An analysis of cyclic timetables for suburban rail services

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THOUGHTS ON A STATION PLATFORM
It ought to be plain: how little you gain: by getting excited: and vexed.
You'll always be late: for the previous train,: and always in time : for the next
Piet Hien: Mathematician and Poet

1. Introduction: Suburban train services in India run to a publicly announced timetable. The timetable is a document of great customer concern as it specifies the level of service that commuters in different segments can expect. The very act of publishing it invites a certain responsibility on the part of the railways and regulators of urban transport, including commuter organizations. This note discusses some aspects of this activity of timetable preparation and publication. We first analyse the need for a timetable per se, and then examine different possibilities in construction of timetables, for various purposes. In this, we specifically consider the possibility of a cyclic timetable and its possible application to operations in India. We conclude with some examples. At some points in the paper, we refer to some ongoing and past research work at IIT Bombay, where this topic is being studied, along with many other operational issues in rail operations. We do not attempt to survey the international literature comprehensively in this introductory article.

2. Timetables and the need for them: A timetable is a plan of operation of services. A typical suburban timetable lists, usually in tabular format, the services that are operated, with origin, intermediate stations, destination station, timings at all the halts (sometimes only departure times, and sometimes arrival and departure times when halts are larger) and additional information about the type of service (number of cars, reservation of coaches for segments of travellers, days of operation, etc.). This information is of obvious use to passengers but is also absolutely essential for operating personnel in the railways. There is a temptation to use a common or largely common document for both these purposes.

2.1 Public timetable: In a city like Mumbai, the public timetable is a document that is eagerly awaited, much discussed and an object of intense scrutiny. But this is one form of public interface as far as service information is concerned. For the bulk of passengers, a case can be made that what is of importance is the level of service in terms of frequency and availability to a given destination from an origin.

Behavioural assumptions about commuter traffic usually propose a rate of traffic between different origin destination pairs. This implies either a continuous flow of traffic or a randomized pattern of arrivals, which is to be serviced by the set of services. A key result here is that for a uniform rate (or completely random – usually modelled as a Poisson rate of arrivals), of arrivals, the best arrangement of services is to have services at a constant frequency. This pattern of services will minimize the total waiting time of all commuters, which is a reasonable measure of services. Ideally this should hold for all sets of origin-destination streams of traffic, but operating constraints may not permit this. Such a timetable can be called a frequency oriented timetable.

An optimal arrangement of services on a single line of operation (one origin- say a Central Business District to several locations) is discussed in Trivedi et al [6]. For services on a network, the problem is one of route network design and service design which is quite complex and has been studied both for bus networks [1] and train networks.

Another example of public timetables is that of bus services. In Mumbai, the public timetable (published very infrequently) carries information about timings of first and last services, and frequency of services at other times (sometimes in several time slabs). This is discussed in (Mumbai Navigator), for example [3]. In cities such as Bangalore, the public bus timetable carries specific timings of individual services.

2.2 Operating timetable: In Indian Railways, there is a separate operating timetable (with accompanying documents) for use by the railways, which contains several items of technical necessity (such as speed restrictions, operating rules, rake link information, platform occupancy charts) which are used during normal and abnormal running conditions. These are for both planning and monitoring purposes.

The operating timetable (also called a working timetable) serves a variety of purposes for the transport service provider. Even for a frequency oriented public timetable, a detailed service plan is required for the service provider in order to plan rakes, crew and other resources and also to plan maintenance activities and rescheduling in the presence of delays, failures etc. Therefore the working timetable is typically much more detailed than the public timetable. There are some other crucial differences in the actual data contained in the two timetables, mainly to do with margins or slacks in operating times which need to be provided in the operating timetable.

2.3 Summary: We summarize the discussion on the need for timetables as below:

- The public need for information can be met in a variety of ways. The major service parameters do not need full time information to quantify these measures.

- The operating and public timetables need not be in the same format and for example, the public timetable can have abstract timings and frequency information rather than exact times, while the operating timetable can have a base schedule.

- A frequency based timetable is optimal as far as waiting times for customers is concerned. It is also convenient for some operating plans (from the cost point of view).

- Even for an announced timetable (with timings), a frequency basis is preferable for all or most locations.

We now discuss a specific type of timetable, which is frequency based, referred to as a cyclic timetable.

3. Cyclic timetables: A cyclic timetable can be defined as follows. A period N (minutes) can be defined after which a certain pattern of services repeats itself. During this period of N minutes, services would cover all the major locations (origins and destinations of traffic). An example of a purely cyclic timetable is as below:

6.00 a.m. to 10 a.m. – Services from City Centre to ABC every hour at 5, 15, 25, 35, 45 and 55 minutes past the hour

Services from City Centre to DEF every hour at 10, 30 and 50 minutes past the hour

Services from City Centre to GHI every hour at 5, 15, 25, 35, 45 and 55 minutes past the hour

The general principle that the frequency of services to different locations would be in proportion to the traffic to those locations would be applicable. The relationship would be exact if there are non-stop services to each location. If locations share services (e.g. if traffic to location A can be combined with traffic to location B), the problem is a little more complex. This may be important if the available traffic or rake capacity is such that frequent services need to be run and where overtaking of services is not possible on the network.

In actual operation, such a timetable is ideally accompanied by real time information to customer as to when the next service to a particular location is due. This is different from the information made available to customers in the timing based schedule, where the scheduled and anticipated times of services are displayed.

A cyclic timetable has the following advantages.

- The timetable has a very concise and transparent description to customers. In the period of interest, customers travelling to and fro between locations know the frequency of services and are able to estimate their waiting/total travel time appropriately.

- The timetable permits easy quantification of waiting time related service measures for customers.

