White Paper: Railroading in the Canadian Winter

This document details the impact of winter on Canadian Pacific (CP)'s operations, including how we measure the magnitude with a series of critical operational metrics that constantly assess the performance and health of the rail system. We explain the robust forecasting and predictive winter modelling exercises used to plan for winter each year. Since our network traverses steep mountain ranges, avalanches represent a critical threat to fluid rail operations. We have therefore dedicated a section on our comprehensive avalanche monitoring, control, and recovery practices. We discuss the importance of interoperable rail equipment throughout the industry – on both sides of the Canada-United States border. Finally, we highlight the partnership established in 2012 between the rail industry and the University of Alberta to conduct important research on additional opportunities to improve winter railway operations.

Impact of winter on the railway

Effective winter planning is essential for CP because winter weather conditions can profoundly affect railway operations.

Railways are no different from other modes of transportation that operate in challenging winter conditions. Snowstorms often cause significant traffic congestion as vehicle speeds are reduced, thereby lowering the road network's volume capacity. Similarly, Canadians are familiar with the consequences of winter weather for air travel: extreme cold temperatures or major snowstorms can cause flight delays or cancellations. These disruptions affect an airline's entire network and reduce the overall system's capacity to move passengers, until it can recover from the poor weather conditions. Winter weather is an inescapable reality for all transportation modes in Canada.

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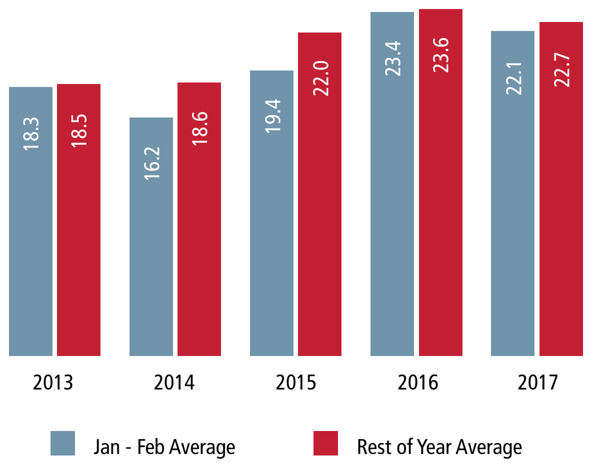
Severe winter weather requires adjustments to railway operations in order to ensure safety – which is always CP's number one priority. When temperatures drop below negative 25 degrees Celsius, a train's speed and length must be reduced. These necessary operational changes unavoidably lower the system's overall velocity, which in turn reduces the supply chain's shipping capacity. Winter storms that cause snowfall and ice require the deployment of significant assets and resources to keep track corridors and railway yards clear and safe. Given our network reach through numerous mountain ranges, we must also be vigilant to the threat posed by avalanches, and prepared to respond rapidly and effectively if our corridor is impacted. Furthermore, when an incident occurs on the railway, the system can take longer to recover in challenging winter conditions.

CP measures the magnitude of winter's impact on the performance of the rail system with two critical metrics: train speed and train length.

Train Speed

Train speed is crucial to CP's ability to provide service and maintain throughput capacity. A train's maximum speed must be reduced by at least 10 miles per hour (MPH) when temperatures drop below negative 25 degrees Celsius, and by at least 20 MPH when temperatures drop below negative 35 degrees Celsius. These speed reductions are critical to safe operations in extreme cold. During winter conditions, the system's overall velocity is also reduced because equipment and infrastructure failures are more frequent. For example, harsh winter conditions can increase the propensity for broken rails and switches, signal outages, locomotive failures, and rail car defects. Each of these occurrences require time and resources to repair. Taken together, these factors have the potential to significantly erode system velocity and capacity during winter conditions. Figure 1 compares CP's average system train speed in the winter months of January and February to the other 10 months of the year, clearly demonstrating the lower system velocity observed during the winter.

Figure 1: Average System Train Speed (MPH), 2013-2017



The rail system's performance during winter months is worse compared to the other months of any given year when weather conditions are more favourable. That being said, in recent years CP has achieved material improvements to our average system train speed, including during winter months. CP's average system train speed for January and February in 2017 (22.1 MPH) exceeded the average system train speed during the non-winter months of 2015 (22 MPH). These gains have been realized by significant capital investments, better winter planning, and other operational changes.

