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Towards a Fair and Transparent Fuel Surcharge Mechanism in Truck Transportation: Incorporating Regional Diesel Price Variations and Payload Dependent Fuel Economy

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Abstract

Fuel surcharges (FSC) are widely used in American truck transportation to compensate carriers for fuel price volatility. Current FSC schedules, however, typically rely on a single national average diesel price, even for lanes traversing regions with widely differing fuel costs. This introduces systemic unfairness: carriers may refuel in markets where diesel is cheaper or more expensive than the national average, yet reimbursement remains unchanged, distorting true cost recovery. Trucks account for over 68% of domestic freight tonnage and 73% of shipment value in the United States (Commodity Flow Survey, 2022). Given the geographic diversity of freight movement, FSC reimbursement based on national averages often misaligns with actual regional fuel costs. Diesel prices used in this study are derived from U.S. Department of Energy weekly publications, which provide transparent regional benchmarks. This study extends regional FSC modeling by addressing a second structural limitation of current practice: the assumption of constant fuel economy. Heavy-duty vehicle fuel consumption varies with gross vehicle weight, yet conventional FSC schedules apply a single fuel-efficiency parameter to all shipments. By incorporating a payload-dependent fuel economy relationship into the FSC formula, the model evaluates reimbursement differences across shipments of varying weights in addition to regional price exposure. The proposed framework integrates regional fuel price variation and weight-dependent fuel consumption within the existing surcharge structure. The approach provides a transparent and operationally implementable method to better align fuel reimbursement with actual fuel usage and improve cost allocation between shippers and carriers.

Keywords
Logistics and Transportation, Operations Cost Modeling, Supply Chain Management, Supply Chain Sustainability

1. Introduction

The North American trucking markets first saw the introduction of Fuel Surcharges (FSCs) as a response to the sharp increase of diesel prices. Over time, the FSCs became a standard component of the rating model in transportation through which carriers recovered the diesel cost volatility from shippers. Despite FSCs being commonplace and widely used in the North American trucking market, the method of calculation remains largely unstandardized, with variations from shipper to shipper or from carrier to carrier. The method largely relies on oversimplified assumptions that tend to cause inefficiencies and raise fairness concerns.

Prior research, accepted for presentation at the Institute of Industrial and Systems Engineers Annual Conference, has highlighted the limitations of prevailing FSC structures and proposed a framework that accounts for variation of diesel prices according to the geographical regions that the lane traverses. While this approach improves alignment between fuel reimbursement and actual market conditions, it implicitly assumes uniform fuel consumption across shipments, regardless of payload or route characteristics.

However, in practice, fuel consumption in trucking is strongly influenced by operational factors such as trailer payload and roadway grade. Empirical studies by Franzese and Davidson (2011) show that vehicle fuel efficiency deteriorates as payload increases and varies substantially across flat or mountainous terrain. The omission of the effect of these factors from FSC design may result in systematic inaccuracies even when geographical diesel price variation is accurately reflected.

We refine the traditional geographical FSC framework by accounting for a critical variable often overlooked in industry standards: payload or shipment weight, in terms of Gross Vehicle Weight. Our approach converts non-linear fuel efficiency data into accessible coefficients, providing shippers and carriers with a more realistic and fair cost-recovery mechanism that remains simple enough for broad industrial adoption.

1.1 Objectives

- Extend a geographically indexed fuel surcharge framework, building on the prior work accepted for presentation at the 2026 IISE Annual Conference
- Develop a payload-based fuel efficiency adjustment by translating existing empirical relationships between trailer payload and fuel efficiency (MPG) into standardized, practitioner-friendly coefficients
- Demonstrate the combined impact of geography and payload on fuel surcharge fairness

2. Literature Review

2.1 Fuel surcharges as a freight pricing mechanism

Fuel surcharges (FSC) are widely used in freight transportation contracts to compensate carriers for fluctuations in diesel fuel prices. Motor carriers developed fuel surcharge programs as a mechanism to translate changes in fuel price into a standardized per-mile adjustment to freight rates rather than repeatedly renegotiating base transportation rates (Midwest Transportation Consortium 2007). Because fuel represents a significant portion of operating expenses in trucking, contracts commonly include an automatic adjustment tied to a publicly available diesel price index (Leslie and Murray 2025).

