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ADVANCING THE SCIENCE OF YARD DESIGN AND OPERATIONS WITH THE CSX HUMP YARD SIMULATION SYSTEM

C. Tyler Dick, P.E.
University of Illinois at Urbana-Champaign
Urbana, Illinois, USA

Jeremiah R. Dirnberger
CSX Transportation
Jacksonville, Florida, USA

ABSTRACT

The Class 1 railroads in North America have made substantial investments in mainline and intermodal terminal capacity during the past two decades to meet growing traffic demand. Investments to increase hump classification yard capacity have been less frequent, with a handful of yard projects in the late 1990s and the last major round of new hump yards constructed in the late 1970s. At this time of large investment in yards, much basic research was conducted on hump yard design and performance, while more recent studies have looked at applying lean process improvement and block optimization to hump yards. Due to the complexity of the problem, these studies tend to focus on one aspect of the terminal capacity question at a time, leaving the industry without a comprehensive understanding of the fundamental interrelationships between all aspects of hump yard performance in terms of volume, utilization and reliability. Without such an understanding, the industry cannot make fully informed decisions regarding the hump yard capacity investments that are now the subject of renewed interest due to the combination of carload market shifts, traffic growth facilitated by mainline capacity investment, and aging congested yard infrastructure. To address this need, CSX Transportation developed its Hump Yard Simulation System (HYSS). HYSS considers the operations, process and infrastructure parameters of a hump yard, and their interactions, in a single simulation to evaluate terminal performance. In the HYSS graphical environment, users can evaluate any combination of changes to terminal operating plans, yard processes and infrastructure layout. While developed to address specific business needs, as a simulation tool, HYSS has the potential to investigate the fundamental relationships governing hump yard operations in a manner not possible before. To realize this potential, CSX is partnering with the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois to deploy HYSS in an academic research environment. Design of experiments techniques will be used to conduct a series of HYSS simulations to quantify the interaction between hump yard throughput, number of blocks and the delivered level of service at the terminal, and the sensitivity of this relationship to other operational and infrastructure variables. This paper will introduce HYSS as a research tool, examine how its various outputs are used to quantify terminal performance, and describe the planned research program aimed at advancing the science of hump yard design and operations.

INTRODUCTION

The past two decades have been marked by a dramatic increase in freight traffic on Class 1 railroads in North America. From 1993 to 2012, Class 1 railroad revenue ton-miles increased by 54 percent [1]. This increase in traffic has been highlighted by a rapid expansion of intermodal traffic, with total intermodal units (trailers and containers) handled nearly doubling over this same period. Coal traffic also increased steadily, with tons originated increasing by 46 percent between 1993 and the peak year of 2008 [2]. Since both intermodal and coal traffic move in dedicated or solid “unit” trains between loading and unloading terminals, they bypass railroad classification yards. Thus, the addition of intermodal and coal trains to the network increases demand for line-haul transportation without the need for additional railcar classification. With these two commodity groups grabbing much of the attention, the railroads have made substantial investments in mainline and intermodal terminal capacity to meet this growing traffic demand.

Correspondingly, investments to increase classification capacity, specifically in hump classification yards, have been less frequent. During this same 20-year period that saw the construction of dozens of intermodal facilities and thousands of miles of new passing sidings and second main track, only a handful of hump yard capacity projects were undertaken. The most notable hump yard projects, those at the BNSF Argentine Yard, Union Pacific Roseville (Davis) Yard, CSX Willard Yard and CN Harrison (Johnston) Yard were all related to changing traffic patterns and consolidation of terminal facilities following major railroad mergers and acquisitions. These capacity projects were justified less by natural traffic increases and more out of a desire to increase efficiency and eliminate duplicate facilities through consolidation. It could be argued that only the construction of the Union Pacific Livonia Yard in Louisiana in 1994 was driven purely by the need to increase capacity in response to traffic growth stemming from the demand for chemical production on the Gulf Coast.

