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16. Abstract

The Moving Ahead for Progress in the 21st Century Act includes a number of provisions advocating improving the condition and performance of the national freight network through targeted investments and policies by the Department of Transportation and state agencies. Critical to this network are freight corridors which serve as major trade gateways connecting multiple cities and regions. However, transportation planners and policy makers are limited by the number of tools available to assess the performance and condition of these corridors. Most current tools and models require data which is either unavailable, outdated or insufficient for analysis. To address this need, a truck-rail intermodal toolkit was developed for multimodal corridor analysis and enables planners and other stakeholders examine freight movement along corridors based on mode and route characteristics. The toolkit includes techniques to acquire data for simulating line-haul movements, and models to evaluate multiple freight movement scenarios along corridors. Example analyses examining truck and rail movements along 5 mode-competitive corridors are presented in addition to a case study of the Gulf Coast Megaregion. The methodology described herein can be used in other multistate corridors and serve as an initial assessment of the condition and performance of the national freight network.

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A Transportation Corridor Analysis Toolkit

by

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Research Report SWUTC/13/600451-00066-1

Southwest Region University Transportation Center
Center for Transportation Research
The University of Texas at Austin

October 2013

Executive Summary

The Moving Ahead for Progress in the 21st Century Act establishes a national freight policy to improve the condition and performance of the national freight network through initiatives such as: assessing the condition and performance of the network; identifying highway bottlenecks that cause significant freight congestion; identifying major trade gateways and national freight corridors; identifying best practices for improving the performance of the national freight network; and mitigating the impacts of freight movement on communities [§1115; 23 USC 167]. The United States' freight network includes more than one million miles of highways (of which 26,000 miles of highway are major freight corridors), railways, and inland waterways. The Federal Highway Administration quantitatively defines major freight corridors as "… segments of the freight transportation network which moves more than 50 million tons [annually]" – equating to approximately 8,500 trucks per day assuming each truck carried 16 tons of cargo (Federal Highway Administration, 2008). Considering the importance of freight corridors, a vast number of studies have been performed to project future trends, compare different methods for measuring corridor effectiveness, and examine how successful corridors have developed over the years.

This report seeks to add to this literature by demonstrating how broad corridor analysis of various modes can be performed using newly-developed tools. A Truck-Rail Intermodal Toolkit (TRIT), developed in an earlier study, was used in examining truck and rail movements along multiple freight corridors and the Gulf Coast megaregion. TRIT is made up of two main models: 1) the truck operating cost model (CT-Vcost), and 2) the rail operating cost components (CTRail). Comparative variables used in both models include the ability to incorporate roadway and track characteristic (elevations and grades), travel speeds, changes in fuel prices, maintenance cost, labor cost and tonnage**Error! Bookmark not defined.**. Outputs from both models include fuel consumption and cost, travel time and payload cost per ton-mile. In order to use the truck operating cost model, data is required for roadway elevations, grades, and traffic speed. For the rail operating cost model, data is required for track elevations, grades and posted speeds. Roadway and rail track elevation and grade data was acquired through the use of GIS data sources which are described in the Route Data Acquisition section of this report. Average truck traffic speed data was obtained from the National Corridors Analysis and Speed Tool (N-CAST). The methodology described in this report can be used in other multistate corridors and serve as an initial assessment of the condition and performance of the national freight network.

Model output from TRIT performed relatively well for five rail movements when compared with data from the FRA study. Calculated errors for payload ton-miles per gallon were 13.60% for Columbus-Savannah, 20.11% for Detroit-Fort Wayne, 11.14% for Atlanta-Huntsville, 1.59% for Detroit-Decatur, and 13.02% for Memphis-Atlanta (see Figure ES.1). For double-stacked movements, the model's fuel efficiencies were 444 and 260 compared to 384 and 226 ton-miles per gallon from the FRA study. For gondolas, the model's fuel efficiencies were 377 and 313 compared to 301 and 278 ton-miles per gallon from the FRA study. For the single auto rack movement from Detroit to Decatur, the model's fuel efficiency was 159 compared to

156 ton-miles per gallon from the FRA study. Reasons for the errors include differences in path characteristics (i.e. distance and grades), exclusion of curvature, different locomotive types and differences in travel speeds. On average, the travel speeds for TRIT were much higher than that of the FRA study with differences ranging from 1 mile per hour (mph) for Detroit-Decatur to 7 mph for Memphis to Atlanta.

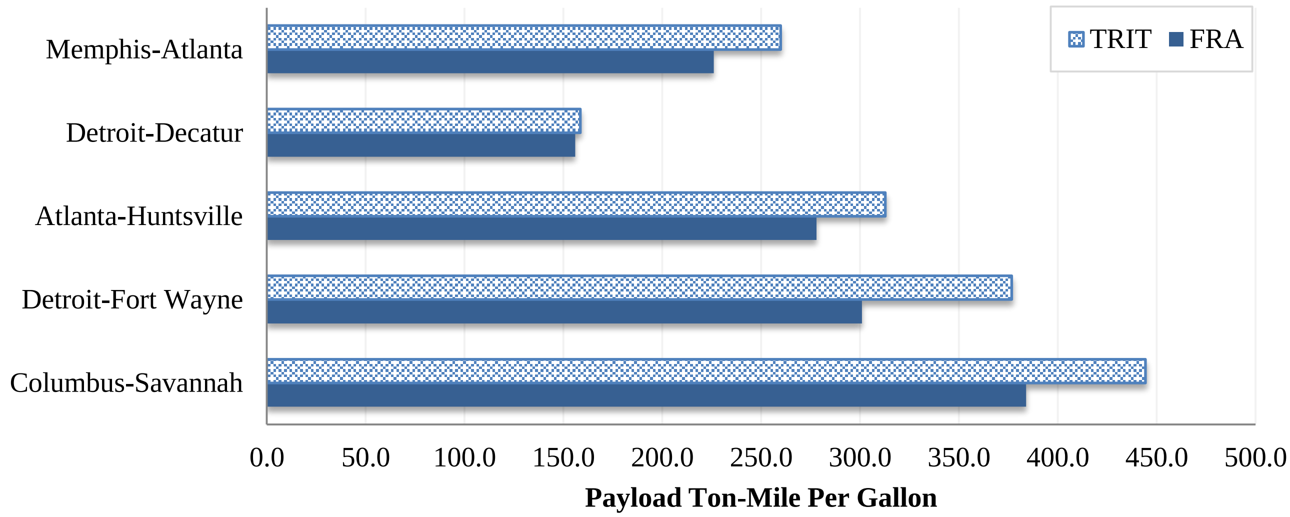

Figure ES.1: Comparison of Rail Payload Ton-Mile Per Gallon

Similar to rail movements, truck movements were compared along the same corridors and performed relatively better than rail movements when the model's theoretical values are compared with values obtained from the FRA study (see Figure ES.2). This can be attributed to the fewer number of variables used in the analysis of truck movements, and truck fuel efficiency was found to be very sensitive to average truck engine and drive train efficiencies. These were set to 25% and 82.5%, respectively, for all trips, to adopt consistency in the analysis. Should any of these efficiency values be varied for each route, it is possible to achieve very similar results as the FRA study. Calculated errors for payload ton-miles per gallon were 0.2% for Columbus-Savannah, 13.5% for Detroit-Fort Wayne, 14.1% for Atlanta-Huntsville, 4.3% for Detroit-Decatur, and 4.2% for Memphis-Atlanta. Truck fuel economy ranged from 4.71 to 6.21 miles per gallon. The largest difference in fuel economy was for the Detroit-Fort Wayne route, which the model recorded at 5.6 mpg in comparison to the FRA value of 5.4 mpg. Reasons for errors include differences in distance travelled, vehicle types, and travel speeds.

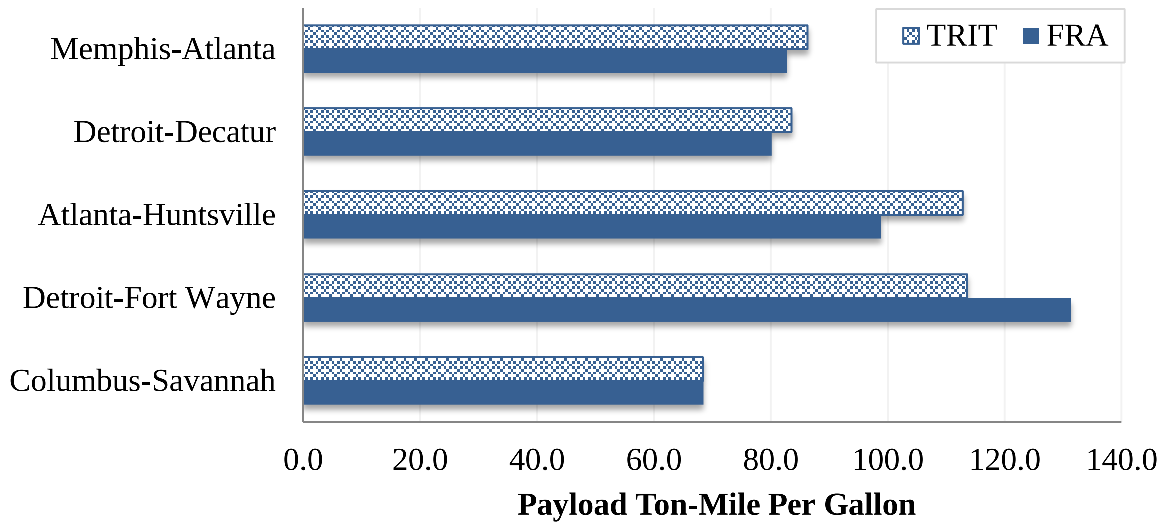

Figure ES.2: Comparison of Truck Payload Ton-Mile Per Gallon

In addition to the FRA study comparison, TRIT was used in examining truck and rail movements along the IH-10 Gulf Coast megaregion corridor. The corridor analysis, which stretched from Houston, Texas to New Orleans, Louisiana, determined that congested vehicular traffic conditions along the corridor did not heavily influence the cost, travel time and overall operations of truck movements. There was little difference in overall travel time, fuel consumption, and vehicle operating costs when PM peak traffic condition were compared to off-peak traffic conditions. This can be attributed to the relatively-modest current congestion along the corridor between Houston and New Orleans, with Baton Rouge being the only choking point where traffic speeds were sometimes as low as 20 mph during the PM peak period.

Rail movement along the same corridor from Houston to New Orleans was found to be heavily influenced by posted speed limits. Despite an increase in fuel consumption for the 40 mph posted speed, travel time decreased by as much as 7.43 hours. Trucks were found to be twice as expensive as rail on a payload per ton-mile basis; however, travel time and speed may be the biggest challenge to rail competiveness along the corridor.

The overall results are sufficiently positive to position the work to be more thoroughly tested in state DOT/MPO planning activities. Three initiatives are recommended. The model should be evaluated using Class 1 railroad data to build on the insight gained from the FRA data. Second, it should be tested in more detail on an additional corridor, such as a long section of IH-35 that carries NAFTA freight and where both rail and truck compete for business. The Texas DOT does not have sufficient funding for IH-35 expansion in the face of increasing U.S. trade with Mexico and rail intermodal operations could mitigate growth in truck movements. Finally, the two activities just described would act as a bridge by facilitating a dialog between researchers, modal providers, and transportation planners. It could measure performance and identify bottlenecks where targeted investments would yield a high return on the scarce resources currently available for highway investments.

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Disclaimer

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Chapter 1. Background and Current State of Corridor Analysis

The Moving Ahead for Progress in the 21st Century Act establishes a national freight policy to improve the condition and performance of the national freight network through initiatives such as: assessing the condition and performance of the network; identifying highway bottlenecks that cause significant freight congestion; identifying major trade gateways and national freight corridors; identifying best practices for improving the performance of the national freight network; and mitigating the impacts of freight movement on communities [§1115; 23 USC 167]. The United States' freight network includes more than one million miles of highways (of which 26,000 miles of highway are major freight corridors), railways, and inland waterways. The Federal Highway Administration quantitatively defines major freight corridors as "… segments of the freight transportation network which moves more than 50 million tons [annually]" – equating to approximately 8,500 trucks per day assuming each truck carried 16 tons of cargo (Federal Highway Administration, 2008). Considering the importance of freight corridors, a vast number of studies have been performed to project future trends, compare different methods for measuring corridor effectiveness, and examine how successful corridors have developed over the years.