- The timetable allows for cyclic plans for rakes, crew and other resources. In particular, rostering of crew duties is much simplified.

- Techniques for construction of “good” cyclic timetables are more efficient, since the pattern (for a short duration) can be optimised based on given criteria. For timetables which require specific timings of all services, both the optimization criteria and the methods for construction are cumbersome.

- In actual operation, the timetable allows easy recovery from minor disruptions to services.

- The timetable allows customers to plan journeys more precisely, without necessarily having access to a complicated timetable document. This leads to better spread of load on coaches and better utilisation of available rolling stock.

Cyclic timetables have been demanded by large passenger associations (which represent a large commuting group), because of the benefits stated above, although there will always be specific demands of local groups for specific services.

There are some practical difficulties in operating cyclic timetables in the Indian environment. Some of them are as below.

- Terminal facilities do not exist at all stations where demand exists for originating services.

- Some locations are served by very occasional services where a frequency based service does not make sense to commuters. For such locations, timed services are preferred by customers.

- Suburban services are run on tracks which are also shared by long distance services which run at certain specified times, which may not be suitable for a cyclic timetable.

- Customers are used to timings that are announced in advance, even though they are not necessarily followed to the minute.

It must be emphasised that the benefit of a cyclic timetable is more during peak commuting times where the customer pattern is of the stated time. At other times, other timetables may be quite acceptable from the various points of view that have been discussed. So it is entirely feasible to have a combination of a cyclic timetable during peak hours and a non-cyclic timetable during other times. Announcing times in case of a cyclic timetable is an option: for a non cyclic timetable, announcing times is generally practiced.

4. Construction of timetables: A cyclic timetable can be specified concisely and can be abstracted using a limited number of patterns [5]. Once this is done, an optimization procedure is possible using this representation.

On the other hand, a timetable, which requires specific times of all services, is difficult to optimize and generally, more attention is paid to helping the timetabler to construct an operationally feasible timetable. In fact, the factors that make it difficult to construct cyclic timetables are; one-off services, non-regular requirements and a large number of service patterns. These factors make it necessary to allow the timetabler more control of the construction procedure and checking feasibility itself is a non-trivial task. Constraint based techniques seem best suited for this purpose [5].

Apart from railway constructed timetables, an example of a cyclic timetable proposed by passenger groups is the one suggested by the Mumbai Suburban Railways Passenger Association [2].

5. Examples: We now list several examples of cyclic and non-cyclic timetables in rail, bus and air operations in India. These examples are illustrative in nature and the specific timetables continue to evolve as the networks and the demand for services continue to change over time.

- Harbour line operations on Central Railway in Mumbai:
  i. CST- Panvel: Cyclic. In a time cycle of one hour, the following pattern is observed. Roughly four trains within one hour, two trains on CST-Panvel section followed by one train on CST-Andheri section with a time gap 5min-5min-10 min-5min-5min-10min…
  ii. CST-Andheri: Partly cyclic with trains every 30 min. to Andheri, alternate trains on CST-Andheri and CST-Bandra sections

- Main line operations on Central Railway in Mumbai:
  i. Slow corridor: Cyclic at Kurla station with trains every 5 min.
  ii. Fast corridor: Not cyclic.

- Western Railway operations in Mumbai are largely cyclic during the peak hours.

- Suburban operations on the Arakkonam corridor in Chennai: Not cyclic, no definite frequency

- Suburban operations on the Gummidipundi corridor in Chennai: Partly cyclic with trains every 30 min. from 6:30 a.m. to 2:30 p.m. and 4:30 p.m. to 8:30 p.m.

- Suburban operations in Kolkata:
  i. Sealdah (south) Diamond Harbour corridor: Not cyclic, no definite frequency
  ii. Sealdah (South)-Budge Budge corridor: Cyclic. Trains approximately every 40 - 50 min
  iii. Sealdah-Ranaghat corridor: Cyclic. Trains approximately every 30 min
  iv. Sealdah-Bangaon corridor: Not cyclic, no definite frequency

- Suburban operations between Howrah-Kharagpur: Partly cyclic, trains approximately every 20 min. in the morning and approximately every 10-15 min during the rest of the day

- Suburban operations in Hyderabad:

i. Secunderabad-Bolarum corridor: Not cyclic, but trains approximately every 75 min. in the morning (7:00 a.m. to 11:00 a.m.)
ii. Secunderabad-Falaknuma corridor: Not cyclic, no definite frequency

- Bus operations on most routes in Mumbai are frequency based.

- Bus operations on many routes in Chennai (which serve specific locations) are not frequency based. Operations on trunk routes are frequency based.

- Air services on the Mumbai Delhi sector: Flights every hour in the morning (6:00 to 9:00 a.m.) and evening (5:00 to 8:00 p.m.)

References:

1. Marius Sinclair, Dirk L. van Oudheusden (1997) Case Study in Heavily Congested Cities, *European Journal of Operational Research*, 103, 18-27.

2. Manuscript of Mumbai Suburban Railways Passenger Association.

3. Mayur Datar and Abhiram Ranade, Commuting with delay prone buses, Proceedings of SODA 2000 (at *http://www.cse.iitb.ac.in/~ranade/navigator.ps*) and Abhiram Ranade, Mumbai Navigator, *http://www.cse.iitb.ac.in/navigator*

4. Public railway timetables of Central Railway, Western Railway, Southern Railway, Eastern Railway, South Central Railway and South Eastern Railway.

5. Narayan Rangaraj, Milind Sohoni, Time-tabling of Suburban Train Services, *http://www.cse.iitb.ac.in/~sohoni.*

6. Trivedi, Hemant (1999), Time tabling of rail services, *Master's Thesis*, *Industrial Engineering & Operations Research*, IIT Bombay.