Figure 1 also demonstrates not all winters are alike. For example, the data for 2014 illustrate the impact on train speed caused by extreme, prolonged cold temperatures in western Canada that winter. The impact of winter on system velocity will depend on the severity, duration, and geographic scope of winter conditions.

Train Length

Train length is another important measurement of how winter can constrain a railway's operations. Cold weather increases air leakage in a train's air brake system, which results in varying air pressures between the head end and tail end of a train. This is a major challenge. In order to release brakes, the train's air brake system must maintain similar air pressure throughout the entire length of the train. Therefore, trains must be shortened when the temperature is below negative 25 degrees Celsius to maintain similar air pressure throughout the air brake system. For example, a 10,000-foot train arriving at a terminal may be restricted to 7,000 feet upon departure. These 3,000 feet of rail traffic left in the terminal, multiplied by the number of arriving trains, contributes to congestion, slows car processing, and delays the building of outbound trains, resulting in significant constraints on system capacity and yard performance.

Distributed power is an important operating practice in the railway industry. This term refers to the practice of placing locomotives at multiple locations throughout a train to improve train handling and maintain consistent air pressure. Distributed power accelerates the time required to pressurize the air brake system, which takes longer in cold winter conditions. The use of distributed power allows CP to run longer trains safely.

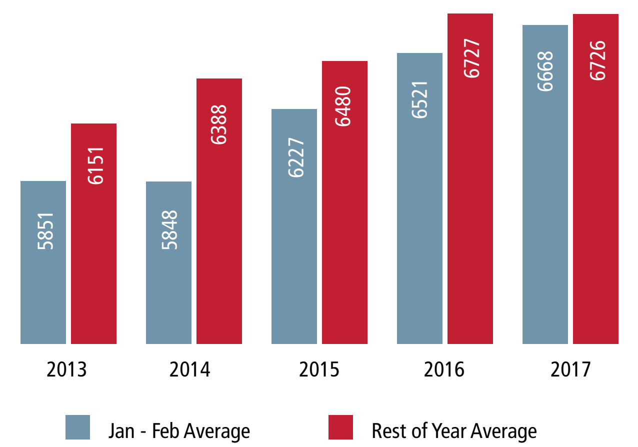
In extreme cold, it is essential to remove moisture from train air brake lines to prevent freezing. Locomotives use air dryers to prevent moisture from entering airbrake lines, but these devices significantly reduce the locomotive's capacity to pressurize the train's air brake lines. Therefore, more time is required to pressurize a train's air brake system and then conduct the required safety tests before the train can leave a terminal. This unavoidably increases the train's terminal dwell time.

CP has recently introduced a "power-on" train model for select Canadian grain customers, whereby the locomotives stay connected to the train while it is loaded. This model allows for continued air pressure through the braking system, thereby helping reduce some of delays associated with air brake systems in cold weather.

Like train speed, the train length metric is consistently worse in winter months compared to the rest of the year. CP has nevertheless achieved a steady increase in winter train length in recent years. As illustrated in Figure 2, between 2013-2017 average winter train length increased by 14 percent. In January and February 2017, CP's average train length exceeded the average train length during the March to December period of 2015.

Like train speed, the improvement to train length performance is attributed to CP's increased capital investments, stronger winter planning, and other operational changes that have been implemented since 2012.

Figure 2: CP Average Train Length (feet), 2013-2017



It is also important to note that significant precipitation during winter can force restrictions to a train's weight to account for reduced traction on moderate to heavy grades. Wet and snowy conditions on rail tracks can cause locomotive wheel slip. If this occurs frequently during a train's assent on a steep grade, the train could stall, creating a dangerous situation. Accordingly, CP adjusts train weight to ensure safe operations. The type of locomotive and physical limits of the rail corridor determine the magnitude of weight adjustment.

Fluid terminal operations are also an important factor that affects rail service reliability. Terminal functions include:

- Processing inbound trains;
- Building outbound trains;
- Inspecting inbound and outbound trains, cars, and locomotives;
- Switching out and repairing defective cars and locomotives; and
- Servicing locomotives (refueling, oiling, adding traction sand, cleaning, etcetera).

To avoid delays and reduce yard congestion, snow and ice must be cleared from yard tracks and switches as quickly as possible.

CP has made significant investments in recent years to improve efficiency at our terminals, including during winter.

