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**Quantifying Intermodal Facility Capacity Factor Interactions through Simulation**

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## DISCLAIMER

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**TECHNICAL SUMMARY**

**Title**

Quantifying Intermodal Facility Capacity Factor Interactions through Simulation

**Introduction**

Intermodal hubs play an important role in the operation of railway networks. Intermodal freight is a primary revenue stream for Class I railroads in the United States. Intermodal traffic volume has increased approximately 10 percent since 2011 and reached new all-time record volumes during the summer of 2017. This growth combined with shifts in traffic patterns and a move from trailers to containers, has strained the capacity of existing intermodal terminals. In response, railroads are expanding their intermodal service capabilities by upgrading existing terminals and building new ones. Although intermodal freight generates substantial revenue, its operating and capital investment requirements are substantial. Under constrained capital budgets, railroads must make informed decisions regarding investments in new intermodal terminals, facility expansion and optimizing the efficiency and capacity of existing facilities. These decisions require a detailed understanding of intermodal facility capacity factors and their interactions, including size and layout of the facilities, and number and type of lift equipment. Currently, intermodal terminal capacity is largely evaluated on the basis of practitioner planning experience and a limited number of independent capacity factors. There is a need for a more thorough understanding of the interaction between fundamental factors that influence intermodal terminal capacity.

**Approach and Methodology**

To meet the goal of better understanding the factors constraining the capacity of domestic intermodal terminals, this research develops a representative intermodal terminal model by creating a series of sub-models that accurately capture the entire intermodal terminal process. This research uses AnyLogic® software to develop the simulation models. AnyLogic® is a Java-based simulation software with applications in a wide variety of fields, including transportation planning and operations research. A strength of AnyLogic® in the context of this research is its special-purpose road and rail libraries that allow users to develop large-scale, multi-purpose intermodal terminal models using interactive agents instead of a discrete-event approach. The original AnyLogic® model of a representative domestic intermodal terminal developed by the project team is subsequently used to conduct a series of simulation experiments designed to investigate the relationships between different terminal layout and operating factors. Different factorial combinations of the following factors are simulated in the experiment design: overall rail and roadway arrangement (i.e. length and number of strip tracks, and amount and arrangement of parking space), number of yard hostlers to dray trailers between the strip tracks and parking and expected trailer dwell times.

Three simulation models, each corresponding to a different representative intermodal terminal layout configuration, were developed to test the effect of different terminal layout properties on overall capacity. The overall size of the parking area, as well as the number of cranes and the total length of strip track, were kept constant between all models. The major difference between each simulated configuration is the layout of the strip tracks. The first model contains a single 8,000-foot strip (2,438.4 meters) track where trailers and transloaded to and from railcars, the second has two 4,000-foot (1,219.2 meters) strip tracks, and the final model has four 2,000-foot (609.6 meters) strip tracks. All three models have a constant parking lot capacity of 1,440 trailers.

The three facility layouts are designed to highlight a trade-off between two conflicting trends that are hypothesized to limit the capacity of the facility. The single-track facility will not lose any production time to switching railcars between tracks, potentially benefitting capacity compared to the four-track facility where more time is consumed by switching operations. Conversely, capacity of the single-track facility may be hindered by longer hostler travel distances that increase the time required to unload and reload a train, while the four-track facility can take advantage of its shorter strip tracks to minimize hostler travel distance.

In addition to the primary effect of the three different terminal layout configurations, the effects of two additional variables on terminal capacity are investigated through the experiment design: the number of hostlers and the pickup delay distribution. The number of hostlers determines how many tractors are available to transport trailers between the strip tracks and parking area. Although it is expected that capacity will rise as the number of hostlers is increased, including this variable may highlight differences in the hostler cycle times of different facility layouts and their effect on the relative capacity of each particular layout. The pickup delay distribution is defined as a predetermined range of times, along with their probability of occurrence, at which tractors arrive at the facility to pick up trailers that have been unloaded from a train. Each model is run under uniformly distributed ranges as short as 1 hour up to 144 hours. It is hypothesized that different pickup delay distributions and time ranges may cause congestion within the terminal due to periods of peak demand and high numbers of trucks entering and leaving the facility.

## Findings

To provide a baseline context for the simulation results, the capacity of each layout is calculated using the American Railway Engineering and Maintenance-of-Way Association (AREMA) method. Because the AREMA approach only considers total length of strip track (8,000 feet) and not the specific track arrangement, the theoretical capacity of the three layouts is identical at 1,316 lifts per day.

