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Development of Railway Terminals Within the Context of Precision Scheduled Railroading Principles

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ABSTRACT

Rail transportation is a fundamental component of Canada's Economic Corridors, supporting our economy and driving growth potential. Recent disruptions to our national railway service have highlighted the importance of this service to the health of our economy and wellbeing of our nation.

Systematically, our railway networks are comprised of nodes (terminals) and links (rail lines). Efficiency of the network involves efficiency of both Industry terminals and rail lines. Functionally, Railways have adopted the principles of Precision Scheduled Railroading (PSR) in their business and operating practices. PSR's objectives are to create a safe, reliable, cost-effective, efficient, and timely transportation service. It involves controlling costs, maximizing asset utilization, highly precise operations planning, and synergy across all processes.

PSR focuses on the carload (customer shipment). It optimizes the rail network from an endpoint-to-endpoint perspective. Trains must run on time to meet customer commitments. When focusing on carload, Railroaders examine every process effecting on-time delivery, constantly fine tuning.

Industry terminal operations are a key component of the overall railway transportation service. PSR has changed the way Railways operate. It demands that Industry also change how they plan, design, and operate their terminals. This paper will discuss:

- Interfaces between Industry terminal and Railway operations
- Industry terminal operating practices through the lens of PSR
- Improvements in the planning, design, construction, maintenance, and operations of Industry terminals
- Use of new technologies to further improve safety, efficiency, and cost effectiveness of terminal operations

The goal of PSR is excellence in rail transportation service through safe, efficient, predictable, and reliable operations. For the customer, this translates into faster transportation service, lower transportation costs, overall supply chain stability, and reduced demand for transportation assets. For the Canadian economy, this translates to a competitive advantage in global and domestic marketplaces, lower costs for our goods and services, and opportunities for sustainable growth.

1 INTRODUCTION

A supply chain is a cycle commencing with the sourcing of raw materials to the ***delivery*** of finished products to end-users. The cycle begins with sourcing raw materials which are ***transported*** by a logistics provider to a supplier, which acts as the wholesaler. The materials are ***transported*** to a manufacturer that refine and process them into a finished product. These products are ***transported*** to a distributor that wholesales the finished product, which is then ***delivered*** to a retailer. The retailer sells the product to consumers. Consumption completes the cycle, but creates demand that drives the production of more raw materials, and the cycle continues.

Figure 1 – Supply Chain Cycle (FCI Web site)

The supply chain is a fragile system dependent upon numerous parties to function and communicate efficiently and cooperatively. A disruption in any link will impact the entire chain resulting in systemic delays which drive up costs. This system relies on safe, efficient, cost effective, reliable and dependable transportation services to keep things moving.

Rail transportation is a fundamental component of Canada's Economic Corridors, supporting both domestic and international supply chains, driving our economic growth potential. The health of our national economy is often gauged by the volume of goods being transported.

Due to the expanded reach of railway networks, local disruptions to rail traffic will translate into extensive delays over thousands of kilometres resulting in congestion of rail lines, yards, and terminals. These delays will also translate into a higher demand for resources such as railcars, locomotives, and train crews. Recovery from short term delays locally, will require extended timeframes to re-establish fluidity across the network.

Over the past 15 to 20 years, North American Railways have developed and adopted the principles of Precision Scheduled Railroading (PSR) to guide their business and operating practices. The reliability of efficient and fluid railway networks, however, relies on the seamless interface between rail yard and terminal operations, and rail line operations. Industrial processes and railway operations are an integrated fluid process designed to keep things moving safely, efficiently, and cost effectively. For the benefits of PSR to be truly realized, it demands that Industry also adopt these principles related to how they plan, design, and operate their plants and terminals. For these reasons, Terminal operating practices, as well as, engineering planning and design, construction, and maintenance practices, all need to be evaluated through the lens of PSR.

Why does this matter? The goal of PSR is excellence in rail transportation service leading to a more valued and profitable transportation industry through safe, efficient, predictable, and reliable operations. For Industry, this translates into faster transportation service, lower transportation costs, overall supply chain stability, and reduced demand for transportation assets.

Why is this important? Recent disruptions to our national railway service have highlighted the importance of rail service to the supply chain cycle, the health of our economy, and wellbeing of our nation.

For the Canadian economy, this translates to a competitive advantage in global and domestic marketplaces, lower costs for our goods and services, and opportunities for sustainable growth. Collectively, everyone benefits.