McCray (1998) examined trade corridors connecting the United States to Mexico, and projected the dramatic growth of traffic along these corridors in relation to North American Free Trade Agreement (NAFTA). His study outlined how major trade corridors can be identified and further developed to accommodate future growth in trade (McCray 1998). A study from Cambridge Systematics (2007) examined the long-term expansion needs of the continental United States freight railroads. The study, commissioned by the Association of American Railroads, used the Department of Transportation's demand projections through 2035, and focused on over 50,000 miles of freight corridor. The study found that nearly $150 billion would need to be spent between 2007 and 2035 on rail tracks, signals, bridges, tunnels, and terminals to keep up with projected demand (Grenzeback & Hunt 2007). Additional studies described major trends in intermodal shipping impacting Texas's intermodal trade corridors including key supply and demand forces that underpin intermodal service and routing options, the impact of continued Asian containerized trade growth, and corridor improvement initiatives at Texas seaports contemplating future container operations (Harrison et al. 2010; Harrison et al. 2006; Harrison et al. 2005). The American Transportation Research Institute examined corridors to try to identify the best methods to measure freight performance along the nation's highways. That study concluded that positioning data obtained from individual trucks (such as GPS data) could be used to find the average speed along the corridor, which might be a good metric for the corridor's overall performance. (Jones, Murray, & Short, 2005). Monios and Lambert (2011) identified specific types of corridors and examined the issues relevant to stakeholders, which have influenced the emergence and continuation of those corridors. The study examined corridors connecting seaports with inland intermodal terminals and concluded that crucial to long-term corridor success is an alignment of stakeholder concerns with the available funding sources

(Monios & Lambert 2011). Wilmsmeier, et al. (2011) observed corridor development from the perspective of whether development is driven by inland terminals seeking greater integration with their ports, or by port actors seeking to expand their hinterland. This study developed a separate model for either type of development, and looked at three nations with three different levels of government intervention – Sweden, Scotland, and the United States – to determine which model of development is more indicative of reality. This type of analysis, according to the authors, is important in analyzing what role regulation plays in the establishment of a successful transportation corridor (Wilmsmeier et al. 2011).

This report seeks to add to this literature by demonstrating how broad corridor analysis of various modes can be performed using newly-developed tools. A truck-rail intermodal toolkit is used in examining the impact of cargo weight, running speeds, network capacity, or route characteristics on truck and rail movements along freight corridors. Techniques to acquire data to be used by TRIT for simulating line-haul movements are discussed and the model is tested on five mode-competitive trade corridors. In addition, an example analysis examining truck and rail movements along the Gulf Coast megaregion is presented. The methodology described herein can be used in other multistate corridors and serve as an initial assessment of the condition and performance of the national freight network.

Chapter 2. The Truck-Rail Intermodal Toolkit

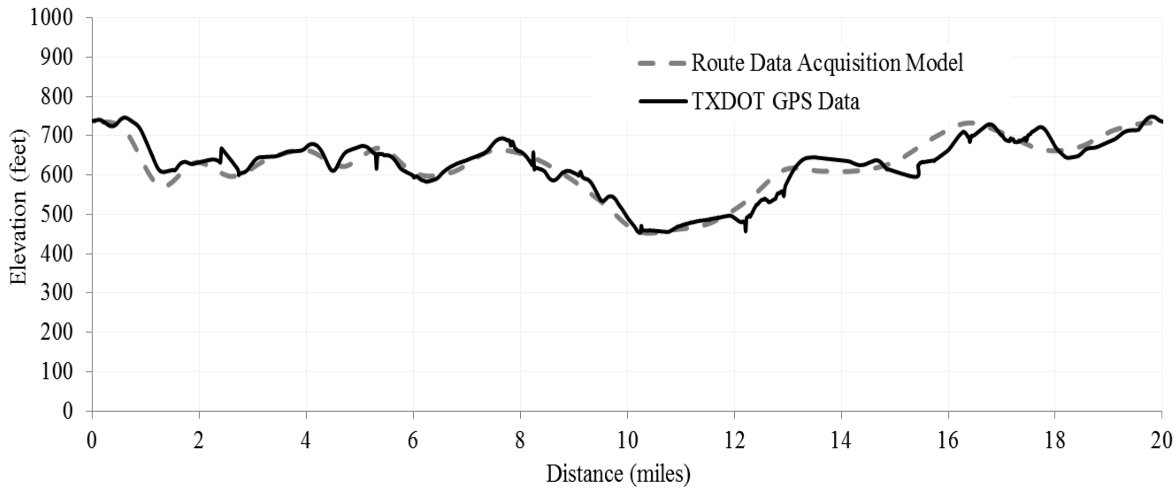
The Truck-Rail Intermodal Toolkit (TRIT) was developed in an earlier study to help planners equally compare truck and rail freight movements for specific corridors and to give insight to some of the associated variables needed when dealing with each mode (Harrison et al. 2013). The toolkit is made up of two main models: 1) the truck operating cost model (CT-Vcost), and 2) the rail operating cost components (CTRail) (Matthews et al. 2011; Seedah et al. 2012). Comparative variables used in both models include the ability to incorporate roadway and track characteristic (elevations and grades), travel speeds, changes in fuel prices, maintenance cost, labor cost and tonnage (Owens et al. 2013)**Error! Bookmark not defined.**. Outputs from both models include fuel consumption and cost, travel time and payload cost per ton-mile. In order to use the truck operating cost model, data is required for roadway elevations, grades, and traffic speed. For the rail operating cost model, data is required for track elevations, grades and posted speeds.

Both roadway and rail track elevation and grade data can be acquired through the use of GIS data sources, which are described in the Route Data Acquisition section of this report. Average truck traffic speed data can be obtained from the National Corridors Analysis and Speed Tool (N-CAST) or similar dataset, and rail speed data can be derived from the Center for Transportation Analysis rail network dataset using the main line class information field.

2.1 Route Data Acquisition

Road and track grades, the rate of change of vertical alignment, affects vehicle speed and vehicle control, particularly for large trucks and definitely for freight rail trains (Federal Highway Administration 2007). Freight rail and other heavy vehicles lose speed on steep grades and tend to consume more fuel when climbing ascending grades.

Route data acquisition requires two GIS data sources: network data and Digital Elevation Models (DEM), which are three-dimensional representations of a terrain's surface. By overlaying the road and rail networks on top of the DEM data file, it is possible to obtain the digital elevations of the network at 0.01 mile using GIS software (Harrison et al. 2013). The data can then be processed and used for determining route elevation profile. An example showing how this methodology compared with post processed mapping grade GPS (two feet horizontal, four feet vertical) field data (Matthews et al. 2011) of a section of northbound Interstate Highway 35, between State Highway 45 and three miles north of U.S. Highway 183, is shown in Figure 2.1.



Elevation Data Comparison (Harrison et al. 2013)

A visual assessment of the two datasets displays few differences in elevations changes. These changes correlate to roadway grade changes that are necessary for accurately determining fuel consumption of heavy duty trucks. A limitation of using the data acquisition model is its inability to accurately capture elevated structures such as overpasses and bridges. The GIS profile data follows the land's topography and therefore elevated structures may not be captured. This limitation can be mitigated by analyzing extreme changes in elevation with a map that shows riverbeds, low-lying spots, bridges and overpasses, and adjusting the points accordingly using available data or linear interpolation where possible. It is therefore recommended that modelers investigate discrepancies in the data as this may be an error in the model's output.

An alternative method for acquiring elevation data is by using Google's Elevation API, which enables querying of elevation data for points along a path (Google Inc. 2013). By converting the network GIS SHP files to KML formats, a simple script can be developed to loop through each point along the path, send a query of each point's latitude and longitude information to the Google Elevation API service, and acquire elevation information for that point. There are; however, usage limits on the number of requests that can be made and this may result in running this script over a longer time period.

2.2 Truck Corridor Operating Cost Analysis

CT-Vcost utilizes a unique vehicle identifier algorithm for data storage and cost calculations. The unique vehicle ID property enables vehicles to retain their identities and data values when dealing with multiple vehicles, vehicle classes, and vehicle fleets. The toolkit's default data is based on verified secondary vehicle cost data and certified vehicle databases such as the EPA's Fuel Economy database and Annual Certification Test Results databases. The toolkit also allows users to change parameters so that cost calculations are specific to any particular situation and can be updated as the economic or technological landscape changes (Matthews et al. 2011; Seedah et al. 2012). Cost categories in the CT-Vcost toolkit include depreciation, financing, insurance, maintenance, fuel, driver, road use fees (e.g., tolls), and other fixed costs such as annual vehicle registration and inspection fees. An improvement to CT-Vcost involves the integration of a fuel economy prediction model developed by Safoutin (2013) that enables CT-Vcost to capture elevation and traffic speed changes along the corridor, thus simulating actual roadway conditions.

2.2.1 The Fuel Economy Model

Safoutin's fuel economy model, "computes the power and energy that a powertrain must successfully deliver to the wheels of a vehicle in order to make it achieve the velocities contained in a second-by-second driving cycle" (Safoutin 2013). For each time increment, the vehicle's tractive energy and power demands are computed for a drive cycle given the vehicle's mass, cargo weight, drag coefficient, frontal area, rolling resistance coefficient, and other parameters. The total power demand is then used in determining the amount of fuel consumed by the vehicle (Safoutin 2013).

The computation is based on a simple equation-of-motion driving model. The three types of forces opposing a vehicle in motion are the force due to rolling resistance ($\mathrm{F_{RR}}$), the force due to aerodynamic drag ($\mathrm{F_{AD}}$), and the force needed to overcome inertia ($\mathrm{F_{I}}$) - acceleration, deceleration, and traversing a grade. The sum of all three forces is equal to the total force or tractive force ($\mathrm{F_{T}}$) as shown in Equation 1.

$$F_T = F_{RR} + F_{AD} + F_I \qquad \text{(Eq. 1)}$$

For the fuel economy model, the force due to rolling resistance is a function of vehicle mass (m), gravity (g) and the rolling resistance coefficient ($\mathrm{C_{RR}}$) which is a dimensionless quantity that describes resistance to a vehicle's forward motion. Aerodynamic drag is the force that acts on a vehicle's surface caused by moving air and depends mainly on the vehicle's frontal area ($\mathrm{A_{F}}$), density of air (rho), the mean velocity of the vehicle ($\mathrm{V_{m}}$) and the dimensionless drag coefficient ($\mathrm{C_{D}}$). The force due to inertia is a function of the vehicle mass (m), rotational inertia (r), mean velocity ($\mathrm{V_{m}}$), gravity (g), and grade (k). Substituting these variables into Equation 1, the average tractive power demand (Equation 2) that is numerically equivalent to energy demand for one-second time increments, can be represented as Equation 3, where $\mathrm{V_{i}}$is velocity at current time increment and $\mathrm{V_{i-1}}$ is velocity at previous time increment (Safoutin 2013).

$$P_{tr} = (F_{RR} + F_{AD} + F_I) \times V_m \qquad \text{(Eq. 2)}$$

$$P_{tr\ i} = \left[mgC_{RR} + \frac{1}{2}\rho C_D A_F \left(\frac{V_i + V_{i-1}}{2}\right)^2 + mr(V_i + V_{i-1}) + mg(\sin k_i)\right]\left(\frac{V_i + V_{i-1}}{2}\right) \qquad \text{(Eq. 3)}$$

Distinguishing between various driving modes such as positive acceleration, cruising, deceleration, and braking, the energy and power demands are computed for each time increment. The total power demand for the trip ($\mathrm{P_{Tot}}$), total distance travelled (D), the Fuel Heating Value (FHV), average engine efficiency (η_e) and average drivetrain efficiency (η_d) can then be used to determine the fuel economy of the vehicle for the trip using Equation 4 where D is in miles, FHV is in btu/gal, and $\mathrm{P_{tot}}$ is in Joules.

$$FE = \left(\frac{D \times \mathrm{FHV}}{P_{Tot} \times 9.48E^{-4}}\right) \eta_e \eta_d \qquad \text{(Eq. 4)}$$

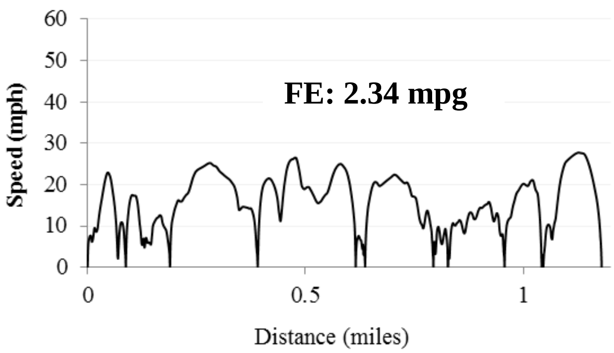
2.2.2 Model Testing

To validate the fuel economy model for trucks, three Environmental Protection Agency (EPA) dynamometer drive schedules were used (US EPA 2012). The schedules were chosen to represent three types of traffic conditions - congested, moderate and free flow. The drive cycles were converted from time versus speed graphs to speed versus distance graphs, which is the input required by the fuel economy model. Additional vehicle input data for the model include the following.

