International Council on Clean Transportation
Fuel Economy Standards Compliance, #1
Working Paper Series
December 2010

CAFE Data Collection and Verification

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The US has implemented the corporate average fuel economy regulation for light-duty vehicles for more than thirty years, with laudable enforcement. A sound data collection and verification system is crucial for effective enforcement. This memo summarizes key procedures in fuel economy data collection and verification in the United States. The key procedures are detailed in the following sections.

MANUFACTURER TEST

The US Environmental Protection Agency (EPA) is in charge of corporate average fuel economy (CAFE) data collection and fuel economy tests.[1] But EPA does not test all new models itself. Instead, EPA requires manufacturers to conduct the tests and submit a majority of the fuel economy data. EPA only conducts confirmatory tests of 10-15 percent of all new models. This approach significantly reduces EPA's test burden but requires a strict verification system.

EPA developed requirements on test equipment, equipment calibration, fuel specification, driving cycle and test procedures. Since fuel economy data is calculated using carbon mass balance method from various exhaust emissions levels, EPA also developed standard formulae for such calculation. Manufacturers must strictly follow these guidelines for their fuel economy test and report any deviations from the test requirements to EPA.

Manufacturers are not required to test all model variations. With today's market diversification, each model type may have multiple features (for example, same model with a different body style – two door or four door, tire, or road load setting). Testing each of these variations would cause enormous workload for manufacturers. Thus EPA requires grouping of vehicles into a hierarchy wherein data is

1 EPA also specifies how to generate roadload curves, determine manual transmission shift schedules, select tires, handle optional equipment for calculating weight and test installation, accumulate mileage on the vehicle, adjust the test results for vehicles with more than 6,200 miles on them, prep the vehicle for the test, etc.

harmonically averaged[2] on a sales weighted basis at each level as it is aggregated up into the next level in the hierarchy. The hierarchy levels, ranging from most detailed to most aggregated, are sub-configuration, configuration, base level, and model type.[3] For calculation of fuel economy labels, which is done prior to the sales of the model year, projected sales data is used for the averaging. The minimum data requirement is that only the highest selling configuration[4] (and the highest selling sub-configuration within that configuration) needs to be tested within each base level. The CAFE value is computed at the end of the model year and actual sales data is used. For CAFE, the minimum data requirement is that manufacturer must submit data covering 90% of actual sales by configuration.

DATA SUBMISSION

Along with fuel economy data, the manufacturer must also submit a description of each test vehicle including vehicle physical attributes, mileage accumulated, exhaust test results, deterioration factors, test condition and a statement regarding each test vehicle. The statement must contain the following information: i) if the test has been conducted in accordance with applicable requirements, ii) if the test vehicle is, to the best knowledge of the manufacturer, representative of the configuration listed and iii) if the vehicle is in compliance with applicable tailpipe emission standards.

DATA REVIEW AND EVALUATION BY EPA

After receiving manufacturer data, EPA will review the resultant fuel economy data and evaluate their acceptability and reasonability. All test vehicles must i) have accumulated no more than 10,000 miles, ii) have met exhaust emission standards and iii) be representative for the configuration that they stand for. To judge reasonability and representativeness of fuel economy data, EPA administrators will, when possible, compare the results of a test vehicle to those of other similar test vehicles.

EPA CONFIRMATORY TEST

While reviewing manufacturer data, EPA selects 10-15 percent of the vehicles for confirmatory tests conducted in EPA's own laboratory. Some confirmatory testing is selected at random and some is targeted. Targeted testing focuses on factors such as new technology or vehicles with suspected problems. After the first test, EPA compares its results to those submitted by the manufacturer. If the two results are consistent, EPA will use their own fuel economy value for the particular vehicle configuration. If the data do not match,[5] EPA will repeat the test up to four times until one of the following two situations occurs: if two or more EPA tests show consistent fuel economy values, EPA will use the harmonic average of all of its own matching test results as the official fuel economy of the test vehicle or, if none of the EPA test results matches the manufacturer's data and, at the same time, there is disparity among EPA's own test results, EPA will reject the fuel economy data and the vehicle. If this situation consistently occurs during testing other representative vehicles from the same manufacturer, EPA may dispute all fuel economy data from that manufacturer. The manufacturer can retest rejected vehicles and justify where disparities originate, or accept EPA's fuel economy value.

