LOCOMOTIVE ASSIGNMENT PROBLEM – INTEGRATING THE STRATEGIC, TACTICAL & OPERATIONAL LEVEL ASPECTS

ABSTRACT

Since the first appearance of mechanised rail transport systems in England in the 1820s, railways have developed to a great extent to become the primary form of long-distance land transportation for people as well as bulk materials across the world. Over the past couple of centuries, with increase in the significance of railways to the economy, the complexity of railway networks and consequently the decision making involved has only increased. Depending on the scope, time horizon and investment requirements, the level of decision making in railways management varies in scope to a substantial extent. Railways management can be explained in a hierarchical approach to describe three levels of decision making involved in railways management namely: strategic, tactical and operational. Broadly speaking, railway operations can be viewed as allocation of resources and facilities to meet the demand of different trains based on a predetermined timetable (Operational level). To enable this, decisions pertaining to the frequency and length of trains, train selection and routing, allocation of locomotive types to trains, network design, location of yards, fleet sizing etc. need to be taken beforehand (Strategic/ Tactical level).

Among the host of problems in railways management, one of the most important is the Locomotive Assignment Problem (LAP). The LAP is as old as the railways

itself. The objective of the LAP is to assign a fleet of locomotives at minimum cost to pre-scheduled trains subject to a host of constraints. The size of the railways company (in terms of number of locomotives and trains) and the complexity of the network (in terms of number of yards, stations, single/ multiple lines) render the LAP computationally intractable. Over the years, lot of researchers have tried addressing the problem of LAP by taking in to account several real-life constraints. However, despite the advancement in technology and improvement in the modelling approaches, there is still adequate scope for further improvement. Constraints pertaining to the maintenance requirements in entirety or constraints pertaining to speed requirements of the train have not been modelled fully. Moreover, the existing models adopt a stage-wise approach for solving the LAP which leads to suboptimal solutions. This research work aims at integration of different strategic, tactical and operational aspects of the LAP which were hitherto not considered.

In this work, we attempt to develop solution methodologies based on exact and heuristic approaches for solving the integrated LAP that takes in to consideration the strategic, tactical and operational level aspects. We develop two Mixed Integer Linear Programming (MILP) models, an arc-based and a path-based, for obtaining exact solutions. In the arc-based formulation, the model was able to converge to optimality only in problem instances of smaller size. In contrast, in the case of path-based formulation, the model was able to solve even larger problem instances. However, the time taken for the path-based formulation was higher as compared to the arc-based formulation. Moreover, in the arc-based formulation, we also demonstrate that by adding a valid inequality, the lower bounds can be improved substantially resulting in a substantial reduction in solution times for the problem instances.

Since the problem is a proven NP-complete problem, we resorted to heuristics/ metaheuristics for obtaining solutions. This thesis has proposed two heuristics to solve the integrated LAP, a Dijkstra's algorithm-based heuristic and an Ant Colony Optimization (ACO) based heuristic. Both heuristics were able to provide good quality solutions within computational times deemed practical. We also test the heuristics on problem instances generated from the railway timetable for the Southern Zone of Indian Railways.