

Incremental Capacity in Transitioning from Double to Triple Track on Shared Rail Corridors

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Abstract

The North American freight railroad network is projected to experience rising transportation demand in the coming decades, leading to increased congestion on many rail lines. Capacity is further strained by increased interest in increasing the speed and frequency of passenger service on shared rail corridors. Since passenger trains in North America predominantly operate on corridors where freight railroads own the track infrastructure and are responsible for train dispatching and control, continued hybridization of these freight rail lines by introducing passenger train operations jeopardizes operational fluidity of the network. Capacity loss due to heterogeneity between passenger and freight operations is particularly critical in the North American context since the majority of mainline corridors are single-track with passing sidings or with short segments of double-track. These track arrangements lack the flexibility to handle dense traffic composed of multiple train types. Increasing capacity through triple-track installation, however, requires significant capital investment, right-of-way, and environmental permitting, and so the third main track must be allocated along a line in an optimal manner to provide maximum return on investment. The research presented in this study seeks to characterize the relationship between incremental line-capacity and the phased transition from double to triple track. Results suggest a linear relationship between train delay and percent triple-track installed, regardless of crossover arrangement. While railroads must consider many factors in selecting capital expansion projects, the guidelines presented here can streamline the decision process by helping to quickly identify projects with the most potential for more detailed engineering evaluation.

Keywords

Triple track, Train delay, Shared rail corridor, Rail capacity, Simulation

1 Introduction

The North American railroad landscape consists primarily of single-track mainline corridors with passing sidings or short segments of double track. Many of these double-track segments are in urban areas where freight rail operations share track with passenger rail services. Anticipation of traffic growth and the expansion of commuter rail services on key mainlines serving major urban areas leads to the investigation of triple track segments as a vital capacity upgrade measure in accommodating future rail network volumes. Consideration of this additional infrastructure investment is strengthened further by the increasing speed and frequency of passenger train operations on historically freight-dominated rail lines. The capacity loss and deterioration of service quality resulting from the simultaneous operation of freight and passenger trains on a shared rail corridor is

quantified by Cambridge Systematics (2007), who discovered that the practical capacity of single track drops from 48 to 30 trains per day, and double track from 100 to 75 trains per day, when subject to mixed freight and passenger operations. This will be particularly important in urban areas where freight, regional intercity passenger service, and local commuter rail services must use the same track infrastructure. Under these conditions, the capacity of full triple track is estimated as 133 trains per day. The threshold for the requirement of triple track is specified by Martland (2008), who cites one particular North American Class I Railroad as considering triple track once traffic volume reaches 100 trains per day, and steep grades/slow speeds or passenger operations are present.

Previous research has focused on North American applications of partial triple track installation and a subsequent qualitative discussion on the capacity benefits of this type of infrastructure expansion. More specifically, Tobias et al. (2010) investigated, via simulation models, the inability of double-track corridors to provide sufficient capacity to sustain the expected 20-year passenger and traffic growth along a particular shared-use rail corridor in the United States. Double track, while physically allowing the simultaneous operation of freight and passenger trains, led to an unacceptable overall decrease in train speeds, significant increase in delays, subpar on-time performance, and poor resiliency to recover from disruptions. Tobias forecasted the physical need for triple track installation to deal with these operational maladies.

The research presented in this study seeks to characterize the relationship between incremental line-capacity and the phased transition from double to triple track. This characterization considers both the aggregate perspective of overall length of triple track along a route, but also how turnout arrangement at crossovers influences capacity.

Previous research conducted by Lindfeldt (2012), Sogin et al. (2013) and Atanassov et al. (2014) revealed that for idealized single-track corridors with even siding spacing, double-track installation provided a linear reduction in train delay (a metric for capacity) across a wide range of freight traffic volumes. A chart from Atanassov et al. (2014) depicting this linearity (for an initial single-track route with evenly distributed sidings spaced 16 miles apart) is reprinted in Figure 1.

