Understanding Freight Vehicle Pavement Impacts: How do Passenger Vehicles and Trucks Compare?

MID-AMERICA FREIGHT COALITION

CFIRE National Center for Freight & Infrastructure Research & Education

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Introduction

With annual logistics costs equal to more than 8 percent of the US GDP,[1] and an average of 64 percent of the nation's freight moving solely on trucks,[2] policy makers and the traveling public often question what impact truck traffic has on the condition and service life of roadway pavements. Both policy makers and the general public often consider this problem in terms of number of cars that could use the facility with the same wear and tear as the average truck. In short, the question becomes this: how many cars could use the roadway before creating the same impact as one average truck?

Rule of Thumb

The number of car equivalent units depends on a given truck's configuration and its load distribution, as well as the pavement type, design, and condition. Given the variability in truck loading, configurations, and pavement types, many state DOTs have studied truck axle weights to better inform roadway design. State DOTs use weigh-in-motion (WIM) stations along roadways to collect vehicle type and weight data. States in turn use the WIM data and roadway characteristics to calculate Equivalent Single Axle Loads (ESALs). ESALs act as a common unit for all roadway loads, which allows for a comparison axle loads among vehicles of different types. A compilation of available state ESAL factors suggests that the wear and tear of one average five-axle truck on flexible pavement equates to approximately 4,000 cars. For rigid pavements, this ratio increases to approximately 6,200 cars for one truck.

Measuring Truck Loads

Given the many factors associated with estimating truck ESALs, we reviewed research reports and engineering design guidance from 2000 to 2014. From these reports we compared the methods and results to identify a reasonable range of values for car equivalents by pavement type. Each study reported ESALs under different sets of assumptions. When possible, we focused on five-axle (FHWA vehicle class 9) trucks traveling on interstate roadways. Total truck ESALs are calculated by summing the ESALs from each axle. Axles will have different ESALs depending on the load each axle bears. Trucks carrying very dense commodities can have much higher ESALs if the weight is not distributed between the axles. Load distribution will directly affect the total ESALs of a truck. For example, trucks carrying overweight loads often add axles to support the load and thereby reduce the ESALs for the load. Table 1 displays a collection of ESAL values derived from state WIM studies and design guidance. An ESAL equal to one is equivalent to an 18,000-pound load on a single axle. Five-axle combination vehicles use tandem axles that lower the total ESALs for the truck configuration, which explains why some ESAL values are near one. Note the difference in ESAL values between the pavement types: rigid (concrete) or flexible (asphalt). Rigid and flexible pavements have different ESAL equations because they react to loads differently.

Table 1: 5 Axle Combination Truck ESALs

	Observed within State ESAL Values								
Pavement Type	AL[3]	AZ[4]	CO[5]	IN[6]	MN[7]	NV[8]	OH[9]	VA[10]	WI[11]
Rigid	1.50	2.13	1.74	2.13	1.89	1.78	1.89	1.67	1.60
Flexible	0.94	1.45	1.12	1.36	1.13	1.21	1.22	1.06	0.90

The ESALs that a car generates also vary with the overall car weight. Virginia DOT estimates cars generate 0.0002 and 0.0003 ESALs on flexible and rigid pavements respectively.[12] Other estimates put car ESALs at 0.0004 for rigid pavement.[13] Still other research calls the impact of cars on roadways insignificant for design purposes and implicitly questions the validity of any comparisons between the two vehicle types.[14,15] When available, this compilation uses the reported inputs for the ESAL calculation from each study to define the ESALs contributed by each car. To provide standardization across passenger vehicles each car is assumed to weigh 3,603 pounds, the sales weighted average of a 2012 mid-size car.[16] The average weight of a car has been relatively constant over time; therefore we assume all cars have a constant weight.

If truck ESALs are divided by estimated car ESALs, the car equivalents can be determined. For example on flexible pavement in Minnesota, the ESAL value for trucks of 1.13 is divided by the car ESALs value of 0.000262 to arrive at a car equivalent value of about 4,300 passenger cars. Table 2 shows the relative impact of trucks in terms of equivalent cars for each study based on the ESALs calculated for trucks and cars.

Table 2: Relative Impact of Trucks to Cars

	Observed within State Car Equivalent Values								
Pavement type	AL	AZ	CO	IN	MN	NV	OH	VA	WI
Rigid	5,100	7,300	5,800	7,300	6,200	6,200	6,500	5,800	5,500
Flexible	3,600	3,900	4,300	5,200	4,300	2,700	4,700	4,200	3,400

The authors recognize that many states are moving away from ESALs in roadway design and applying the Mechanistic-Empirical Design Guide (MEPDG). While MEPDG represents the state of the art in pavement design, ESALs allow a simple comparison of trucks and cars to inform policy makers and the public. Therefore, we believe ESALs still provide value in this application.

Conclusion and Recommendations

The car-to-truck equivalents identified in this report represent a high-level extraction of research findings to convey this complex relationship. This report focuses on the average ESAL factors for five-axle combination trucks on interstate roadways compared to the sales weighted average of a 2012 mid-sized car.

For flexible pavements the average value derived from nine of the most recent analysis efforts is that the impact of one truck is equal to approximately 4,000 passenger cars. Based on the state research reports, the range of values provided for car to trucks ranges from 2,700 to 1 to 5,200 to 1.

For rigid pavements in the research reviewed, car-to-truck equivalents range from 5,100 to 7,300 cars for each commercial truck. The average value for car-to-truck equivalents on rigid pavements comes to 6,200 car trips to equal the impact of one five-axle truck.

Table 3: Estimated Average Impact of Trucks to Cars

Pavement Type	Average # of Cars Equal to One Truck
Flexible	4,000
Rigid	6,200

Given the variability in findings and design guidance regarding the impact of trucks, freight corridor management, pavement design, and performance management would benefit from a better understanding and use of these relationships. This corridor-specific approach would enable agencies to better assess, design, and manage these high-performance pavements.

Additionally, with continuous innovation in truck and pavement technologies, and the variability in truckloads, state, and even corridor-specific information could vary widely across regions and over time. With trucks providing two-thirds of the freight to meet our daily needs, researchers and policy makers need a comprehensive understanding of the truckloads and their state-level and corridor-specific consequences.

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