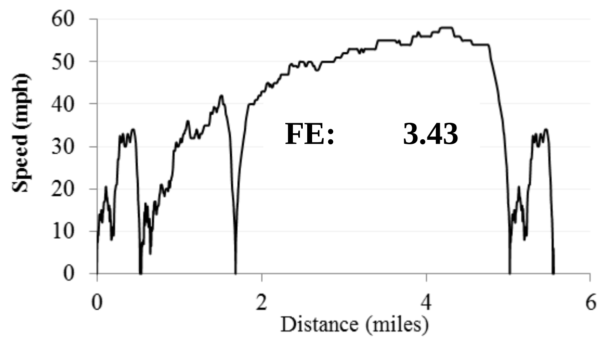
- Cargo Weight: 50,000 lbs.
- Vehicle Tare Weight (including trailer): 30,000 lbs.
- Total Vehicle Mass (m): 80,000 lbs.
- Force of Gravity (g): 32.17405 ft/s^2
- Tire Rolling Resistance Coefficient (C_{RR}): 0.008 (Michelin America 2013)
- Drag Coefficient (C_D):): 0.6 (Wood 2012)
- Density of air (ρ): 0.074887 lbm/ft^3
- Vehicle's Projected Frontal Area (A_F): 115 ft^2
- Rotational Inertia Compensation Factor (r) : 1.04
- Average engine thermal efficiency (η_e): 40% (Gravel 2012)
- Average drivetrain efficiency (η_d): 90% (Caterpillar 2007)
- Fuel Heating Value (FHV) of Diesel: 129,500 btu/gal

The New York City Cycle represents low speed stop-and-go traffic conditions, and recorded a 2.34 miles per gallon (mpg) fuel economy (Figure 2.2a). The Heavy Duty Urban Dynamometer Driving Schedule, which also represents city driving conditions but with fewer stops, resulted in a 3.43 mpg fuel economy (Figure 2.2b). The Highway Fuel Economy Driving Schedule which represents highway driving conditions under 60 miles per hour (mph) recorded a

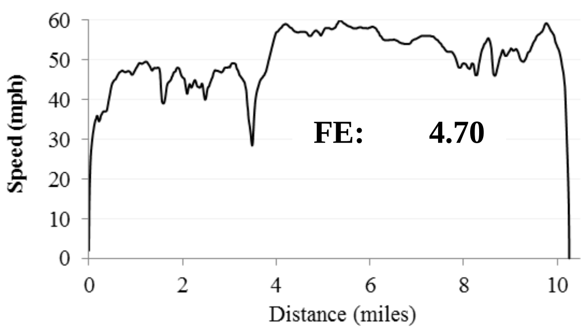
4.70 mpg fuel economy (Figure 2.2c). The results of the three case studies are within reported general fuel economy values of truckers in various driving conditions. The model is very sensitive to the average engine and drivetrain efficiencies specified by the user. Drive train efficiencies vary between 90% for tandem drive axles and 95% for single drive axles. Increasing the drive train efficiency to 95% instead of the default 90%, increases fuel economy by an average of 5.5% for all three drive cycles. Similarly, increasing the engine efficiency from 40% to 45%, at 90% drive train efficiency, will result in an average increase in fuel economy of 12.5%. Other vehicle design variables that influence fuel economy include tire rolling resistance, projected frontal area, and vehicle mass.



(a) New York City Cycle



(b) Heavy Duty Urban Dynamometer Driving Schedule



(c) Highway Fuel Economy Driving Schedule

Validation Results for the Fuel Economy Model using EPA Dynamometer Driving Schedules

2.2.3 Incorporating Corridor Modeling Data

The American Transportation Research Institute, in collaboration with the Federal Highway Administration, launched the Freight Performance Measures Initiative to "… continuously generate[s] and monitor[s] a variety of performance measures related to the nation's freight transportation system." The program utilizes a dataset of "… billions of truck global position system data points, to analyze truck travel data, patterns and performance" (American Transportation Research Institute 2012). Average truck operating speeds from "anonymous private-sector truck data from several hundred thousand unique freight trucks" on the interstate highways and segments of the National Highway System (NHS), are included in the National Corridors Analysis and Speed Tool (N-CAST) dataset. Roadway segments in N-CAST are divided into one-mile segments for each direction and include information such as the location state, route type, route number, and direction of travel, which are all reported in a GIS shape file format. Traffic speed data is sorted into five time bins enabling researchers to determine average speeds on a roadway segment for a given time period. Available time bins include:

- AM – AM Peak (6:00AM – 9:59AM)
- MD – Midday (10:00 AM – 2:59 PM)
- PM – PM Peak (3:00 PM – 6:59 PM)
- OP – Off-Peak (7:00 PM – 5:59 AM)
- AVG – Average of all hours (12:00 AM – 11:59 PM)

CT-Vcost ability to capture roadway traffic speed information enhances its ability to be used for transportation corridor analysis. Traffic speed data from the N-CAST dataset can be incorporated into CT-Vcost and used in the determination of truck operating costs along many of the roadways on the national freight network.

2.3 Rail Corridor Operating Cost Analysis

CT-Rail was developed out of the need for a non-proprietary, extendable and easily incorporable set of rail operating cost models that can be used for multimodal corridor planning (Harrison et al. 2013). Most current rail models are limited in their ability to being incorporated into planning models because they are proprietary and are built to be standalone applications. CTRail allows planners to test rail corridor operations through a combination of train characteristics such as type of car, type of container, cargo weight, number of locomotives, and HPTT (horsepower per trailing ton) ratio, and accounts for operating variables such as train crew costs, maintenance costs, and loading/unloading costs. However, CTRail requires data on track elevation, grades, posted speed and curvature. Using the route data acquisition model, route elevation and grade information for most corridors can be acquired from the CTA Railroad Network which is a representation of the North American railroad system (Oak Ridge National Laboratory 2012). Track speed information can be acquired from railroad employee timetables, or derived from the FRA track class in the CTA network. The FRA track class implies an upper speed limit of a section of rail track but is often lower due to geometry, grades, and grade crossings. In principle, most A- and B-mains in the CTA network are class 4 (60 mph) and C-mains are mostly class 3 (40 mph), with Arizona being the only state with track class marked in the network (Peterson 2013). Rail track curvature can also be derived using tools such as the Curvature Extension for ArcMap which determines, using GIS, the radius of horizontal curves (American Association of State Highway and Transportation Officials 2012).

2.3.1 Train in Motion Calculations

CTRail simulates train motion along a specified route by calculating resistances, determining horsepower required, running speeds achieved, and fuel consumed in small incremental steps along the route (Owens et al. 2013). Locomotive and car resistances are calculated to find the total resistance and posted speed limits are used in determining the minimum required horsepower: HP_{min}, via Equation 5. The train's actual running speed V_i is then solved iteratively using the Equation of Motion defined as $f(V_i)$ and Newton's method (see Equation 6 and 7):

$$\mathrm{HP}_{min} = \frac{\mathrm{R_t}*\mathrm{V}}{375*e} \qquad \text{(Eq. 5)}$$

$$f(V_i) = 308 * HP_{min} - [1.3W_L + 0.6K_{adj}W_C + (20G + 0.8C_V)W + 29A_L + 20K_{adj}A_C]V_i - [0.03W_L + 0.01K_{adj}]V_i^2 - [0.3N_L + K_{adj}KN_C]V_i^{\ 3} \qquad \text{(Eq. 6)}$$

$$V_{i+1} = V_i - \frac{f(V_i)}{f\prime(V_i)} \qquad \text{(Eq. 7)}$$

where

W_L = total weight of all locomotives tons
W_c = total weight of all rail cars in tons
W = total gross weight of the train in tons
G = rail track grade
C_v = rail track curvature
N_L = number of locomotives
N_C = number of rail cars
A_c = number of rail car axles
A_L = number of locomotive axles
V = train speed
i = a section of the rail track
$f'(V_i)$ = derivative of $f(V_i)$
K = equipment drag coefficient which varies based on equipment type
K_{adj} = adjustment factor to modernize the Davis equation $\left(1.3 + \frac{29}{\left(\frac{W}{A}\right)} + bV + \frac{caV^2}{\left(\frac{W}{A}\right)*n}\right)W$
a =cross-sectional area
b = coefficient of flange friction
c = drag coefficient of air

CTRail uses an algorithm similar to the General Automatic Train-controller to set train-handling rules that operate the train at different throttle positions and minimizes the speed error between the current reference speed and the actual train speed (Drish 1995). Fuel consumption is calculated using reported fuel consumption rates (FCR) at the train's current throttle position multiplied by the time the throttle stays at that position – which is determined by the train distance moved divided by running speed (Equation 8). This process is then repeated at small incremental sections along the route.

$$FC = FCR(Throttle\ Position) \times \frac{Distance\ Moved}{V_i} \qquad \text{(Eq. 8)}$$

Chapter 3. Application to Multiple Corridors

In 2009, the Federal Railroad Administration (FRA) released a study that compared rail and truck fuel efficiencies and consumption on competitive corridors (ICF International 2009). The study examined 23 movements consisting of short, medium and long-distance movements, different commodities, and geographic regions. The Truck-Rail Intermodal Toolkit (TRIT) was used in simulating line-haul movements for 5 of the 23 corridors and fuel efficiency output for both truck and rail was compared.

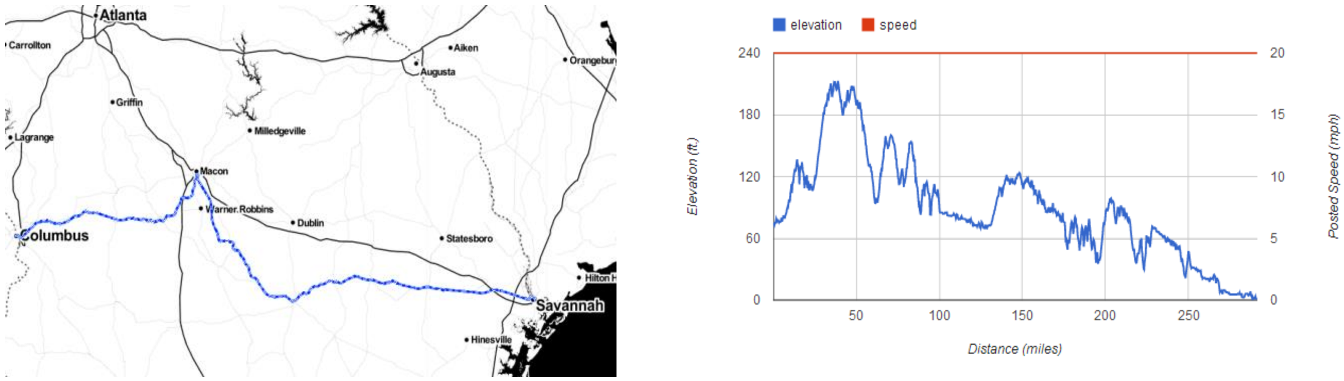
3.1 Rail Movements

Rail movements were compared along 5corridors selected from the FRA study as shown in Figure 3.1. Detailed information on input values for TRIT and the FRA study can be found in Table 3.1. Assumptions used in the comparison include the following.

