ON OPTIMAL DESIGN OF TIME TABLES FOR LARGE RAILWAYS UNDER RESOURCE CONSTRAINTS

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Abstract

Timetables are pre-determined schedules designed to aid the customer and the train scheduler.

The proper design of timetables is the key to the maintenance of punctuality of trains. Timetables should be robust to minor perturbations and should allow minimum propagation of delays across trains and across the network.

Timetable design affects the planning process, at all levels- strategic, tactical and operational, and is of major consequence in deciding the bottom line of the railways. Suprisingly however, the aspect has received scant attention, so far as improving on the manual methods used at present.

The dissertation presents a framework for optimum design of timetables to maximise schedule robustness and minimise resource deployment, especially for large railway networks.

Research on the area of optimising crew and rolling stock deployment for a given timetable and construction of timetables using mathematical modelling on a very small scale have been reported. However, problem of timetable design, to optimize resource deployment and maximise schedule robustness has not been tackled so far, and this dissertation is a maiden effort in this direction.

Given the complete absence of research in the area of timetable design, the study identified the decision variables and their relationship to the decision criteria of the

timetable. Further metrics for quantification of the decision criteria were developed to enable the formulation of the problem in terms of a mathematical model.

Simulation, using C programs specifically developed for the purpose as part of the dissertation, has been used to derive relationships, in instances not amenable to analytic derivations. Further, a Timed Colored Petri Net Model has been developed as part of this dissertation and demonstrated on a test case to simulate the movement of trains in order to obtain the rolling stock and crew deployment for various combinations of slack times, cycle times, trip times and lie-over times in a timetable. The various values of rolling stock and crew deployment thus obtained can be used to obtain a mathematical expression giving the rolling stock and crew deployment as a function of slack times, cycle times, trip times and lie-over times. The simulation of train movement using Timed Colored Petri Net for evaluation of timetables adds to the repertoire of industrial applications of Petri Nets.

Mathematical programming when applied to cases of large railways suffer from a singular handicap, in that, the size of the problem usually exceeds tolerable limits of available computing power. Decomposition of the problem to manageable pieces results in losing the power of comprehensive analysis of the problem. The concept of route is thus proposed and demonstrated to reduce the problem size, without sacrificing the information and constraints involved.

The timetable design problem has been formulated as a multi-objective non-linear mathematical model. An Analytic Hierarchy Process (AHP) method, used for ranking of objectives, the Global Criteria Approach (GCA) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) have been used to solve the model on a test case. A GAMS program has been developed for the purpose as part of the dissertation.

The dissertation does not purport to provide a design method, which can be used immediately for real life situations. Its seminal contribution is the formulation of the problem as a mathematical model using methods to reduce the problem size to computationally manageable proportions, and thus enable planners to undertake network-wide optimisation studies. The dissertation has thus demonstrated that the design of timetables can be spread over a canvas incorporating not only over the entire railway network, thus enabling study of the mutual interactions across the network, but also involving the optimisation of vital resources like crew and rolling stock in the purview of the model. This can thus emulate the planning process more truthfully, wherein piecemeal optimisations are of little import.