A Decision Support System for Scheduling a New Train In Indian Railway Network

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Abstract **- The current schedule for Indian Railways trains has an extensive and complex data. It requires a semi-structured process for its design, development and modification. Scheduling a new train to such a system should maintain stability, robustness and consistency of existing trains along with the best utilization of resources. This process involves a combination of human judgment and standard solution procedures.**

This paper presents a Decision Support System (DSS) to assist the divisional timetable planning team for preparation of planning level timetable to schedule a new train. Considering the availability and utilization of shared infrastructure resources at each stoppage, the controller performs capacity allocation. To manage optimization of timing coordination, the planning team draws a new train diagram on graphics timetable (GTT). The proposed DSS focuses on automatic detection and visualization of resources over allocation on GTT. Mathematically, the problem is formulated as a constraint optimization problem. The objective function is minimization of the average total running time of a new train with defined speed and minimum time deviation of existing trains. Objectives of conflict resolutions are overall timetable stability, coherence and preserving connection of trains. A resolution aspect identifies optimization of timing coordination and capacity reallocation for track and platform conflicts of a new train.

A Linear Programming model involves the optimization of linear functions subject to linear constraint. It moves from one basic feasible solution to another until a solution is found or until it is determined that the problem is unbounded.

Keywords: Decision Support System (DSS), Planning Timetable, Track and Platform Conflict, Linear Programming, Iiterative repair

I. INTRODUCTION

The vast Indian Railways network is one of Asia's best-organized and managed transportation network. A Railway Timetable defines the aim of railways to produce transportation plan and it is also used as an input for many downstream planning activities. Local public demands, business prospects, encouragement of tourism are some factors considered by the ministry for scheduling a new train. The process of scheduling a new train includes following four rigorous components to be planned simultaneously to exploit the railway network capability to the greatest extent and maximize the system's productivity and efficiency [1].

1. Network route design.
2. Establishing timetables.
3. Proper scheduling of rake link.
4. Allocation of crew.

The problem of finding a feasible timetable of a train is NP – complete [4].

A Decision Support System not only stores large amounts of data, but also aims at assisting the decision-maker in exploring the meanings of that data. Decision-maker makes decisions based on an understanding, or for evaluation of opportunities in the problem area [6]. Currently new train scheduling in Indian Railway Network is a three-step process.

1. Divisional level Scheduling
2. Zonal level Decisions
3. Approval of schedule by IRTC (Indian Railway Timetabling Conference)

In the early stage of timetable preparation process at divisional level, conflicts arising are unavoidable. Many fine detailed operational constraints of network would be ignored initially to produce 'planning timetable', and it is used as the basis for final planning and further negotiations [2] at zonal and national level.

Scheduling of a new train is a complex and semi-structured process [8]. This process needs to take into account both 'demand side' factors (often called 'commercial specifications') and 'supply side' constraints (such as 'available resources') [7]. Several attempts have been made in the past to tackle the complexities involved in the automatic generation of railway timetables. Recently search methods like simulated annealing [7] and tabu-search [3] have emerged. Following are the modules for DSS development process of planning timetable

The Initial Scheduler Module performs route processing to find the appropriate platform and track assignments for a new train. An initial schedule of the new train is established according to train parameters and represented on Graphics

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Time Table (GTT). Schedule of existing trains may conflict with the schedule of the new train "about to schedule".

The Conflicts Detection Module finds platform and track conflicts in the Initial Schedule.

The Iterative Resolution of Conflicts Module has an iterative resolution algorithm based on linear search techniques that are applied to repair the flawed schedule. The search is guided by an earliest-conflict-first heuristic that attempts to repair the earliest constraint violation [3]. Timetable Controller can analyze technical challenges of varying train parameters and related impact on schedule through user friendliness and flexibility. The system schedules a new train on a selected route with analyzed and negotiated solutions to identify conflicts.

