

describe each supply line coming into his plant, for example, 22.5 hr \pm ___ hr.

This is the way in which modern industrial America is thinking. And to participate in this renaissance, the railroads must consider the customer resource cost in the productivity equation. It may appear that this has little to do with unit trains but that is not so--the unit-train principles have to be understood. These provide a uniformity of operation that allows the cost elements and service criteria to be controlled. The uniformity allows precision production with reduced crew cost, reduced fuel, reduced horsepower, reduced car fleets (controlled car cycles), reduced support forces, and minimum trackage. These all stem from controlling variability so that resources are not wasted on buffers to isolate uncoordinated operations of labor, plant, equipment, and customer inventories.

Excellent examples of this step forward in the industry can be found. The interplant automobile trains of the Consolidated Rail Corporation, which have three-man run-through crews, operate on utterly

reliable schedules between parts plants and assembly plants. Other emerging potentials can be found in the operations of steel distribution centers and lumber drop points. Some of these ideas are still emerging, but the unit-train potential is there.

The problem is not just productivity; it is productivity in a precision freight system. Unit-train operations and operations that mimic unit-train principles stand a strong chance of providing the industry the productivity and precision that it needs. Last, it must not be forgotten that the productivity sought is a ratio (Equation 1) and that productivity times volume leads to profits. Although one likes to think in physical units, the worth of what is done will be measured in dollars by the productivity equation.

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Optimal Use of Classification Yards

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ABSTRACT

Railroad classification yards are an integral part of a railroad network. At these yards cars are classified, assembled or reassembled, and dispatched in trains from origin to destination. The objective of the classification yard is to eliminate reclassification of cars at intermediate yards between origin and destination. The efficiency of the classification yard is determined by its location, design, and operation. The design and productivity of flat and hump yards are discussed as well as a proposed method for upgrading hump-yard analog control systems.

The optimum railroad operating system provides transportation service between traffic origin and destination in the shortest time and at the least cost.

In general, freight traffic is consolidated at a yard located at or near its origin for movement in trains to its destination. The nature and volume of traffic moving between origin and destination pairs govern the frequency of operation and the physical facilities required for providing optimum service. The geometry of the yard design is a function of these volume requirements and the nature of the business. An analysis of traffic flow between origin-destination (OD) pairs will help to determine the optimum location, size, and design of a yard.

Although it is desirable to transport traffic in unit trains directly from origin to destination, it is unlikely--except for the movement of coal, ore, grain, and containers--to find a sufficient traffic

volume from a single source to a single destination to operate unit-train service. On the Consolidated Rail Corporation (Conrail) 20 percent of the traffic moves in unit grain, coal, or ore trains, 19 percent in Trailvan (TV) trains, and the remainder (61 percent) in symbol trains that must be classified through yards. Therefore, it is necessary to emulate unit trains by creating through trains between the major gateways of the system. These gateways are identified as freight traffic centers at major industrial locations, intersecting railroad routes, and junctions with other railroads.

The evolution of the large automatic hump yard, which is the key to the optimum rail network, began in 1924 when the first retarder was installed at Gibson Yard on the Indiana Harbor Belt Railroad.

The improved efficiency of the hump yard attracted more traffic, and as motive power increased in size and trains grew longer and heavier, classi-

fication yards were required to handle more cars. In the 1950s and 1960s the modern analog computer-controlled retarder yard provided a tool for consolidating more traffic in a single hump yard and eliminating numerous flat and rider hump yards. Railroad mergers of the 1960s and 1970s, deregulation, contract service, and increased competition have resulted in new traffic patterns. Many of the older yards are no longer needed for classifying cars and are being converted to handle intermodal traffic. Some of the remaining yards are therefore required to classify more traffic than they were originally designed to handle and may need restructuring.

Recent trends in modal-choice decisions by shippers could have significant implications on classification yards in future years. There is more of a tendency in the shipping community to reduce in-transit inventories, placing a premium on faster deliveries. The extreme example is the "just-in-time" inventory system being adopted by automobile manufacturers. This places rail boxcar traffic under extreme pressure. For example, between 1977 and 1984, plain boxcar loadings in the U.S. rail industry declined by 69 percent. Similarly, rail piggyback traffic during that period increased 60 percent. The time lost in classification yards is becoming more critical to the railroad industry, and railroads are opting to completely bypass intermediate classification yards wherever possible.