Pre-winter planning and forecasting

CP's comprehensive and robust winter planning begins each fall. We start by analyzing weather data and studying the best predictive modelling available to forecast the type, severity, and geographical scope of conditions the railroad is likely to encounter during the upcoming winter. Higher probability forecasts generally start to become available in mid-October. As the data become more probable, CP refines its forecasts and adjusts winter asset and resource deployment plans.

To complement our own in-house forecasting expertise, CP also retains an outside weather service to supply the railway with data and guidance on current and forecasted winter weather. The suite of products provided to CP is extensive: twice-daily weather condition and forecast planning reports for each railway subdivision, real time monitoring and warning protocols, and meteorologist network surveillance. These products are distributed across the network to assist with accurate and efficient decision-making for necessary operational adjustments and winter assets deployment.

As with any weather forecast, it is a prediction based on the most accurate data available at the time; we never can be 100 percent certain that the predicted weather will materialize. Therefore, CP must always be prepared for any winter scenario.

CP Network Ambient Temperature (Hot Box) Monitoring System

Winter readiness

Based on our winter prediction models and the extensive railroading experience of our employees, CP develops comprehensive winter plans for both equipment assets and human resources. Specific winter plans are developed for each region, subdivision, rail yard, and facility across our network.

We strategically place assets and resources, such as snow removal equipment and sand, across the network to ensure rapid deployment when needed to respond to winter weather. CP has 914 switch heaters across the network. We use specialized trucks, backpack blowers, and heated blowers to remove snow from tracks and switches. Since 2017, we have added the following snow fighting equipment to our fleet: eight RPM Air Force 1 Hi-Rail Cold Air Blowers and nine Knox Kershaw KSF 940 Snow fighters. All these assets and resources help CP mitigate winter conditions to keep the railway operating as fluidly as possible, twenty-four hours a day, seven days a week, even during the most harsh winter weather.

CP Plow

CP Snowfighter

Similarly, we develop specific winter plans for our human resources, including our Train and Engine employees, Engineering and Mechanical personnel, and our Operation Centre teams in Calgary and Minneapolis. For example, we will dispatch snow removal crews at targeted locations across the network, train new snowplow and spreader operators, install new snow fences, and complete switch heater installations and renewals.

Our robust planning helps CP operate safely in difficult winter conditions, wherever they may appear across the network.

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Avalanche preparedness

CP's busiest corridor runs through the Alberta and British Columbia mountain ranges that receive significant annual snowfall. Avalanches always pose a risk to our operations in this region. We must therefore take a number of steps to mitigate the risk and plan for an effective response. We have installed 29 snow and rockslide fences, which are systems of poles and connecting wires that trigger the railway signal system to prevent trains from advancing if snow or rocks are detected. We have also constructed snow sheds in areas particularly prone to avalanches. A snow shed is a structure that provides overhead protection by allowing snow to pass over the rail corridor during an avalanche. We now have seven snow sheds on our corridor, one in Alberta and six in BC. This important infrastructure helps protect the rail corridor and improve safety in avalanche prone areas of our network.

We have experts in the field that monitor snow pack conditions in proximity to our track. They will set off controlled avalanches when there is a high risk of a natural avalanche occurrence. We also dedicate equipment and crews to help the rail system recover quickly following a line-outage caused by an avalanche. Avalanche recovery is critically important to ensuring the fluidity of our network.

Snow Shed

Avalanche Control

Snow Fence

Snow Pack Monitoring

CP collaborates with many government agencies and departments, including Parks Canada and British Columbia's Ministry of Highways, to ensure a safe, coordinated, and efficient response to any avalanche affecting our corridor.

Finally, it is important to highlight that the avalanche risk through the mountains, as well as frequent winter rain on the BC coast, can have a significant impact on the grain supply chain in particular. Over the last several years, there has been increased reliance on the Port of Vancouver for the export of grain. This increases the fragility of the grain supply chain since most of the movements are from cold prairie origins through mountain ranges that receive major annual snowfalls and are therefore prone to avalanches. Further, there is significant need to improve the ability to load grain in Vancouver during the rainy season from November through March.

Technological advances and interoperability

The railway industry continues to look for technological improvements to mitigate the impact of winter on operations. This is necessarily an industry-wide endeavor, on both sides of the Canada-United States border, because the interoperability of rail equipment throughout the North American rail industry must be maintained to preserve efficient supply chains.