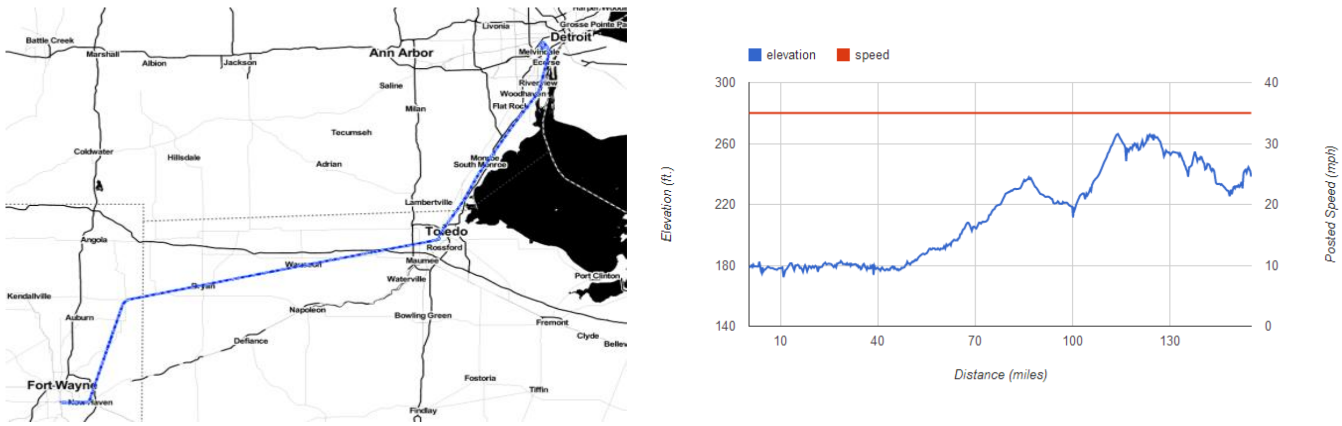
1. The five routes chosen from the FRA study for comparison were all less than 500 miles and were selected based on the intuition that trucks clearly have an advantage over rail in terms of travel speed and time.
2. For each origin and destination point used in TRIT, the routes were selected based on the path that matched closely with the FRA study distances as actual paths used in the FRA study were unknown.
3. The route data acquisition model was used in acquiring track data. Track data includes mileposts, elevations, grades, and posted speed. Posted speeds were set to be constant as actual speed data for the routes were unknown. Rail track curvature was excluded in the analysis.
4. Train data include trailing weight, number of locomotives, horsepower per trailing ton ratio, and locomotive horsepower. The EMD SD70 MAC with 4,000HP was used for all scenarios.
5. The required horsepower for each move was distributed equally amongst 2 or more locomotives, which is not always the case as current technology enables a more efficient distribution of power.
6. Default values from TRIT were used if data was not available. For example, train efficiency was always set at 85% and driving behavior is based on these rules (Drish 1995).

```
IF RECOMMENDED_THROTTLE_POSITION > CURRENT_THROTTLE_POSITION
                  INCREASE THROTTLE POSITION
IF RECOMMENDED_THROTTLE_POSITION < CURRENT_THROTTLE_POSITION
                  DECREASE THROTTLE POSITION
```

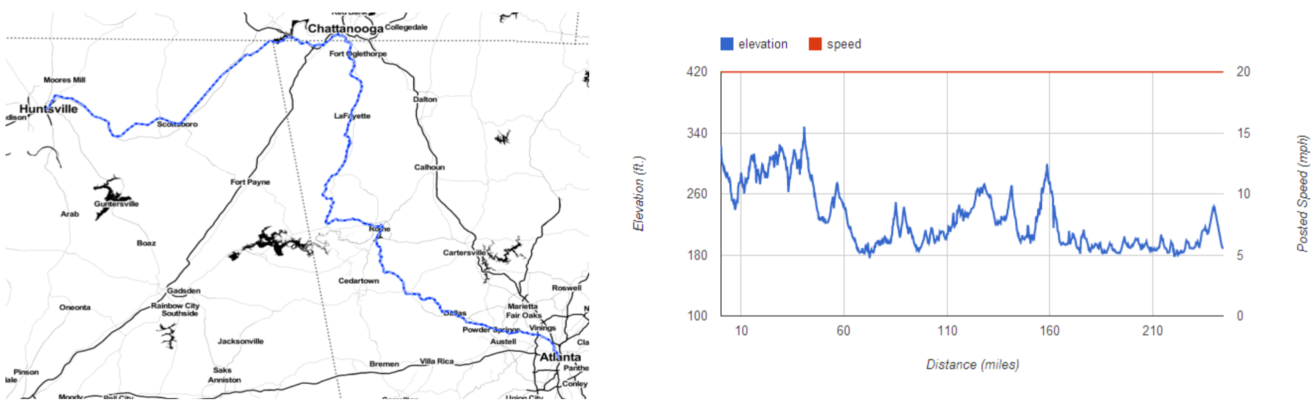
7. Dynamic and air braking behavior is also currently excluded from TRIT because of insufficient data. “Braking” is performed using the throttle positions.



(a) Columbus, GA to Savannah, GA

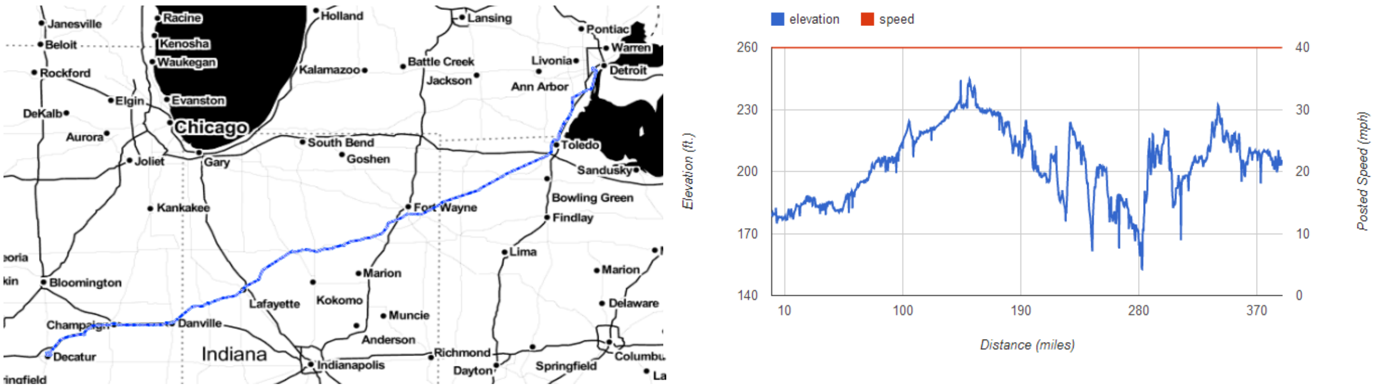


(b) Detroit, MI to Fort Wayne, IN

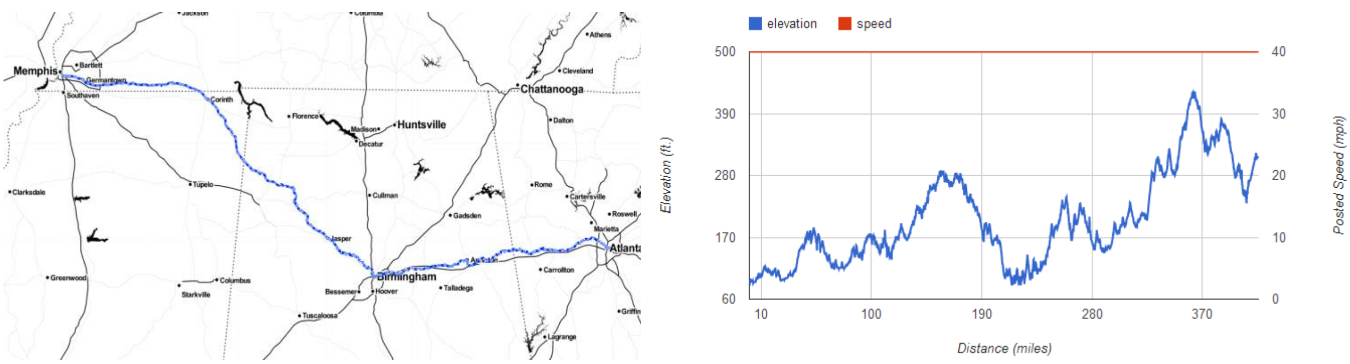


(c) Atlanta, GA to Huntsville, AL

TRIT Truck Route Paths and Speed Profiles



(d) Detroit, MI to Decatur, IL



(e) Memphis, TN to Atlanta, GA

Figure 3.1 (continued): TRIT Rail Route Paths and Speed Profiles

As shown in Table 3.1, differences in distances ranged from 2 miles for the Atlanta-Huntsville route to 34 miles for the Memphis-Atlanta route. HPTT ratios ranged from 1.4 (Detroit-Decatur) to 2.0 (Atlanta-Huntsville). The FRA study reported rail grades using a rating system where the entire length of the route is divided into sections of similar grade and each section given a rating based on scale. This scaled value is then multiplied by the share of miles each section represents out of the entire route. Since the actual paths and sections used in the FRA study were unknown, only the maximum grade for the routes used in TRIT is reported. These grades are thus not comparable and are provided for informational purposes only. Trailing weight here is the weight of only the cargo and cars being moved and excludes the weight of the locomotives.

Table 3.1: Comparison of Rail Movements

Move	Origin	Destination	Train Type	Route Distance (Miles)		Rail Grade[1]		Locomotives		HPTT Ratio[2]
				FRA	TRIT	FRA	TRIT[3]	HP	Number	
1	Columbus, GA	Savannah, GA	Double-Stack	294	291	0.30%	0.69%	4,000	2	1.5
2	Detroit, MI	Fort Wayne, IN	Mixed	133	155	0.11%	0.41%	4,000	2	1.9
3	Atlanta, GA	Huntsville, AL	Mixed	242	244	0.45%	0.58%	4,000	2	2.0
4	Detroit, MI	Decatur, IL	Auto	367	389	0.15%	0.46%	4,000	1	1.4
5	Memphis, TN	Atlanta, GA	Double-Stack	450	416	0.45%	1.09%	4,000	2	1.9

Move	Cars		Trailing Weight (tons)	Load (tons)		Average Speed (mph)		Total Fuel Consumed (gallons)		Trailing Weight-mile per Gallon		Fuel Efficiency (Payload ton-miles per gallon)	
	Type[4]	**Number**		**Tare**	**Payload**	**FRA**	**TRIT**	**FRA**	**TRIT**	**FRA**	**TRIT**	**FRA**	**TRIT**
1	DS	40	5,508	2,537	2,971	18	20	2,166	1946	747	824	384	444
2	G	36	4,116	1,362	2,754	31	34	1,217	1134	450	563	301	377
3	G	85	4,026	978	3,048	17	18	2,653	2378	367	413	278	313
4	A	43	2,903	2,168	735	27	28	1,729	1805	616	626	156	159
5	DS	39	4,243	2,611	1,632	29	36	3,249	2611	588	676	226	260

[1] The FRA study utilizes a scalar rating system where each route is divided into sections of similar grade. This scaled value is then multiplied by the percentage of total miles in each route section. Further details of the Grade Severity Rating scale can be found in Exhibit C-1 of the FRA report.