In practice, fuel surcharge tables reference external fuel price benchmarks, most commonly the U.S. Energy Information Administration (EIA) weekly on-highway diesel price series (EIA 2023). Industry discussions acknowledge that such surcharge schedules are designed to simplify administration and stabilize carrier revenue rather than precisely measure fuel consumed on individual shipments (FleetOwner 2011). Similar mechanisms have also appeared in other freight modes, including rail transportation, further demonstrating that fuel surcharges function primarily as pricing instruments rather than engineering measurements of fuel usage (Federal Register 2007).

Because the surcharge converts a fuel price change into a mileage-based adjustment, the calculation implicitly requires an assumed average fuel economy. However, the assumed fuel economy is typically treated as a constant parameter within the surcharge schedule.

2.2 Variability of heavy-duty truck fuel consumption

Transportation engineering research demonstrates that heavy-duty truck fuel consumption is not constant. Fuel use is governed by vehicle resistance forces, including aerodynamic drag, rolling resistance, and vehicle mass (Muster 2000).

Unlike passenger vehicles, trucks transport freight, and therefore efficiency is more appropriately evaluated based on work performed, such as ton-miles of payload moved rather than a single fuel economy value (Woodrooffe 2014). Empirical studies confirm that operating conditions significantly affect fuel consumption. Instrumented Class-8 truck observations show that fuel economy decreases as payload weight increases and declines further when operating on positive roadway grades (Franzese and Davidson 2011). More recent real-world driving analyses similarly demonstrate that payload weight has a measurable impact on fuel consumption under actual operating conditions (Duran et al. 2023). Simulation and dynamometer studies further show that fuel consumption varies approximately linearly with vehicle weight and resistance parameters such as aerodynamic drag and rolling resistance (Wang et al. 2015). Additionally, fuel usage varies with speed and terrain even when advanced vehicle control strategies are used (Taylor et al. 2020).

Collectively, these studies establish that fuel consumption depends on shipment characteristics and operating environment rather than a single representative fuel economy.

2.3 Economic implications of fuel consumption variability

Fuel price is a major determinant of freight operating cost and increases in fuel price directly affect transportation expenses (Gohari et al. 2018). Because freight contracts rely on fuel surcharges to allocate fuel cost risk between shippers and carriers, the surcharge mechanism attempts to approximate fuel usage through a simplified formula. However, the surcharge structure converts fuel price changes into reimbursement using a constant fuel economy assumption, while engineering research shows that fuel consumption varies significantly across loads and operating conditions.

As a result, two shipments traveling the same distance, in the same shipment corridor, but carrying different payloads may consume different quantities of fuel while receiving the same fuel surcharge reimbursement. The surcharge therefore functions as an economic approximation rather than a consumption-based compensation mechanism.

Existing literature addresses two separate topics. Transportation engineering research quantifies how trucks consume fuel under varying operating conditions, while freight transportation practice applies standardized fuel surcharge tables to compensate for fuel price volatility. Despite extensive research on truck fuel efficiency and widespread industry use of fuel surcharges, little research has examined whether fuel surcharge calculations accurately reflect differences in fuel consumed across shipments.

This study bridges that gap by incorporating payload weight into fuel economy estimation for fuel surcharge calculation. The approach links physical fuel consumption behavior to contractual reimbursement.