II. GRAPHIC TIMETABLE (GTT)

A classical tool intensive used to construct train timetables is the Graphic Timetable (GTT) of railway line. It is a space x time graphic in a orthogonal axis system, where stations in a sequence at predefined distance scale are represented on the Y–axis and the time on the X–axis at an interval of 5 minutes. As we can see in figure 1, a train is represented by a sequence of lines, where horizontal segment represent stops at stations, inclined segment represents the movement of the train between stations and their slop with the distance axis represents the train average speed. Analyzing a vertical line (at a given point in time) in a GTT, we have a picture of the train's positions at that specific time. When we analyze a horizontal line the sequence of trains is given with the information about the arrival and departure time of each one at that point, crossing time of a train at station (if station is not a stoppage) and timing interval between trains. GTT helps to compute existing train parameters at each stoppage and the new train schedule can be represented in GTT. The aim of railway scheduling is to draw a new train on GTT. This new train should not affect the schedule of existing trains; hence it is left to the decision maker (human judgment) to maximize (or minimize) certain train parameters (speed, departure time, stoppages, and halt time) to avoid the conflicts.

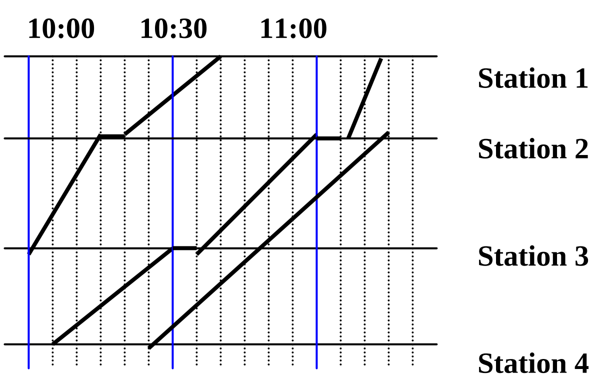


Figure1. Graphics Timetable with a simple train diagram

III. CONFLICTS

Timings between trains at stations are considered to be important. A "good timing" means that a passenger can change trains with a maximum delay of 5 minutes at a station. Constraints represent scheduling problems mathematically [5]. The physical constraints to a train scheduling are as follows

1. Running time constraint
2. Minimum stopover time constraint
3. Minimum headway constraints
4. Level crossing constraint
5. Platform assignment constraints

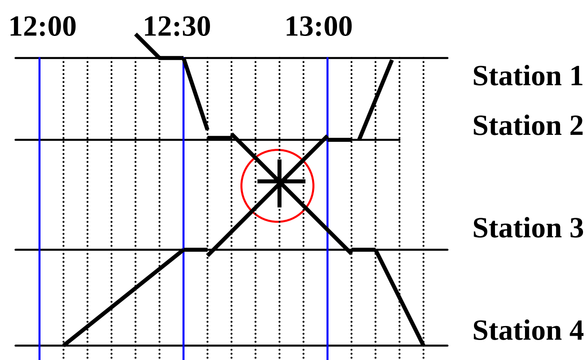
- *Conflict Types*

i. Track conflict

Track is a rail line between two successive stations. The track should be available throughout the running phase of a train from source to destination station. Number of tracks (single or double) between two successive stations plays an important role for identification and resolution of track conflict. Figs 2 (a) represents track conflict scenario.

ii.Platform Conflict

The Timetable Controller selects the number of stoppages for a new train. System maintains the information about each station of the route. For a new train, platform should be available at each stoppage, at respective arrival time. Maximum number of trains at a station on particular time can be equal to number of platforms; otherwise it will result in a platform conflict. For a single-track rail line, track remains occupied until the train reaches from one station to next station and depends upon time taken by a train to travel up to the next station plus level crossing constraints. If a new train is scheduled on an occupied track, then there will be a track conflict. For double track rail line, no possibility of track conflict between trains running in opposite direction. If a track is occupied, and a new train tries to overtake or is overtaken by an existing train, then there will be track conflict. Numbers of trains between two stations should be at the most the numbers of tracks between two stations. Figure 2 (b) platform conflict scenarios.