2 PSR – HOW DOES IT WORK? A RAILWAY PERSPECTIVE

PSR's objectives are to create a safe, cost-effective, efficient, and timely transportation service. It involves controlling costs, maximizing asset utilization, highly precise operations planning, and synergy across all processes. PSR is based on optimizing the rail network from a comprehensive end to end perspective of operations and management. This practice deviates from a more regional, and internally competitive, perspective of railway operating practices.

PSR focuses on the carload (customer shipment) rather than the train carrying the carload. Velocity and train length are still important, however, the focus on moving cars takes precedence. Trains must run on time to meet customer commitments. When focusing on carload, every process effecting on-time delivery must be optimized, and constantly fine tuned (plan – execute – monitor – analyze – revise the plan).

Train delays result in network congestion and increased terminal dwell time and congestion resulting in an increased demand for assets (railcars, locomotives, and train crews), higher costs, and less dependable service. PSR promotes higher efficiency, network fluidity, and a well-balanced operation leading to lower costs and more reliable service. A balanced operation ensures the right resources are in the right locations at the right times. This results in shipments moving with discipline, precision, and synchronization.

2.1. PSR's Guiding Principles

North American Railroads have established a fairly common set of guiding principles as the foundation of operating and business efforts. These principles are constant in planning and execution, globally applicable, and form the business and cultural context of the company. These principles are all related and co-dependent. The belief is that strict adherence to these guiding principles will lead to a high level of customer satisfaction and exceptional financial performance. The following are typical examples of the guiding principles adopted by Railroads practicing Precision Scheduled Railroading.

<u>Safety</u> – is essential in protecting the public, the environment, employees, and the company, which translates into good business; the more predictable an operation or process is, the fewer exceptions will occur, thus ensuring a high level of safety

<u>Timely Service</u> – encompasses the belief that a customer who pays for timely service should receive timely service; from a Railroad perspective this is known as "doing what you say you are going to do".

<u>Cost Control</u> – focuses on executing continually refined, fine-tuned, processes in synch with other processes, removing redundancies; it does not promote indiscriminate cost cutting

Asset Utilization – the more efficient the asset, the fewer assets an operation requires; assets only provide a return when serving the intended purpose, otherwise they are a liability; assets need to earn their keep (idle cars cost money and do not make money).

People – PSR recognizes that people are the foundation in which all other principles are built.

2.2. PSR's Service Design Principles

Service Design Principles are subordinate and complementary to PSR's Guiding Principles, and most directly support Asset Utilization. Due to the complex inter-connectedness of railroad operations, optimizing one principle does not necessarily optimize the others. Too great a focus on any one principle can have a negative impact on the others. Balance is the key.

2.2.1 Optimize Car Asset Utilization

Optimizing car assets include efforts to minimize car dwell in yards and minimize car handling. Minimizing car dwell reduces the cost impact in consumed yard capacity, and the overall number of cars needed. Minimizing car handling improves the car cycle, increases car velocity, allowing more productive car use, ultimately reducing the car fleet while optimizing costs.

2.2.2 Optimize Fuel Efficiency, Power Requirements, and Train Builds

A locomotive is the most expensive piece of rolling stock on the railroad, and fuel is one of the highest operating costs. Overpowering a train typically generates more waste than productive speed. The objective to fuel efficiency and optimized power requirements are to right-size the pulling horsepower with the trailing load, taking into consideration the terrain and relative average speeds.

Optimizing train builds focuses on maximizing train length by territory, thus minimizing train starts which reduces demand for locomotive power, fuel, and train crews while reducing demand on network capacity.

From an operating perspective, the Service Plan governs power utilization by minimizing unused slots to maximize train efficiency, and by ensuring downstream yards are receiving the power they require to maintain their operations. Further, locomotives have prescribed maintenance requirements and schedules, as such, they need to be in the right place at the right time.

2.2.3 Manifest and Unit Train Service

There are two basic types of train service – general-purpose or manifest, and special-purpose or unit trains. Unit trains are often considered an efficient, low-cost alternative to manifest service. This is based on the belief that unit trains provide faster transit times by avoiding intermediate handling thus saving operating expenses. Often, a total cost approach, involving a detailed operations analysis, can reveal that the opposite is true, if special conditions for unit trains are not met. Unit trains are most efficient and economical when the following conditions apply:

- Loading and unloading operations are completed on a daily basis (within 24 hours)
- Daily carloads are in the range of 100 or more
- Trains cycle in a closed loop between a single origin / destination pair
- Trains operate 7 days a week
- Locomotives remain with the train consist

If any condition is not met, the economics and efficiency of the service diminishes. Inefficiencies can arise due to increased in-transit inventory, poor car velocity, and locomotive and crew imbalances. PSR utilizes mixed traffic, which minimizes the number of train starts and frees up capacity.