Optimum use of the remaining classification yards may require design modifications to meet the demands imposed by changing traffic patterns.

YARD CAPACITY AND DESIGN

In this paper yard capacity and the design characteristics of both flat and hump yards are discussed and no attempt is made to address the subject of network models such as the Princeton model or the Southwest Research Institute (SRI) CAPACITY model. These computer-based models, however, are useful tools for determining optimum traffic flow. Their application can result in considerable man-hour savings in the necessary operations planning efforts before any major yard reconstruction project. Fur-

ther proposed changes may become unnecessary when the effect of scheduling or blocking modifications on yard efficiency is illustrated.

Flat Yard: Need, Location, and Design

Flat yards are often required to hold cars in support of major industries and are essential as gathering points for assembling blocks of cars between through trains at intersections of principal routes.

An efficient flat yard can be designed to handle and classify as many as 1,000 to 1,200 cars per day. The former New York Central Suspension Bridge Yard (Niagara Falls, New York), now operated by Conrail, is a good example of a high-production flat yard (Figure 1). Before the construction of Suspension Bridge Yard, inspection trips to several new and older flat yards throughout the country were made to observe the operations at these facilities. The Illinois Central Landers Yard and Indiana Harbor Belt Norpaul Yard at Chicago as well as the Kansas City Southern Facility at Shreveport, Louisiana, were visited and analyzed to determine the most efficient size and geometry for a flat yard. Any design selected was a compromise to accommodate the variation in car characteristics; however, the following profile appears to provide the best solution.

In general, the proposed yard grade (Figure 1) of the ladder was -0.27 percent (normally an accelerating grade) and -0.15 percent throughout the body. Velocity head calculation for an average car with a rolling resistance of 4.4 lb/ton and a variance of 2 lb/ton for the easy-rolling car and 6 lb/ton for the hard roller appeared reasonable. (Head loss from curve resistance was selected at -0.025 ft per degree of central angle.) The track design employed a tandem ladder configuration using number 8 turnouts and a ladder angle of 19.5 degrees. The use of the tandem ladder for Suspension Bridge Yard had the advantage of a shorter ladder, resulting in less walking for the switchman and a shorter distance for the cars to travel to the clearance point, thus reducing catch-ups. The disadvantage of the tandem ladder is the length of curve from the switch point to the clearance point. Accelerating grades of -0.5

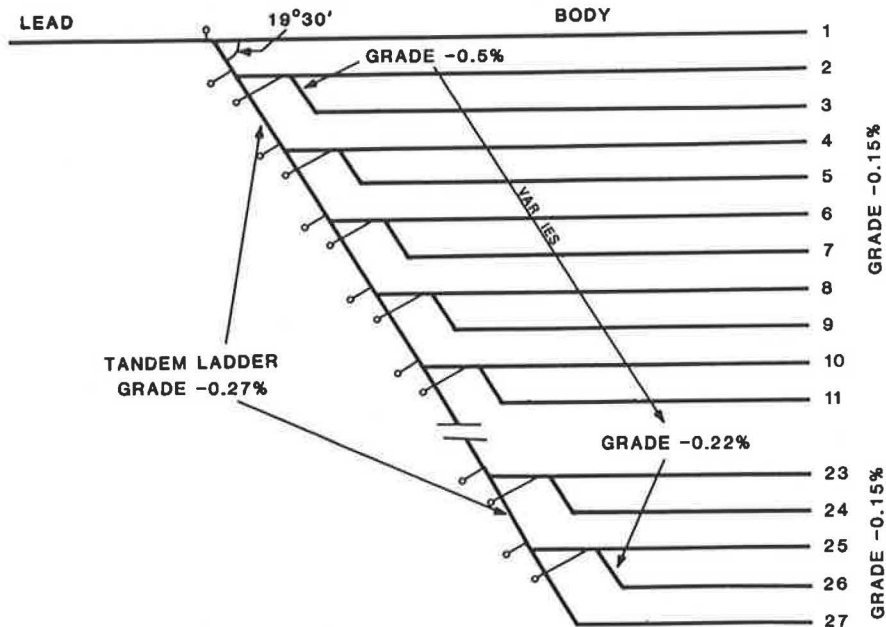


FIGURE 1 Suspension Bridge Yard, Niagara Falls, N.Y.: ladder configuration and grades.

to -0.2 percent were designed through the curve section.

