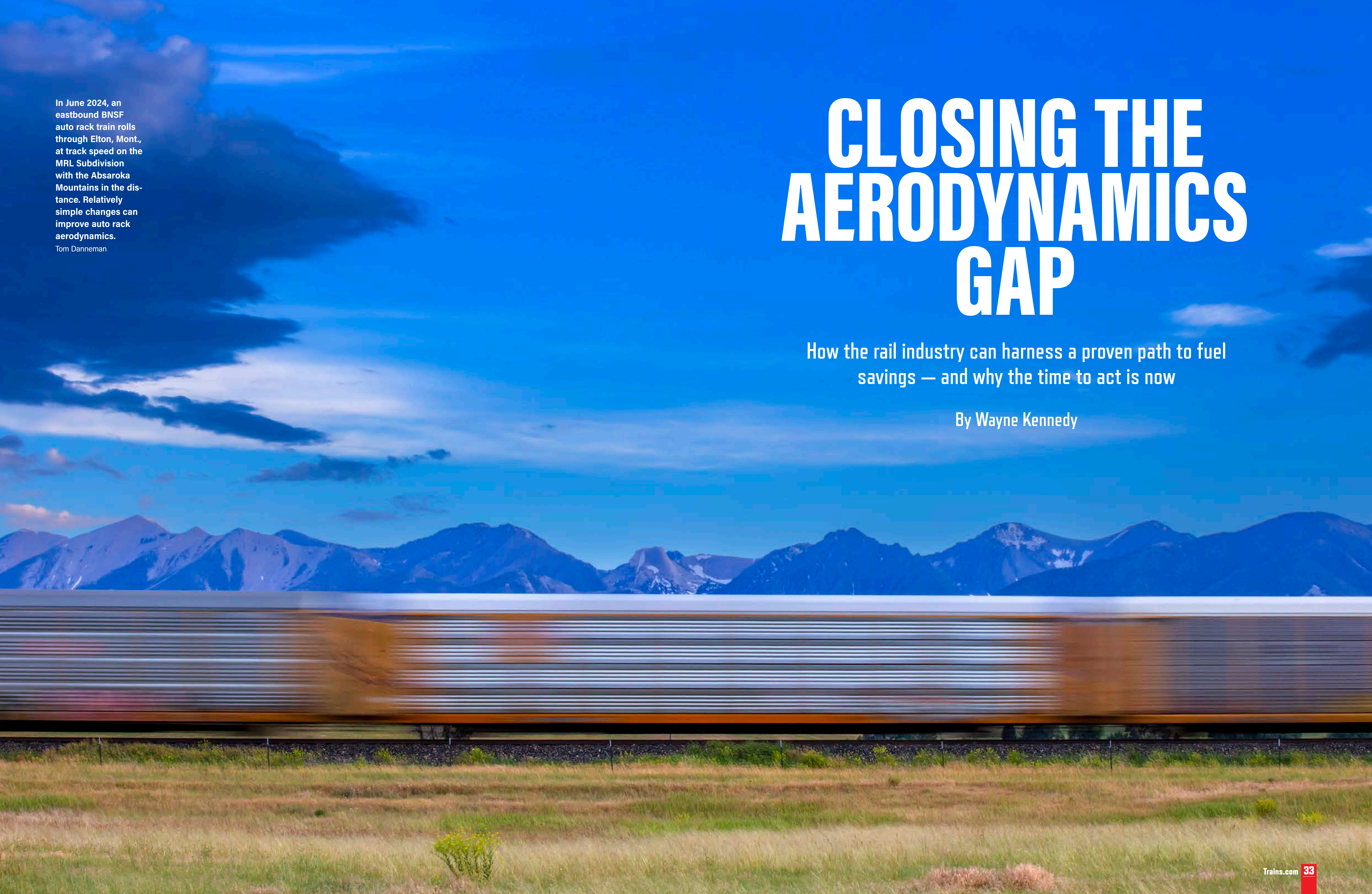


In June 2024, an eastbound BNSF auto rack train rolls through Elton, Mont., at track speed on the MRL Subdivision with the Absaroka Mountains in the distance. Relatively simple changes can improve auto rack aerodynamics.
Tom Danneman

CLOSING THE AERODYNAMICS GAP

How the rail industry can harness a proven path to fuel savings — and why the time to act is now

By Wayne Kennedy

For nearly a century, the shapes of freight cars changed little. Designers prioritized durability, manufacturing simplicity, and lowest cost.