2.2.4 Optimizing The Service Plan

The Service Plan is focused on car deliveries, not trainloads. It can be optimized through the use of multiple traffic outlets and by balancing traffic by direction. Multiple traffic outlets involve having more than one way of moving cars to destination. Using multiple outlets increases flexibility and lowers operating risk. Scheduled trains do not necessarily have consistent carloads day to day. Some days they may run short, and overflow other days. Running short wastes train productivity, overflow risks service failure.

In optimizing the Service Plan, PSR strives for train balance (equal number in both directions) to further minimize costs and provide a higher level of service reliability. A balance accomplishes this by reducing empty car moves or asset repositioning, which do not produce revenue. It also avoids holding accumulated cars in yards for strategic departure risking congestion, and increased dwell time. It is focused on overall network operations performance over a regional operations success. Optimizing the Service Plan involves balancing train movements and fluidity to the fullest extent possible. It minimizes costs as well as excess train capacity.

2.3 Supply Chain Considerations

With Precision Scheduled Railroading, there are recognized constraints, not under the direct control of the Railroad, to achieving an optimized Service Plan and network operation. These may include operating efficiencies in the supply chain involving a customer's rail yard or terminal, port terminals, and interchanges with other Class 1 or Shortline Railroads. PSR focuses on establishing shared goals across the supply chain to optimize throughput for all, thus, benefitting all parties involved.

3 PSR - A RAILWAY TERMINAL PERSPECTIVE

3.1 Rail Terminal Components and Configurations

The purpose of the rail terminal is to provide an interface between Industry and the Railroad. This interface is comprised of the following basic components:

- Product loading/unloading tracks
- Railcar storage tracks
- Railroad arrival and departure tracks
- Spur track connecting the arrival and departure tracks to the Railroad's mainline

Rail terminals can have a variety of configurations based on physical site constraints, type of train service (manifest or unit trains), and terminal operations. The two most common configurations are ladder and loop tracks.

Figure 2 provides an illustration of a typical ladder track configuration, which includes supporting runaround and pull-back tracks, used to facilitate staging on inbound and outbound trains, and the movements of cuts of railcars between the loading/unloading, storage, and arrival/departure tracks. Ladder tracks are typically used with both manifest or unit train service.

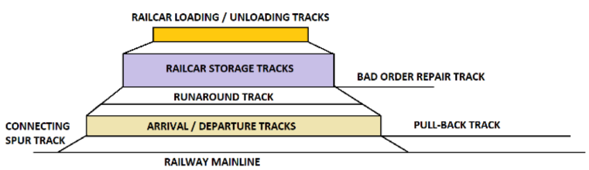

Figure 2 – Typical Ladder Track Terminal Configuration

Consistent with their attention to PSR, Railroad's service is primarily focused on, what is commonly called, a "hook and haul" operation. This involves a scheduled arrival to deliver loads/empties to an empty arrivals' tracks, then pick up empties/loads from an adjacent departure track, and depart. Railroad's discourage services involving storage of costumer railcars, or switching railcars within the terminal, by imposing significant surcharges for these "additional" services.

Figure 3 provides an illustration of a typical loop track configuration. In this configuration, inbound and outbound trains are accommodated on opposite sides of the loop, with loading/unloading at the middle of the loop. Storage and additional capacity can be accommodated with multiple loops. Loop tracks are typically used with unit train service. They typically require a larger terminal footprint than ladder tracks, though they require fewer turnouts, which are costly trackwork components requiring additional capital and higher maintenance costs. The operational benefits of loop tracks include fewer resources due to less switching in not having to disassemble or assemble arriving/departing trains, as well as, the opportunity of keeping the locomotive power with the train.

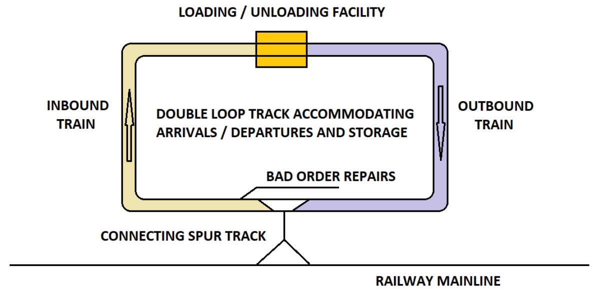

Figure 3 – Typical Loop Track Terminal Configuration

As a means of establishing a consistent PSR approach between Railroad and Industry terminal operations, loop track configurations are best suited for the following conditions:

- Unit trains consisting of at least 100 cars
- Daily plant production of unit train capacity
- Seven day per week terminal/plant operations