Suspension Bridge and other flat yards constructed to these specifications have proven successful in cases where traffic density does not demand or justify the expense of a complex computer-controlled hump yard.

Hump Yard: Need, Location, and Design

Hump yards are needed for consolidating and classifying large volumes of traffic within a short time schedule for movement to destination. Location is governed by origin or destination volume or both. The optimum use of the hump yard is based on the economics of consolidating traffic for movement between origin and destination utilizing new or existing yards and facilities. New traffic patterns demand higher productivity from existing hump yards.

Hump-yard productivity is generally governed by the design and operation of the facility. The operation includes arrival and departure train schedules, total number of trains, and car volume and classification distribution. The design includes not only physical configuration but the sophistication of the yard retarder control system as well. The function of a hump yard can be analyzed in two steps--the humping or sorting operation and the pulling or train-makeup operation.

Hump productivity is measured by the number of cars humped per day and is generally governed by the number of cars available for switching. Productivity is usually less than the capacity of the hump. The hump capacity is limited by the facility design and the ability to obtain maximum utilization of the hump and humping speed. Time between trains and time spent "trimming" (shoving track or reswitching cars routed to the wrong track) decreases the hump utilization. A good yard design will provide a facility for minimizing this lost time between trains and the amount of trimming necessary. Trimming is usually caused by stalling of cars before they reach coupling or by catch-up (when cars enter retarders or the switch protection circuits before the preceding cars clear). Catch-ups are caused by cars with wide variance in rolling resistance (usually an easy-rolling car requiring heavy retardation followed by a hard-rolling car requiring no retardation). The humping rate (cars per minute over the hump or miles per hour of humping) is controlled by the catch-up problem.

High-production yards are designed to separate cars as quickly as possible by providing a steep accelerating grade (5 percent) from the crest of the hump. The hump crest should be on a 100-ft vertical curve. Most of today's modern yards use a two-point retarding system--automatic speed control and switch operation. Some of the older yards built in the late 1920s to early 1950s have master, intermediate, and group retarders. These yards were operated from a series of retarder towers where speed was manually controlled to maintain car spacing for manually lined routes. A few of the new high-production yards of the 1980s are equipped with a three-point retarder system. The third retarder in these yards is located on each classification track at the tangent point.

The use of this system permits higher velocity of cars from the group retarder through the "fan" (switch system for routing cars into the classification tracks), thus reducing the potential for catch-up. Use of tangent-point retarders will increase the humping rate from between 2 and 2.7 mph to between 3 and 3.5 mph. (Two pinpullers are required to maintain this high-speed humping rate.)

Although the humping rate can be increased and car control improved through the use of tangent-point retarders, the additional cost of this equipment is difficult to justify.

Most modern yards utilize a two-point control system--master and group retarders. The yard may have two master retarders, depending on the total tracks in the yard, and one group retarder for each 6 to 10 tracks.

The first modern retarder control systems were introduced in the early 1950s. These systems included remote-control switch machines using relay logic for establishing routes from the hump crest to the classification tracks and an analog computer to automatically control the car speed through the retarders. These systems are now obsolete and are candidates for replacement with microprocessors programmed to route cars to their preassigned classification track, control speed for damage-free coupling, maintain performance records, control locomotive humping speed, and furnish a perpetual inventory of cars within the yard. Most of the old clerical functions of keeping the car records in the yard are absorbed within the microprocessor system.

MICROPROCESSOR SYSTEM

At Conrail, plans are being finalized to upgrade the five obsolete analog-controlled yards to a modular microprocessor system. Expectations from the modular approach using microprocessors are as follows:

- Reduce computer hardware costs,
- Reduce maintenance costs (replacement of smaller computers when required),
- Reduce cost of redundant back-up equipment,
- Interface with present field equipment,
- Expansion to include additional controls and track design changes,
- Adjustment for automatic fine-tuning speed control,
- Ability to be installed to operate in parallel with the analog system (avoidance of shutdown for conversion),
- Installation and testing of each module separately before "cut-in,"
- Interface with the management information system (MIS), and
- Upgrading of older manual retarder yards by selected modules.

Although the final design of the analog conversion has not been selected, the preliminary proposal subdivides the control system into six principal functions. Each function is programmed to operate independently and, through interconnected circuits, to relay data to the succeeding modules. The six principal modules include

1. Operating data link,
2. Automatic route and switch control,
3. Classification-track and distance-to-coupling measure,
4. Rolling-resistance measure and retarder exit speed calculation,
5. Retarder control, and
6. System testing and diagnostics.