Not much, if any, consideration was given to aerodynamics. Every day, that decision costs the rail industry through sub-optimal fuel consumption. And higher fuel use hinders railroads' ability to fully achieve their climate goals.

North America's Class I railroads have pledged—through the Science Based Targets initiative (SBTi)—to dramatically reduce greenhouse gas emissions. The targets are aggressive, the timeline compressed, and the margin for error slim.

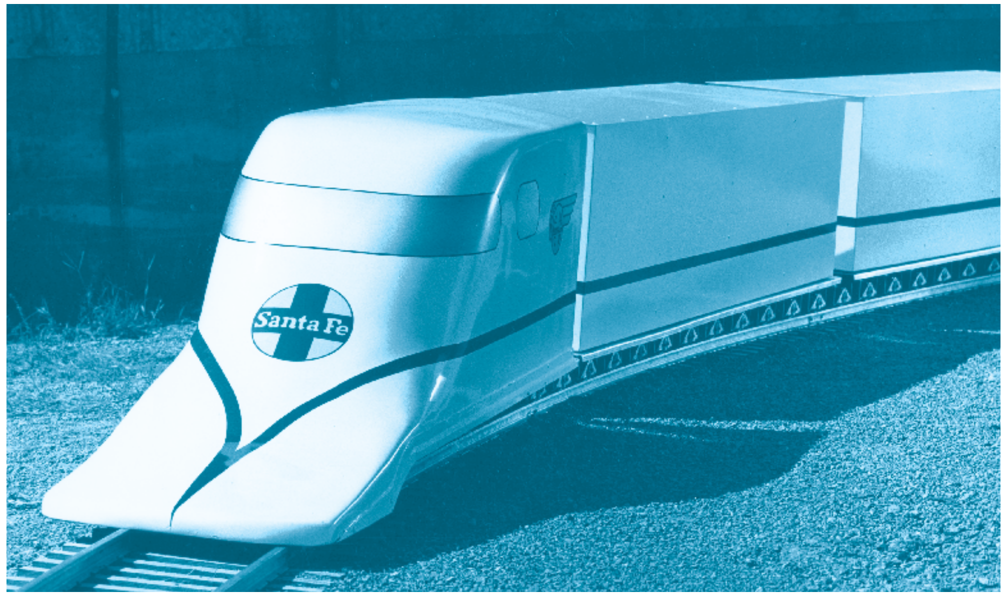
Yet industry performance reveals a troubling reality: Most railroads are off pace. The industry faces a widening gap between where they are and where they committed to be by 2030.

Since the beginning of the 21st century, freight railroad fuel efficiency has improved along a trendline of roughly 1% per year. The improvements have mainly come from purchasing newer, more fuel-efficient locomotives and operating longer trains. But that improvement trend (with the noted exception of NS, which was late in joining the fuel conservation party) has generally flattened out since roughly 2020.

The chief issue is that many of the technologies that worked in the past have already matured. The Energy Management Systems used on today's road locomotives, Trip Optimizer and LEADER, are already being used on a majority of trip segments 15 years after being introduced. Additionally, initiatives like reducing Horsepower-Per-Trailing-Ton (HPTT) have begun to reach their limit as to how much more they can produce in terms of ongoing fuel savings. In other words, railroads are close to reaching the point of diminishing returns.

At their current rate of improvement, whether measured in fuel efficiency (Gallons/1000 Gross Ton Miles) or GHG emissions reduction, the industry is not on-track to meet its SBTi goals by 2030.