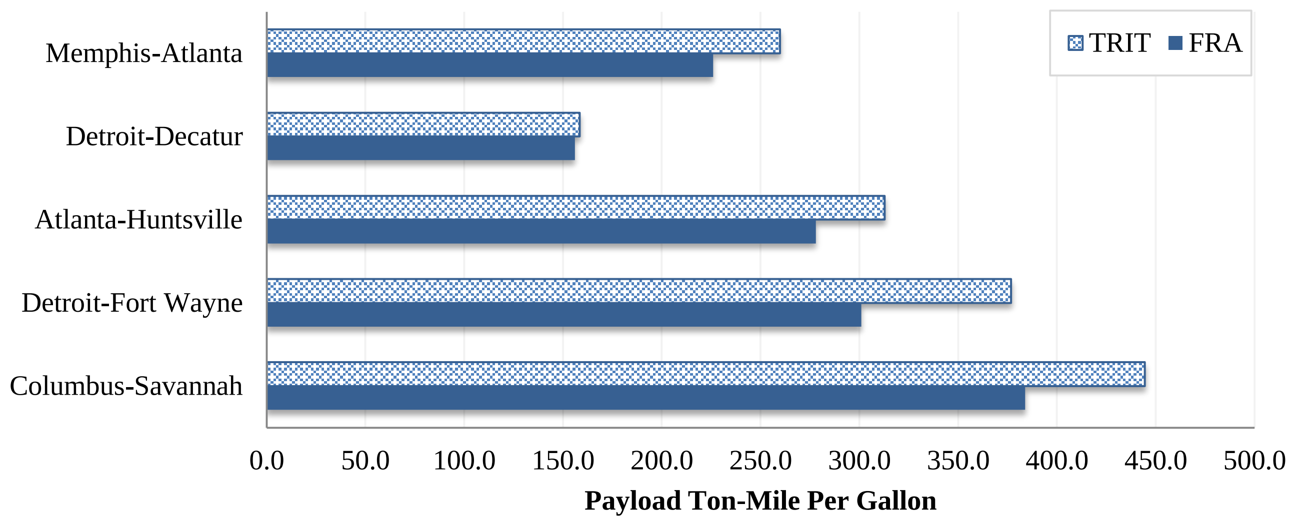
[2] Horsepower per Trailing Ton

[3] Denotes maximum grade along route

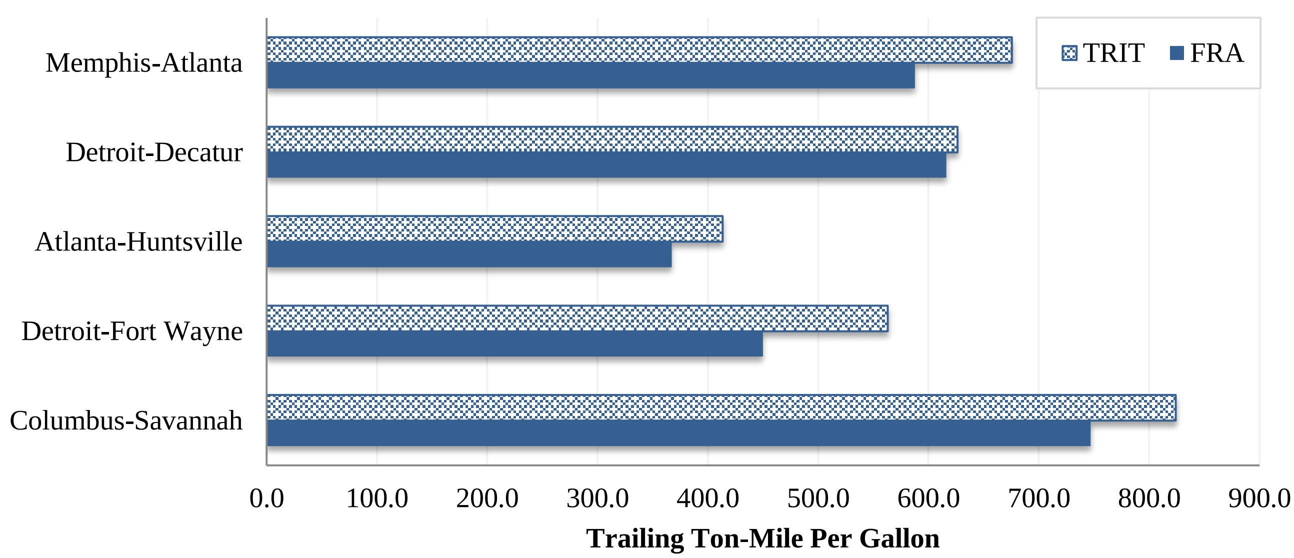
[4] A = Auto Rack, DS = Double-stack, G = Gondola

3.1.2 Discussion of Results

Table 3.1 and Figures 3.2 and 3.3 show that output from TRIT performed relatively well for all the routes analyzed considering the data limitations and assumptions used in the model. Calculated errors for payload ton-miles per gallon were 13.60% for Columbus-Savannah, 20.11% for Detroit-Fort Wayne, 11.14% for Atlanta-Huntsville, 1.59% for Detroit-Decatur, and 13.02% for Memphis-Atlanta.



Comparison of Rail Payload Ton-Mile Per Gallon



Comparison of Rail Trailing Ton-Mile Per Gallon

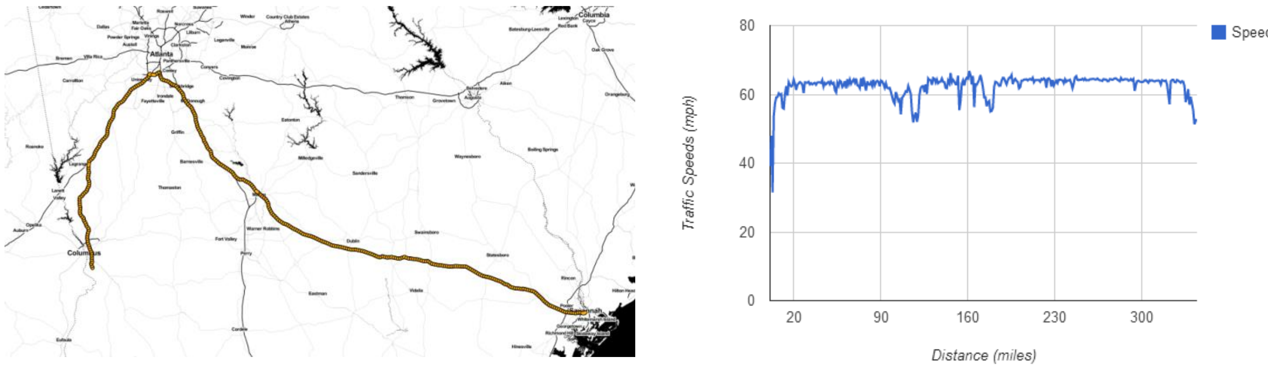
For double-stacked movements, model’s fuel efficiencies were 444 and 260 compared to 384 and 226 ton-miles per gallon from the FRA study. For gondolas, the model’s fuel efficiencies were 377 and 313 compared to 301 and 278 ton-miles per gallon from the FRA study. For the single auto rack movement from Detroit to Decatur, the model’s fuel efficiency was 159 compared to 156 ton-miles per gallon from the FRA study.

Reasons for the errors include differences in path characteristics (i.e. distance and grades), exclusion of curvature, different locomotive types and differences in travel speeds. On average, the travel speeds for TRIT were higher than that of the FRA study with differences ranging from 1 mile per hour (mph) for Detroit-Decatur to 7 mph for Memphis to Atlanta.

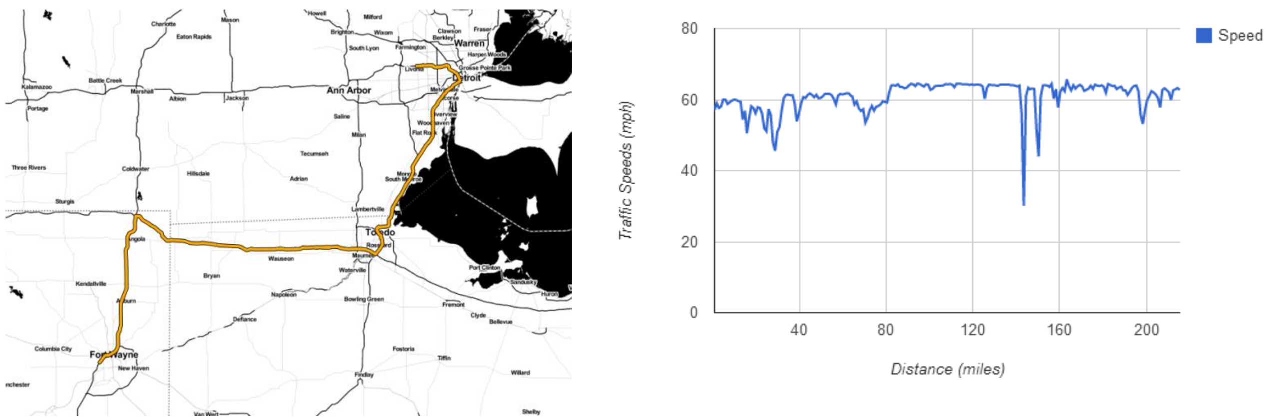
3.2 Truck Movements

Similar to rail movements, truck movements were compared along the same 5 corridors from the FRA study. Information on input values for TRIT and the FRA study can be found in Table 3.2 and assumptions used in the comparison include the following.

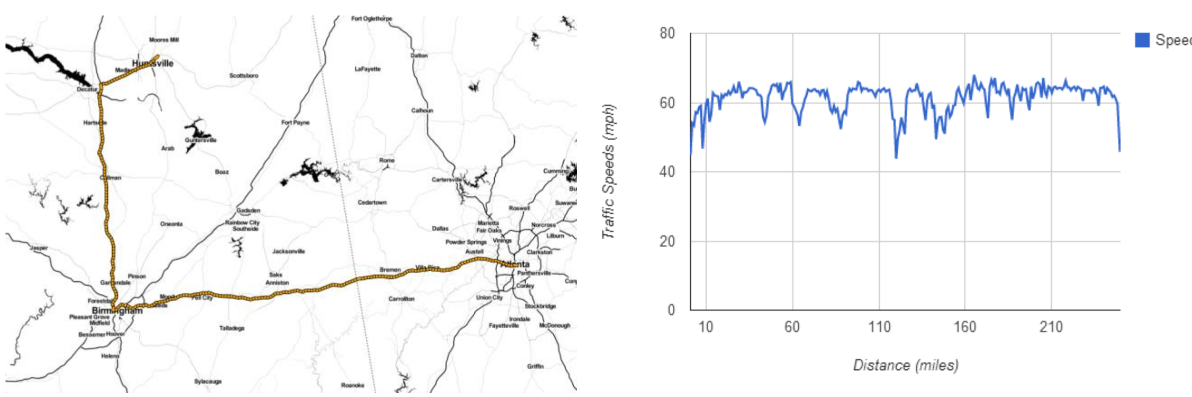
1. The five routes chosen for comparison were selected based on distances for which trucks clearly have an advantage in terms of speed and travel time.
2. For each route’s origin and destination points, routes were selected based on distance that matched closely with the FRA study distances since actual paths used in the FRA study were unknown.
3. Roadway data includes distance and speed information. Grade data was excluded in this comparison but roadway elevation data can be acquired using methods described in the route data acquisition model.
4. Roadway speed information is from the most recent release of the N-CAST database, dated June 2012.
5. Truck engine and drive train efficiencies were set at 25% and 82.5%, respectively, for all routes.