3.2 Terminal Production

Terminal Production is the basis from which the details of fleet sizing, terminal design, and operations are derived. There are three (3) basic components to Terminal Production:

1. Product to be transported and product properties (i.e., density, solid, liquid, gas)
2. Production rate (annual, weekly, daily)
3. Frequency of rail service

3.2.1 Product Being Shipped

Product type and material properties will define

- Railcar type and capacity
- Terminal material handling equipment
- Material storage requirements
- Spill containment/response
- Terminal operating safety requirements

3.2.2 Railcar Fleet

From a PSR perspective, the objective of railcar selection is to minimize the number of railcars (assets) required to satisfy production and maintain operational reliability. This involves selecting railcars which have:

- The largest gross weight capacity allowed on the rail line
- The largest load limit capacity within the gross weight capacity class
- A consistent railcar length to suit fixed loading/unloading infrastructure configurations
- The shortest railcar length to minimize rail terminal track lengths and maximize railcar useable space

The railway network is made up of series of links and nodes. The links are comprised of mainlines and branchlines, where mainlines service national and regional economic corridors, and the branchlines feed the mainlines, as tributaries to a major river. The nodes are comprised of terminals, whether they be mainline classification yards or Industrial terminals.

Mainlines and branchlines are broken down into discrete segments called Subdivisions. Each Subdivision is comprised of unique physical components of rail line, sidings, and double tracking, with unique horizontal and vertical (grade) alignment characteristics. They also have defined operating constraints based on these characteristics and the condition of railroad infrastructure (grade, drainage, track, structures, crossings, signals) which may limit allowable Subdivision railcar weight and train speeds. Allowable Subdivision railcar gross weights are classified by industry standard classes of gross railcar weights.

It is not uncommon for branchlines, which typically have less traffic, to be maintained to a lesser standard than mainlines, with reduced allowable railcar weights and slower train speeds. In North America, the standard maximum allowable mainline gross railcar weight is 286,000 lbs. This has set the standard regarding the manufacture of railcars and the supply of railcars within industry. Branchlines, however, can be limited to lower allowable gross railcar weights of 268,000 lbs. (7% reduction) and 263,000 lbs. (9% reduction). Some Subdivisions in the US (Union Pacific, Norfolk Southern) have increased their allowable railcar weights to 315,000 lbs. (10% increase) to handle bulk commodity unit trains. These services require a special fleet of heavier capacity railcars, and these Subdivisions require infrastructure (track and structures) which can handle these additional loads, as well as, a higher level of maintenance.

Reduced railcar capacity will result in the need for more railcars (more assets), which in turn will lead to longer tracks (more assets), and more time for switching and loading/unloading (less efficiency). All of these will drive up capital and operating costs. Reduced train speeds will result in longer origin/destination cycle times, which will also drive up the need for more railcars (more assets), also driving up capital and operating costs. As such, plant/terminal site selection, through the lens of PSR, can be key in managing railcar assets, rail terminal infrastructure and operations, as well as, material handling systems (loading/unloading).

In addition to determining fleet size based on production demand, an allowance for additional assets will be required to accommodate scheduled maintenance and unscheduled bad order repairs. This allowance can be in the order of +/- 5% of the production fleet. Additional assets also need to accommodate downstream terminal and Railroad service delays and disruptions (washouts, derailments, yard and mainline congestion, locomotive and crew shortages, etc.). These are typically assessed in terms of a number of days of reserve production capacity. These additional assets require additional infrastructure (storage) and resources to manage them, incurring additional costs.

Fleet management is essential in assessing utilization of railcar assets (service time, distance traveled, % loaded/unloaded), as well as, asset health (repair history, maintenance schedules). Today, sensors can be installed on railcars to record and monitor this data. Sensors can track location and measure load status, brake status, wheel and bearing performance, and hatch or door securement. As an example, Amsted Digital Solutions have created a tele-metrics platform designed to collect accurate, real-time data which can generate actionable and predictive intelligence which can be used to optimize fleet performance and number of assets required, improve safety, and reduce costs, while delivering the required level of service.

3.3 Rail Terminal Operations

Planning rail terminals begins with initial and forecasted annual production estimates (i.e., tonnes, barrels, gallons, etc.). From these, estimates for daily production can be developed such that daily terminal operations can be defined, along with the associated infrastructure, fleet size, and resource pool. Where future expansions are anticipated, it is essential that these terminal concepts be developed early in order to ensure that adequate space is available, initial configurations can be readily expanded without significant interruptions to existing operations, and that future operations can deliver the anticipated production levels.