Part of the solution to improving fuel efficiency and lowering GHG emissions, some aerodynamicists argue, isn't exotic. It's aerodynamics—the same physics that turbocharged the trucking industry's efficiency gains over the past 15 years. The technology already exists, has been proven in practice, and remaining obstacles are primarily commercial rather than technical. So the challenges can be addressed through creativity and better alignment among stakeholders.

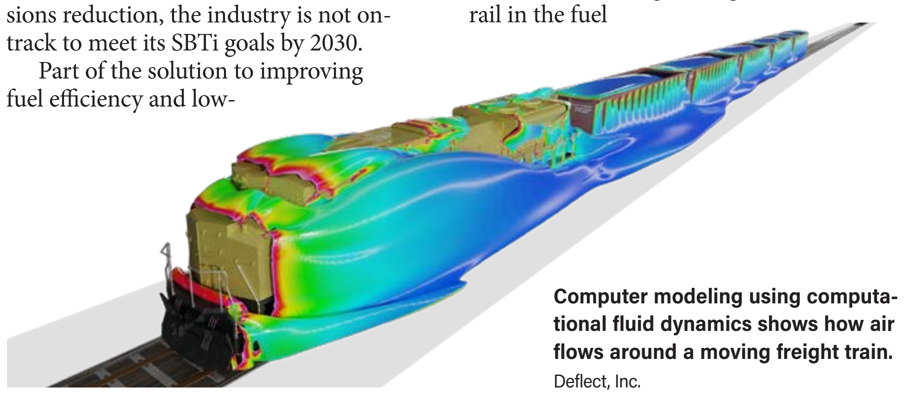


In 1969, Santa Fe developed a high-speed "coaxial train" concept. "It is a low-slung, low center of gravity train with a platypus-shaped lead unit to produce a desirable aerodynamic effect, and individually powered wheels spaced at four-foot intervals," the railway said. Santa Fe

Recent research, conducted by Brigham Young University, Dassault Systemes, and Wabtec, reveals a significant opportunity. Modest, low-cost modifications to locomotives and freight cars could yield fuel savings of 5% to 10% or more—a magnitude of improvement that could bridge a big part of the gap between current trajectories and 2030 fuel efficiency and GHG emissions reduction targets.

Yet despite proof from wind-tunnel testing, computational fluid dynamics (CFD) modeling, and real-world revenue service trials, the industry has adopted these treatments at a crawl.

The reasons illuminate both the promise and the challenge facing rail in the fuel efficiency improvement, GHG emissions reduction era.



Computer modeling using computational fluid dynamics shows how air flows around a moving freight train. Deflect, Inc.

A COMMITMENT UNDER PRESSURE

Around 2019, all of the Class I railroads pledged aggressive greenhouse gas reduction targets aligned with the 2016 Paris Agreement using SBTi science-based frameworks. By 2030, or soon thereafter, the railroads committed to cutting emissions by an average of over 40% compared to a 2019 baseline. Three North American Class I railroads have gone further, targeting net-zero emissions by 2050.