(f) Columbus, GA to Savannah, GA

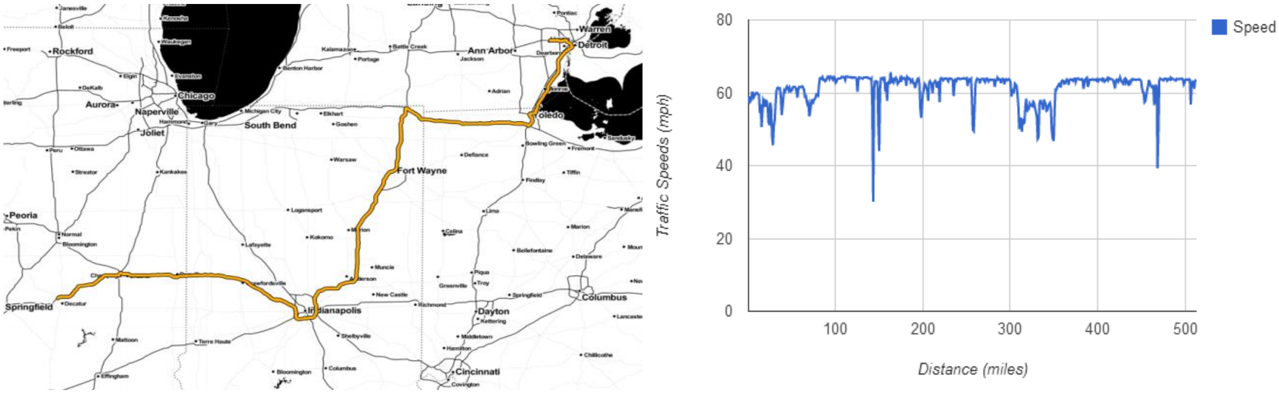


(g) Detroit, MI to Fort Wayne, IN

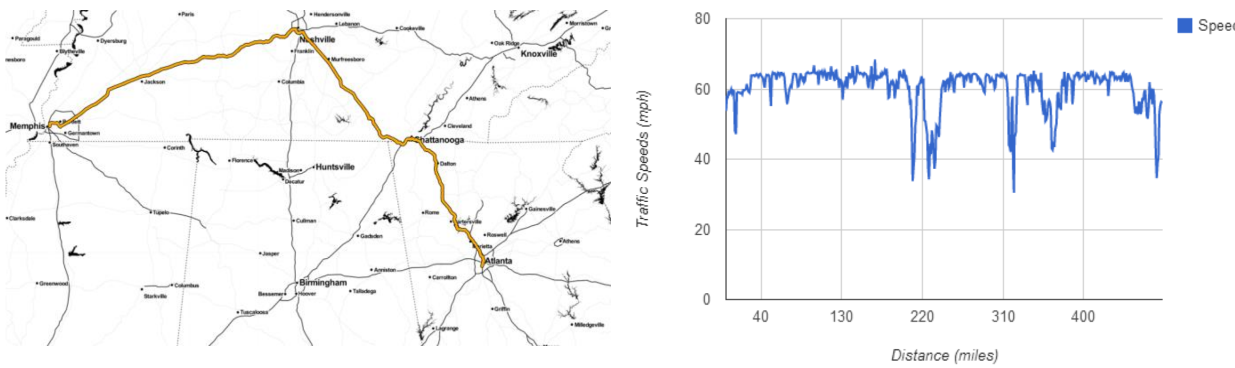


(h) Atlanta, GA to Huntsville, AL

TRIT Truck Route Paths and Speed Profiles



(i) Detroit, MI to Decatur, IL



(j) Memphis, TN to Atlanta, GA

Figure 3.4 (continued): TRIT Truck Route Paths and Speed Profiles

Table 3.2: Comparison of Truck Movements

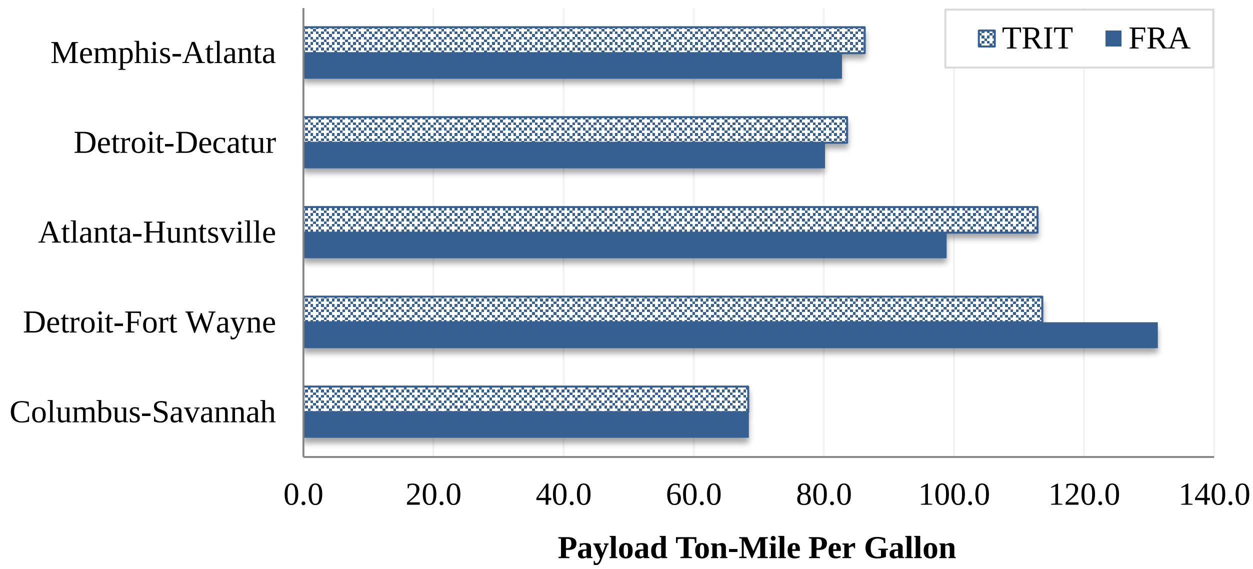
Move	Origin	Destination	Commodity	Route Distance (Miles)	
				FRA	TRIT
1	Columbus, GA	Savannah, GA	Intermodal	330	341
2	Detroit, MI	Fort Wayne, IN	Waste/Scrap	197	214
3	Atlanta, GA	Huntsville, AL	Waste/Scrap	239	247
4	Detroit, MI	Decatur, IL	Motorized Vehicles	326	508
5	Memphis, TN	Atlanta, GA	Intermodal	447	483

Move	Load (tons)		Average Travel Speed (mph)[5]	Total Fuel Consumed (gallons)		Fuel Economy (miles per gallon)		Fuel Efficiency (Payload ton-miles per gallon)	
	Tare	**Payload**	TRIT	FRA	TRIT	FRA	TRIT	FRA	TRIT
1	14	11	62.4	53	55	6.2	6.2	69	68
2	14	24	61.0	36	45	5.4	4.7	131	114
3	14	24	61.4	58	53	4.1	4.7	99	113
4	15	15	61.3	61	91	5.4	5.6	80	84
5	14	15	61.3	81	84	5.5	5.8	83	86

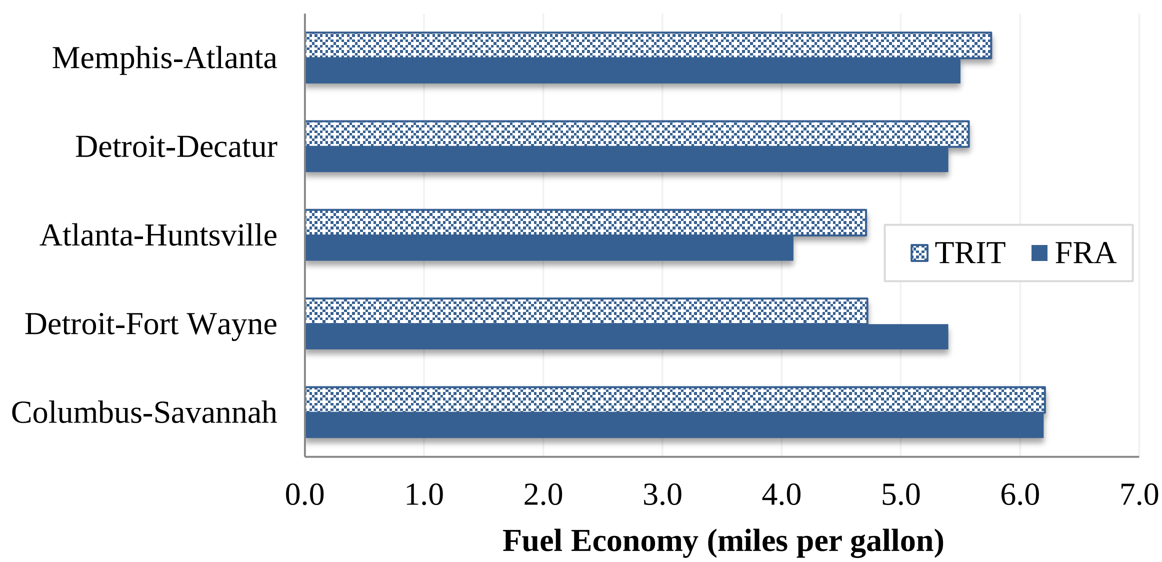
[5] Average travel speed was not reported by the FRA study.

3.2.1 Discussion of Results

Table 3.2 and Figures 3.4 and 3.5 show that truck movements performed relatively better than rail movements when the model's theoretical values are compared with values obtained from the FRA study. This can be attributed to the fewer number of variables used in the analysis of truck movements. Truck fuel efficiency tends to be very sensitive to average truck engine and drive train efficiencies. These were set to 25% and 82.5%, respectively, for all trips to adopt consistency in the analysis. Should any of these efficiency values be varied for each route, it is possible to achieve very similar results as the FRA study.



Comparison of Truck Payload Ton-Mile Per Gallon



Comparison of Truck Fuel Economy

Calculated errors for payload ton-miles per gallon were 0.2% for Columbus-Savannah, 13.5% for Detroit-Fort Wayne, 14.1% for Atlanta-Huntsville, 4.3% for Detroit-Decatur, and 4.2% for Memphis-Atlanta. Truck fuel economy ranged from 4.71 to 6.21 miles per gallon. The largest difference in fuel economy was for the Detroit-Fort Wayne route, which the model recorded a 5.6 mpg in comparison to the FRA value of 5.4 mpg. Reasons for errors include differences in distance travelled, vehicle types and travel speeds.

Chapter 4. Gulf Coast Megaregion Corridor Case Study

Megaregions are defined by the Regional Planning Association as “large networks of metropolitan regions linked by environmental systems and geography, infrastructure systems, economic linkages, settlement patterns and shared culture and history” (Regional Plan Association 2006). Although some planners are skeptical as to how this concept might enhance traditional planning, it does merit examination in the context of the freight transportation sector where trucking and rail companies tend to travel much longer distances compared with passenger commutes. Megaregional planning theoretically provides better benefits for freight users than the traditional planning schemes of MPOs. According to Ross et al. (2008), the current system where states or local governments compete for funds can be replaced by inter-jurisdictional cooperation: “planning at an inter-jurisdictional level, with an emphasis on how economic and network interactions are set in a spatial context which could lead to more efficient public investments resulting in increased global economic competitiveness” (Ross et al. 2008). In addition, megaregional planning recognizes the new context in which large-scale regions exist—one of global economic and environmental issues taking place on a larger scale and presents a new way of approaching large-scale transportation systems, green infrastructure, and economic development. It provides an effective strategy for researchers, planners, engineers, politicians, and decision- makers to tackle regional issues, economic development planning, and transportation planning (Ross et al. 2008; Zhang et al. 2007).