2 All average values referred to in this memo are calculated using harmonic averaging, as opposed to arithmetic average. Appendix C provides more information about harmonic averaging.

3 The full hierarchy and definition of the terms can be found in Appendix A.

4 Vehicle configuration means a unique combination of manufacturer, engine displacement, number of cylinders, fuel system (as distinguished by number of carburetor barrels or use/type of fuel injection), catalyst usage, engine code (each unique engine calibration is assigned a different engine code), inertia weight class, transmission configuration, and axle ratio.

5 Matching is defined as within 3%. This used to be a requirement outlined only in policy guidance letter but has subsequently been incorporated in the regulations.

AVERAGE FUEL ECONOMY AND MODEL YEAR REPORT

The CAFE is the actual sales-weighted average fuel economy of all models. In order to calculate average fuel economy, EPA requires manufacturers to supply actual production data for each model year. The information is included in a model year report. Manufacturers shall submit the report no later than 60 days after the final production quarter of that particular model year.

The authenticity and accuracy of production data must be attested to by the corporation that manufactures the vehicle and shall bear the signature of an officer (a corporate executive of at least the rank of vice-president) designated by the corporation. Such attestation shall show that the manufacturer has established reasonable and prudent procedures to ascertain and provide accurate and authentic production data and that correct procedures have been followed by employees who are involved in the reporting process.

In addition to the attestation, publicly available third-party reported vehicle production and sales data makes it difficult for US manufacturers to distort production data. In the U.S., there are several auto-market research companies (e.g. Polk and CSM) that track vehicle sales/production data closely. Some of them get data from vehicle registration agencies. The media regularly reports data from these third party research companies; it is easy for EPA to discover any significant misreport from manufacturers by comparing manufacturers' numbers with these sources. In fact, EPA also periodically collects data from various Departments of Motor Vehicles (which are the local vehicle registration agencies) and other independent sources to track the authenticity of manufacturer reports on production, even though such effort is not explicitly specified in the regulation.

