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Spacing and Length of Passing Sidings and the Incremental Capacity of Single Track

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DISCLAIMER

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TECHNICAL SUMMARY

Title

Spacing and Length of Passing Sidings and the Incremental Capacity of Single Track

Introduction

The objective of this study was to evaluate the effect of initial siding spacing and distribution of siding length on the incremental capacity of infrastructure investments on single-track railway lines. Previous research showed a linear reduction in train delay as sections of a single-track line with uniform initial siding spacing and length are converted to double track. This first phase of this project determined if this same relationship was observed on lines with different initial uniform siding spacing. Both homogenous heterogeneous traffic mixtures were considered. The second phase of this project examined single-track lines that exhibited a more realistic non-uniform distribution of siding spacing. The study of non-uniform siding spacing determined if the linear trend observed previously could be used to infer the incremental capacity of investment in double-track siding connections of different lengths. The third phase of this research investigated the relationship between siding length, train length and capacity of single-track lines. This project investigated the relationship between the proportion of long sidings on a route and the number of long trains it can support (as a fraction of total traffic) for a given level of service. Statistical analysis of RTC simulation software results were used for all phases of this research.

Approach and Methodology

All project tasks were completed by a student Graduate Research Assistant. In Task 1 RTC was used to simulate homogenous and heterogeneous train operations on single-track lines with different values of uniform initial siding spacing. The simulations were repeated for routes with an increasing number of sidings connected with double-track segments until the entire route was double track with universal crossovers. JMP statistical software was used to analyze the results and investigate the relationship between train delay, amount of double track, initial siding spacing and traffic volume.

In Task 2 RTC was used to simulate homogenous and heterogeneous train operations on a single-track line with a distribution of initial siding spacing. The simulations were repeated at different levels of double track as double-track segments were added according to one of two different connection strategies: shortest-to-longest and longest-to-shortest. JMP statistical software was used to analyze the results and investigate the relationship between reduction in train delay, length of double-track segment added and amount of double track for a given traffic volume and traffic composition. The process was repeated for a second route with the exact opposite distribution of initial siding spacing (i.e. the positions of the longest single-track segments become the positions of the shortest single-track segments etc.). The simulation results between the two routes were compared to determine if the length or relative position of the added double-track segment had a greater influence on the reduction in train delay.

Task 3 investigated the relationship between train delay, the number of long sidings and number of long trains, JMP was used to create an experiment design matrix that included percent long sidings, percent long trains, long train directional distribution and total throughput volume as factors. RTC was used to run the simulation trials and JMP was used to analyze the results. In addition to train delay, consideration was given to balancing crews and equipment for scenarios where there was an uneven directional distribution of long trains.

Task 4 extended the research completed under Task 1 and 2 to conduct an initial investigation of the incremental capacity of transitioning double track to triple track. RTC simulations were conducted on two routes with different initial crossover configurations.

Findings

Results for Task 1 indicate that routes with sparse sidings experience larger reductions in train delay (i.e. more congestion relief) via double-track installation compared to routes with sidings spaced closer together. Further comparisons revealed that siding spacing has a disproportionately larger impact on delay for lines with higher traffic volumes than for those with relatively lower volumes.

In regards to non-uniform siding spacing and connection strategies, the Task 2 results showed that when the entire progression from single to double track is considered, there appears to be no difference in double-tracking longer bottleneck sections before shorter ones. The implication for railway applications is that the lowest-cost option (likely to be the connection of shorter-spaced sidings) should be the preferred option regardless of track infrastructure locations. The results did suggest that connecting the longest bottleneck sections first leads to the greatest initial return on investment in terms of reduction in train delay per unit of double track installed.

Additional experiments conducted for Task 2 indicate that the delay response of siding connection projects is influenced not only by the length of the connection being made, but by its position along the route, as well as the order that these connections are made within the full progression from single to double track. In particular, double-tracking projects completed in the latter half of the entire progression from single to double track appear to have a greater delay-based return on investment. While longer connections appear to provide more consistent delay reduction, shorter connections are more sensitive to the effects of route position and connection order, and can provide substantial delay reductions under the right conditions.