(a) Track Conflict

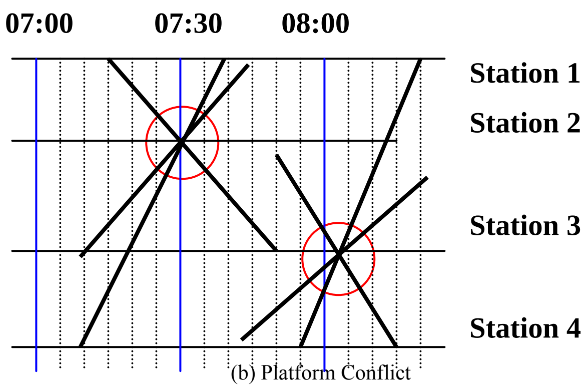


Figure2. Single Track Conflict scenarios

- Different possibilities of conflict are:
    1. Platform conflict at the source station
    2. Platform conflict (arrival and departure time) at intermediate stations.
    3. Track conflict -A train crossing or overtaking with other trains between two stations on a single track
    4. Track conflict - A train overtaking with other trains between two stations on a double track

Automatic conflict detection helps the Timetable Controller in the decision process, by identifying stations of conflicts to concentrate on. Moreover, certain empirical rules that define minimum time interval between trains at stations so as to avoid succession and crossings help to implement automatic conflict detection. Figure 2 represents conflict detection and representation on GTT.

- *Conflict resolution*

Conflict resolution can be a complex problem. One simple solution to a small conflict can create other conflicts with one or more trains in a network. Resolution process is composed of a set of decisions along with judgment, local analysis and a wider view of the problem.

- Steps in the conflict resolution process:
    1. Priorities can be assigned to trains as a result of commercial concerns
    2. Stability of timetable is key issue along with the robustness of a solution
    3. Flexibility is allowance of infrastructure capacity to accommodate additional trains/contingencies.
    4. Overall timetable coherence and preserving connections of trains

All these aspects cannot be easily formalized. Some objectives are contradictory and some form of compromise must be achieved. Hence, conflict resolution is perceptually a semi structured decision process. The experience and judgment of a Timetable Controller are key assets in generating and evaluating alternatives.

IV. LINEAR PROGRAMMING

A Linear Programming model involves optimization of linear functions subject to linear constraints on the variables. The technique embraces almost every functional area of business-production [9].

i. Problem formulation

Mathematical model is composed of a set of constraints and various notations to define infrastructure resources like tracks and platforms, set of trains, their track occupation timings, conflicts identification, and resolution proposals.

ii. To define a new train in timetable the following elements are needed.

K – Set of stations

M – Set of trains

hm – Predefined departure time of existing train m Є M at the source station

pmk – Sequence of order of stoppages k Є K in the path of train m Є M.

rmk – Minimum run time that train belonging to the m Є M takes to arrive at Station k Є K from the previous station. (k-1) Є K (Normal running time)

smk – Minimum stopping time of a train m Є M at stoppage k Є K

iii. The decision variables are as follows

amk – Arrival time of a train m Є M at station k Є K

amk = dmk’ + rmk V m Є M; k Є K; k’ Є pmk (k’= k -1); pmk > 1

dmk – Departure time of a train m Є M at station k Є K

dmk = dmk’ + rmk + smk V m Є M; k Є K; k’ Є pmk (k’= k -1); pmk > 1

ym – Speed of train m Є M

ack – Arrival time of a new train at station k Є K.

dck – Departure time of a new train at station k Є K.

yc – Speed of train to be scheduled

rmk – δ(k,k-1)/ ym

kk – Platform conflict at station k Є K ; 0 if no Conflict else 1

lk – Track conflict at station (k and (k+1)), k Є K ; 0 if No Conflict else 1

otc(k,k+1) – Track occupation time for a new train between stations k and k+1 k Є K

otm(k,k+1) – Track occupation time for existing train m Є M between stations k and k+1 k Є K

Departure time for each train at the Source Station will be given by:

dmk = hm V m Є M; k Є K; (pmk = 1)