As one example, train braking systems must be interoperable with all seven North American Class 1 railways and hundreds of short line railways. There are approximately 1.5 million rail cars in North America, half of which are owned by customers or leasing companies, plus 30,000 locomotives that would need to be retrofitted to fully implement new technology across the industry. Railcars have a useful life of 50 years. The interoperability of equipment benefits shippers and supply chains, as rail cars and locomotives can be seamlessly and efficiently routed between North American railroads. An efficient rail supply chain is one of the many reasons why average freight rates in Canada and the U.S. are among the lowest in the world, an important competiveness factor for shippers in North America.

Not all railways are affected by winter or affected the same way. Therefore, a delicate balance must be struck between developing better winter technology and optimal technology for year-round operations throughout an integrated North American rail industry. For example, if you engineer rail steel, rail strength and wear resistance to be optimal for year round operations, you have to sacrifice fracture toughness, which helps in extremely cold weather. This is similar to the physics of a vehicle's winter tires: softer rubber is ideal in extreme cold, but it performs poorly in warm temperatures, actually reducing brake performance and accelerating the tire's wear.

Research in railway technologies, including equipment design, is primarily focused on finding improvements that will benefit all or most of the railways, all or most of the time. Nonetheless, there has been, and continues to be, a concerted effort to look for improvements to overcome winter operating challenges.

Research and development focused on Canada’s rail needs

In 2012, the Canadian Rail Research Laboratory (CaRRL) was established at the University of Alberta to be Canada's premier education and research program in railway engineering. It has developed a specialized research program focused on the unique challenges of railroading in Canada. CaRRL is also part of the affiliated lab program of the industry funded Association of American Railroads’ Transportation Technology Center, Inc. (AAR-TTCI).

Notably, CP and the Western Grain Elevators Association (WGEA) collaborated on a study with the CaRRL, which suggested winter operating performance could be improved with new gasket materials for air brake components, and procedures to ensure air hose coupling components are equipped with new gaskets when cars are repaired. This is an excellent example of railway cooperation with the grain industry to improve winter performance.

Current research undertaken by CaRRL, and supported by CP, includes:

- Assessing and improving track performance and reliability
- Assessing ballast quality and degradation
- Establishing a quantitative risk management process

CaRRL’s past research projects:

- Analysis of Canadian Train Derailments from 2001 to 2014
- An Investigation of the Effects of Axle Spacing on the Rail Bending Stress Behavior
- Quantifying the Distribution of Rail Bending Stresses along the Track using Train Mounted Deflection Measurements
- A Quantitative Evaluation of the Impact of Soft Subgrades on Railway Track Structure
- Reliability Centered Maintenance (RCM) and Ultrasonic Leakage Detection (ULD) as a Maintenance and Condition Monitoring Technique for Freight Rail Airbrakes in Cold Weather Conditions
- Reliability Study and Maintenance Decision Making of Wheel Temperature Detectors
- Reducing Frequency of Slow Orders Resulting from Ground Hazards
- New Destructive and Non-Destructive Methods to Quantify Fracture Toughness of High Strength Rail Steels
- Landslide Risk and Resilience in the Ashcroft Thompson River Valley, British Columbia

This valuable research deepens the industry’s understanding of the challenges of operating in Canada, including in harsh winter conditions.

At CP significant resources are mobilized each year to forecast and plan for winter, and then mitigate the impact, wherever winter conditions materialize across the network.

Conclusion

Harsh winter operating conditions are an inescapable reality in Canada’s northern climate. Winter has a profound impact on a railway’s operations and its ability to maintain service for its customers. As we have reviewed, the breadth and depth of winter’s impact is measured primarily by train speed and train length. These key metrics fall as winter conditions worsen, thereby eroding the rail system’s performance, and the overall supply chain’s capacity to move freight.

At CP, significant resources are mobilized each year to forecast and plan for winter, and then mitigate the impact, wherever winter conditions materialize across the network. Fortunately, in recent years, CP has achieved winter performance improvements through significant investments in track infrastructure and rolling stock, and strong winter planning with both our customers and the broader supply chain. CP continually looks for additional opportunities to improve performance and service, including during winter. This includes working with industry partners to support academic research to advance innovations that would strengthen railway operations in a challenging winter environment.

Nevertheless, the impact of winter on a railway’s performance can never be eliminated: no matter what action is taken, tough winter conditions will always reduce train speed and length, increase the frequency of equipment failures, and ultimately constrain the system’s capacity, hurting service. Proper planning is essential, but it can never fully insulate a railway from the effects of winter.

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