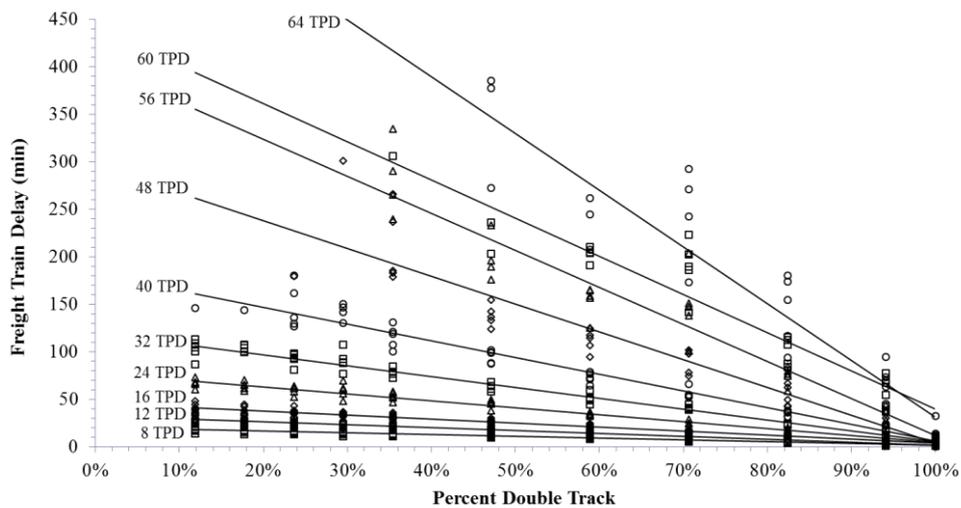


Figure 1: Response of freight train delay in a single-to-double track progression with varying trains per day (TPD)

The study detailed in the following sections explores the train delay response associated with third-mainline construction – a process exponentially more complex than its single-to-double track counterpart on account of the added consideration of crossover locations, turnout arrangements at crossovers and their varying ability to support certain train maneuvers between mainlines, and passenger train station platform stop locations.

2 Rail Traffic Controller

This research develops train delay and capacity metrics with the use of Rail Traffic Controller (RTC), the industry-leading rail traffic simulation software in the United States. Specially developed for the North American railway operating environment, RTC emulates dispatcher decisions in simulating the movement of trains over rail lines subject to specific route characteristics. Its application is widespread, seeing extensive use by a wide range of public and private organizations, including most Class I railroads, Amtrak, and Bay Area Rapid Transit (BART). Inputs for the simulations run in RTC include factors such as track layout, signaling, speed limits and train consists (Wilson (2014)). Output includes train delay, dwell, siding usage, and train energy consumption. In using RTC, results are aggregated over a specified number of simulation days and a specified number of simulation repetitions.

For the analyses that follow, infrastructure (in the form of triple track segments) and train parameters are variable inputs, while train delay is the desired output. Each track arrangement described in the methodology section is run for five simulation days and includes five repetitions. Thus, each simulation data point is based on an average of 25 days of simulated train operations. To be consistent with flexible North American freight rail operating practices, each repetition specifies a different train operating pattern where each train departs randomly from its respective terminal within a 24-hour window. Passenger trains had 7 dedicated, evenly-spaced station stops along the route (on the outside tracks, in case of three mainlines), with a 3-minute station dwell at each. A summary of the initial two-mainline route and train characteristics used throughout this study are summarized in Table 1.

Table 1: Initial route and train characteristics

Route Characteristic	Value
Length	386km
Crossover Spacing	26km
Total No. of Crossovers	14
Traffic Control System	2-block, 3-aspect CTC
Train Characteristic	Value
Freight Train Consist	115 loads, 1,928m
Maximum Freight Speed	80kph (64kph through turnout)
Passenger Train Consist	7 coaches, 152m
Maximum Passenger Speed	177kph (64kph through turnout)
Traffic Composition	heterogeneous, variable

3 Methodology

The overarching methodology for this study involves the incremental build-out of triple track on what is initially a fully double-track, 386km route segment between terminal yards. However, as mentioned earlier, triple-track installation involves the added complexity of deciding on a particular turnout arrangement at crossovers to provide a train dispatcher with the required train routing flexibility between each mainline track. The two crossover arrangements analysed in this study are the “parallel” arrangement and the “herringbone”, both of which are depicted in Figure 2.

There are unique advantages, and disadvantages, to the two types of crossover arrangements shown in Figure 2. Appropriately named, the *parallel* crossover arrangement allows for simultaneous parallel train moves between Mainlines 1 and 2, and Mainlines 2 and 3. However, as can be seen in Figure 2, there is no way for a train to get all the way from one outer track to the other (i.e. Mainline 1 to 3) at a single crossover location with this turnout arrangement. Two crossover moves at successive crossover locations are required to move between outside tracks. This constrains routing flexibility and may be unsuitable for particular corridors where such maneuvers may be required. However, the advantage of the *parallel* arrangement is that it allows the two parallel moves (Mainline 1 to 2, and 2 to 3) to occur simultaneously; one movement does not interfere with the other. This allows the middle track to be effectively used as a series of center sidings between the two outside tracks. Trains heading towards each other on the center track in adjacent triple-track sections can simultaneously diverge to either of the outside tracks at a single crossover location without conflicting with the opposing center-track movement.

