Fuel Economy Comparison of Four West Coast Rail Corridors using a Streamlined Analysis Methodology

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Introduction

As shippers grow more concerned about the environmental footprint of their supply chains, they are taking greater interest in the fuel economy associated with rail freight movement. This requires a holistic analysis of a goods movement corridor, rather than a calculation of locomotive fuel economy.

Findings

- Fuel economy along these corridors varies widely, from 340/508 RTM/gal.
- Total origin-to-destination fuel consumed along the corridor varies from 104 to 149 gal per container.
- Drayage truck trips account for up to 15.2 percent of total fuel consumption.
- Empty car mileage up to 4.6 percent of total fuel consumption.
- Our methodology can be applied by researchers without needing proprietary data sources or simulation tools.

Modeling Approach

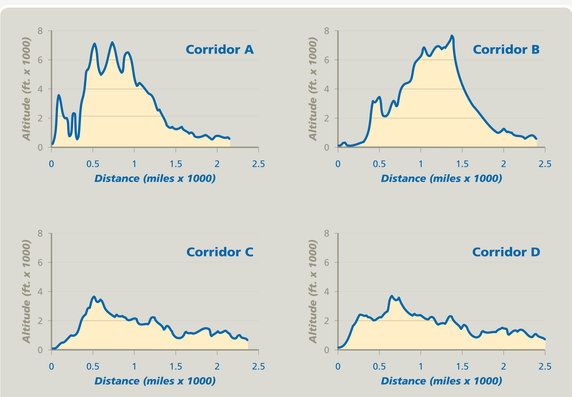
The approach developed for this study is based on a vehicle-specific power (VSP) analysis of locomotive fuel use across the length of the rail corridor. The VSP calculation is based on four forces operating on a train: aerodynamic resistance, rolling resistance, grade resistance, and inertial resistance. Each corridor is divided into rail segments of 0.1 mile, with segments populated with data on corridor and operation properties including track grade and train speed to determine fuel use across the segment.

The calculations rely on a grade profile and speed profile for each route:

- **Grade:** using GIS, a grade profile shows track grade as a function of distance along the corridor, and determines the effort that a train must expend to overcome altitude changes along the corridor.
- **Speed:** a speed profile of each corridor shows the speed at which a train travels as a function of distance. This profile is based on the posted track speed along each segment, available from published guides to the railroad network and takes into account speed bottlenecks due to railyards, sidings, and other track restrictions.

These grade and speed profiles are used to calculate the energy consumed by a train traveling along a corridor, broken up into a multitude of short segments. Energy use is then aggregated over the entire corridor to calculate total energy expended from origin to destination, and converted to fuel consumption using brake-specific fuel consumption (BSFC) factors.

FIGURE 1: **The elevation profile of each route directly influences route fuel economy**



Factors that Influence Fuel Economy

Grade

The greatest difference among the four routes is the grade profile and maximum altitude of each corridor. The maximum altitude of each route varies greatly from 3,763 feet along corridors C and D, to 7,089 along corridor A and 7,851 feet along corridor B.

The severity of grades varies greatly. While corridor D route includes 22 miles of track with grades greater than 0.5 percent, corridor A route has 265 miles of track and corridor B has 115 miles of track at these elevated grades.

The grade resistance along the high-altitude corridors exceeds any other force. Along corridor A, grade resistance has the greatest impact, accounting for 40.3 percent of fuel used in the highest case. In comparison, the route with the lowest grade resistance requires just 21.5 percent, nearly half that of the prior route. Notably, while the peak altitude of corridor A is less than that of corridor B, the cumulative elevation is greater. More fuel is required to overcome grade resistance on B than A, even though the former is shorter and has a lower peak elevation.

Speed

The speed of trains along each route has a significant impact on fuel economy. As trains travel faster, the air resistance they encounter increases dramatically. Corridors A and B allow for high-speed traffic along much of the length – 61.0 percent of the former route and 52.0 percent of the latter route are rated above 60 MPH. In contrast, corridor D runs at slower posted speeds, with 47.5 percent of the route length rated between 50 and 60 MPH, and the remainder rated slower.

Ancillary Activities:

A significant portion is used by drayage trucks, intermodal yard equipment, and empty railcar movements. In the four corridors we analyzed, these ancillary movements account for 14.4 to 19.6 percent of overall fuel consumption.

Drayage movements are the largest source of fuel use. Drays must move containerized cargo at the origin, from the port terminal to the rail yard, and at the destination, from the rail yard to the shipper's ultimate destination (distribution center or retail location). This analysis assumes that all corridors terminate with a 30-mile dray trip from the rail yard to the destination, consuming 0.64 gal/RT. However, the amount of drayage activity at the origin of each corridor varies depending on the use of on-dock vs. near-dock rail at each port terminal.

TABLE 1: **Corridor Fuel Economy Results**

Route	Fuel Economy (RTM/gal)	Fuel Consumption (gal/RT)	GHG Emissions (kg CO2/RT)
Corridor A	340	6.43	64.9
Corridor B	362	7.09	71.7
Corridor C	485	4.93	49.8
Corridor D	508	5.09	51.4

TABLE 2: **Fuel Consumed by Ancillary Activities (gal/RT)**

Route	Drayage at Origin	Drayage at Destination	Intermodal Equipment	Empty Car Movement
Corridor A	0.34	0.64	0.0029	0.28
Corridor B	0.05	0.64	0.0029	0.32
Corridor C	0.00	0.64	0.0029	0.22
Corridor D	0.00	0.64	0.0029	0.23

Conclusions and Next Steps

The fuel economy of rail corridors varies, depending on properties of each corridor and trains traveling from origin to destination. The primary factors are grade profile of the route and speed profile of the train. These inputs determine the tractive effort a locomotive must provide to overcome four forces operating on the train: rolling resistance, aerodynamic resistance, grade resistance, and inertial resistance.

This model can be applied in a variety of analyses of rail and goods movement efficiency. In particular, this model can calculate differences in fuel economy across different routes, types of goods (e.g., doublestack intermodal, auto-rack, passenger), and train operation characteristics (speed profile). Unlike proprietary train energy models, the data sources and calculation methodologies used in this analysis are publicly accessible.

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