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Blocking Capacity and Level of Service in Railway Hump Classification Yards

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DISCLAIMER

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TECHNICAL SUMMARY

Title

Blocking Capacity and Level of Service in Railway Hump Classification Yards

Introduction

To create capacity for future freight rail transportation demand, billions of dollars must be invested in both the mainline route network and yards and terminals. Under growing traffic and limited capital budgets, railroads have a strong economic incentive to properly match both mainline and yard capacity to traffic demands. Prudent decisions regarding allocation of capacity expansion funds between mainline projects and those in yards and terminals require detailed knowledge of the different factors and relationships that govern the capacity and performance of these disparate yet complementary facilities.

Despite the important role of both types of facilities in freight rail transportation performance, the majority of railway industry and academic analytical efforts are focused on improving the "line-haul" performance of mainline trains and developing tools for mainline capacity analysis. Much less attention is devoted to investigations of yard and terminal performance, and there are few tools to analyze yard capacity. There has been even less academic study of how mainline capacity and performance interacts with yard capacity and performance. Despite observable interactions between the performance of nodes and connecting links within the rail network, most mainline capacity tools do not consider the effects of yard operations and approaches to yard capacity often ignore the constraints of mainline capacity.

This research seeks to develop a stronger fundamental understanding of railway classification yard capacity and performance, and its connection to the capacity, performance and infrastructure planning of railway mainlines under flexible operations.

Approach and Methodology

This research seeks to answer three principal classification yard research questions:

- Can other factors supplement daily railcar volume in predicting the performance of classification yards?
- What are the fundamental hump classification yard capacity relationships between level of service performance metrics and throughput volume of railcars as a function of the number of outbound blocks created, outbound trains assembled and distribution of outbound block sizes?

- What is the influence of inbound traffic volume variation and schedule flexibility on hump classification yard performance and capacity?

This research addresses the above questions in the context of North American freight railway transportation with its associated schedule flexibility, performance metrics and other business practices. The research specifically focuses on hump classification yards as they form the backbone of the manifest train network. Although hump classification yards differ in many respects from flat-switching yards and other types of yards and terminals, knowledge of hump classification yard capacity and performance relationships stemming from this research will likely provide insight into the operations of these other yard and terminal facilities.

To improve upon current volume-based representations of yard capacity, the concept of classification yard traffic complexity was introduced. An original exploratory simulation model of a hypothetical yard operation was developed in SIGMA and used to create a yard capacity constraint involving railcar volume, number of blocks, and number of outbound trains.

Traffic complexity and schedule flexibility in hump classification yards were further investigated through the first academic research implementation of YardSYM, a discrete-event simulation model of yard operations. The model was used to conduct controlled simulation experiments in which combinations of railcar throughput volume, number of blocks, number of outbound trains, block size distribution, train departure patterns, arriving train schedule flexibility, and inbound block variability were varied for the eastbound operation at the Belt Railway Company of Chicago Clearing Yard. Regression analysis yielded a yard capacity model that quantified trade-offs between throughput volume and number of blocks as a function of maximum allowable average railcar dwell. To better understand and explain the mechanics of the yard operation, the concept of "adjusted number of blocks" was developed. Adjusted number of blocks was then used to describe the effect of poorly matched block sizes and classification track lengths on yard performance and capacity.

Findings

Output from the exploratory SIGMA simulation model indicated that a combination of factors describing traffic complexity is a better predictor of yard performance than volume alone. Simulation results can be transformed into capacity constraints that describe the interaction between the maximum allowable daily number of railcars, blocks and train processed by a hump classification yard. A fixed overall capacity dictates that an increase in one traffic factor requires corresponding changes in other factors describing the overall traffic complexity in the yard. When a yard is making a small number of blocks, distributing those blocks over an additional outbound train can increase allowable railcar throughput volume by eliminating time-consuming switching moves to "double" blocks from multiple classification tracks into a single outbound train.

Through YardSYM simulations, the yard under study exhibits the expected trend of exponentially increasing average railcar dwell with increasing railcar throughput volume. Railcar dwell increases more rapidly with increasing volume when the yard handles a greater number of blocks, exhibiting a trade-off between maximum traffic volume and the number of blocks handled by the yard. Increasing the number of outbound trains while keeping railcar throughput volume and number of blocks constant can shorten processing time and improve yard performance, consistent with the observations of the exploratory simulation model for a small number of blocks. However, if the size of outbound trains is kept constant, along with the effort required to assemble them, bunched train departures are detrimental to yard performance.

Actual train operations exhibit a wide range of arriving train schedule flexibility and inbound block volume variability. While some freight trains consistently arrive at the same time every day, others arrive seemingly at random. Train sizes can be consistent or widely varying from day-to-day depending on the business purpose of a particular train. As arriving train schedule flexibility increases, yard performance deteriorates. Classification yards act to both amplify and dampen schedule flexibility to the range of +/-120 to 180 minutes. Classification yards transform arriving train schedule flexibility into increased variability in departing train length. Classification yards act to amplify volume variability as outbound train sizes consistently show greater variation than inbound train sizes.

Conclusions

The yard simulation results indicate that the amount of yard capacity potentially gained through operational changes to reduce traffic complexity is limited by track length constraints. Unless yard tracks are extremely long or railcar throughput volumes are low, efforts to reduce traffic complexity by forming fewer larger blocks will artificially create new traffic complexity when block lengths exceed classification track lengths. Industry practitioners should take advantage of otherwise wasted switching effort and define new blocks that are better matched to available classification track lengths. The creation of these blocks can improve the overall network LOS by providing additional direct block connections and reducing switching work at other classification yards.

The results of the yard simulation experiments also demonstrate the need for a network perspective in developing railway operating plans. Efforts to manage outbound trains in a manner that improves performance at one yard may create inbound train conditions that are even more detrimental to destination yards. Since schedule flexibility is more detrimental to yard performance than volume variability, practitioners have an incentive to prioritize on-time originations to reduce arrival time variability at destination yards. In general, classification yards are disruptive to efforts to operate trains on precise schedules and with consistent train sizes.

Recommendations

For future work, the YardSYM model offers the potential to investigate other variables, such as crew resources, and to simulate additional track layouts in a similar manner to how Rail Traffic Controller (RTC) has been used in academia to research mainline capacity and performance. There is a strong motivation for future research comparing hump yard layouts and pull-down lead configurations as there are still few tools to quickly and quantitatively assess the impact of yard layout decisions during the design process. It is difficult for yard designers to quantify the benefit of additional crossovers or longer tracks without conducting a full simulation. Parametric or other models derived from controlled simulation experiments involving different layouts could greatly improve the yard design process.

Publications

Dick, C.T., 2019. *Influence of Traffic Complexity and Schedule Flexibility on Railway Classification Yard Capacity and Mainline Performance*. PhD Dissertation. University of Illinois at Urbana-Champaign, Urbana, IL.

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APPENDIX A

INFLUENCE OF TRAFFIC COMPLEXITY AND SCHEDULE FLEXIBILITY ON RAILWAY CLASSIFICATION YARD CAPACITY AND MAINLINE PERFORMANCE

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Doctoral dissertation to be published in May 2021 by the University of Illinois at Urbana-Champaign, which will be made available at:

https://www.ideals.illinois.edu/