The lack of pure investments in hump classification yard capacity should not be interpreted as a sign that carload and manifest traffic declined in both volume and importance to the railroads during this period. The statistics presented earlier suggest that increases in coal and intermodal traffic alone cannot account for the entire increase in revenue ton-miles experienced during the period. Indeed, traffic in other commodity groups, including those that move mainly by the carload in manifest trains via classification yards, also increased. For example, tons originated in the chemical and allied products commodity group increased by over 32 percent between 1993 and 2012 [1]. AAR study has concluded the increase in carload traffic through classification terminals that was not matched with investment in increased classification yard capacity was the root cause of much of the network congestion experience during this period of overall traffic growth [3]. To some degree, railroad investment in mainline capacity during this period merely addressed the line-haul delay symptom of network congestion and not its root cause: aging and increasingly congested classification terminals.

Commodities that typically move in carload or manifest service retain their importance to the railroads as they consistently generate more revenue per carload than mixed miscellaneous shipments (intermodal) and commodities handled in bulk unit trains [4]. Because of this, carload traffic remains a significant source of revenue for the railroads and will only grow in importance as coal traffic declines due to a shift to electric power generation from natural gas [5]. In 2012, manifest traffic accounted for approximately 40 percent of Class 1 railroad revenue despite only contributing 25 percent of tonnage [6]. Moving this carload traffic in a cost-effective and reliable manner can only be accomplished through a series of efficient classification terminals that aggregate the individual carloads into blocks and manifest trains. The quality of service provided to carload shippers is entirely dependent on the performance of these classification terminals. Thus, adequate classification terminal capacity is required to ensure reliable train connections. In addition to the potential loss of carload shipment revenue due to a failure to meet service standards, the increased yard dwell times associated with congestion and poor classification yard performance come with a direct financial penalty in the form of car-hire, the opportunity cost of poor asset utilization and the ownership cost of maintaining a larger fleet of railcars. With the typical railcar in carload service spending approximately half of its trip time in classification yards, small improvements in yard dwell times can result in large financial rewards [4, 7]. This also means that even a slight degradation in classification yard performance as a terminal nears capacity can have substantial financial consequences.

FUTURE YARD INVESTMENTS

Currently the backbone of the Class 1 railroad carload service network is the 51 major hump classification yards in the United States that together process over 28 million railcars per year [8]. Previous study has acknowledged that investments in these terminals will be required to support future traffic growth with the 2007 National Rail Freight Infrastructure Capacity and Investment Study concluding that over $6.6 billion in carload terminal investment would be required by 2035 to support projected traffic levels [9]. The need for this terminal investment is already being felt on certain corridors where a combination of increased traffic facilitated by expansion of mainline capacity and shifting traffic patterns due to changes in commodity market flows has begun to create congestion on aging hump yard infrastructure. Thus there is a renewed interest in investments to increase hump yard capacity. Norfolk Southern has started construction to expand its hump yard in Bellevue, Ohio while Union Pacific is actively designing a new hump yard for a site near Hearne, Texas, and other yard projects are under study.

As the industry contemplates what this next generation of hump classifications yards will look like and where they will be located, the lack of substantial research in this area for close to 30 years has become readily apparent. With the estimated cost of a new greenfield major hump retarder yard well in excess of $500 million, such investments must be made carefully and with sound justification based on the best information possible. However, as will be discussed in the following section, a long hiatus in basic yard research has left the industry without a comprehensive understanding of the fundamental interrelationships between all aspects of hump yard performance in terms of volume, utilization and reliability, and their relationship to various terminal layout and design parameters. Without such an understanding, the industry cannot make fully informed decisions regarding the hump yard capacity investments that are essential to future success.