Plant production, rail terminal operations, and Railroad services are integrated processes. Disruptions to any one potentially impacts the other two. Figure 4 shows a flow chart illustrating the interfaces between plant production and material storage, rail terminal operations, and Railroad product delivery and empty railcar returns.

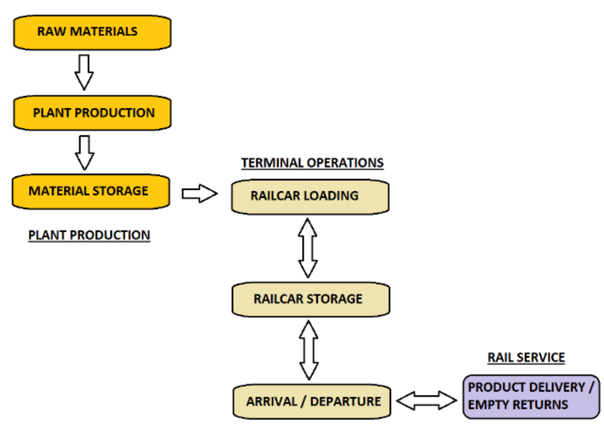

Figure 4 – Rail Terminal Interfaces

3.3.1 Storage

To compensate for day to day variations in production and unplanned disruptions, storage is required. As illustrated in Figure 4, there are two types of storage required – material storage and railcar storage. Material storage looks after variability in Plant Production, while railcar storage looks after variability in rail service. From a PSR perspective, both require assets and resources and attract costs to the operation. Efficient utilization of these assets is the key to controlling these costs while maintaining the desired level of service.

Storage capacity is typically measured in days of production. It is defined by the range between minimum and maximum volumes required to maintain a sustainable work flow and operation. Evaluation of storage capacity comes down to a risk assessment involving the frequency and magnitude of shortages related to plant, rail terminal, and rail service operations, and their associated costs.

Common forms of material storage include tanks, for liquids; bins and stockpiles, for bulk commodities; and stacks for containerized products. Excess storage is not efficient utilization of assets, though it does not produce a risk to plant, rail terminal, or rail service operations. Insufficient storage will shut down the plant and create disruptions to normal plant operations, but not rail terminal or rail service operations.

Railcar storage requires tracks and real estate, along with equipment and resources to switch out railcars. Excess storage is not efficient utilization of assets which does not produce a risk to plant, rail terminal, or rail service operations. Insufficient storage imposes considerably more risk impacting plant, rail terminal, and rail service operations. As previously noted, allowances need to accommodate scheduled maintenance, unscheduled bad order repairs, downstream terminals, and Railroad service disruptions. Keep in mind that downstream terminal and Railroad operations are outside the control of the product producer.

Insufficient access to railcars will result in a reduction in daily railcar loading capacity, which will translate into an increase in material storage, which when exceeded, will result in a slow down, and eventual shut down, of plant production.

Consider the following production with manifest rail service:

- A = 50 railcars loading per day
- B = 15 day transit cycle time
- C = 1 day additional terminal storage
- D = 1 set of railcars on the loading track
- E = 5% additional railcar allowance

Estimated Fleet Size (F) = A*(B+C+D)*(1+E)   [1]

Using this simplified approach, the estimated fleet size would be 893 railcars. Of these, 700 (78%) are in transit (outside the terminal) leaving 150 (17%) in the terminal and 43 (5%) being repaired or maintained. This is assuming the terminal is holding one set of 50 railcars on the loading track, one set of railcars on the storage tracks, and one set of railcars has been delivered to the arrivals track.

In this example, as long as the terminal operates 7 days per week, and there are no service disruptions, the flow of railcars will cycle in such a fashion as not to generate additional railcar storage in the terminal. Should this operation work only 5 days per week (Monday to Friday), the following imbalances in railcar flow will occur at varying times:

- Some cuts of 50 railcars will arrive on weekends, thus requiring storage and additional resources to receive these railcars
- Some days of production will not have returning cuts of 50 railcars, thus requiring cars from storage
- Some days will see two (2) cuts of 50 railcars arriving, thus requiring storage for at least one cut

This example highlights the benefits prescribed by PSR service principles involving a steady 7 day per week work flow in the rail terminal. With only one day storage, this terminal could run out of capacity should any other service delays occur.

Also from this example, unit train service of 100 railcars could be considered every second day, assuming a 7 day per week operation. This would have no impact on the railcar loading operations, but would require additional tracks to store the extra days production. Further, it could influence the consideration of a loop track configuration as a means of simplifying the rail terminal operations. As previously highlighted, other than daily unit train service is not considered consistent with PSR service principles. Alternating unit train service will produce inconsistencies in train balance creating the potential for congestion along the mainlines and in classification yards, as well as, imbalances in demand for locomotive power and train crews.