3. Methods

3.1 Baseline Fuel Surcharge Formulation

Fuel surcharges (FSC) in North American truckload (TL) transportation are commonly implemented through a step-based schedule that converts prevailing diesel prices into a cents-per-mile (CPM) adjustment to the linehaul transportation rate. The schedule specifies a base diesel price below which no fuel surcharge applies and defines incremental diesel price bands above the base price. Each band increases the FSC by a fixed CPM amount. The magnitude of each incremental step is determined by an assumed average fuel efficiency for the vehicle fleet. The relationship between diesel price change and surcharge increment can be expressed as:

$$FSC_{increment} = \frac{\Delta P}{MPG}$$

Where,
ΔP = diesel price change in USD per gallon within surcharge step, and
MPG = Assumed fuel efficiency of truck in Miles Per Gallon
For example, under an assumed fuel economy of 6 mpg, a $0.06 per gallon increase in diesel price corresponds to a 1 cent-per-mile increase in the fuel surcharge. The surcharge schedule is contractually defined and communicated to carriers prior to execution of transportation agreements.

The diesel price input to the schedule is typically obtained from a publicly available benchmark such as the U.S. Energy Information Administration weekly on-highway diesel price series. (Gasoline and Diesel Fuel Update, n.d.) The prior study on regional diesel prices extended this by replacing national average of diesel price with a route specific weighted diesel price to better represent the variation in diesel prices across different geographical regions in the US, to calculate the actual fuel cost recovery for a shipment lane. The weight diesel price is calculated as:

$$P_{weighted} = \sum_{i=1}^{n} w_i P_i$$

Where,
w_i denotes the share of total route miles in region i, and
P_i represents the diesel price in the region in USD
Regardless of whether a national average or weighted regional diesel price is used, the surcharge calculation retains a constant fuel economy parameter. Consequently, all shipments traveling the same distance receive the same fuel surcharge adjustment even if the actual fuel consumed differs due to payload or operating conditions.

3.2 Payload Sensitivity Coefficient

In order to incorporate effects of payload or trailer weight into the fuel surcharge calculation, a relationship between vehicle weight and fuel economy is required. Prior studies demonstrate that the fuel efficiency decreases as vehicle weight increases.

Franzese and Davidson (2011) at the Oak Ridge National Laboratory analyzed real-world Class 8 truck operations using the "Heavy-Truck Duty Cycle" dataset and report decreasing fuel economy across increasing gross vehicle weight ranges. Their dataset includes trucks operating near highway cruise speeds on relatively level terrain and reports fuel economy values for multiple weight intervals. The reported fuel economy declines from approximately 9.2 mpg near 45,000 lbs. Gross Vehicle Weight (GVW) to approximately 7.9 mpg near 66,000–73,000 lbs. (GVW). This trend corresponds to an approximate 8% fuel economy reduction for about a 20% increase in vehicle weight, implying an elasticity near −0.40.

Elasticity measures, if weight changes by X%, how much does MPG change by (in %). For example, according to Franzese and Davidson (2011), if fuel economy decreases from approximately 9.2 mpg to approximately 7.9 mpg, this corresponds to a fuel economy change of -14%. And a weight change of approximately,

$$\%\Delta W \approx \frac{(66{,}000\ to\ 73{,}000) - 45{,}000}{45{,}000} \approx +47\%\ to + 62\%$$

Where,
$\%\Delta W$ means a % change in GVW
Which yields an implied elasticity in the order of:

$$eMPG, W \approx \frac{-14\%}{47\%\ to\ 62\%} \approx -0.30\ to - 0.45$$

Where,
$eMPG, W$ represents the sensitivity of fuel to the GVW
Complementary simulation results from Wang et al. (2015) indicate that a 20% reduction in vehicle weight can reduce fuel consumption by up to 12%, which corresponds to a similar magnitude fuel-economy response, and this corresponds to an elasticity magnitude near −0.60. Together these studies imply a fuel-economy elasticity with respect to weight of vehicle, in the approximate range −0.40 to −0.60. A midpoint value of −0.50 is adopted for the baseline model and evaluated through sensitivity analysis.
To portray this formally,

$$\frac{\Delta MPG}{MPG} \approx eMPG, W \frac{\Delta W}{W}$$

The equation expresses the relationship between changes in vehicle weight and changes to the fuel economy using elasticity. The midpoint value of -0.50 adopted, indicates that a 1% increase in GVW produces an approximate 0.5% decrease in fuel economy.