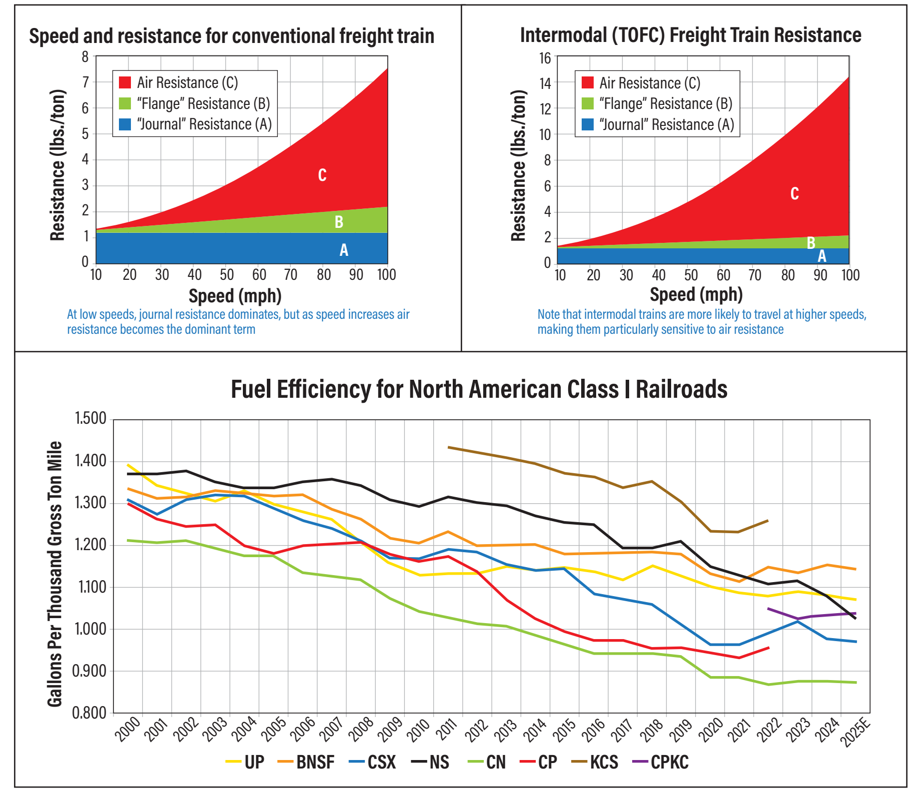
These aren't casual goals. They're backed by investor pressure, customer demands, and regulatory risk. They're being tracked yearly and reported to shareholders and environmental stakeholders. And they're proving more challenging to achieve than anyone anticipated.

Why? Because historical fuel efficiency improvements averaging 1% per year are insufficient. To meet 2030 targets, railroads need to improve fuel efficiency several times greater than their historical average performance, which is difficult to do without new and innovative approaches.

The math is unforgiving. Given that if the industry maintains its historical 1% annual improvement rate through 2030, it will miss its collective SBTi target by approximately 30%. With five years remaining, the runway is disappearing quickly.

THE PHYSICS OF DRAG

Any rail engineer knows that train resistance arises from multiple sources: rolling friction at the wheel/rail interface, mechanical losses in the drivetrain, and aerodynamic drag. At low speeds, rolling friction dominates. But as trains accelerate, drag becomes increasingly important.



These charts of a standard freight train and an intermodal train show how aerodynamic drag increases with the square of velocity and the cube of power. At 60 mph and up, drag becomes the dominant force. Below, fuel efficiency gains have plateaued at the Class I railroads.

At 60 mph, aerodynamic drag accounts for a significant portion of the total power needed to move the train. The relationship is nonlinear: Drag increases with the square of velocity, and the power required to overcome that drag rises with the cube of velocity. So as railroads push toward higher network velocities to improve fluidity and service, they simultaneously drive up the fuel cost of every ton-mile.

This reality creates an opportunity. By smoothing the flow of air around locomotives and freight cars, engineers can reduce drag—and fuel consumption—without sacrificing speed, capacity, or safety.

The proof is substantial.

A unit train of 112 covered hoppers modified with simple aerodynamic treatments—enclosing gaps around bottom chutes and underbody fairings—consumed 7% less fuel than comparable unmodified trains operating over the same territory.

For a reefer boxcar fitted with a smooth roof, low-profile side skirts, and modified couplers to reduce inter-car gaps, CFD analysis and field testing indicated fuel savings approaching 9%.

For autoracks, modifications to the punch-hole pattern of side screens and smooth roof panels showed 3% to 4% fuel savings depending on operating speed.

The advantages of aerodynamics are fuel-agnostic. Whether a locomotive runs on diesel today or on battery-electric or hydrogen power in the future, reducing drag lowers energy consumption and allows each unit of stored or delivered energy—every watt of battery capacity or kilogram of hydrogen—to move freight farther.

WHERE AERODYNAMICS LIVES TODAY

Some concepts have crossed from laboratory to production. The most visible example: The modified punch-hole pattern on autorack side screens, built by Corrugated Metals and called the Aeroscreen. This innovation, developed through extensive wind-tunnel testing and validated through full-scale energy trials, is now becoming standard in new autorack production. Customers recognize the fuel benefit and market advantage.