DEVELOPMENT OF YARD SCIENCE

The seminal work on the subject of classification yards remains “Freight Terminals & Trains” by J.A. Droege. Many of the fundamental concepts related to terminal process and operations presented in the original 1912 text and updated second edition dating from 1925 are still valid. For example, Droege acknowledges that railcars spend much of their time idle in classification yards, representing major productivity loss and increasing the number of railcars required to move a given amount of freight [10]. However, new yard technology has made some of the concepts obsolete and changed or even reversed basic relationships. Droege describes the hump operation, specifically the need to efficiently return car riders to the crest at the required rate to provide braking control for each railcar, as the key bottleneck process that constrains hump yard throughput. With the advent of automatic retarder brakes eliminating the constraint of car rider availability, current research indicates that the trim or pull-down process is the bottleneck in hump yard operations, reversing the earlier relationship [4].

In the 1950s, hump yard research focused on technological advancements such as radar to improve car speed control exiting retarders through servo loops [11]. Early computers were then employed to process the inputs from scales, timing circuits, radar speed measurements and other presence detection devices to create fully automated car speed control systems for hump yards [12]. These systems eliminated the need for retarder operators and increased productivity by reducing the number of stalled cars stopping short of their coupling target and the number of over-speed couplings and associated impacts. Later systems would incorporate switch lists, blocking and routing into the computer control to fully automate the hump yard sorting process.

In the 1960s, computers became a tool to plan and optimize hump yard operations under different operating scenarios through mathematical models. Early terminal simulation computer programs used models and logic to sequence the different elements of the hump yard process and track the time histories of individual railcars through the yard to measure average dwell and throughput. Changes in input parameters allowed users to evaluate alternative infrastructure and operating plans for future implementation [13].

The 1970s marked a golden age of hump yard activity and research. Hump classification yards were a major concern in this era of "loose car" railroading immediately prior to deregulation. Regulations in place at the time provided less incentive for multi-car shipments and the operation of unit trains that bypassed yards. Regulation also gave rise to incentive per-diem freight cars that passed through multiple classification yards on each trip as the cars were continually shuttled around the network. More Class 1 railroads were in operation at the time, increasing the need for interchange and forcing more blocks of smaller size to be formed at many more yard locations. In 1975, there were 152 hump classification yards in operation, triple the current number of hump yards, and together they processed 60 million railcars per year, double the current processing rate [14, 15]. In the latter years of the decade, many new hump yards were constructed as eastern railroads consolidated their operations: Osborn Yard, Louisville KY in 1977; Rice Yard, Waycross GA in 1978; Spencer Yard, Linwood NC in 1979 (last greenfield construction); Queensgate, Cincinnati OH in 1980 and Bellevue Yard, Bellevue OH in 1982. Notable projects from the western railroads during the same period include Barstow Yard, Barstow CA in 1976 and Hinkle Yard in Hinkle OR in 1977 [16, 17].

During this period of great interest in hump classification yard expansion, the FRA conducted a series of Classification Yard Technology Workshops between 1979 and 1983. The workshops led to the development of the Railroad Classification Yard Technology Manual that organized the current knowledge of yard design and operations around three themes: yard infrastructure configuration and track layout; computers and automated yard control systems; and rolling resistance (or rollability) or railcars [15, 16]. The FRA research on infrastructure and yard design was complimented by classification yard operations research conducted during the same time period. The most notable results from these efforts are the probabilistic regression models of classification yard performance using PMAKE functions developed by MIT [18]. The studies, technologies and models developed and presented during this period represent the single largest research thrust in this area before or since. The presented findings and design manuals form the foundation of the industry's current knowledge of the science of yard design and operations. Many of the research topics have not been revisited during the ensuing 30 years.

The abrupt end to interest in hump classification yard research can be attributed to a combination of many factors: the recession of the early 1980s, deregulation, deindustrialization, a shift of traffic to unit trains and intermodal trains that bypassed classification yards, branchline abandonment and reduced interchange due to railroad mergers. This perfect storm led to the closure of many hump yards that, in many cases, were subsequently converted into intermodal terminals. However, the railroads did implement new technology during this period of declining interest including three-point control using tangent point retarders and continuous speed control using piston retarders.