Departure time from other stations of the route:

dmk = dmk’ + rmk + smk V m Є M; k Є K; k’ Є K: (pjk > 1 ^ pjk’ = pjk - 1)

Compute dmk V m Є M; k Є K

iv. Proposed Algorithms conflict identification

- *Platform Conflict at station k Є K*

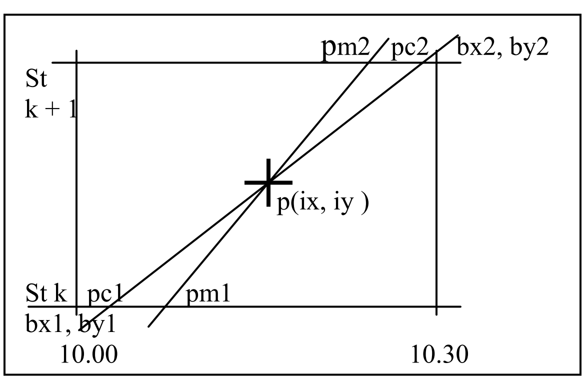
```
if ((amk < ack && amk > dck && ack > dmk)==1)
// where k Є K and m Є M
    kk = 0;
Else  kk = 1;
if (kk == 1)   // Where k Є K
      //Apply Conflict Resolution
```

- *Track Conflict lk between two stations (k and (k+1)) Є K*

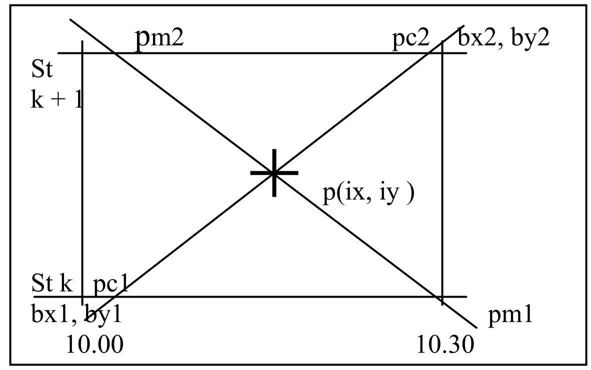
If otc(k, k+1) and otm(k, k+1) are overlapping then there may be conflict lk. To confirm track conflict, we convert these time slots to line segments on space versus Time graph (GTT). Station k maps on Y-axis and Time maps to X-axis. If train to be scheduled is mapped on the graph by points Pc1 & Pc2 and train m, where m Є M is mapped with points Pm1 and Pm2. Now, with this representation we can check for conflict by calculating intersection point of two line segments [(Pc1, y1),(Pc2, y2)] and [(Pm1, y1),(Pm2, y2)]. Figure 3 represents conflict scenarios and the intersection point be represented by P (ix, i y) which is calculated as:

$$iy = \frac{[(Pc_2*y_1 - P_{c1}*y_2) * (y_1 - y_2)] + [(Pm_1*y_2 - Pm_2*y_1)*(y_1 - y_2)]}{(y_1 - y_2)*(Pc_2 - Pc_1) - (y_1 - y_2)*(Pm_2 - Pm_1)}$$

$$ix = \frac{[(Pm_1*y_2 - Pm_2*y_1) * (Pc_2 - Pc_1)] + [(Pc_2*y_1 - P_{c1}*y_2) * (Pm_2 - Pm_1)]}{(y_1 - y_2) * (Pm_2 - Pm_1) - (y_1 - y_2) * (Pc_2 - Pc_1)}$$



(a) Overtaking



(b) Crossing

Figure 3 Shows representation of track conflicts scenarios on GTT.

If P (ix, iy) is within boundaries of Pc1, Pc2 and Pm1, Pm2 then lk = 1.