Several freight car builders, including Greenbrier and National Steel Car, now offer aerodynamic variants. Greenbrier's Tsunami Gate covered hopper incorporates aerodynamic refinement alongside safety improvements, as does its Auto-Max II autorack. A prototype smooth-sided coal car from National Steel Car, the Transverse Ultra-Fast-Flow or TUFF car, represents new thinking about car design.

Yet these options remain a minority choice. Most customers still opt for conventional designs, drawn by their lower upfront capital cost, even if the price difference between the aerodynamic and standard version is only a 1% to 2% increase in the total build price.

Some of the railcar categories that exhibit the highest amount of drag are empty open hopper and gondola cars. Coal cars may sometimes consume as much fuel when traveling empty as loaded due to the large amount of aerodynamic drag when empty. A number of solutions to this have been developed, including coal car covers as sold by Ecofab and Solurail.

Wind tunnel studies by NASA-Ames and BYU have found that these railcar covers can substantially reduce aerodynamic drag by over 40%. They also can help to prevent material loss and environmental contamination.

Further, some of the major car builders are looking at automated hatch covers for covered hoppers, which would remove the roof walkways. In addition to being a huge safety improvement, this would also produce significant fuel savings through re-

Greenbrier's Tsunami Gate covered hopper features aerodynamic refinements, most noticeable around the bottom gate, that reduce aerodynamic drag by 56%. Greenbrier

Union Pacific ordered 112 streamlined covered hoppers in 2018 after wind tunnel testing of G scale models proved the fuel saving potential of such aerodynamic design modifications, including enclosing the gaps between dump gates and new walkway supports that are one long continuous piece instead of individual brackets. Early testing of solid train sets of these covered hoppers, like this one at Green River, Wyo., showed that they reduced fuel usage by 4% to 6%. Andy Kirol

duced aerodynamic drag because the current roof walkways produce a lot of drag.

For intermodal containers, autoracks and other railcar types, inter-car gaps are often one of the largest sources of drag. Larger gaps between railcars as on intermodal trains reduce savings that can be achieved from drafting one behind another. This impact is increased in crosswinds, where following cars are less protected.

Deflect Inc sells low-cost RoofRider and SideRider deflectors which can be attached at the ends of containers and autoracks to deflect air away from these gaps. They have been shown to work in wind tunnel testing at BYU and the Technical University of Berlin, and should reduce fuel consumption by 1% to 2% on fully equipped trains.

The wind tunnel that catalyzed much of this research has itself become a symbol of the industry's half-measures. Purchased by a major Class I railroad in 2015 and later donated to the Transportation Technology Center at TTCI (now MxV Rail) in Pueblo, Colo., the rail-centric wind tunnel—capable of testing G-scale models of locomotives and freight cars—sat dormant for years before being moved to MxV Rail. Without dedicated funding or a paying customer, this facility, one of the few medium-scale wind tunnels in North America capable of rail-specific aerodynamic research, awaits reassembly and reactivation.

WHY ADOPTION STALLS

The aerodynamic opportunity is real. The technology is proven. So why hasn't the industry moved faster?

The answer lies in the fractured ownership of rolling stock. Class I railroads own roughly 15% to 40% of the freight cars they operate. The rest belong to customers (for whom specialized equipment like grain hoppers, autoracks, or tank cars are essential to operations) or to leasing companies or TTX, the equipment pooling company.

When a railroad invests in aerodynamic modifications to a covered hopper, the primary beneficiary should be the shipper who owns the car—or the leasing company. Fuel savings accrue to whoever pays the railroad to move the car. However, the railroads bear risk: What if the modification interferes with loading or inspection procedures? What if customers resist?

For new builds, the math is cleaner. The incremental cost to build an aerodynamically optimized car from the start is minimal, perhaps 1% to 2% more depending on the scale of modifications. But customers see it as higher capital expenses and go with the cheaper option.

