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Train re-scheduling with genetic algorithms and artificial neural networks for single-track railways

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ABSTRACT

Train re-scheduling problems are popular among researchers who have interest in the railway planning and operations fields. Deviations from normal operation may cause inter-train conflicts which have to be detected and timely resolved. Except for very few applications, these tasks are usually performed by train dispatchers. Due to the complexity of re-scheduling problems, dispatchers utilize some simplifying rules to resolve conflicts and implement their decisions accordingly. From the system effectiveness and efficiency point of view, their decisions should be supported with appropriate tools because their immediate decisions may cause considerable train delays in future interferences. Such a decision support tool should be able to predict overall implications of the alternative solutions. Genetic algorithms (GAs) for conflict resolutions were developed and evaluated against the dispatchers' and the exact solutions. The comparison measures are the computation time and total (weighted) delay due to conflict resolutions. For benchmarking purposes, artificial neural networks (ANNs) were developed to mimic the decision behavior of train dispatchers so as to reproduce their conflict resolutions. The ANN was trained and tested with data extracted from conflict resolutions in actual train operations in Turkish State Railways. The GA developed was able to find the optimal solutions for small sized problems in short times, and to reduce total delay times by around half in comparison to the ANN (i.e., train dispatchers).

1. Introduction

Developing better solutions for train (re-)scheduling problems has been drawing the attention of researchers for decades. Railway authorities aim to provide transportation services to their customers in a safe as well as effective and efficient manner. The two main constraints forcing them to regulate their services are the limitation of resources and the competition among service providers. Planning train services in tactical level (or medium term) and operational level (or short term) gain particular importance in this respect. In both planning processes inter-train conflicts are detected and resolved to produce feasible and desirable schedules. When trains interfere with one another during actual operation, some trains are delayed by stopping them at meet points (stations or sidings) to allow some others to pass without interruption. So the conflict resolution process most likely causes delay to some trains. If the total delay time incurred by a train does not exceed its recovery time or a conflict resolution delay at a particular meet point does not exceed the associated buffer time, train services are considered to be on time. However, some trains may move considerably away from their schedules, causing unplanned

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interferences with some other trains. In such cases train dispatchers take necessary actions to resolve inter-train conflicts. Their primary responsibility is to maintain safety in train movements. They are also responsible to keep trains on schedule by taking some controlling actions. Because conflict resolution delays contribute to trains' overall lateness, the goodness of dispatchers' resolutions for conflicts is one of the measures for system's effectiveness and efficiency. The conflict resolution process, which includes a series of tasks, such as monitoring, data gathering, data processing, forecasting, decision making, and decision implementation, is only one of the responsibilities train dispatchers have to deal with during their service hours. When inter-train conflicts are anticipated to arise, dispatchers have to act effectively to re-schedule train movements by changing the locations and times of their planned meet/pass in order to maintain feasible train movements. A framework for systems approach to train re-scheduling process is depicted in Fig. 1, in which train movements are processed according to a pre-established schedule as input, and each of actual train movements is the output of the system. Trains operate in an environment with physical, managerial, and legal constraints imposing on the system. Train dispatchers continuously monitor the system and take necessary actions in a dynamic environment, in which trains are in movement during the dispatching process. This requires urgent decisions. However, train re-scheduling, like other scheduling problems, falls into a hard-to-solve (or NP-complete) class of problems (Garey and Johnson, 1979). From the system optimization point of view, conflict resolutions within a realistic time frame may have an enormous number of alternatives due to problem complexity. The number of solution alternatives increases exponentially with problem size (e.g., number of trains and meet points). Depending on the problem size, the optimal solution of train re-scheduling problems may be beyond the cognitive capability of train dispatchers. This is also the case for computers running an exact solution model established for a realistic size problem instance. The heuristic techniques that have been developed so far to solve (train) scheduling problems can provide near optimal solutions. In order to judge how good the solutions provided by train dispatchers and the heuristics developed are, one has to evaluate the provided solutions by comparison.