3.3.2 Terminal Production

With daily plant output production defined, the following terminal planning issues can be assessed and decided:

- The type of rail service – manifest or unit trains
- The number of cars to be loaded and shipped
- The number and frequency of Railroad switches
- The number of loading stations, speed of loading, and equipment/resources required for loading
- Number and length of rail terminal tracks, including the use of ladder and/or loop track configurations
- A daily rail terminal operating plan

The Rail Terminal Operating plan will include a detailed, minute by minute, outline of sequential tasks and durations. Some of these tasks could include the following:

- Shift start up – hand-off from the previous shift, reviewing daily switching plans, safety briefing
- Movement of railcars from storage to loading tracks
- Loading of railcars
- Movement of loaded railcars to the departure track
- Breaks

- Inspection of arriving train with empties
- Movement of Bad Orders to repair tracks
- Movement of arriving empties to storage tracks
- Inspection of departing train
- Set up railcars and railcar moving equipment for next shift
- Shift wind down - hand-off to the next shift

Depending on production rates, rail terminal operations can be completed by single or multiple daily shifts. Should daily rail terminal operations have the ability to be completed within a 12 hour shift, daily output can be doubled without the need for additional infrastructure by adding on a second 12 hour shift. Additional resources to man the second shift would, however, be required.

3.3.3 Switching Rail Terminals

Railcar moving equipment are assets which impact the efficiency of rail terminal operations. Examples of such equipment include:

- Railcar indexers for small cuts of railcars along the loading/unloading tracks
- Track mounted, self-propelled, railcar movers (trucks, loaders, car-movers) for general terminal service (loading/unloading and switching)
- Locomotive switching units (smaller locomotives) for general terminal service (loading/unloading and switching)
- Larger locomotives with higher horsepower and tractive effort for moving large cuts of railcars for general terminal service (loading/unloading and switching)

Switching in a rail yard or terminal is hazardous work. Turnouts need to be aligned properly to ensure railcars are lined into the correct tracks. Railcars can be moving on multiple tracks, lines of sight are often restricted, and you will not necessarily hear a cut of railcars rolling in your direction. The outcomes of accidents can be deadly.

Safety is one of PSR’s guiding principles and fundamental to rail terminal operations. The best way to minimize safety risk is to minimize the opportunity for an accident to occur. Technologies currently employed to improve safety and operating efficiency may include some of the following:

<u>Remote Control of Railcar Moving Equipment</u>

“Belt Packs” are hand held control panels that allow one to operate switching locomotives from the ground. They can allow switching crews a better visual perspective aimed at avoiding collisions, though the downside is this requires the operator to be on the ground and not on the equipment.

For larger operations, like unit trains on loop tracks, locomotives can be controlled remotely from a Rail Terminal Control Centre. This eliminates the need for resources on the ground altogether. Loop track operations are inherently safer due to the reduced amount of switching required.

<u>Remote Control Turnouts</u>

The ability to remotely operate turnouts significantly improve the efficiency of rail terminal operations and reduces the risks to accidents on the ground. Dual controlled turnouts can be operated either through radio communications (DTMF) or using software from a Rail Terminal Control Centre.

<u>New Rail Yard Hazard Detection Systems</u>

Miller Ingenuity has developed an electronic hazard protection system (ZoneGuard) used to protect workers in active rail operation zones. A sensor can be position on a track tie between the rails to detect track mounted work equipment or railcars and send an alert to workers using wearable devices.

Loram Technologies has developed an area monitoring system which automatically detects objects in the path of track mounted equipment. Objects which come within a defined work zone will activate an alert for the equipment operator.

These technologies are not intended to substitute defined terminal worker safety protocols but to be used as aids in enhancing equipment operator and terminal worker awareness of their surroundings, thus providing an additional layer of vigilance and protection.

3.3.4 Rail Terminal Operating Technologies

3.3.4.1 AEI Railcar Tracking

AEI (Automatic Equipment Identification) is an electronic railcar recognition system used by the North American railroads industry. They consist of passive tags mounted on each side of rolling stock and active trackside readers using RF technology to identify railroad equipment. Historically, AEI railcar readers have been used to capture a consist of trains entering and departing yards. They had been considered not cost effective to implement within railyards; however, the lack of accurate railcar tracking information can result in significant costs.