To convert the elasticity relationship into a usable fuel-economy adjustment, a representative operating condition must be selected. The real-world dataset reported by Franzese and Davidson (2011) provides fuel economy values across weight ranges. A gross vehicle weight near 73,000 lbs. is chosen as the reference condition because it lies within the typical operating range of a loaded Class-8 tractor trailer and corresponds to a reported fuel economy of approximately 7.9 mpg in the dataset. This operating point represents steady highway cruise conditions and is used solely to calibrate the sensitivity of fuel economy to Gross Vehicle Weight.

3.3 Conversion to MPG change per payload increment

Consider an increase of 5,000 lbs. in payload weight. At the representative condition:

$$W = 73{,}000\ lbs.$$
$$MPG = 7.9$$
$$\Delta W = 5{,}000\ lbs.$$

First, we compute the percent increase in total weight:

$$\frac{\Delta W}{W} = \frac{5{,}000}{73{,}000} \approx 0.0685\ (6.85\%)$$

Using the adopted midpoint elasticity $eMPG, W = -0.50$:

$$\%\Delta MPG = -0.50 \times 6.85\% = -3.43\%$$

Now convert the percentage change into an MPG change:

$$\Delta MPG = 7.9 \times 0.0343 \approx 0.27\ (MPG)$$

Therefore, a 5,000 lbs. increase in trailer payload reduces fuel economy by approximately 0.27 mpg under representative highway conditions. Applying the elasticity bounds of (-0.40 to -0.60) produces a range of 0.22 to 0.32 mpg per 5,000 lbs.

4. Data Collection

To ensure realistic operating conditions, representative North American tractor-trailer weight characteristics were obtained from regulatory and industry sources. The federal GVW for a standard five-axle tractor-semitrailer operating on the U.S. Interstate System is 80,000 lbs. (FHWA 2016). This configuration represents the dominant vehicle used in long-haul truckload transportation.

A typical Class 8 truck tractor weighs approximately 17,000 lbs., with an operational range of roughly 10,000–25,000 lbs. depending on sleeper configuration and equipment (U.S. Department of Energy 2010; Driver Resource Center 2023). A standard 48–53 ft dry-van trailer has an empty (tare) weight of approximately 10,000–14,000 lbs. (Schneider 2023). Consequently, an unloaded tractor-trailer combination typically weighs 30,000–35,000 lbs. (Ritchie Bros. Auctioneers 2022).

Given the 80,000 lbs. legal GVW limit, the remaining allowable payload is approximately 45,000 lbs. (ULG Attorneys 2021). Under typical operating conditions, the trailer and cargo therefore account for approximately 75–80% of the total vehicle weight. Because the majority of GVW is attributable to payload rather than the tractor itself, variations in shipment weight materially influence vehicle fuel consumption. This characteristic motivates incorporating payload into the fuel surcharge calculation.

5. Results and Discussion

5.1 Numerical Results

To illustrate the economic impact of payload variation, a comparison was conducted between a 64,000 lbs. shipment and a 79,000 lbs. shipment, representing a 15,000 lbs. difference in gross vehicle weight. The baseline fuel economy is assumed to be 6.5 mpg.

Using the calibrated payload sensitivity coefficient of 0.27 mpg per 5,000 lbs., the 15,000 lbs. increase, reduces fuel economy by 0.81 mpg, yielding a fuel economy of 5.69 mpg at 79,000 lbs. Sensitivity bounds of 0.22–0.32 mpg per 5,000 lbs. result in fuel economy values ranging from 5.84 mpg (low sensitivity) to 5.54 mpg (high sensitivity).
For a $1.00 per gallon diesel price increase, the baseline FSC at 64,000 lbs. is:

$$FSC_{64k} = \frac{1}{6.5} = 15.38\ cents\ per\ mile$$

At 79,000 lbs., the required fuel surcharge ranges from:

- 17.12 cents per mile (low sensitivity),
- 17.58 cents per mile (baseline),
- 18.05 cents per mile (high sensitivity).