Module 1 (operating data link) is designed to receive information directly from Conrail's MIS. It will have the capacity to store all trains and cars en route, trains and cars in the receiving yard, cars in the classification yard and the car repair facility, and cars and trains in the departure yard. As the switching operation progresses and additional

data or data corrections are received, this module will continue to be updated, transferring information from the en-route file to the receiving-yard file, to the classification-yard file, to the departure-yard file, and to Module 2.

Module 2 (automatic route and switch control) is designed to receive data from Module 1 and, in parallel with Module 1, to receive data from the yardmaster or operator (or from both) governing the yard operation, that is, swings, add car, missing car, catch-up, switch failure. Module 2 is programmed to automatically route trains from the road to the assigned receiving yard track and to the hump and cars from the hump crest to the classification yard. Module 2 is designed to control the hump locomotive operating speed. Updated switching data are automatically transferred back to Module 1. After switching has been completed and corrections identified, Module 1 will be updated and an as-hump list printed.

During the humping process car identification and classification information will be transferred from Module 2 to Modules 3 and 4.

Module 3 (classification-track distance-to-coupling measure) is designed to provide continuous surveillance of the classification track distance from the clearance point of the group switch to the last car and to transfer this information to Module 1 for the track capacity table and to Module 4 for calculating retarder exit speed. Module 3 is also programmed to measure car rolling resistance on tangent track and to relay this data to Module 4, where a performance table will be maintained for actual rolling resistance measured on each track and for each prescribed weight and general car type.

Module 4 (rolling-resistance measure and retarder exit speed calculation) is designed to receive velocity measurements of cars rolling over the test section and to correlate the acceleration, car weight, distance to coupling, curve resistance, and car characteristics with the actual performance table to compute the desired retarder release speed for the master and group retarders. The equation will also recognize ambient temperature, wind velocity and direction, moisture, and car surface area and will modify the release speed calculation accordingly. Information derived from Module 4 is transferred to Module 5 and back to Module 1 to be tabulated with performance data used in Module 6.

Module 5 (retarder control) receives the information from Module 4 and also receives the weight rail and radar speed measurement for applying retarder pressure to reduce the car speed to the predicted release from the master and group retarders. The actual release speed from the master and group retarders is transferred to Module 4 along with the initial tangent-point velocity for calculating the curve component used in the retarder release speed equation. Performance data from Module 5 are transferred to Modules 1 and 6.

Module 6 (system testing and diagnostics) is the testing module designed to simulate the entire sequence of operation and to test each function of mechanical and electrical performance, identifying all malfunctions.

TRAIN MAKEUP

The second step in the general yard design deals with the track configuration and the train makeup abilities of the yard. There are three basic components in all hump yards--the receiving yard, the classification yard, and the departure yard. The configuration of these components can range from a straight in-line style to a totally parallel style, or any combination of in line and parallel (Figure

2). For example, the straight in-line yard has a receiving yard in line with the classification yard and the classification yard in line with a departure yard. This configuration provides for one-direction movement from the entrance of the receiving yard to the exit from the departure yard. The early hump yards were in-line designs. The main problem with this design is congestion at the makeup end of the yard caused by doubling or coupling blocks of cars from separate classification tracks while trains are being assembled.

Most modern hump yards and all of Conrail's major hump yards built since 1954 have departure yards parallel to the classification yard. Frontier yard at Buffalo, Big Four Yard at Indianapolis, and Buckeye Yard at Columbus, Ohio, have both the receiving and departure yards parallel to the classification yard. At high-volume yards, such as Elkhart and Selkirk, where the predominant traffic volume arrives and departs in long road trains, the departure yard tracks are located on each side of the classification yard and the receiving yard is in line with the classification yard.

The critical areas of a major high-productivity hump yard are

- Entrance to and exit from the receiving and departure yards,
- The area between the receiving yard and the hump crest,
- The area between the hump crest and tangent point of the classification tracks, and
- The area between the classification tracks, pull-out leads, and the departure yard.

These areas should be designed to eliminate congestion and interference.