Train re-scheduling problems have been undertaken in various modeling and solution frameworks in the literature. Three decades ago, Assad (1980) published a comprehensive survey on railway transportation models including train scheduling models. About two decades later, another survey appeared in the literature (Cordeau et al., 1998), concentrating on optimization models for the commonly studied railway routing and scheduling problems. Fay (2000), presents a fuzzy logic-based algorithm. Decisions given by train dispatchers during a 10-h period are used to develop a rule base. Trains are evaluated in a

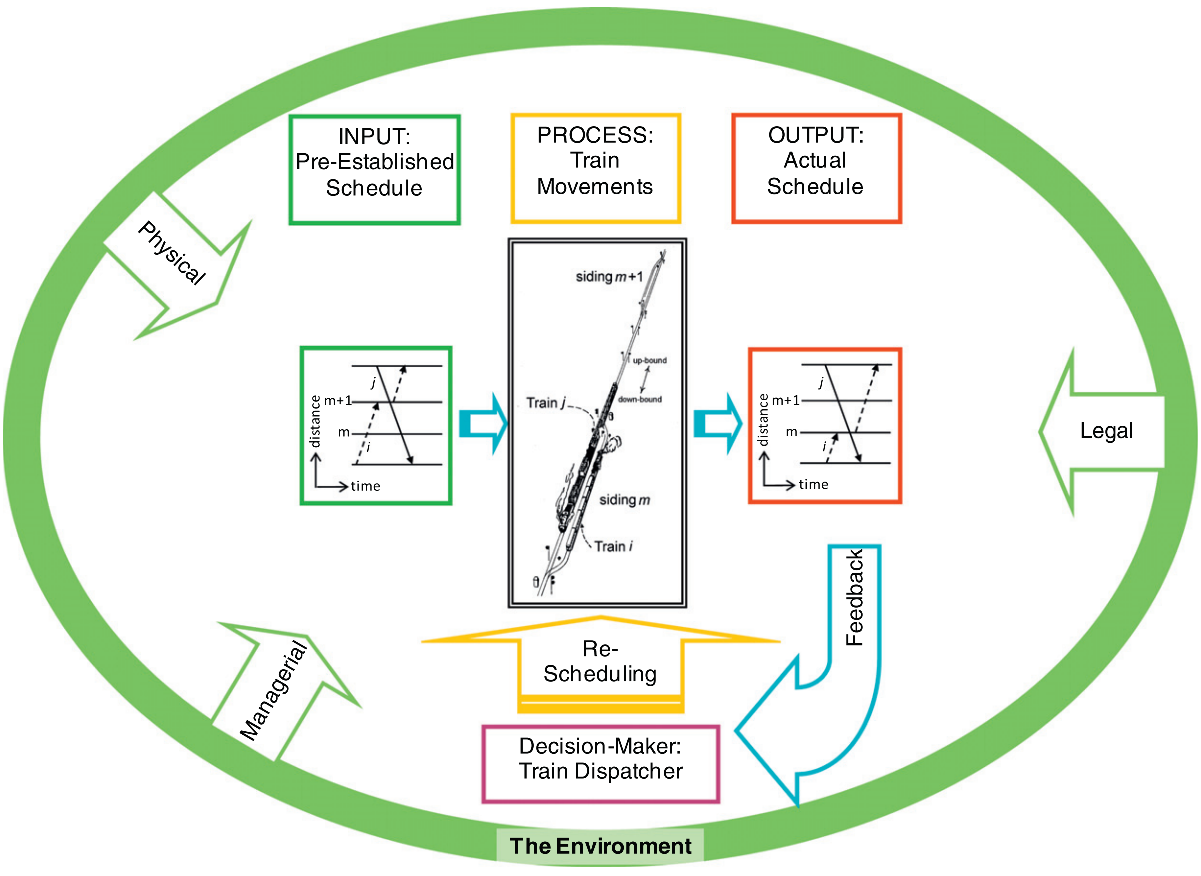

Fig. 1. A systems approach to train re-scheduling process.