CURRENT STATE OF YARD SCIENCE

The hump yard research conducted during the past 30 years has been less focused on developing fundamental relationships and more concentrated on obtaining certain performance improvements, improving efficiency and asset utilization and reducing crew and operator resource requirements. This research has often been centered on specific case studies and is focused on one of two areas: process improvement and operations plan optimization. Process improvement research has looked at employing concepts of lean manufacturing to the entire process of sorting and building trains within hump yards to increase efficiency and utilization [19]. Operations plan optimization has used dynamic programming and other operations research techniques to optimize the block-to-train, block-to-track and inbound hump sequence aspects of the

TABLE 1: HIERARCHY OF RAIL NETWORK MANAGEMENT DECISIONS

Level	Time Horizon	Rail Decisions
Planning	Long term (strategy) (Greater than 6 months)	LOR capital investment Yard capital investment Terminal capital investment Locomotive acquisition New yard construction Existing yard closure/downgrade Yard automation investment Real-time decision support system investment
Scheduling	Intermediate term (tactics) (Less than 6 months)	Train plan/routing Classification policy Train make-up policy Resource scheduling Curfew planning
Production	Short term (operational) (Real-time to less than 1 week)	Train build sequence Locomotive distribution Car scheduling Empty car distribution Crew scheduling Hump sequence Block-to-track assignment

classification process. Operating plans featuring novel methods of sorting railcars such as triangular, geometric and matrix switching have also been researched to make more effective use of available classification track infrastructure [20, 21, 22].

Due to the complexity of the hump yard problem, these studies tend to focus on one aspect of the terminal capacity question at a time. The process focus looks at the actions and sequence of activities required to execute a given operating plan on fixed infrastructure while the optimization focus concentrates on the terminal operating plan given a fixed process and yard infrastructure. Case-study research is also often specific to individual yards and may not apply to different yard configurations. For example, a process model for an in-line departure yard would be quite different than one for a parallel departure yard. It is also recognized that regression models of operating parameters based on previous yard performance cannot be used to explicitly predict what may happen if changes are made to the baseline infrastructure or process and may ignore the details of terminal processing operations that play a critical role in determining yard performance [7]. The result is that the railroad industry is left without a comprehensive understanding of the fundamental interrelationships between all aspects of hump yard performance in terms of volume, utilization and reliability. Without such an understanding, the industry cannot make fully informed decisions regarding the hump yard capacity investments that are now the subject of renewed interest.

To provide the industry with this fundamental understanding, a model that considers the operations, process and infrastructure parameters of a hump yard, and their interactions, in a single simulation of terminal performance is required. An early effort to create such a model was made by Canadian National in the form of their Terminal Interactive Model (TRIM) but the constraints of computer computational power at the time limited the amount of infrastructure detail considered by the model [23]. Modern computing power can allow for detailed infrastructure considerations within a more comprehensive model framework as in the model proposed by Lin and Cheng [24]. To address this need, CSX Transportation developed its Hump Yard Simulation System (HYSS).

CSX HUMP YARD SIMULATION SYSTEM

There is a three-level hierarchy of problems in rail network management: planning, scheduling and production [4]. Planning problems are long-term (greater than six months) and strategic in nature. Scheduling problems have an intermediate time-horizon (greater than one week to less than six months) and are more tactical in nature. Production problems have a

