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# Capacity factors of a mixed speed railway network

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ABSTRACT

Fifty-four combinations of track network and speed differential are evaluated within a linear, discrete time network model that maximizes an objective function of train volume, delays, and idle train time. The results contradict accepted dispatching practice by suggesting that when introducing a priority, high-speed train onto a network, maximum network flow is attained when the priority train operates at maximum speed. In addition, increasing siding capacity at meeting points may offer a network capacity improvement comparable to partial double track.

## 1. Introduction

On July 18, 2006 then President David Hughes of Amtrak, Chief Operating Officer Tony Ingram of CSX, and a number of additional senior officers met to negotiate solutions to recurring delays to Amtrak passenger trains, which operate under trackage rights on a number of CSX owned and managed routes. Amtrak's premise for the meeting was that Amtrak trains were suffering delays largely due to dispatching decisions, that dispatching was under the control of CSX, and therefore it was the responsibility of CSX to enact changes. The options and outcomes were grave for both parties. CSX's position was that offering priority dispatching to all Amtrak trains at all junctions would significantly reduce network capacity, below the minimum capacity necessary to carry existing freight commitments, and that Amtrak trains must slow their schedules. Amtrak's rebuttal position was that Federal law guaranteed Amtrak trains priority dispatching over any host railroad's other trains, and it was obvious to Amtrak riders that this priority was not honored. In June of 2006, 29% of Amtrak's Washington DC to Florida trips were greater than 4 h late. A similar conflict exists between Amtrak and Union Pacific over delays to long-distance trains in the western United States (Frailey, 2006), and between the State of Illinois and Canadian National over passenger train paths between Chicago and St. Louis (Hilkevitch, 2006). Resolution of conflicts between passenger and freight trains is extremely important because Amtrak's most recent business plan emphasizes passenger trains operating at 80 to 100 mph on mixed use corridors (Machalaba, 2006).

Timekeeping of Amtrak trains was not a new problem in 2006, nor has it yet been resolved. The most famous case of conflict between Amtrak and a host railroad involved extraordinary delays to Amtrak's Los Angeles to New Orleans Sunset Limited hosted by the Southern Pacific Railroad (Larson, 1998). In spite of 3 h of schedule recovery time (slack), the Sunset Limit posted a zero on time performance record from July through October of 1979. Amtrak's only recourse was to request the US Department of Justice to file suit against Southern Pacific. The resulting consent order was not lifted until February 7, 1984. More recently, Martland (2008) recommends acceptance of the status quo and rescheduling Amtrak trains to match past performance ("experience based scheduling"). Surprisingly, only with the signing of Public Law 110-432 on October 16, 2008, 27

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years after its founding, has Amtrak, through the Surface Transportation Board, obtained the authority to levy fines against host railroads for failure to provide dispatch priority to passenger trains (110 Congress, 2008).

Conflicts between passenger and freight train schedules are frequently publicized, but conflicts between freight trains of different speeds (*heterogeneous* traffic) are also common, and an obstacle to new transportation products. These operational issues will be more prominent as additional passenger trains are initiated (Wrinn, 2008) and after major intermodal corridors are opened from Ohio to the eastern seaboard. These corridors, typical of which are Norfolk Southern's Heartland Corridor and CSX's National Corridor (Withers, 2008), are predominantly single track lines through rugged and confined rights of way, where additional tracks are expensive or infeasible to construct.

Higher speeds are necessary for railways to attract higher value traffic from competing highway lanes, but even on legacy multi-track fast corridors in western North America there are operational obstacles to fast freight traffic. For example, Frailey (2005) reports on United Parcel Service's inability to reduce its 5 day package trip time via BNSF and CSX due to conflicts with slower freight traffic. Although test trains successfully completed the Los Angeles to New York City journey in 65 h, BNSF found the priority schedule created significant conflicts with other traffic. In contrast, contemporary passenger systems report that heterogeneous traffic can be managed with sufficient planning. Johnston (2005) reports that careful scheduling allows a varied mix of passenger train speeds on the 77 km (48 miles) San Jose to San Francisco Caltrain route. Caltrain (2006) schedules eleven round trips which make the journey in 25% less time than adjacent departures.

Railroad management today asserts a firm position that faster speeds for a minority of priority trains incur a disproportionate, unacceptable cost on a network dominated by slower traffic (Beck, 2007, 2008). Yet, two generations ago, mixing of trains with speed differentials as high as 2:1 was commonplace. For example, the Santa Fe (present day BNSF) double track mainline between Winslow, Arizona and Gallup, New Mexico possessed automatic block signals and additional sidings to facilitate passes (overtakes) of 40 mph freight trains by 100 mph streamliners, such as the *Super Chief*. On this district, the Santa Fe devised a decentralized form of train control. Priority trains followed a strict published timetable, and slower train crews operated with strict instructions to take individual responsibility for selecting the best location to take siding and allow a scheduled train to pass. Crew members on both the locomotive and trailing caboose facilitated the operation of manually thrown switches (Hellman, 2003).

Unfortunately, any direct inference from this anecdote is nullified by the extreme difference in operating characteristics between railroads in the age of steam and cabooses, and today. A review of the literature does not satisfactorily establish whether the current difficulty of mixing high speed and common trains results from fundamental properties of railway technology, or whether it is an artifact of contemporary dispatch rules and management assumptions.

The primary question posed here is, what impact does a non-conforming train, a train which has markedly different speed or handling properties, have upon a congested or tightly packed homogenous flow of trains? What penalty does the operation of that additional train incur on the network? What operating practices or track enhancements will minimize the non-conforming train's costs? To explore these questions, a tightly packed optimal flow of homogeneous trains is configured, a baseline objective value is observed (utility), and then non-conforming priority trains are overlaid onto the network, an optimal dispatch pattern is determined, and a new utility value recorded, disregarding the value of the overlaid trains. The difference between the baseline and overlay utility values is then presented as the marginal cost of providing a network path for the overlaid trains. Planning options considered in this study include configuration of rail track and sidings and the magnitude of the speed differential in heterogeneous traffic.

### 1.1. Characteristics of the considered railway problem

Single track railways allow a flow of trains in opposing directions by the careful planning, location, and use of sidings or sections of multiple track. In the case of trains of differing speeds, sidings also allow passes, where faster trains overtake slower trains. Various strategies are employed by railway management to plan these train meet/passes, which usually derive from the assigned priority to each class of train.

If trains operate at homogeneous speeds the optimal network flow forms a cyclical pattern. Frank (1966) validates these cyclical patterns and defines two network types, $T_1$ which allows one train to wait clear of the main track, and $T_2$ which allows two trains to wait clear of the main track, examples of which are shown in Fig. 1. Frank demonstrates that under selected dispatch patterns a $T_2$ network offers greater capacity.

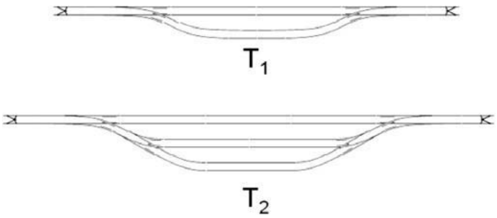

**Fig. 1.** Track Layout of $T_1$ and $T_2$ Networks.