Currently, a dozen megaregions lie within the U.S., Canada, and Mexico – although they lack a federal definition to identify them with any precision (Regional Plan Association 2006). The Gulf Coast megaregion identified by Lang and Dhavale (2005) is characterized to be primarily as a goods-driven megaregion that, stretches from Corpus Christi to the Florida Panhandle, and centering centers on the strength of the energy and petroleum industries (Harrison et al. 2012). Major cities within this triangle include Corpus Christi, Houston, Beaumont, Lake Charles, Baton Rouge, New Orleans, and Mobile. This megaregion includes two of the busiest maritime ports in the United States – the Port of Houston and the Port of New Orleans. These ports are major employers within their respective metropolitan areas and provide the infrastructure necessary to the continued growth of the petrochemical industry. This megaregion is also linked by its susceptibility to hurricanes, thus, a megaregional planning approach provides an opportunity to create better plans to protect residents from future hurricanes and devise more efficient disaster response and evacuation systems.

According to data from the Freight Analysis Framework (FHWA 2013), in 2010, the Gulf Coast megaregion accounted for 46% by weight and 43% by value of all flows through the states of Alabama, Louisiana, Mississippi and Texas in 2010. For imports into the four states, the megaregion accounted for 62% of commodities by weight and 38% by value. For exports from the four states, it accounted for 74% by weight and 56% by value all commodities. For domestic flows, the megaregion recorded a 42% by weight and 42% by value of all commodities moved domestically in all four states.

The Gulf Coast megaregion can take advantage of the megaregional planning perspective to facilitate future transportation planning goals by identifying current and future metropolitan transportation links which impact regional goods movements, and their impact on regional freight movement (Seedah & Harrison 2011). Local planning organizations can identify corridors that have an impact on other cities and act swiftly on issues that have a much broader impact on the region's economy than just their locality.

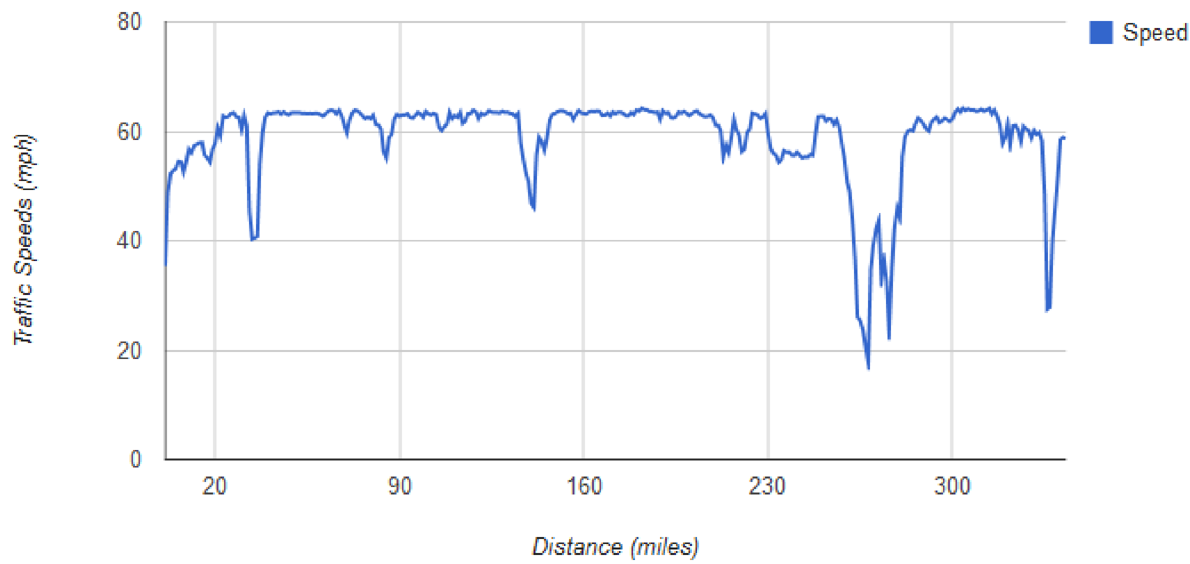
To test this hypothesis, TRIT is used in comparing four different scenarios involving truck and rail movements from Houston to New Orleans. The first two scenarios evaluate truck movements on the IH-10 corridor during PM Peak and Off-Peak periods as defined in the N-CAST database. The last two scenarios evaluate rail movements at average speeds of 20 mph and 50 mph.

4.1 Truck Scenarios

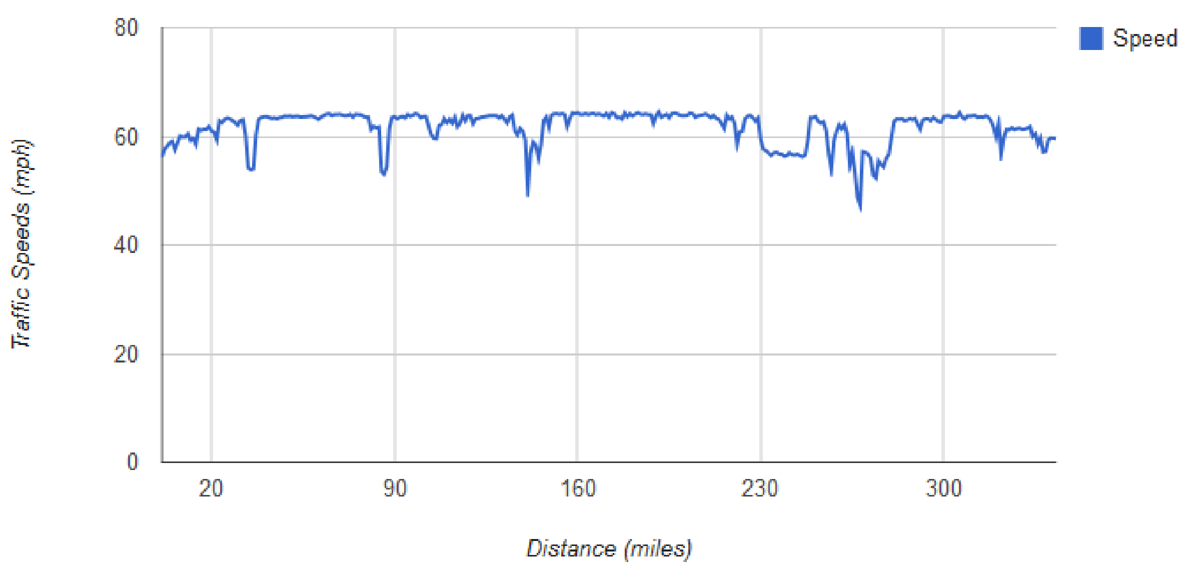
Figures 4.1 to 4.3 demonstrate the truck route path and traffic speed profiles from Houston to New Orleans. The path selected was the shortest path along the IH-10 corridor and was 340 miles long. Speed data is from the June 2012 N-CAST dataset for the PM Peak (3:00 PM – 6:59 PM) and the Off Peak (7:00 PM – 5:59 AM) time periods. Major cities within this corridor include Houston, Beaumont, Baton Rouge, and New Orleans.

PM Peak Traffic for IH 10 Corridor from Houston to New Orleans

As shown in Figure 4.2, traffic congestion or reduced speeds during the PM peak period can be observed in the areas of Houston (mile post 0), Baytown area (mile post 30), Lake Charles (mile post 150), Baton Rouge (mile post 260) and New Orleans (mile post 350). Reduced truck traffic speeds in some of the smaller cities (e.g. Lake Charles and the outskirts of Baton Rouge) can be attributed to lower posted speed limits of less than 60 mph in those cities as Figure 4.3 shows similar traffic patterns during the off-peak period.



PM Peak Traffic for IH 10 Corridor from Houston to New Orleans



PM Peak Traffic for IH 10 Corridor from Houston to New Orleans

Other input values used in the modeling truck movements include the following.

- Cargo Weight: 50,000 lbs.
- Vehicle Tare Weight (including trailer): 30,000 lbs.
- Total Vehicle Mass (m): 80,000 lbs.
- Force of Gravity (g): 32.17405 ft/s^2
- Tire Rolling Resistance Coefficient (C_{RR}): 0.008
- Drag Coefficient (C_D):): 0.6

- Density of air (ρ): 0.074887 lbm/ft^3
- Vehicle's Projected Frontal Area (A_F): 115 ft^2
- Rotational Inertia Compensation Factor (r) : 1.04
- Average engine thermal efficiency (η_e): 25%
- Average drivetrain efficiency (η_d): 82.5%
- Fuel Heating Value (FHV) of Diesel: 129,500 btu/gal
- Diesel Price: $3.50
- Annual Mileage: 100,000 miles each year for 10 years
- Annual Maintenance Cost: $14,600
- Driver wage: $0.53 per mile
- Depreciation: 20% first year, 15 % subsequent years
- New Vehicle Price: $120,000
- Financing: $80,000 down payment, 36-month loan, interest rate of 4.55%
- Insurance: $5,500 a year
- Registration and Permit Fees: $2,300 a year

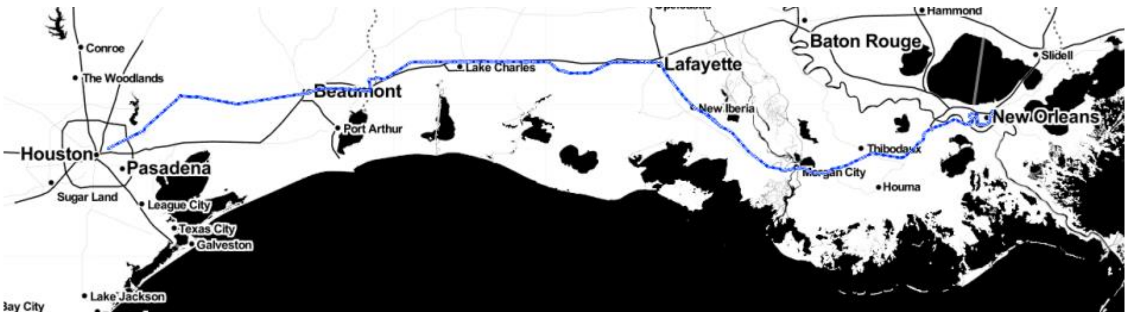
Table 4.1: Model Output for Truck Scenarios

Parameter	PM Peak Period	Off-Peak Period
Distance traveled	**340 miles**	**340 miles**
Gross thermal fuel economy	**22.36 mpg**	**21.93 mpg**
Net Fuel Economy (engine 25.0%, drivetrain 82.5%)	**4.61 mpg**	**4.52 mpg**
Total fuel consumed	**73.72 gallons**	**75.18 gallons**
Total travel time	**5.78 hours**	**5.51 hours**
Average travel speed	**58.9 mph**	**61.7 mph**
Fuel Consumed (payload ton-mile per gallon)	**115.30**	**113.06**
Fuel Consumed (trailing ton-mile per gallon)	**184.48**	**180.90**
Payload ton-mile costs:		
Fuel	**$0.0304**	**$0.0310**
Labor	**$0.0212**	**$0.0212**
Maintenance cost	**$0.0058**	**$0.0058**
Insurance	**$0.0022**	**$0.0022**
Financing	**$0.0018**	**$0.0018**
Depreciation	**$0.0015**	**$0.0015**
Permits/licenses	**$0.0009**	**$0.0009**
Total	**$0.0637**	**$0.0643**
Fuel cost per mile	**$0.76**	**$0.77**
Total cost per mile	**$1.59**	**$1.61**

