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Combined empty and loaded train scheduling for dedicated freight railway corridors ☆

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ABSTRACT

The efficient utilization of expensive rolling-stock has become imperative for all railroads. In this paper, we study the combined empty and loaded train-scheduling problem for the upcoming dedicated freight corridors in India. Existing optimization models either do not consider the simultaneous optimization of the loaded and empty flows or are not solvable for large railroads. Our model is the first of its kind to incorporate link capacity constraints in an IP formulation for this operational level problem. A simulated annealing algorithm hybridized with a constructive heuristic is proposed as the solution method. The computational experiments show that the proposed heuristic performs well both in terms of runtime and solution quality.

1. Introduction

Indian Railways (IR) is the largest railroad under single management (Ministry of Railways) in the world. It moves over sixteen million passengers and over two million tonnes of freight daily. There are mixed passenger and freight operations sharing the common network. Currently, the existing trunk routes of the Eastern and Western Corridors are highly saturated. The surge in power needs, infrastructure construction and international trade has led to the conception of the Dedicated Freight Corridors (DFC), as shown in Fig. 1 (DFCCIL, 2011). Dedicated Freight Corridor Corporation of India (DFCCIL) has the responsibility of development and operation of the DFC. The DFC are seen as a panacea for the problems of freight traffic (passenger trains having priority) and as a need of the fast growing Indian economy.

However, Indian Railways' freight operations are significantly less efficient than the other comparable large railroads in the world (AAR, 2012). One of the reasons is the lack of appropriate optimization and stochastic models in the railway's operations management. For the planning of DFC, it is highly desirable to develop appropriate operations research models to support the strategic decisions and also to support operations policy making. Due to the special characteristics of the DFC (discussed in details in Section 3), there is clearly much scope and need of optimization models for efficient operations and improved service quality. The motivation for this study was that such timely research will help in planning and will obviate the difficulty of changing the operations of the huge organization (having monopoly and state-owned) in future. This research could be valuable for other DFCs, for example, Betuwe route in the Netherlands (Koetse & Rouwendal, 2008) and proposed dedicated freight rail corridor in eastern Australia (PBPL, 2013).

In this paper, to the best of our knowledge the first to specifically address the OR problems for DFC, the combined empty and loaded train scheduling problem (CELSP) is considered. Every loaded train after unloading at its destination becomes available as empty rake.[2] After cleaning and maintenance, if needed, the rakes can be further assigned to meet demands at the same yard or at other yards. Due to the unbalanced demands over time and space, empty rakes often need to be repositioned dynamically from rake surplus yards to rake deficit yards.

The rolling-stock, being enormously expensive, needs to be utilized to fullest extent. CELSP is an operational level problem where the goal is to optimally redistribute empty rakes to other yards and schedule loaded trains over planning horizon. As discussed in Sections 2 and 3, CELSP is a complex managerial problem.

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[2] Rake is a formation of coupled wagons that makes up a train minus the locomotive.