CONCLUSIONS

Advantages of parallel receiving and departure yards, as listed by the Union Pacific Yard Design Group, are as follows:

- Outbound trains can be made by handling 25 to 40 cars each move, thereby enabling switch engines to move at a faster rate.
- The classification yard is supplemented. Larger blocks are allowed to be set out, thereby reducing congestion in the classification yard.
- Clerical personnel are allowed to perform a portion of the clerical work before the train is called.
- Mechanical personnel can perform light repair before the train is called.
- Bad orders can sometimes be detected before the train is called.
- They can be designed to serve as receiving yards in emergency situations.
- Company road crossings are never blocked for long periods of time.
- All operations can be viewed from one strategic location, enabling reduction in overtime by yard crews and terminal time by road crews and improving efficiency of the entire terminal.
- All departure tracks can be utilized for train makeup.
- It is not necessary to hold the departure track clear for returning trim engines.
- It eliminates the hazards of yard engines moving back and forth through the departure yard, endangering mechanical employees who are working the trains.
- Outbound road engines can be hosted to departure tracks ahead of the actual call time, reduc-

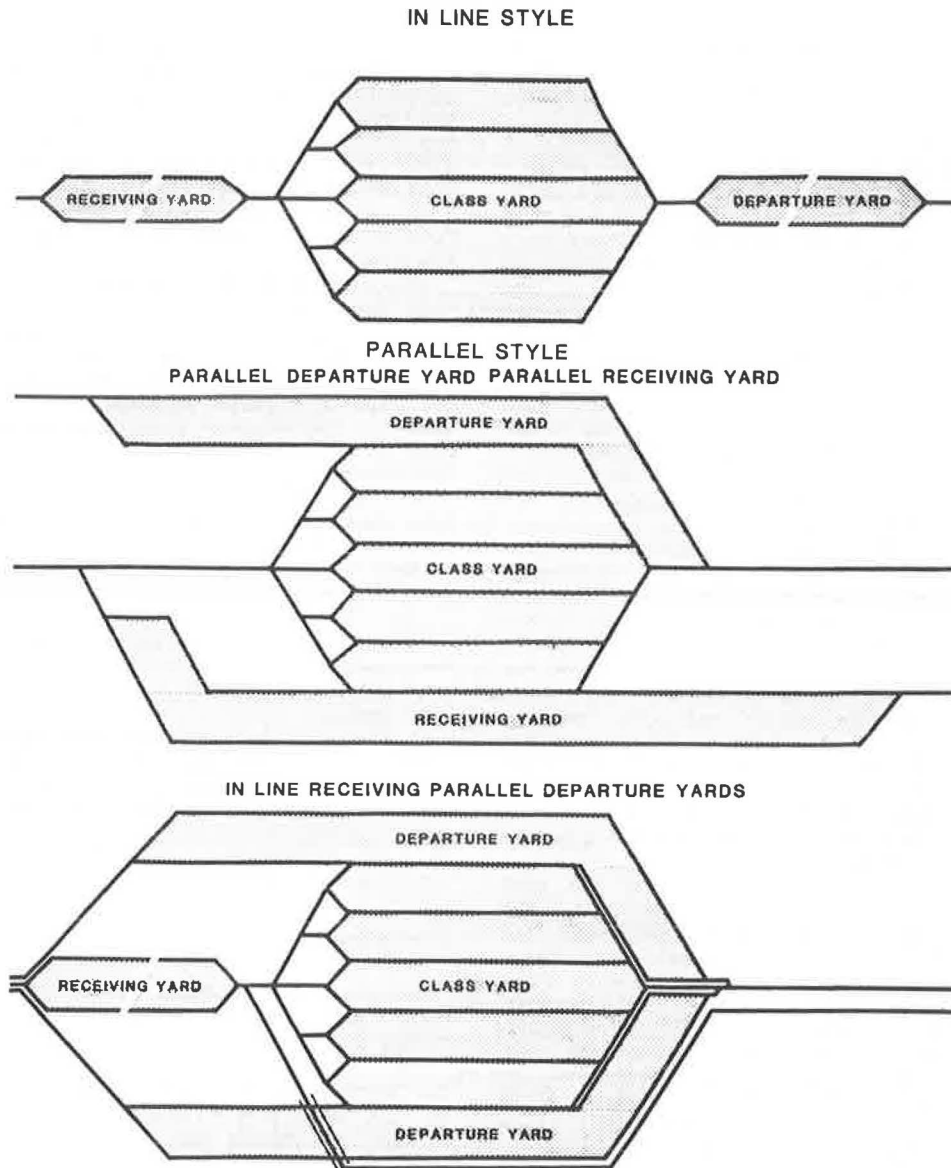


FIGURE 2 Hump yard types.

ing congestion in the shop area as well as terminal time for the outbound crew.