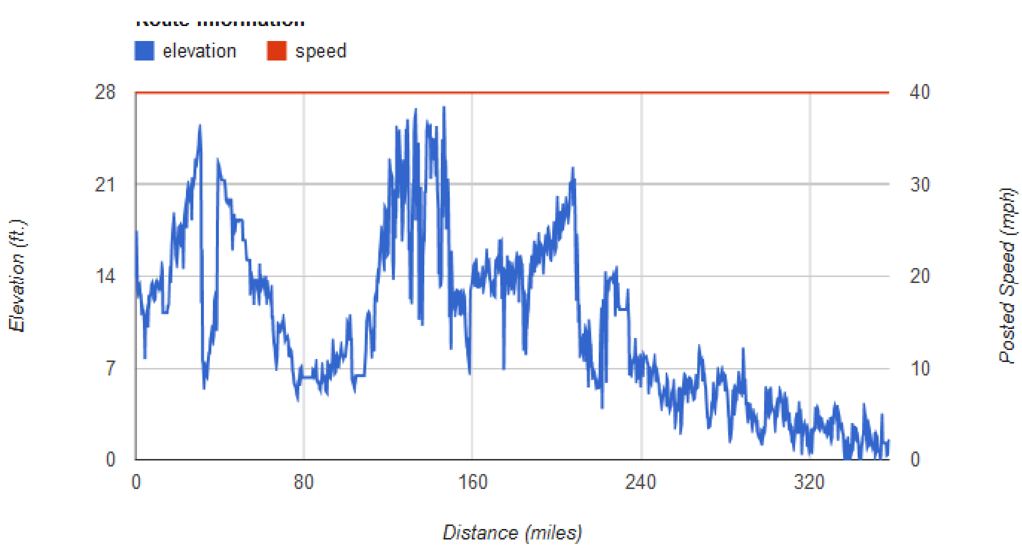
Table 4.1 shows little difference in overall travel time, fuel consumption, and vehicle operating costs along the IH-10 corridor from Houston to New Orleans. This can be attributed to the relatively modest congestion along the corridor between the two cities, with Baton Rouge being the only choking point where traffic speeds were sometimes as low as 20 mph during the PM peak period. Total fuel consumed during the off-peak period was 75.18 gallons compared to 73.72 gallons recorded for the PM peak period. The slightly higher fuel consumption for the off-peak period can be attributed to the higher average traveling speed of 61.7 mph compared to the 58.9 mph experienced during the PM peak period. Fuel remained the highest operating cost for both scenarios, making up approximately 48% of total payload cost per ton-mile.

4.2 Rail Scenarios

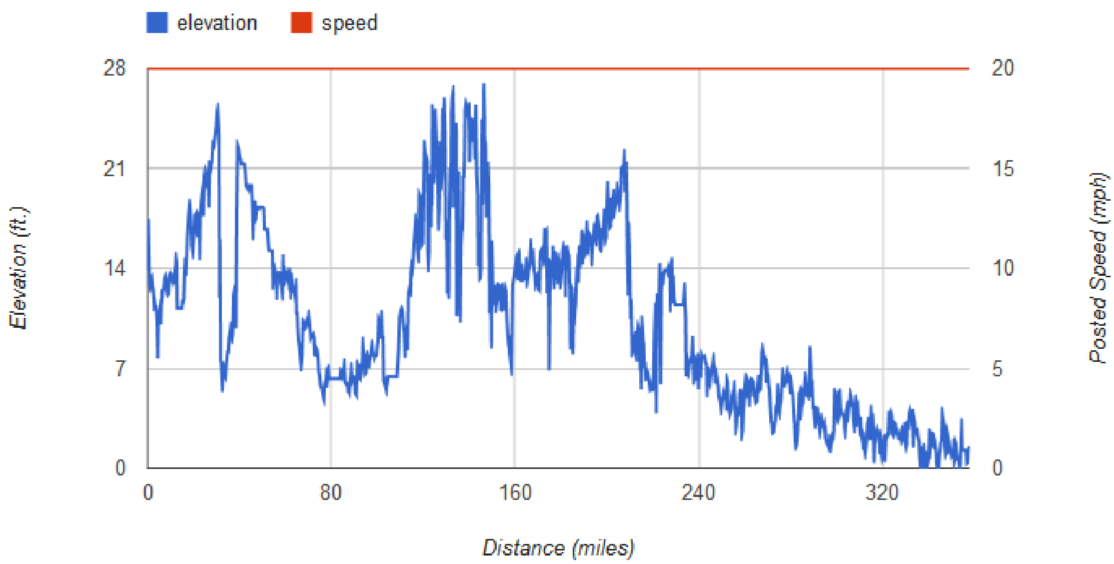
Figures 4.4 to 4.6 illustrate the rail route, elevation profiles, and posted speeds from Houston to New Orleans. The path selected was 358 miles long and the cities along the corridor include Houston, Beaumont, Lafayette, Morgan City, and New Orleans. 40 mph and 20 mph posted speed limits were tested as shown in Figures 4.5 and 4.6, respectively.



Selected Rail Route from Houston to New Orleans



40 mph posted speed limit from Houston to New Orleans



20 mph posted speed limit from Houston to New Orleans

A summary of input values are as follows.

- Distance of route: 358 miles
- Tare weight of one 40-ft container: 4.2 tons
- Rail car: 53 feet double-stack car weighing 31 tons
- Payload weight per container: 25 tons
- Number of containers: 120
- Utilization ratio: 100%
- Engine Efficiency: 85%
- 2 EMD SD 70MAC locomotives with 4,000 HP each
- Number of crew members: two
- Average crew wage rate per mile: $1.53
- Fuel price: $3.50/gal,
- Track maintenance: $0.0020 per gross ton-mile – calculated using reported repair and maintenance operating expenses and gross ton-miles by five Class 1 Railroads in 2011 (Owens et al. 2013)
- Car maintenance: $0.13 per mile
- Locomotive maintenance: $2.21 per mile
- Depreciation: $2,100,000 locomotive and $70,000 per rail car for 20 years with 10% salvage value
- Terminal Loading Cost: $75, Unloading Cost: $75
- HPTT ratio: 1.8

Table 4.2: Model Output for Rail Scenarios

Parameter	20mph posted speed	40mph posted speed
Distance traveled	**358 miles**	**358 miles**
Train length	**3,180 feet**	**3,180 feet**
Trailing weight	**5,964 tons**	**5,964 tons**
Total fuel consumed	**2,828 gallons**	**3,446 gallons**
Total travel time	**17.72 hours**	**10.29**
Average travel speed	**20.19 mph**	**34.95**
Fuel consumed (payload ton-mile per gallon)	**455.28**	**368.82**
Fuel consumed (trailing ton-mile per gallon)	**754.25**	**611.01**
Payload cost per ton-mile:		
Fuel	**$0.00769**	**$0.00949**
Labor	**$0.00085**	**$0.00085**
Terminal Operations	**$0.01398**	**$0.01398**
Maintenance	**$0.00709**	**$0.00709**
Depreciation	**$0.00030**	**$0.00017**
Total	**$0.03700**	**$0.03868**

Table 4.2 shows the impacts of posted speed limits on the rail operations along the rail corridor from Houston to New Orleans. Despite an increase in fuel consumption for the 40 mph posted speed, which can be attributed to higher operating throttle positions, travel time decreased by as much as 7.43 hours. Total payload cost per ton-mile was 0.1 cent higher for the 40 mph train, which is much more competitive to trucking than the 20 mph train. It is also to be noted that faster trains do result in loss of track capacity, especially for single-tracked lines, thus there may be other indirect costs associated with running the slightly faster train on the overall network, which is not being captured in the model. Comparing truck and rail payload costs per ton-mile, it is shown that rail is economically more efficient than trucking. Trucks were twice as expensive as rail on a payload per ton-mile basis. However, travel time and speed may be the biggest challenge to rail competiveness. On average, trucks are 4.51 hours faster than rail, even in congested conditions along the corridor.

Chapter 5. Conclusions

This study was a response to the FHWA 2012 Moving Ahead for Progress in the 21st Century (MAP-21) legislation which established a national freight policy to improve the condition and performance of the national freight network. Key modeling activities needed to identify and assess the condition and performance of major trade gateways and national freight corridors are limited by current data which are unavailable, outdated, or insufficient for analysis. The study offers a contribution for planners evaluating modal corridors—a truck-rail intermodal toolkit (TRIT) that examines freight movement along corridors based on mode and route characteristics. The toolkit includes techniques to acquire data for simulating line-haul movements, and models (CT-Vcost and CT-Rail) to evaluate multiple freight movement scenarios along corridors. Example analyses comparing the model's output with five truck and rail movements published in an FRA study were presented. In addition, a case study of the Gulf Coast megaregion corridor examined truck and rail movements along the IH-10 corridor.

Model output from TRIT performed relatively well for rail movements when compared with data from the FRA study. Calculated errors for payload ton-miles per gallon were 13.60% for Columbus-Savannah, 20.11% for Detroit-Fort Wayne, 11.14% for Atlanta-Huntsville, 1.59% for Detroit-Decatur, and 13.02% for Memphis-Atlanta. For double-stacked movements, the model's fuel efficiencies were 444 and 260 compared to 384 and 226 ton-miles per gallon from the FRA study. For gondolas, the model's fuel efficiencies were 377 and 313 compared to 301 and 278 ton-miles per gallon from the FRA study. For the single auto rack movement from Detroit to Decatur, the model's fuel efficiency was 159 compared to 156 ton-miles per gallon from the FRA study. Reasons for the errors include differences in path characteristics (i.e. distance and grades), exclusion of curvature, different locomotive types and differences in travel speeds. On average, the travel speeds for TRIT were much higher than that of the FRA study with differences ranging from 1 mile per hour (mph) for Detroit-Decatur to 7 mph for Memphis to Atlanta.

Similar to rail movements, truck movements were compared along the same corridors and performed relatively better than rail movements when the model's theoretical values are compared with values obtained from the FRA study. This can be attributed to the fewer number of variables used in the analysis of truck movements, and truck fuel efficiency was found to be very sensitive to average truck engine and drive train efficiencies. These were set to 25% and 82.5%, respectively, for all trips to adopt consistency in the analysis. Should any of these efficiency values be varied for each route, it is possible to achieve very similar results as the FRA study. Calculated errors for payload ton-miles per gallon were 0.2% for Columbus-Savannah, 13.5% for Detroit-Fort Wayne, 14.1% for Atlanta-Huntsville, 4.3% for Detroit-Decatur, and 4.2% for Memphis-Atlanta. Truck fuel economy ranged from 4.71 to 6.21 miles per gallon. The largest difference in fuel economy was for the Detroit-Fort Wayne route, which the model recorded at 5.6 mpg in comparison to the FRA value of 5.4 mpg. Reasons for errors include differences in distance travelled, vehicle types, and travel speeds.

The IH-10 Gulf Coast megaregion corridor analysis from Houston, Texas to New Orleans, Louisiana, determined that congested vehicular traffic conditions along the corridor did not heavily influence the cost, travel time and overall operations of truck movements. There was little difference in overall travel time, fuel consumption, and vehicle operating costs when PM peak traffic condition were compared to off-peak traffic conditions. This can be attributed to the relatively modest current congestion along the corridor between the two cities with Baton Rouge being the only choking point where traffic speeds were sometimes as low as 20 mph during the PM peak period.

Rail movement along the same corridor from Houston to New Orleans was found to be heavily influenced by posted speed limits. Despite an increase in fuel consumption for the 40 mph posted speed travel time decreased by as much as 7.43 hours. Trucks were found to be twice as expensive as rail on a payload per ton-mile basis; however, travel time and speed may be the biggest challenge to rail competiveness along the corridor.

The overall results are sufficiently positive to position the work to be more thoroughly tested in state DOT/MPO planning activities. Three initiatives are recommended. The model should be evaluated using Class 1 railroad data to build on the insight gained from the FRA data. Second, it should be tested in more detail on an additional corridor, such as a long section of IH-35 that carries NAFTA freight and where both rail and trucking compete for business. The Texas DOT does not have sufficient funding for IH-35 expansion in the face in increasing U.S. trade with Mexico and rail intermodal operations could mitigate growth in truck movements. Finally, the two activities just described would act as a bridge by facilitating a dialog between researchers, modal providers and transportation planners. It could measure performance and identify bottlenecks where targeted investments would yield a high return on the scarce resources currently available for highway investments.

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