Customer-owned fleets add another layer of complexity. A shipper who invests in aerodynamic equipment gets the fuel benefit, but only if the railroad that moves it recognizes and rewards the improvement. Most railroads don't offer rate incentives tied to aerodynamic efficiency.

Leasing companies face a different calculus. An aero-modified car is worth more because it reduces operating costs. But lessees—the railroads or shippers renting the equipment—must be willing to pay a premium lease rate. That premium often fails to materialize because the benefit is hard to quantify on a per-shipment basis.

This dynamic is a classic chicken-and-egg problem. Customers are reluctant to pay for aerodynamic features because they do not purchase the fuel and therefore do not directly capture the savings. Railroads hesitate to prioritize aero because they struggle to demonstrate clear value to customers. And leasing companies are slow to invest when neither shippers nor railroads are willing to pay higher rates that explicitly reflect fuel savings.

THE TRUCKING INDUSTRY'S ANSWER

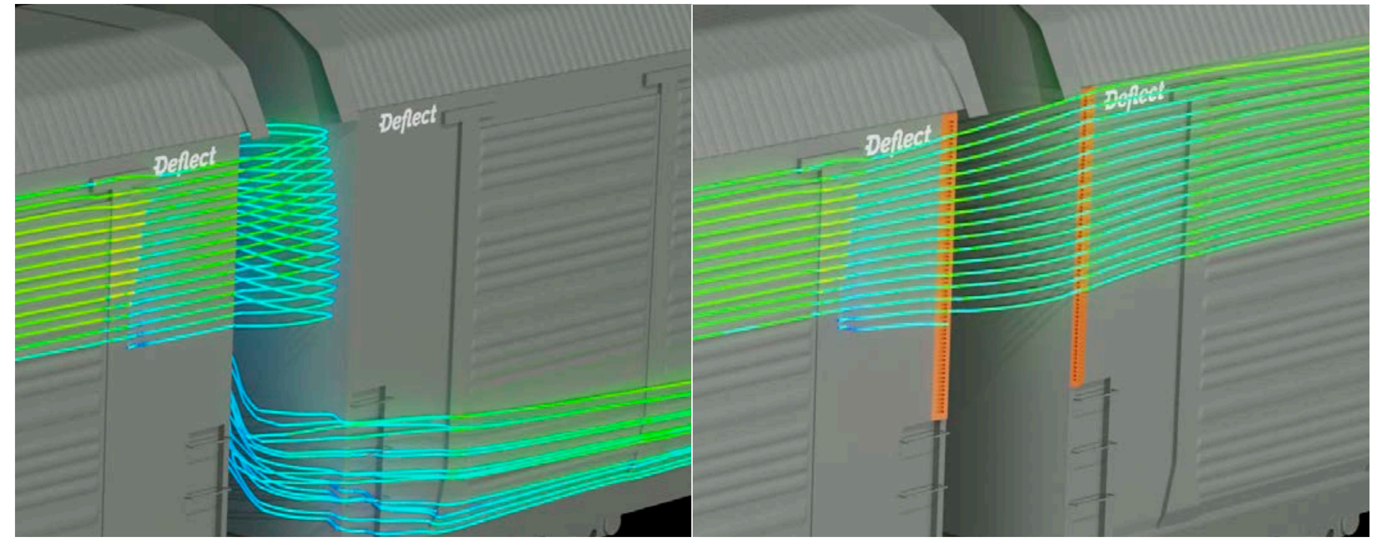
The trucking industry faced the same puzzle—and solved it. Over the past 15 years, the Department of Energy's SuperTruck program invested over $300 million in collaborative research with Class 8 truck manufacturers. The program required the original equipment manufacturers to develop technology demonstrators that achieved 50% higher freight efficiency (ton-miles per gallon) than the best-in-class 2009 baseline.