For the baseline conditions of 10 hostlers and a 24-hour pickup delay distribution, the 4×2000 layout has the largest capacity, followed by the 2×4000 layout and then the 1×8000 layout with the lowest capacity. The shortened travel distances for hostlers between the parking area and strip tracks allow for more frequent turnaround times at the strip tracks, leading to faster train processing times and subsequently the higher volumes observed in the 4×2000 layout. The 4×2000 layout requires additional switching movements to position all the railcars for transloading, lengthening the turnaround time for each train. Although the current model includes the time required to physically move each string of railcars on to a separate track, the model does not currently include any additional delay to account for lining switches and crew walking time. Adding these extra time components may offset the time gained due to shorter hostler travel and reduce the capacity advantage of the 4×2000 layout.

As the number of hostlers increases, the overall terminal capacity increases. The rate of increase gradually diminishes until each facility reaches a maximum capacity. Above 20 hostlers, additional hostlers have minimal impact on terminal capacity. With larger numbers of hostlers, the 2×4000 layout has the largest capacity, followed by the 4×2000 layout, and the 1×8000 layout with the lowest capacity. Between one and 15 hostlers, the 4-strip layout exhibits a higher capacity than either the 2-strip or 1-strip layouts (the latter two exhibit near-identical capacities within this range). Comparing the simulation results to the AREMA capacity calculation, the AREMA method underestimates capacity for the 2×4000 and 1×8000 layouts when 11 or more hostlers are used, while the AREMA method underestimates the capacity of the 4×2000 layout above 8 or 9 hostlers.

As pickup delay increases, there is a slight decrease in terminal capacity due to the longer dwell times for trailers arriving via train. The more time flexibility over-the-road (OTR) trucks have to pick up their trailers that have arrived by train (i.e. longer pick-up delay distributions), the more time trailers will spend parked in the terminal, reducing the number of available parking spots. When fewer parking spots are available, OTR trucks spend more time driving to spaces in less desirable portions of the parking area within the facility. Not only does this increase the time OTR trucks spend in the facility, it also creates congestion that increases the time required for each hostler round trip between parking and the strip tracks. After a certain amount of pick-up delay, the simulations models become infeasible with zero capacity, indicating a lack of available parking space (i.e. full parking lot). With no parking available, OTR trucks cannot drop off trailers to be loaded on outbound trains. Also, when parking becomes full, hostlers cannot clear the strip tracks of trailers that have just arrived by train. In either case, the next train cannot begin loading and delays quickly accumulate.

The results of the simulation scenarios with varying numbers of hostlers and pickup delay allow the maximum capacity of the three different facility layouts to be compared under the most favourable set of conditions for each facility layout. Maximum capacity is reached somewhere between 20 and 25 hostlers, while pickup delay reaches peak capacity between 1 and 12 hours, potentially through faster turnaround times for inbound train-to-road trailers and subsequent availability of parking space. With regard to varying pickup delay, the 4×2000 layout has the largest capacity, while the 1×8000 and 2×4000 have near-identical capacities.

## Conclusions

The primary conclusion of this research is that various layout, resource and traffic factors can interact to influence the overall capacity of an intermodal facility. Standard industry and rail practitioner analytical approaches that rely primarily on the length of strip track, number and type of lift equipment, number of car spots, and overall parking area can overestimate facility capacity if the number of hostlers is too low or drayage distances are too long. Similarly, if drayage distances are short and there are a large number of hostlers, the simulated intermodal facility capacity may exceed that predicted by the analytical models. Terminal layout, hostler resource level and shipment dwell (i.e. traffic haracteristics) are all found to have a substantial influence on terminal capacity. Therefore, these factors should be added to analytical capacity approaches to provide intermodal facility planners, designers and operators with better tools for estimating terminal capacity and performance.

## Recommendations

Future work should use the same models to investigate the capacity impacts of traffic mixture and daily distribution of traffic peaks, priority loads, trailers that require special handling, or other unique operating and facility layout conditions that can be represented by the processes within the AnyLogic model. Additional experimental analysis may reveal primary effects and interactions that further constrain capacity below the upper bound set by the single-factor relationships suggested by AREMA. An expanded factorial design should be conducted to facilitate development of an improved analytical model for intermodal terminal capacity.

## Publications

Chen, W.B., M.J. Pugh and C.T. Dick. 2019. Investigating highway-rail intermodal terminal capacity relationships via simulation. In: *Proceedings of the International Association of Railway Operations Research (IAROR) 8th International Conference on Railway Operations Modelling and Analysis*, Norrkoping, Sweden, June 2019.

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