Bounding box for Pc1, Pc2 and Pm1, Pm2 be represented by (bx1, by1), (bx2, by2) where

bx1 = Min [Pc1, Pc2, Pm1, Pm2]

bx2 = Max [Pc1, Pc2, Pm1, Pm2]

by1 = Min [y1, y2]

by2 = Max [y1, y2]

```
//Check for conflict
if (ix >= bx1 && ix <= bx2)
    if (iy >= by1 && iy <= by2)
           lk=1;
    Else     lk = 0;
Else  lk = 0;
if (lk == 1 ) where k Є K
    //Apply Conflict resolution
Else  //Check conflict for next segment
    k = (k+1) Є K
```

v. Iterative Repair Algorithm

Step 1: 1.1 Generate initial schedule

1.2 Assign infrastructure resources

1.3 Find resource over allocation by applying optimality test 1 and test 2, update kk ,lk

Step2: 2.1 If kk ,= 0, lk=0 then stop and announce initial schedule as a planning timetable

Else select the earliest conflict for resolution.

2.2 Display all resolution proposals for resolution

Step3: 3.1 Select highest priority repair solution (human decision)

3.2 Test to repair selected conflict

Step4: Evaluate initial Schedule

4.1 Update kk ,lk

4.2 Update decision variables

4.3 Go to step 2

vi. Conflict Resolution Proposals

The system will try to move the new train left or right in time axis so that the resources are available. Possible alternatives are as follows:

1. Change Departure at Source Station (dck, k=1)
2. Change Departure at intermediate stoppages (dck, k>1)
3. Change halt smk-1 , k Є K
4. Change speed of a new train (yc)
5. Insert additional stoppage for a new train at intermediate stations.

These proposals imply change in arrival time ack and departure time dck as well as track occupation time otc(k,k+1) where k Є K and yc .

V. CASE STUDY

We tested integer-programming approach to implement planning timetable of a new train with respect to Western Railway region of Indian Railway Network. Following figures show the experimental results.

Figure 4 is a screen shot for accepting new train parameters that are to be processed and initial timing schedule is mapped on GTT. A new train is drawn as Blue line. Red and Green lines are database trains.

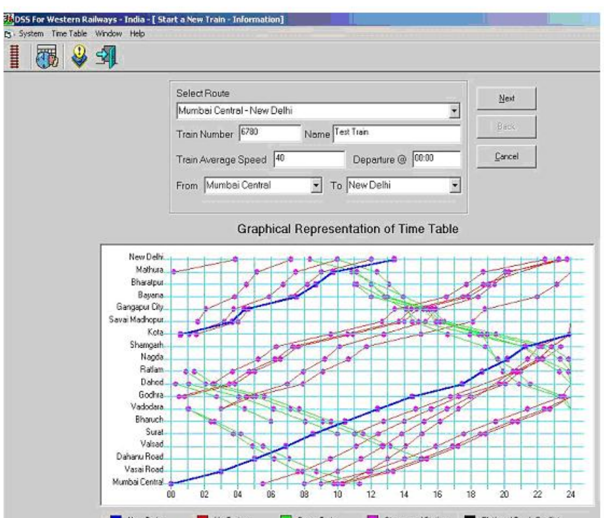


Figure4. Accepting a New Train Information

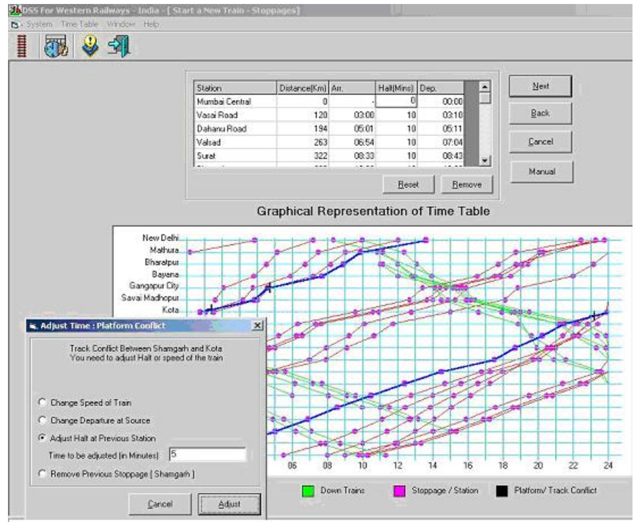


Figure5. Track Conflict Identification and Representation

Figure 5 shows database train timings are conflicting with new train timing. Track conflict of new train with up train are marked by "+" sign.