Most OEMs reached these goals, though adoption is still not complete in revenue service. Aerodynamic improvements—new tractor designs, trailer side skirts, rear fairings, underbody fairings—accounted for a large part of the overall efficiency gains. Today, a modern Class 8 tractor-trailer achieves 25% better fuel economy than its 2009 predecessor, yielding an estimated $30 billion per year in fuel savings for the trucking industry. It's a savings of up to $20,000 annually per vehicle.

How did trucking crack the code?

First, regulatory pressure. The U.S. Environmental Protection Agency required OEMs to certify aerodynamic drag coefficients for vehicle configurations, creating a compliance burden that made aerodynamics a cost of doing business. Virtual certification through CFD reduced the burden, but aerodynamic performance became a competitive differentiator.

Second, industry standards. Customers began specifying aerodynamic features in purchase orders. Leasing companies factored improved resale value and lower operating costs into lease rates. The market



Deflect Inc. makes RoofRider and SideRider deflectors that can be attached to the ends of containers, auto racks, and gondola cars to deflect wind away from gaps between cars. At left, wind tunnel testing shows how wind flows between cars, creating drag. At right, air flows smoothly around the ends of the deflector-equipped cars. Deflect Inc.

Car builder Trinity Rail has a prototype design, left, for an aerodynamic and automated covered hopper hatch called Ecofab. The hatch would eliminate the rooftop walkways that create aerodynamic drag on covered hoppers, like the CSX car at right. Trinity Rail, left; Robert J. Wise, right


Brigham Young University designed this rail-centric wind tunnel that can test airflow on G-scale models. Here, Wayne Kennedy levels track sensors before a test. Wayne Kennedy

A KLLM trailer, pulled by a Freightliner rig, passes Kansas City Southern ES44AC No. 4695 at Kendleton, Texas. Tom Kline

signaled that aero mattered.

Third, funding. Department of Energy grants de-risked research and development costs for truck manufacturers and early adopters. They also shared research infrastructure—wind tunnels, CFD partnerships—accelerated innovation and reduced individual R&D costs.

Fourth, commercial innovation. Leasing companies restructured deals to capture the value of lower fuel consumption. Some operators implemented fuel surcharges for aerodynamically enhanced equipment. Carbon credit programs created additional value streams.

The trucking industry includes thousands of competing fleet operators, while North American freight rail is dominated by just six major Class I carriers.

It is striking that a more fragmented trucking sector has managed to align around aerodynamics while a much more concentrated rail industry has not—a contrast that is both humbling and instructive.

WHAT NEEDS TO HAPPEN

Bridging the gap between opportunity and adoption requires action from multiple stakeholders—and not just the railroads.

Class I Railroads: Set internal standards for all new car purchases, requiring minimum aerodynamic specifications. Pilot high-impact retrofit programs on owned fleets, prioritizing high-utilization cars (covered hoppers, autoracks) with newer model years. Most importantly, establish rate structures that recognize and reward aerodynamic equipment, signaling to customers and lessors that efficiency matters.

Car Builders and OEMs: Bundle aerodynamic features as cost-competitive options on all new models, with a clear roadmap toward making them standard. Develop retrofit kits for existing high-utilization fleets, priced attractively to encourage uptake. Partner with railroads on pilot programs to demonstrate benefits.

Leasing Companies: Adjust lease structures to reward lower operating costs. A newer, aero-modified car should command a higher lease rate than conventional equipment, but the economics should be attractive for the lessee. Also recognize improved resale value in the leasing financial model.

Regulators and Standard Setters: The Association of American Railroads should champion voluntary aerodynamic standards, develop testing protocols, and facilitate knowledge-sharing among members. The Federal Railroad Administration should support infrastructure for testing and validation. There is a house bill, H.R. 1200 the "Freight RAILCAR Act of 2025," currently under review by the House Ways and Means Committee, which would provide a 10% tax credit for railcar replacements or modifications. A fuel efficiency improvement of 8% or an improvement to meet stricter current safety standards would make a modification qualify. This bill could incentivize all railcar owners to improve the efficiency of their fleets.

