such a reasonable solution can he improved by some perturbations. This is quite easy to check as it involves the construction of nearby solutions (say by changing a 0 to a 1 in the solution string) and verifying whether any local improvement is possible. This can be systematized to construct a discrete descent based heuristic, which checks for a certain type of change of the solution and accepts the revised solution, if better.
More sophistication is possible by the use of heuristics such as simulated annealing and genetic algorithms. One advantage with regard to such techniques is that the set of feasible schedules is very large and quite dense in the solution space (i.e. not very difficult to find feasible schedules near any specified solution).

Conclusion

The advantage of the proposed method is that since it is an open policy based on well-defined demand criteria, it would tend to increased user participation in defining demands accurately, accepting the constraints of supply and dealing with tradeoffs.

To the supply authority, (the railways), this method would help in increasing the operational efficiencies, and identifying operational bottlenecks. These effects would have a long-term impact on public acceptance, involvement and commitment to investing and operating public transport systems.

References

Teodar Crainic, Jacques A Ferkand and Jean Marc Rouseau, (1984) A Tactical Planning Model for Rail Freight Transportation, Transportation Science, vol. 18(2) 165-184.

Hemant S.Trivedi and Narayan Rangraj (1999) Timetabling of Rail Services, M.Tech dessertation.

Mahesh Shenoy and Narayan Rangraj (1997) Decision Support System for Timetabling of Western Suburban Railways, M.Tech thesis.

Michiel A Odijk,(1996) A Constraint Generation Algorithm for the construction of Periodic Railway Time Table, Transportation Research B, pp 455-464

CHIP CHIP C++ Library by COSYTEC (1997), version 5.0.1, Installation & Reference manual, France.

Dejan Jovanovic and Patrik T. Harker,(1991) Tactical Scheduling of Rail Operations : The SCAN I System, Transportation Science, vol.23, No.1, 46-64.

Holt J.N., Forbs M.A. and Watts A.M. (1991) Exact solution of Locomotive Scheduling Problems, Journal of Operations Research Society, vol. 42(10), 825-831.

Western Railway Working Time Table. Mumbai Division Suburban Section.