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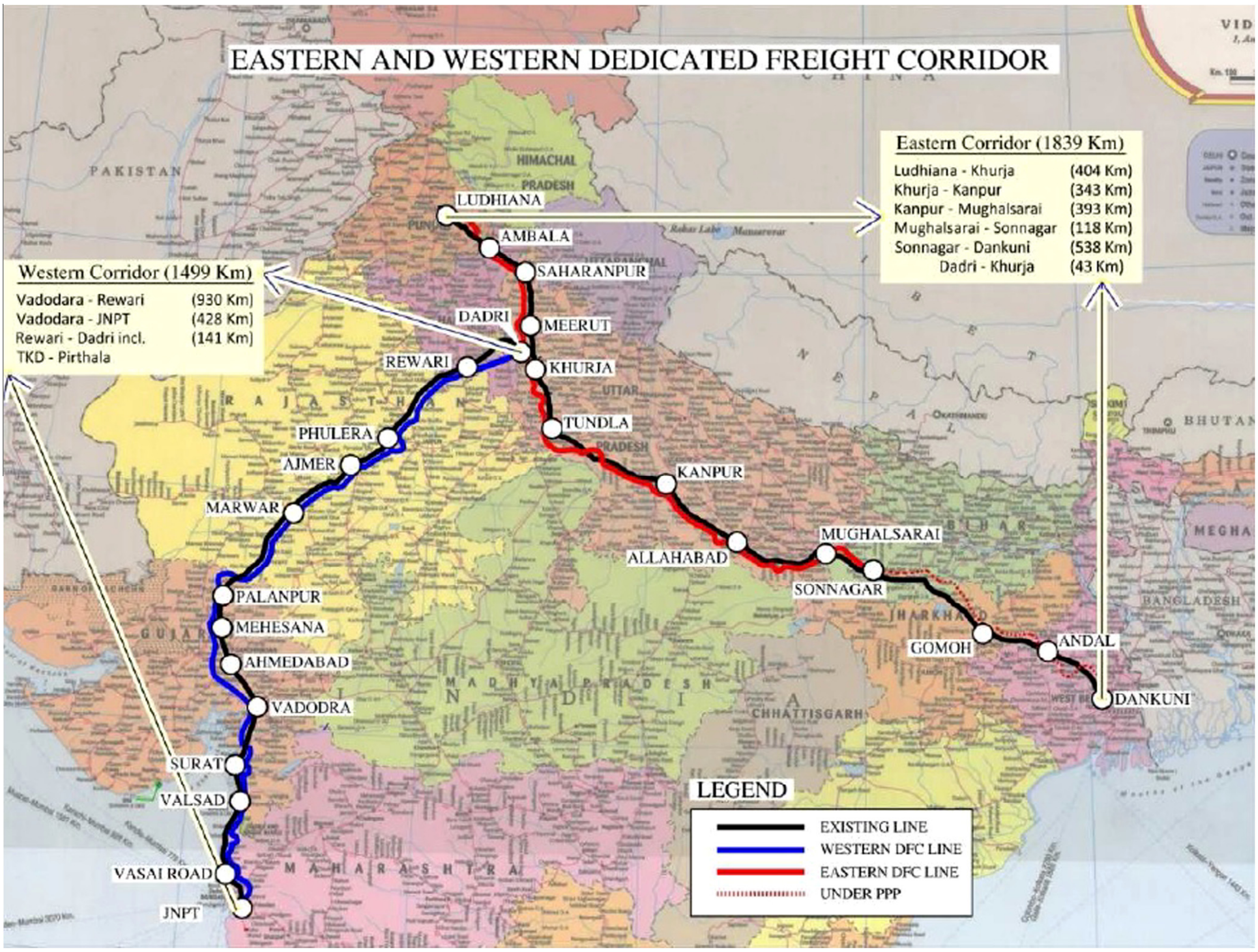

Fig. 1. Dedicated freight corridor network in India (Source: public information brochure, February 2012).

Therefore, we explain the problem through a small example with simplifying assumptions as shown in Fig. 2.

Consider a double tracks linear layout railway network with only four stations (A, B, C, D). Here, customer demands are specified as number of rakes required at (single) origin at given time to be delivered at (single) destination. Assume that there are demands from every station to every other station at times (period 1, 2 and 3). Also, assume that every rake is immediately available after reaching its destination. Due to imbalance in demands over time as well as space, we have two choices to meet the customer demands whenever empty rakes are not available at any station. First, for the supply of empty rakes, we can wait for loaded trains terminating at this station to unload and delay the delivery of shipment. Thereby, we save upon empty traveling cost, but service quality is adversely affected. The second option is to move an empty rake from other stations to deliver this shipment. Thereby, we incur additional empty travel cost but ensure timely delivery of shipment. Therefore, we should strike an optimal balance

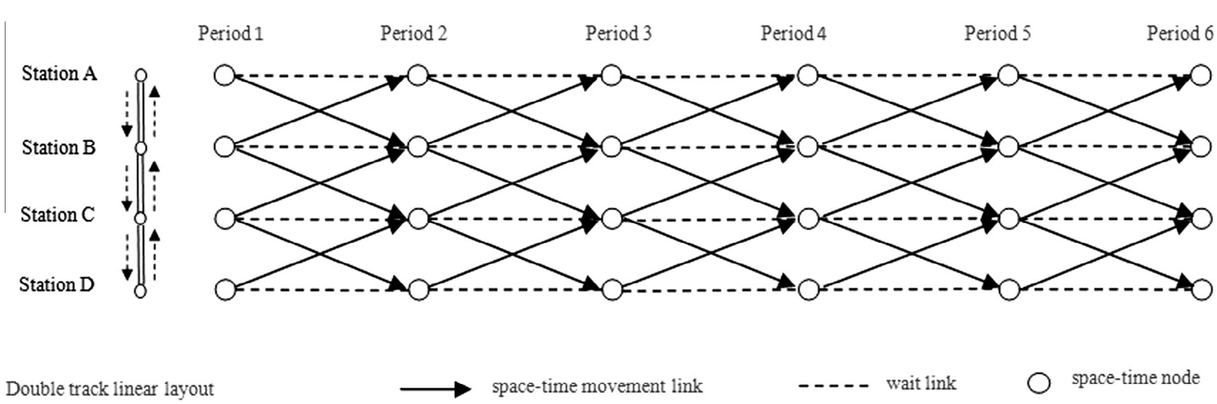

Fig. 2. Space–time network diagram for double tracks linear layout.