Customers and Shippers: Recognize that Scope 3 (supply chain) emissions are increasingly important to investor and regulatory scrutiny. Request aerodynamic equipment in procurement specifications. Support railroads and lessors that invest in efficiency improvements.

Research and Development: Pursue government and AAR funding to reactivate wind tunnel testing and prototype programs. The dormant rail-centric wind tunnel at MxV Rail should be brought back into operation. CFD capabilities should be standardized and funded collaboratively. Universities have developed excellent aerodynamic analysis capabilities; funding should support continued development.

A MULTI-YEAR ROADMAP

Pragmatically, adoption will likely follow this trajectory:

Years 1–2 (2026–2027): Focus on new builds. Establish aerodynamic specifications for all newly manufactured covered hoppers, autoracks, and reefers/boxcars. Cost is minimal; impact is immediate because these cars will operate for up to 50 years. Simultaneously, pilot retrofit programs on the newest, highest-utilization owned fleets—perhaps 15% of the car population—to generate operational data and build business cases.

Older style side screens on auto racks, like the one at left, create aerodynamic drag. Newer versions, right, smooth airflow around the car. Chad Hewitt, left/Wayne Kennedy, right

Years 2–4 (2027–2029): Scale retrofit programs on leased fleets and customer-owned equipment with warranty and performance guarantees. Develop commercial models (lease rate adjustments, fuel surcharges, carbon credits) that distribute benefits fairly. Expand aerodynamic specifications to other car types (gondolas, flat cars, intermodal equipment).

Years 5–10 (2030–2040): Achieve broad-based adoption across new builds and retrofit existing younger fleets. Develop next-generation concepts through resumed R&D funding. Prepare for transition to alternative fuels, ensuring aerodynamic enhancements transfer to battery-electric and hydrogen fuel cell platforms.

Throughout, the key is alignment. The commercial issues are real but they are far from insurmountable. Every one of these challenges has precedents in other industries.

The rail industry simply needs to decide that fuel efficiency and emissions reduction are important enough priorities to warrant solving the associated commercial problems.

CAN RAIL MATCH TRUCKING?

The rail industry's SBTi commitments are genuine. The imperative to save diesel fuel and reduce GHG emissions is clear. The technology is proven. The financial case—$30 billion annually in fuel savings for the trucking industry, with rail facing similar opportunities—is compelling.

The Class I railroads consume roughly 3.6 billion gallons of diesel fuel per year. At an average fuel price of $2.50 per gallon — which is conservative — then a 5% fuel savings for the industry through the application of aerodynamic treatments to rolling stock would net $450 million per year in fuel savings.

What remains to be seen is whether the industry will mobilize with the urgency the moment demands.

Trucking did it, but not overnight. SuperTruck I (2010–2015) required years to gain traction. It wasn't until OEMs saw regulatory requirements and customer demand align that real transformation occurred. Rail faces a similar pivot point. The science is not contested. The opportunity is quantified. The barriers are commercial, not technical.

A Chinese proverb holds that a journey of a thousand miles begins with a single step. For North American rail, that first step could be a Class I railroad or group of car builders agreeing to make aerodynamic features standard on new builds; a major leasing company restructuring lease terms to reward efficiency; a prominent shipper insisting on aero-equipped cars in its procurement; or an industry body or regulator committing to sustained support for aerodynamic research and standards. Such actions would be catalytic moves that can begin to realign incentives and unlock broader adoption.

Those steps won't automatically solve the puzzle. But they'll signal that the industry is serious—that fuel conservation isn't just a 2030 talking point, but a lived commitment.

And in a world that is hungry to reduce diesel fuel consumption and the associated GHG emissions, that commitment, expressed through freight car steel and aluminum and operational service, may be a key driver to meeting their long fuel efficiency and emission reduction goals. I

Wayne Kennedy, a consultant with more than 30 years of experience in the rail industry, holds six patents, primarily in the field of rail aerodynamics. He established a fuel conservation group at Union Pacific, resulting in a 12% improvement in fuel efficiency at the railroad. He actively advocates for technologies aimed at reducing greenhouse gas emissions from locomotives.