The *herringbone* arrangement, on the other hand, allows for a full train movement from Mainline 1 to 3 (and 3 to 1) at a single crossover location. However, this type of movement requires full control of the crossover, thereby locking out any other simultaneous movements. This can adversely affect the utility of the crossover and its effective capacity. This arrangement also limits the utility of the center track as a center siding. Opposing train movements on the center track will directly conflict with each other when they converge on a single crossover location. Regardless of which track the first train is diverging to, the opposing train must stop and wait for the crossover to clear before it is able to diverge to an outside track.

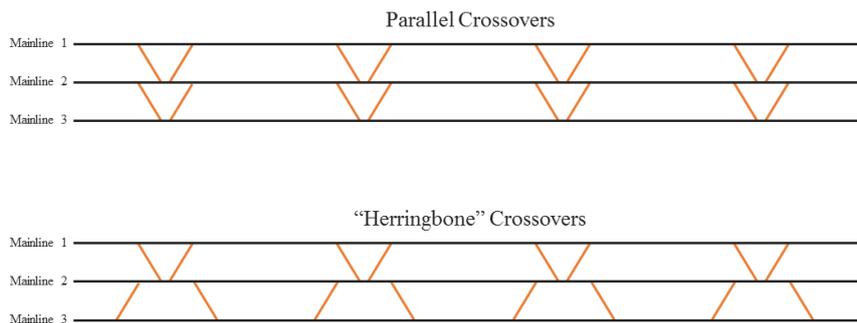


Figure 2: Crossover arrangements on triple track

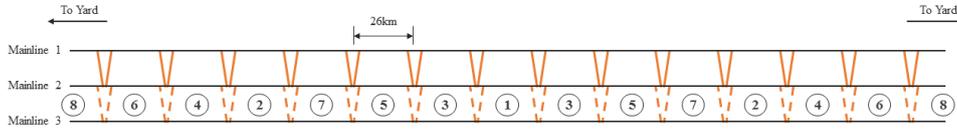


Figure 3: Triple track construction order (circled number)

Although they are isolated for comparison purposes in this study, actual triple track arrangements often consist of a combination of parallel and herringbone crossovers depending on local operational needs. Stations with a single outside platform or connections to branchlines and yards may dictate herringbone crossovers to facilitate the required moves between outside tracks at a single location and avoid extended running against the predominate current of traffic. On routes where the outside tracks are not signalled for operation in both directions and only the center track is bi-directional, the full crossover move may not even be a consideration. In these instances, it is more important to provide the capability for parallel movements at a single crossover location to increase the utility of the third track. Similarly, crossovers adjacent to stations with island platforms may often require simultaneous crossover moves, favouring parallel crossovers for these locations.

In order to isolate the effects of triple-track installation on train delay, a balanced approach was taken in regards to infrastructure expansion. In other words, triple track was added along the route in an evenly distributed fashion, such that the route was always laterally balanced with segments of third-mainline. This balancing strategy aims at avoiding confounded results that may arise from a disproportionate allocation of triple track along the length of the route. Figure 3 shows how the simulated routes were balanced, in addition to the order in which triple track segments were added to the route.

To further clarify, Figure 3 shows that, initially, one 26km triple-track segment is constructed in the middle of the route. The second step then involves the simultaneous construction of two new triple-track segments, such that the route now has three evenly distributed sections of third-mainline track. Once these three segments are constructed, each subsequent step includes the paired construction of two new segments of triple track, extending off either the middle segment, or the two outer segments.

4 Results

Simulations were run for three different traffic mixtures on the shared corridor: 48 freight + 16 passenger trains, 60 freight + 12 passenger trains, and 52 freight + 12 passenger trains. It should be noted, however, that the results that follow do not include delay data at 100-percent triple track (when each yard is connected through to the third mainline), as the final yard-to-mainline triple track connection creates inconsistent simulated delay data that is not representative of the realized benefit. The capacity benefits associated with triple track installation are, as a result, analysed up until final connections to the two yards are made.