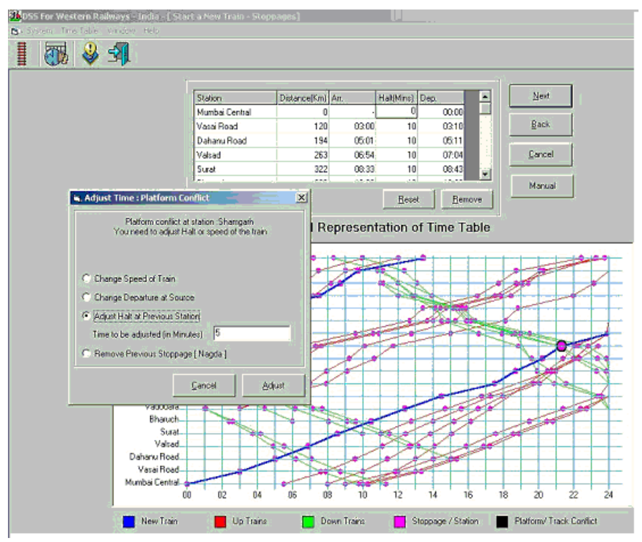


Figure6. Platform Conflict Identification, Representation and Resolution.

Figure 6 showing platform conflict of the new train with existing trains at Shamgadh Station. All trains' arrival and departure timings are around 21.15. Apply appropriate Platform conflict resolution option

VI. CONCLUSION

The Decision Support System improves decision-makings process by providing an interactive environment where decision makers can quickly identify and manipulate the information necessary for the formulation of actions based on the decisions. Allocation of available track and platform would influence the performance of the resulting schedule. Comparing the results with real-life data should enable one to tune the system whenever necessary. This approach generates feasible schedule of a new train. Experimental results have demonstrated that the approach is promising.

VII. REFREENCES

[1] Avi Ceder, "Efficient Timetabling and Vehicle Scheduling for Public Transport" *Proceeding of the 8th Conference on Computer Aided Scheduling of Public Transport, 2000*.

[2] Raymond S K Kwan, Paavan Mistry "A Co-evolutionary Algorithm for Train Timetabling" University of Leeds, School of Computing – Research Reports Series 2003–13.

[3] Te-Wei Chiang, Hai-Yen Hau, "Railway Scheduling System Using Repair-based Approach" *Proceeding of the CSDL IEEE Conference,* pp 71, 1995.

[4] Leon Peetrers, Leo G. Kroon, "An Optimization Approach to Railway Timetabling", Management Report 28 – 1999, Rotterdam School of Management, Erasmus University Rotterdam.

[5] Jurjen S. Hooghiemstra Maurice J. G. Tunisse "The use of simulation in the planning of the Dutch railway services", Proceedings of the 30th conference on winter *simulation* pp.1139-1146, 1998.

[6] S. Ossowski, A. Fernandez, J. M. Serrano, J. L. Perez-de-la-Cruz, M.V. Belmonte, J.Z. Hernadez, A.M. Garica-Serrano, J.M. Maseda, "Designing Multi agent Decision Support System: The case of transportation management", *Proceeding of the Third international Joint Conference on Autonomous Agents and Multi agent Systems* – Volume 3 pp. 1470-1471, 2004.

[7] Robert Watson, Grahme Cooper, Simon Nicholls, Barry Grant, Daren Wood, "The role of Automated Timetable generation in the Development of improved Railway / Mass transit timetables and infrastructure configurations – a simulated Annealing Approach Accessed from a business Perspective" Transport Studies Group, Loughborough University, UK, Railtrack PLC London, AEA Technology Rail, London.

[8] Efraim Turban, Jay E. Aronson, "Decision Support Systems and Intelligent Systems", 6th edition Pearson Education Asia, 2002.

[9] Stephan G. Nash, Ariela Sofer, "Linear and Non Linear Programming" McGraw Hill International Edition 1996

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