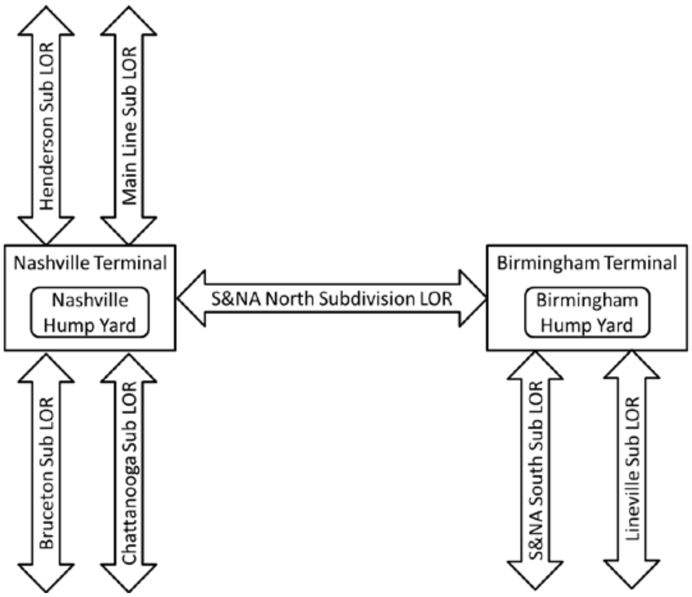

FIGURE 1: SCOPE OF YARD, TERMINAL AND LINE-OF-ROAD MODELS

short time-horizon (real-time to less than one week) and are concerned with operational issues. Table 1 summarizes this hierarchy with example rail problems.

Rail network management can also be divided into three distinct primary functions within the network: yards, terminals and line-of-road (LOR). For the purposes of this paper, a yard function will be defined as a system of tracks/sub-yards within defined limits whose primary purpose is the safe movement of *cars* from one train to another. A terminal function will be defined as a system of tracks within a geographic area whose primary purpose is the safe relaying of *trains* from one LOR subdivision to another subdivision while those trains perform an intermediate work activity (crew change, pick-up/set-off, 1,000-mile inspection, etc.), or from one LOR subdivision to a yard, or from a yard to a LOR subdivision. A LOR function is primarily concerned with the safe movement of *trains* between one terminal and another terminal by meeting and passing trains on mainline tracks. Figure 1 illustrates these definitions using the Nashville-Birmingham corridor on CSX.

Simulation plays a key role in analyzing rail network management problems. A higher-level simulation can assist with planning problems for yards, terminals and LOR. A more detailed simulation model can assist with scheduling problems for all three functions as well (Figure 2). Real-time planning tools are required to assist with production problems. In late 2010, CSX was using the industry-standard Rail Traffic Control (RTC) simulation tool for its LOR planning problems. There was no industry-standard yard simulation tool available, so the company began exploring its options to complement RTC. After determining the available "off-the-shelf" simulation software was inadequate to meet the requirements, CSX decided to partner with Innovative Scheduling (IS) to develop a prototype Hump Yard Simulation System (HYSS). The yard at Hamlet, NC, was chosen to be the first location modeled because of its importance to the part of the network it supports and the overall operation is fairly standard: all trains either originate or terminate at the yard (no trains pick-up or set-off), there is no interchange traffic at the yard, and there is no non-hump work (like an intermodal ramp or block swapping) co-located at the location.

HYSS DEVELOPMENT AND TESTING

Once Hamlet was successfully modeled and validated, the yard at Avon, IN, was selected as the "proof-of-concept" to prove that the modeling process could be duplicated at a yard with more varied operations. Avon has a small intermodal ramp that shares some track resources with the hump operations, some trains pick-up and/or set-out and two short line railroads interchange with CSX there. While the Avon model was undergoing validation, the decision was made to develop four new yard models in 2012. The yards were chosen because of their location on key corridors on the CSX network: Nashville, TN, Birmingham, AL, Willard, OH, and Selkirk, NY. Each yard had different operational caveats that resulted from the different infrastructure layout/orientation and location in the network. Table 2 summarizes the infrastructure and operational characteristics of all six yards that are currently modeled in HYSS. For each yard, the standard input data set is 42 days of actual car and train data. The yard is empty at the start of the simulation, so a standard 7-day warm-up and a 7-day cool-down period are removed from the results to create a 28-day output data set that is used for any necessary analysis.

As the 2012 development push was nearing completion, it was determined that a more thorough testing period was needed to ensure quality and robustness for a wider user base using the models. A 3-step approach was selected:

1. Verification: Using the first 42-day data set:
    a. Ensure that the code executes to completion and writes output data.
    b. In this stage, the model results must be within +/-20% of actual values.