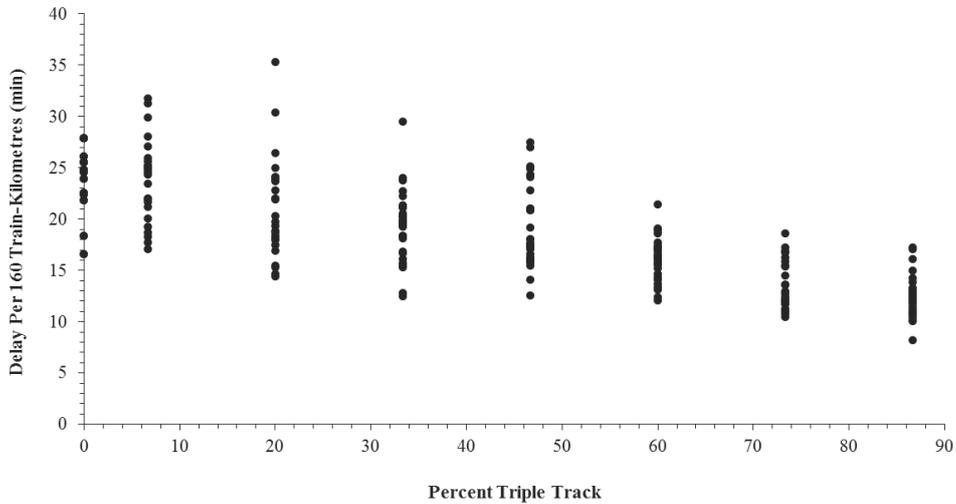


Figure 4: Delay as a function of percent triple track

Delay data resulting from the simulations was aggregated and used to construct the plot shown in Figure 4, whose purpose is to establish a visual characterization of the data, while keeping traffic mixture and crossover arrangement anonymous. These two factors will be plotted in more detail momentarily, but the purpose of Figure 4 is to focus on the trends apparent in the delay data as a whole, while simultaneously prompting the discussion of delay data variability. As shown in Figure 4, the scattering of data suggests a linear relationship between the delay per 160 train-kilometres and the percentage of triple track installed along the route, regardless of either traffic mixture or crossover arrangement. In other words, delay (normalized to 160 train-kilometres) decreases linearly with the addition of triple track segments along the route.

Further inspection of the plot reveals not just a delay trend, but also a trend in delay variability. More specifically, the latter additions of triple track (e.g. >60%) generally show a narrower vertical distribution of delay data, as opposed to the wider bands associated with lower percentages of triple track. This disparity hints at the uncertainty of delay performance when few triple-track projects are in place. For example, when three triple-tracked segments have been constructed (i.e. 20% triple track), the utility of these new segments may depend on train schedule, since it is hard to use a triple track segment if meets/passes are occurring elsewhere along the route. This potential effect produces a future point of interest in observing the delay response associated with a continuous addition of triple-track from one end of the route to the other, or entirely grouped in the center of the route (rather than the balanced distribution presented here).

The delay results for each of the two traffic mixtures and crossover arrangements are parsed out and shown in Figure 5. The linear trend lines in Figure 5 characterize the delay response to triple-track for each combination of route and train characteristics. Immediately apparent is the similarity of all six trend lines in Figure 5, but there is plenty of pattern in the results that should be noted and discussed.

In particular, there is an apparent pattern to the magnitude of delay exhibited by each crossover/train mixture combination. It can be noticed that the highest delay is exhibited by

the route containing the *herringbone* arrangement of crossovers with 60 freight (FRT) and 12 passenger (PAX) trains. The next highest delay is exhibited at the same traffic volume, but with a route containing the *parallel* crossover arrangement. This hierarchy of delay is mimicked in the other traffic scenarios as well, thereby suggesting that the *parallel* crossover arrangement provides a very subtle delay benefit compared to the *herringbone* arrangement. This benefit may stem from the ability to make simultaneous, parallel maneuvers with the *parallel* arrangement (an ability not afforded by the *herringbone*) to better utilize the center track— an advantage that was discussed in the preceding section.