The reporting of railcar location (Track ID) and position (within a cut of railcars) is important for safety and terminal operating efficiency reasons. Automated railcar tracking eliminates the need for manually inventorying and searching for railcars. It can provide real-time railcar information and location as railcars are moved within the terminal. Improper reporting can result in additional effort, cost, and delays in terminal switching and arrival/departure operations.

3.3.4.2 Custody Transfer Systems

Custody Transfer refers to transactions and accurate measurement of physical substances being transported from one party to another. Track mounted weigh scales are often used to weigh bulk commodity railcars entering and exiting loading and unloading facilities. Two main types of weigh scales include static scales, which weigh a single railcar stopped on the scale, or the much more efficient weigh-in-motion scales which weigh railcars as they move across the scale without stopping.

Some bulk railcar loading facilities using overhead bins to load open hopper cars have very accurate bin scales which measure the products being loaded into the empty railcars. Liquids commonly use very sensitive flow metering equipment to measure the volume of product being loaded into tank cars.

3.3.5 Arrivals and Departures

Based on their PSR service principles, Railroad's expect to interface with their customer's terminal within a dedicated arrivals/departure yard. Their preferred "hook and haul" operation will involve dropping empties/loads on the arrival track, hooking onto waiting loads/empties on the departure track, and departing.

From a terminal operator's perspective, this means that the arrival tracks need to be clear and ready to receive railcars. They should be prepared to visually inspect the inbound train and identify any bad orders which they will need to setoff on the bad order track for repairs.

This also means that the departure tracks need to be filled and ready for pickup. Departing railcars will need to be blocked (or grouped) by destination for manifest service. This will minimize the amount of switching the Railroad's will need to do in their classification yards when it come time to build their train sets for destination. This practice will reduce yard dwell time, speed up the transit cycle, thus leading to minimizing the railcar assets required to support the service and reduce the demand for railcar storage, all leading to lower capital and operating costs for the required level of service.

Further, terminal workers will need to ensure all departing railcars are properly coupled and the air brake lines are properly connected. It is common to have a compressor and air line installed along the departure tracks in order to pre-charge the air brake lines before Railroad's arrival. This will facilitate a quicker departure, especially in winter months, when it takes longer to confirm end to end air pressure. The quicker terminal operations can deal with the Railroad's, the more time they will have to focus on their other terminal operations.

Custody Transfer information is also required for regulatory purposes associated with transporting products by railcars. Prior to departure from any terminal, a train manifest needs to be generated for the train crew which includes, in proper sequence (front to back), the railcar ID, the gross weight of the railcar, and whether or not the products are classified as dangerous commodities. It is also important to be able to identify, and resolve, any overloaded or imbalanced railcars, prior to departure.

3.4 Rail Service – Origin to Destination to Origin

Every carload gets assigned a trip plan, by the Railroad, between original and destination. This trip plan includes, not just scheduled pickup and delivery from origin to destination, but also intermediate classification destinations where the railcar might get reclassified from one train to another.

Railcars can experience delays anywhere along their route for a wide variety of reasons. Railcars can get setoff due to mechanical repairs; connections can get missed due to network delays (congestion, cold and hot weather slow orders, track condition, etc.); or classification yards maybe congested. Daily tracking of railcars in transit by the terminal operators is important for two main reasons. First, to know where the railcars get hung up, why, and what is being done to get them moving again. Second, to be able to develop a recovery plan at the terminal, with updated delivery information, which will sustain production.

Railroad's provide daily delivery reports to their customers. Since the advent of PSR, and in efforts to become more transparent and better aligned between rail service and terminal operations, access to Railroad real-time data has become a priority for both customer and service provider.

As an example, CN has recently launched an on-line service called Track and Trace API (Application Program Interface) which provides customers with real-time information about shipment location and status. This system monitors shipment location through the use of GPS tracking. It also provides access to the latest shipment status reports, along with current estimated times of arrival at either an interchange point, rail destination, or customer site.

APIs are designed to accommodate an easier and more cost-effective transmission of real-time data from one computer system to another. The railroad industry has undergone a major transformation in the way goods are moved, with complex supply chains becoming the norm. APIs can provide a competitive advantage to customers. They are part of a multi-faceted effort to forge an end-to-end, seamless, digital platform (The Digital Railroad) that can deliver real-time visibility and connectivity through state-of-the-art technologies.

Today, customers have the ability to apply sensors to their fleet and use third party services to, not just track shipments, but also manage their own supply chain. As an example, Cando Rail Services have recently launched a multi-purpose platform called Quasar which utilizes leading edge Internet of Things technology to create a digit twin of the customer's supply chain. Features include asset management, real-time railcar tracking, shipment management, yard/terminal management, and transportation cost management. It provides performance metrics, as well as, predictive and prescriptive analytics.