The conventional constant MPG schedule therefore underestimates the fuel surcharge for the heavier shipment by 1.74 to 2.67 cents per mile. Under the baseline sensitivity assumption, the deviation is 2.20 cents per mile. For a 1,000 mile shipment, this corresponds to a fuel cost under-recovery of approximately $17–$27 per load for a $1.00 diesel price increase.

These results demonstrate that the constant-MPG fuel surcharge mechanism systematically misallocates fuel cost recovery across shipments with materially different payload weights. The deviation increases proportionally with diesel price changes and shipment distance.

5.2 Graphical Results

The graph below compares the constant-MPG fuel surcharge with the payload-adjusted model across gross vehicle weights from 64,000 lbs. to 80,000 lbs. The constant FSC appears as a horizontal line because reimbursement does not vary with shipment weight. In contrast, the payload-adjusted surcharge increases with vehicle weight as fuel economy declines (Figure 1).

The divergence between the two curves illustrates the mispricing effect. The constant schedule over-recovers fuel cost at lower weights and under-recovers fuel costs at higher weights. The gap widens as weight increases, demonstrating that reimbursement error grows with payload.

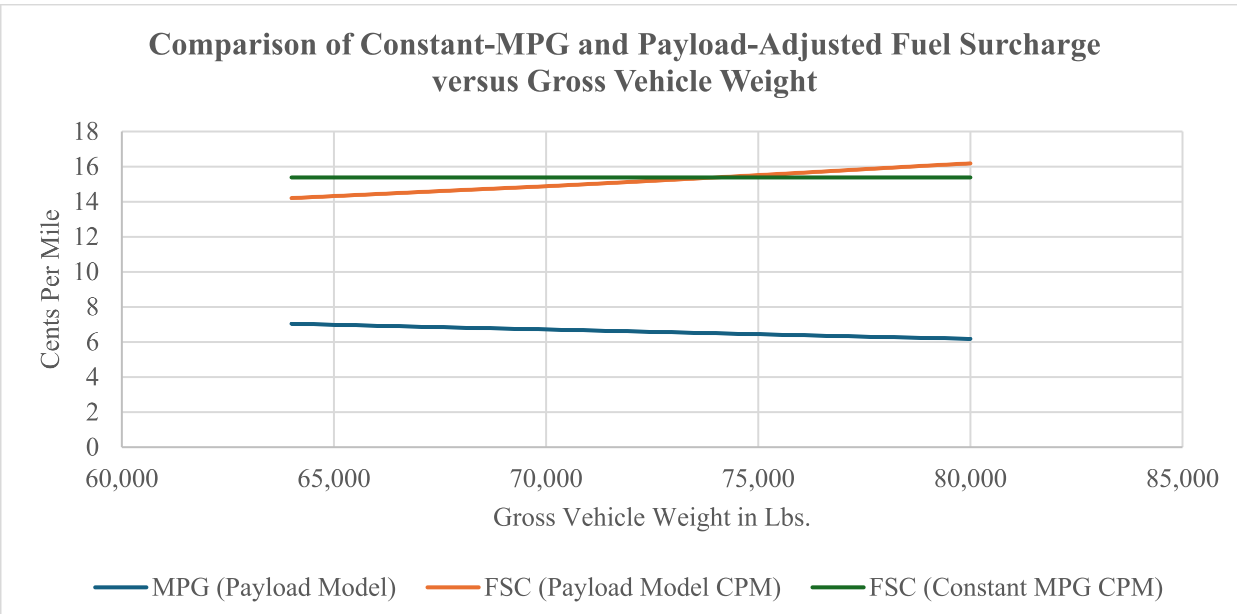

Figure 1. Comparison of Constant-MPG and Payload-Adjusted Fuel Surcharge versus Gross Vehicle Weight

5.3 Proposed Improvements

The proposed improvement is to retain the existing fuel surcharge framework while replacing the constant fuel economy parameter with a payload-adjusted fuel-economy estimate. The modified formulation calculates fuel surcharge as a function of shipment weight by incorporating the calibrated relationship between Gross Vehicle Weight and fuel economy. The structure of the fuel surcharge table remains unchanged, and the diesel price index used in existing contracts can also be maintained.