- A parallel departure yard reduces the length of the entire yard, which in turn reduces the terminal time.

The general design specifications of an efficient hump yard are as follows:

- The yard should be designed to maintain the shortest distance between entrance and exit within the critical areas of the yard.

- The length of the receiving yard and departure yard should be sufficient to hold the longest train.

- The track length in the classification yard should be a minimum of 30-car capacity, with the longest track in the center (teardrop design).

- The ladder on the pull-out end of the yard should provide for parallel-simultaneous pull-out crew operation for transferring cars from the classification yard to the departure yard.

- The pull-out ladders should be tandem design with twice the frog angle construction.

- The pull-out leads should be on a zero grade and extend 10 car lengths longer than the longest classification track.

- Power-operated switches should be provided for automatic, programmed route control between the classification yard and departure yard.

- The classification track fan switch configuration should be designed for 10 track groups.

- The classification tracks should be constructed with a maximum curvature in the fan of 12 degrees 30 min.

- Inert or skate retarders should be installed on a plus grade of 0.3 percent starting 300 ft from the clearance point of the pull-out ladder.

- The hump lead should be as short as possible with a maximum curvature at the base not to exceed 820-ft radius.

- The vertical curve at the crest should be 100 ft with the lead on a +3 percent grade and the grade between the crest and master -5 percent.

- The pin puller walkway should be constructed on the right side of the hump lead.
- Wide track centers (19 ft) should be designed between the receiving yard tracks and between departure yard tracks.
- The departure and receiving yards should have a maximum grade of ± 0.15 percent.
- The car repair facility should be located

parallel to and between the classification yard and departure yard.

- The locomotive service facility should be located between the departure yard and receiving yard.

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Burlington Northern Railroad's View of Intermodal Hub Centers and Their Impact on Productivity and Customer Service

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ABSTRACT

Burlington Northern Railroad (BN) has almost completed the establishment of its network of intermodal hub centers. Since 1982, BN has consolidated 140 rail ramps into 20 hub centers and 21 satellites (some rail, some highway) while expanding the geographic scope of service. BN's hub centers are the key component in implementing two additional strategies: (a) new-technology rail and trailer equipment operating between hub centers on dedicated trains and (b) customer-responsive products and charges. BN hub centers are organized and used as marketing units rather than just as operating entities. Each hub center is regarded as an entrepreneurial joint venture, responsible for sales and pricing as well as operating and administrative functions. Hub center management teams make their own decisions to balance revenues and costs to improve the value of service to the customer and enhance the common profitability. Hub centers are demonstrably more productive than traditional ramps in equipment utilization and cost containment while simultaneously improving service to the customer. Hub centers not only have increased total traffic volume for BN, but also have made possible partnerships with motor carriers to produce new intermodal traffic that formerly moved only by highway. BN's hub centers are proving to be the type of decentralized, customer-responsive organizational structures needed to compete effectively in a deregulated environment, and they have produced a corporate culture conducive to manageability and commitment.

Burlington Northern (BN) began its intermodal hub center program in October 1982 with two pilot hubs at Minneapolis-St. Paul (Midway), Minnesota, and Portland, Oregon. During a 6-month test period, the intermodal growth rate for Midway was 40 percent and for Portland 60 percent.

This improved growth rate, gains in productivity, and better customer service were the primary reasons for BN's expansion of its hub center program. To date, BN has consolidated 140 rail ramps into 20 hub centers and 21 satellites (some rail, some highway) operating under the supervision of hubs and expanded the geographic area served by BN Intermodal.

BN hub centers consolidate high-cost, low-volume rail ramps into efficient shipping and receiving

depots for intermodal service. Because they are specialized and have new-technology rail and trailer equipment, BN hub centers generate enough traffic to justify dedicated train service connecting them.

Organized as marketing units under the leadership of managers with motor-carrier experience, BN hub center management teams are responsible for sales and pricing functions as well as operations and administration. This helps each manager and his team create customer-responsive products and charges while managing his business on a profit-and-loss basis. As a result, hub center management teams control most costs and revenues and are able to make trade-offs necessary to meet customer needs profitably and in an entrepreneurial manner.