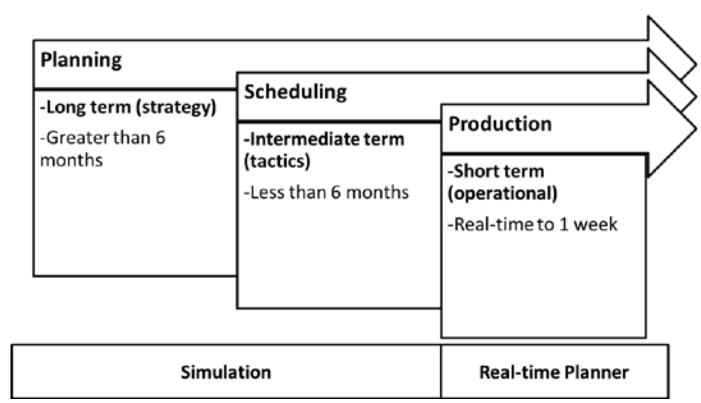

FIGURE 2: ROLE OF SIMULATION AND PLANNING IN RAIL OPERATIONS MANAGEMENT DECISIONS

2. Validation: Using the second 42-day data set:

a. Base case replication consistency: Ensure that the code executes to completion writes output data for 30 different replications using 30 different random seeds. For the 30 replications, a Coefficient of Variance (COV) threshold was established for the four Key Performance Indicators (KPI). In order to pass, the COV of the replications must be less than the threshold. The KPIs tested are:

- Average car dwell (hours)
- Cars processed per day
- % achieved connections (Right Car-Right Train in CSX terms)
- % On-time train originations

Of these, HYSS is most accurate for dwell and cars processed.

b. Base case accuracy: Compare the base case results with the actual values for the selected time period. Depending on the KPI, a 99% confidence interval or +/- acceptable variance level was established.

c. Model robustness and replication consistency for any case: Nine parameters were selected as significant parameters by CSX yard operations experts and nine cases were created (changing one parameter in each case). 30 replications were run for each of the parameter cases and the COV values were compared against the established

TABLE 2: INFRASTRUCTURE AND OPERATIONAL CHARACTERISTICS OF YARDS MODELED IN HYSS

Yard	Layout category	Operational characteristics
Hamlet	Inline receiving/Parallel departure	Terminating trains Originating trains No interchange traffic
Avon	Parallel receiving/Parallel departure	Terminating trains Originating trains Interchange traffic Intermodal ramp inside yard limits Pick-up trains Set-out trains
Nashville	Inline receiving/Inline departure	Terminating trains Originating trains No interchange traffic Intermodal ramp inside yard limits Complex build process
Birmingham	Inline receiving/Parallel departure	Terminating trains Originating trains Interchange traffic Pick-up trains Set-out trains
Willard	Dual hump West-Inline receiving/Parallel departure East-Inline receiving/No departure	Terminating trains Originating trains Interchange traffic Pick-up trains Set-out trains Block swaps
Selkirk	Inline receiving/Parallel departure	Terminating trains Originating trains No interchange traffic Main-line trains run through yard Pick-up trains Set-out trains

thresholds. This created a total of 300 replications for each model. All replications had to run to completion and the results for each of the parameter cases had to make directional sense.

d. System quality: All logic, visualization or User Interface (UI) errors/issues had to be resolved.

3. User Acceptance Testing:

a. Review business logic, model visualization and results with yard management.

b. Test the User Interface, user management, and scenario management functionalities

All six locations passed the expanded testing criteria by mid-2013 and are now being used in a production environment by multiple users.