Results for Task 3 indicate that routes with roughly 50 percent long sidings exhibit no delay-based consequences of running long 150-car trains and short 100-car trains. This finding suggests that to operate with a high percentage of long trains, only half of the sidings on a route need to be extended in order to maintain the baseline level of service (i.e. the average train delay with no long trains in operation). On routes with more than 50 percent long sidings, total train count takes precedence over the ratio of long to short trains in determining train delay. Results also indicate a similarity in delay-reduction patterns regardless of whether long trains operate with a 50-50 directional distribution or with directional preference.

Further research within Task 3 found that the number of siding extensions is a function of the "train replacement ratio" or the ratio of the length of the long trains to the length of the short trains. Increasing the train replacement ration decreases the percent of sidings that must be extended to support operation of long trains.

Results of the Task 4 preliminary investigation of the double to triple-track transition suggested a linear relationship between train delay and percent triple track installed, regardless of crossover arrangement or traffic mixture studied. The results also suggested a possible benefit from a parallel crossover arrangement (compared to the herringbone arrangement).

Conclusions

North American railroads anticipate continued growth in freight traffic and expanded passenger service on freight corridors. In order to avoid congestion with its associated loss in service quality and increased operating costs, railroads need to invest in new and expanded infrastructure. While there are a number of metrics used to measure railway capacity, the principal one used in this thesis is normalized train delay. Three major areas of interest were addressed, beginning with an analysis of long-train operations on routes with short sidings, then an analysis of the incremental capacity of transitioning from single to double track, and concluding with an initial consideration of the effect of incrementally adding a third track.

Results from the long-train short-siding analyses concluded that train replacement ratio (i.e. the ratio in the length of long trains to short trains on a route) strongly affects the infrastructure investment required to support operation of long trains while maintaining baseline levels of service. A declining linear relationship exists between train replacement ratio and required investment in siding extensions (i.e. sidings made long enough to accommodate longer trains). For example, routes with a replacement ratio of 3:2 required that roughly half the sidings on a route be extended in order to maintain existing levels of service. A ratio of 2:1 indicated that only about a third of sidings need to be lengthened. The merits of uni-directional, long-train operations were also evident, since this technique showed no adverse effects on train delay, while simultaneously minimizing infrastructure investment.

Where traffic density and mixtures dictate the need for double tracking, project alternatives are often identified using simple practitioner heuristics regarding siding connection length, position, and order. Results from simulation analyses concluded that no one heuristic was definitive; rather, each played a role in affecting train delay. In particular, double-tracking projects made in the latter half of a full progression from single to double track decreased train delay more substantially. Longer double-tracking projects showed more consistent delay reduction, while shorter projects showed increased sensitivity to the effects of position and order.

In transitioning from double to triple track, the results suggested a linear relationship between train delay and percent triple track installed, and indicated a slight benefit in the implementation of a parallel crossover scheme as opposed to the herringbone arrangement. Triple-tracking 90 percent of a double-track route resulted in a roughly 50 percent reduction in normalized train delay. Although railroads must consider many factors in selecting capital expansion projects, the analyses and guidelines presented here can streamline the decision process by helping to quickly identify projects with the most potential for more detailed engineering evaluation.

Recommendations

While the results shed light on the link between track arrangement and capacity, track construction is a relatively costly alternative to capacity expansion. Consideration should be given to efficient scheduling that maximizes the utility of existing and planned track infrastructure. For example, a siding offers little benefit if trains do not normally meet or pass at its location based on their typical operating schedules. A study that quantifies the interrelationships of train scheduling, track usage, and train delay would be beneficial to a more sophisticated understanding of capacity investment. Each of the research topics addressed here are also, in one form or another, linked to yard and terminal operations. For example, short yard tracks undermine some of the efficiencies of long-train operation. Additionally, yard operations are a source of train delay regardless of mainline capacity. Integrated modeling of the capacity interaction between yards, terminals, and mainlines should be a high priority in future studies of rail capacity.

Publications

Master’s thesis for Ivan Atanassov, attached

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