The patterned arrangement of the trend lines is also indicative of the increased delay associated with higher train counts. This intuitive result was also observed for the transition from single to double track. However, the effect of train volume is more clouded when taking into consideration the relative influence of passenger trains versus freight trains on shared-corridor line delay. In particular, the trend lines in Figure 5 suggest a similar delay response among the three traffic mixtures, each with different levels of train heterogeneity, which may mask a potentially greater difference between these traffic levels under constant ratios of freight to passenger trains. The bunching of data for the 60FRT-12PAX and 48FRT-16PAX traffic volumes indicates the relatively high influence of adding/subtracting higher-speed passenger operations on the shared corridor, in contrast to the lessened effect of adding/removing freight trains on the line. This notion is directly supported through observation of the relatively isolated 52FRT-12PAX data, which has the same total train count as the 48FRT-16PAX case (64 trains per day). The difference between the two cases is a swap of 4 freight for 4 passenger trains. The significantly reduced delay of the 52FRT-12PAX case, however, supports the notion that passenger train operation disproportionately influences line-delay in comparison to freight traffic. The relative influence of additional high-priority, higher-speed passenger trains can be rationalized given that same-speed homogeneous freight traffic could, theoretically, run uninterrupted bi-directionally with just two mainlines. These results emphasize the importance of heterogeneity on line-delay – a condition whose significance was studied by Dingler et al. (2013), and is amplified here by the stark speed difference between the freight and higher-speed passenger trains.

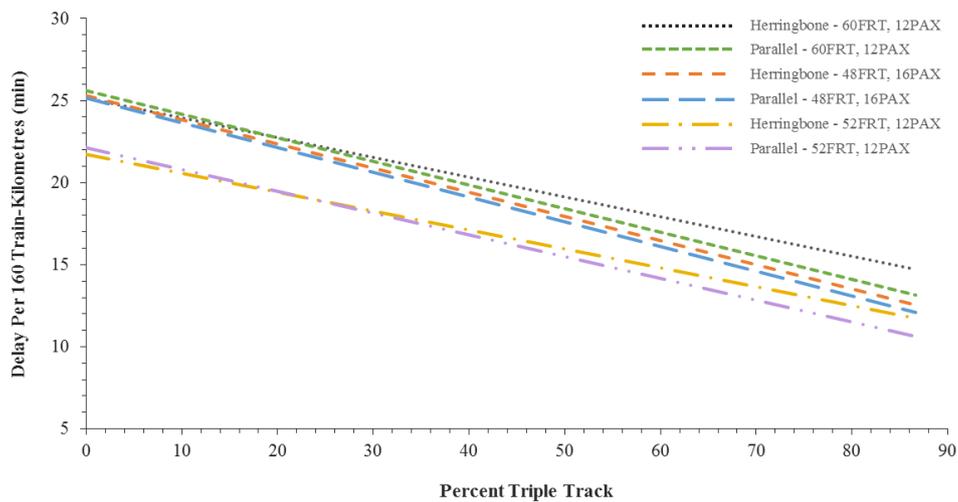


Figure 5: Delay as a function of percent triple track, with respect to crossover arrangement and traffic mixture

Holistically, the results presented in Figure 5 indicate that, regardless of crossover configuration or the three studied traffic mixtures, triple-track cuts delay per 160 train-kilometres by roughly half (~12min). It should be emphasized that since this is in delay per 160-train kilometres, the delay (12min) can be multiplied by 2.4 to achieve the total expected delay in running from one end of the 386km route to the other. The product is approximately 30min, meaning that installing 90% triple track can reduce end-to-end run times by 30min – no small matter when considering the movement cost of freight and the strong competition for passenger transportation offered by personal auto on the highway and other competing modes.

5 Conclusions

Increasing congestion on North American freight rail corridors, coupled with simultaneous interest in increasing passenger train speed and frequency, establishes the need to better understand the line-capacity benefits associated with triple-track installation. This study presents a simulation approach to characterizing the aforementioned relationships, while taking into consideration external factors that may play a role in triple-track infrastructure expansion. Results suggest a linear relationship between train delay and percent triple-track installed, regardless of crossover arrangement or studied traffic mixture. Results also indicated a slight benefit in the implementation of a *parallel* crossover scheme (as opposed to the *herringbone* arrangement), as well as a roughly 50% reduction in normalized train delay after triple-tracking an initial line consisting of two mainlines.

While essential to the North American railroad landscape, research into the incremental capacity in transitioning from double to triple track finds its application within European networks as well. Although most lines in Europe are double track and already support frequent, higher-speed passenger service, there is a desire for operation of longer freight trains over longer distances on this same infrastructure. As the efficiencies of these longer trains are realized, and barriers to international freight interoperability are removed, the European freight rail market share will increase. An increasing number of freight trains on the double-track, passenger-oriented corridors in Europe poses the same concerns regarding the capacity of the existing infrastructure to support future traffic. Under this scenario, European infrastructure owners may face the same prospect of making investments in sections of third mainline track to incrementally increase line capacity.

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