HYSS SPECIFICATIONS

Each yard model inside of HYSS was developed starting with detailed business requirements obtained through on-site visits to each location and extensive interviews with experienced Yardmasters, Train Masters and Superintendents. These business requirements created the framework which was then translated to a comprehensive system design document which included process flow charts that were used to create the code inside of the simulation engine. The code was written in C-Sharp with a Silverlight front-end for a web-based User Interface. The general specifications of the model are:

1. Depending on the yard, between 72-95 operational parameters that users can modify to create custom “what-if” scenarios
2. Depending on the part of the process the parameter is capturing, it will either be a single fixed value (i.e. mph) or a random value calling a triangular or uniform distribution
3. Multiple resource types (i.e. hump job, pull-out job, inbound inspector team, etc.) that users can add and define shift start times, durations, breaks, etc.
4. Actual GIS-based track information that users can modify by adding or removing tracks, changing track types, temporarily taking tracks out-of-service, changing track length, etc.
5. Input of 42 days of actual car and train arrival data or input of planned car and train data
6. Ability to add or remove train leg(s) or modify the arrival times, class code distribution, etc.
7. Visual replay of simulation for field review and training purposes
8. 28 days of output information for 17 performance measures, financial reports, resource utilization, train and car level detail, process durations, etc. with the ability to export the data from the UI

Two enhancements are currently under development to allow for the user to run multiple replications from the UI and to group/display the operational parameters by process with equation information readily available to the user. The model is being used by multiple users to answer long-term strategic planning questions and mid-term scheduling problems. Some example applications are given below:

- Capacity and service-level assessment for yards based on current and potential infrastructure, automation and resourcing
- Prioritization of yard capital projects by understanding the service and capacity impacts then creating a proactive investment plan across the entire network of yards
- Sequencing of proposed yard automation projects to maximize incremental improvement
- Right-sizing of yard resources
- Proactive train plan change review (planned)
- Training tool for demonstrating yard operations to new hires at multiple levels within the company
- Sensitivity analysis of parameter changes to KPI results (planned)

HYSS has provided value to CSX as a fact-based tool that has advanced the understanding of yard operations and led to better planning and scheduling decisions. It creates a large amount of clean data that advanced analytical tools can be readily applied. The investment in the model development and testing has also created a tool that can now be used to advance the science of yards at a level that previously was not possible.

ADVANCING THE SCIENCE OF YARDS

While CSX employs HYSS to investigate many specific business questions, HYSS has the potential to investigate the fundamental relationships governing hump yard operations in a manner not possible before.

In designing a train plan for a railway network, one of the many decisions is to determine the number of blocks to be handled by each train and the number of blocks to be assembled at each classification yard while maintaining a certain level of service standard. These two decisions are not entirely independent as increasing the number of blocks per train will typically increase the number of blocks to be made at certain key hub yards. The decision also exhibits a trade-off aspect as terminal managers can more effectively operate their facilities and gain economies of scale by making fewer larger blocks. Meanwhile, the overall line-haul network operates better if each yard is handling a greater number of smaller blocks as the increased number of routing options and potential for shorter connection times allows for optimized car trip plans. The fundamental research question remains to investigate this trade-off by designing a series of experiments to quantify the interaction between yard throughput, the total number of blocks being made in the yard (or blocks per train) and the delivered level of service at the terminal.

A hypothetical relationship between these parameters is illustrated in Figure 3. At a given state of yard operation (point A), in order to improve the level of service, the terminal