4 RESULTS

The following is a summary of the results obtained from a review of Industry Rail Terminal operations through the lens of PSR.

Rail Terminal Configurations
Ladder tracks can be utilized effectively for manifest or unit train service, however, loop track configurations are best suited for the following conditions:

- Unit trains consisting of at least 100 cars
- Daily plant production of unit train capacity
- Seven day per week terminal/plant operations

Railcar Fleet Selection Criteria

- Largest gross weight capacity allowed on the rail line
- Largest load limit capacity within the gross weight capacity class
- Consistent railcar length to suit fixed loading/unloading infrastructure configurations
- Shortest railcar length to minimize rail terminal track lengths and maximize railcar useable space

Terminal Location Selection
Preferred terminal locations have the following operating characteristics:

- Railroad mainlines or branchlines which accommodate 286,000 lbs. gross railcar weights
- Railroad mainlines or branchlines with minimal operating restrictions (i.e., speed, steep grades)
- Access to destination through multiple routes and/or Railroads

Storage
Ensure sufficient material storage, insufficient storage will shut down the plant and create disruptions to normal plant operations, but not rail terminal, and rail service operations.

Ensure sufficient railcar storage, insufficient storage imposes higher risks impacting plant, rail terminal, and rail service operations.

Terminal Operating Practices
Utilize a steady 7 day per week work flow to optimize efficient and reliable rail transportation services, reduce the demand for railcars and terminal railcar storage, and to reduce capital and operating costs.

Daily terminal output can be doubled without the need for additional assets and infrastructure when there is the opportunity to load a train within 12 hours.

Arrivals and Departures
Railroads preferred “hook and haul” operations.

Arrival tracks need to be clear and ready to receive railcars. Departing railcars need to be blocked by destination for manifest service.

Rail Service – Origin to Destination to Origin
Daily tracking of in-transit railcars is important to know where they get hung up, why, and what is being done to get them moving again, as well as, to be able to develop a recovery plan at the terminal.

Access to real-time performance and predictive data is essential to manage assets, operations, costs, and service.

Information Systems – The Digital Railroad

Information management systems are fundamental to safe and efficient rail terminal and Railroad operations. Information needs to be accurate, real-time, and easily accessible to all stakeholders within the supply chain. Today, the Railway industry has embraced new data management tools such as Big Data, Machine Learning, Artificial Intelligence, and Digital Twinning in order to streamline their operations with superior predictive tools with the PSR objectives in mind for improving safety and efficiency, controlling costs, improving service, and delivering value to their customers. We are seeing the emergence of a truly integrated and transparent Digital Railroad. Some examples highlighted in this paper include:

- Fleet management systems
- Safety management systems
- Rail Terminal Operating technologies
- Railcar tracking systems
- Railroad service information systems

5 CONCLUSIONS

An idea ceases to be an abstract concept and evolves into something transformational when positive results are established on a continuous basis due to successes and maturing of the concepts. Over the past 15 to 20 years, Precision Scheduled Railroading has taken the railroading industry to a higher standard of performance and a higher level of success. With that said, there remains much more to do as these concepts of railroading continue to evolve and develop focused on growing market share for the transportation of goods across North America and providing value to the shippers this industry services.

Rail transportation is a fundamental component of Canada's Economic Corridors, supporting both domestic and international supply chains, driving our economic growth potential. The reliability of efficient and fluid railway networks, however, relies on the seamless interface between Industry terminal and Railroad operations.

Using a common set of operating practices and principles, set out by PSR, this paper has highlighted what these interfaces are, and how they need to interact to create value through faster and more reliable transportation service, lower transportation costs, and overall supply chain stability. For the Canadian economy, this translates to a competitive advantage in global and domestic marketplaces, lower costs for our goods and services, and opportunities for sustainable growth.

Precision Scheduled Railroading is founded upon the endless cycle of plan – execute – monitor – analyze – and revise the plan. It is an ongoing and developing concept that recognizes the balance and dependency of its principles. The future and true potential of PSR (PSR 2.0) will be realized as operating practices between competing railways, customers, ports and other supply chain entities, become standardized, generating closer collaboration and alliances, resulting in greater benefits and better service for customers, regardless of the route or the carriers engaged. This will require that all parties work harmoniously for the greater good of Industry, consumers, and the Railroads. Future success will dependent upon innovation and the ongoing development and implementation of new technologies through the evolution of the Digital Railroad in support of improving safety, reliability, efficiency, and utilization of assets, while managing costs, and delivering superior service.

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