Implementation requires only shipment weight, which is already captured in shipping documentation and transportation management systems. Also, the shipment weight is often a metric that the shipper can easily control. The method therefore does not require route-level modeling, vehicle telematics, or operational changes. By aligning reimbursement with fuel consumed per mile, the proposed approach improves cost allocation between shippers and carriers while preserving the simplicity of current fuel surcharge practices.

6. Conclusion

Fuel surcharge (FSC) mechanisms in truckload transportation are intended to compensate carriers for diesel price volatility by converting fuel price changes into a per-mile reimbursement. Current FSC schedules use a constant fleet fuel-economy assumption, implicitly treating fuel consumption as independent of shipment characteristics. Prior heavy-duty vehicle studies have already established that fuel economy decreases as vehicle weight increases; this study does not re-estimate that physical relationship. Instead, the published weight–fuel economy relationship is incorporated into the FSC calculation to evaluate reimbursement accuracy.

Applying the weight-dependent fuel economy within the surcharge formula shows that shipments with different payloads require different fuel reimbursement even under the same diesel price change. For a representative comparison between 64,000 lbs. and 79,000 lbs. shipments, the constant-MPG FSC under-recovers fuel cost by approximately 1.74–2.67 cents per mile, corresponding to $17–$27 per 1,000 miles for a $1.00 diesel price increase The results indicate that inaccuracies in FSC reimbursement arise not from the diesel price index used, but from the constant fuel-economy parameter embedded in the calculation. Incorporating a payload-adjusted fuel economy aligns reimbursement with fuel consumed while preserving the structure and simplicity of existing surcharge tables and requiring only shipment weight, which is already known at dispatch.

Future work may extend the approach by incorporating roadway grade, speed variation, or corridor-specific operating conditions. Nevertheless, the present results demonstrate that incorporating a payload dependent fuel economy improves fuel cost allocation between shippers and carriers. When combined with established regional diesel price adjustments, the framework more accurately reflects both where fuel is purchased and how much fuel is consumed. The proposed formulation links established vehicle fuel-consumption research with freight pricing practice while remaining directly implementable within existing surcharge structures.

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Biographies

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Dharini Kanagaraj is a Ph.D. candidate at the Illinois Institute of Technology (IIT), Chicago, where her work focuses on environmental engineering, water quality, and remediation technologies aimed at improving environmental sustainability. Her research involves environmental systems analysis and data-driven approaches to addressing water contamination and related environmental challenges. In addition to her academic research, she contributes to sustainability and environmental remediation initiatives associated with the Chicago Watershed. Her broader interests include sustainable infrastructure systems and analytical approaches to improving efficiency in resource-intensive operations. In this work, she contributes to the analysis of fuel cost allocation in trucking by examining regional diesel price variation and payload-dependent fuel economy, highlighting how improved transparency in fuel surcharge mechanisms can also support more efficient fuel utilization in freight transportation.

Ryan Taylor is a is a supply chain and logistics professional with extensive experience spanning both manufacturing and transportation operations. He earned a Bachelor of Science in Business from Indiana University's Kelley School of Business, where he completed a double major in Supply Chain Management and Marketing. Ryan holds a Certified Supply Chain Professional (CSCP) designation from the Association for Supply Chain Management, underscoring his expertise in end-to-end supply chain strategy and execution. He currently serves as a Senior Logistics Analyst at Asahi Kasei Plastics North America. Prior to his current role, he developed a strong foundation in the trucking industry through multiple operations leadership positions, overseeing large driver fleets, dispatch teams, and high-volume freight movement.