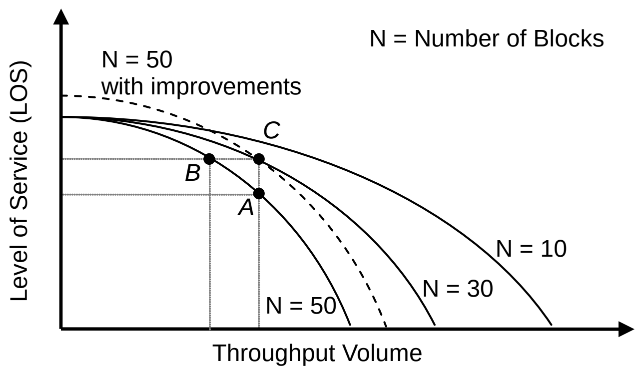

FIGURE 3: HYPOTHETICAL RELATIONSHIP BETWEEN LEVEL OF SERVICE, THROUGHPUT AND BLOCKS

operator has the option to: maintain the number of blocks but decrease volume (point B), maintain volume but decrease the number of blocks (point C), or maintain the current volume and number of blocks but make terminal investments or other process improvements to shift the entire volume-performance relationship to a new curve (dashed curve intercepting point C). The HYSS tool and design of experiments techniques will be used to optimally conduct simulation experiments to quantify these relationships and analyze the sensitivity of the level of service response to the input factors and other operational and infrastructure variables.

Initially, for a given yard layout and set of operating parameters, a factorial experiment will be designed to determine the relationship between yard throughput volume, the total number of blocks processed and the level of service. The number of inbound and outbound trains will be held constant, with the number of blocks per train varied accordingly. Following this initial analysis, the factorial experiment will be expanded to include different levels of other yard operational factors which may influence the relationship between volume, the number of blocks and the level of service. Factors may include the total number of trains being made in the facility, the hump rate, the percent of missed couplings, the number of trim/pull-out engines, the time required to perform inspections and other factors. Later tasks will examine the influence of train arrival rate, yard layout and overall yard configuration on the developed relationship between throughput, number of blocks and level of service.

BUILDING AN ACADEMIC COMMUNITY

Given that HYSS users at CSX are engaged in studies to satisfy business objectives, there is little time to conduct all of the experiments and analysis required to develop the fundamental relationships under study. To realize the potential to advance the science of yard design and operations, CSX is partnering with the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois to deploy HYSS in an academic research environment. Students at RailTEC will be provided with access to HYSS to conduct simulations with a working railcar dataset for a given hump classification yard. As part of their study program in railway civil engineering, the students will analyze the results with sensitivity and regression analysis to define the fundamental relationships in question.

Such an approach is not without precedent. RailTEC and several other academic institutions have been granted access to use the industry-standard Rail Traffic Controller (RTC) line-of-road dispatcher emulation software developed by Berkeley Simulation Software to investigate the fundamental relationships governing rail line capacity. Agreements have also been made for university researchers to employ RailSys in a similar manner. The result has been a wealth of new research, basic knowledge and fundamental understanding of the definition of capacity [25], network effects of capacity [26], the relationship between train type heterogeneity and capacity [27] and the incremental capacity of the transition from single to double track [28].

In addition to the research, the use of industry simulation software by universities has created a stronger rail capacity and simulation research community. Common simulation software allows for more effective collaboration nand the potential to embark on more ambitious, long-term research projects that cannot be tackled by one group alone. For the industry, the benefits also go beyond the research deliverables. The students who use the industry simulation tool to conduct the research will be fully trained on the software even before they graduate. This makes them ideal candidates for internships during the course of their academic program and full-term employment upon graduation.

With HYSS and the proposed investigation of fundamental relationship between volume, blocks and level of service in hump yards, CSX has the potential to open up a whole new line of rail systems research that has largely been untapped in academia for close to 30 years.

CONCLUSION

Hump classification yards still have a prominent role in rail operations, are the subject of many network management decisions and are currently entering an era of yard capacity expansion. Yard plans are based largely on experience, and a gap in knowledge of the fundamental relationships between hump yard operations, process and infrastructure makes it difficult to make informed decisions on alternatives that stray far from the historical record. HYSS provides CSX with a sophisticated tool to answer business questions related to hump classification yards as well as develop fundamental relationships governing hump yard operations in a manner not possible before. Deploying HYSS in the academic community will provide CSX with benefits on two fronts: the answers to fundamental research questions and a supply of students trained in the simulation software and with a deep understanding of hump yard operations. This combination will allow the next generation of hump yards on CSX to be more efficient and cost-effective than ever before.

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