PRE-MODEL YEAR AND MID-MODEL YEAR REPORTS

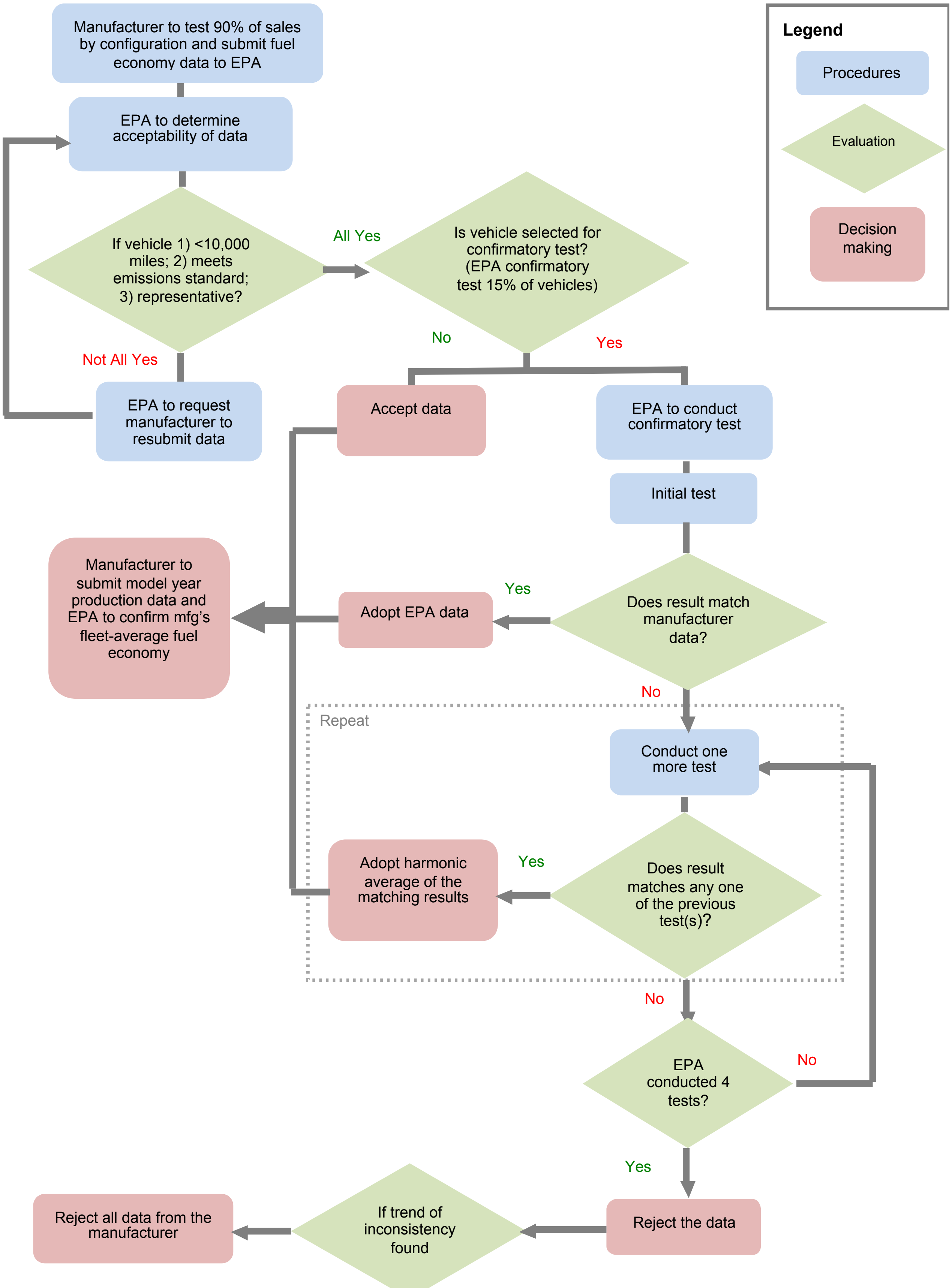
In addition to the model year report submitted to EPA and to the National Highway Traffic Safety Administration (NHTSA), manufacturers submit a pre-model year report and a mid-model year report to NHTSA. NHTSA is in charge of determining a manufacturers' CAFE compliance based on its average fuel economy data confirmed by EPA. The purpose of the pre- and mid- model year reports is to allow NHTSA to track manufacturers' efforts in meeting CAFE standards and improving fleet fuel economy before a model year sales ends.

The contents of a pre-model year report include fuel economy of each vehicle model type and projected average fuel economy of a manufacturer based on sales projections. In the report, manufacturers shall state the likelihood of meeting CAFE requirement at the end of the model year. If, based on current projections, a manufacturer believes it may not meet the standard, it shall also provide NHTSA with a reasonable plan to improve its average fuel economy in order to comply by year end.

In the mid-model year report, variance in projected model year sales versus actual sales in the first two quarters, may adjust a manufacturer's projected average fuel economy. But similar to the pre-model year report, the manufacturer still needs to show evidence, including a written plan to improve fuel economy, that it will comply with the CAFE standards by the end of the model year.

In sum, this memo briefly introduced key steps in fuel economy data collection and verification under the US CAFE system. The steps are: 1.) Manufacturers test 90 percent of vehicle sales by configuration and report the data to EPA; 2.) EPA reviews and judges the acceptability of manufacturer reported data; 3.) In addition to reviewing manufacturer data, EPA conducts confirmatory test for 10-15 percent of fuel economy data vehicles and determines the fuel economy of test vehicles based on comparison of its own results and the data from manufacturers; 4.) After manufacturers submit the actual production data of a model year, EPA calculates and verifies the average fuel economy of the manufacturers and; 5.) NHTSA makes a determination of manufacturers' CAFE compliance.

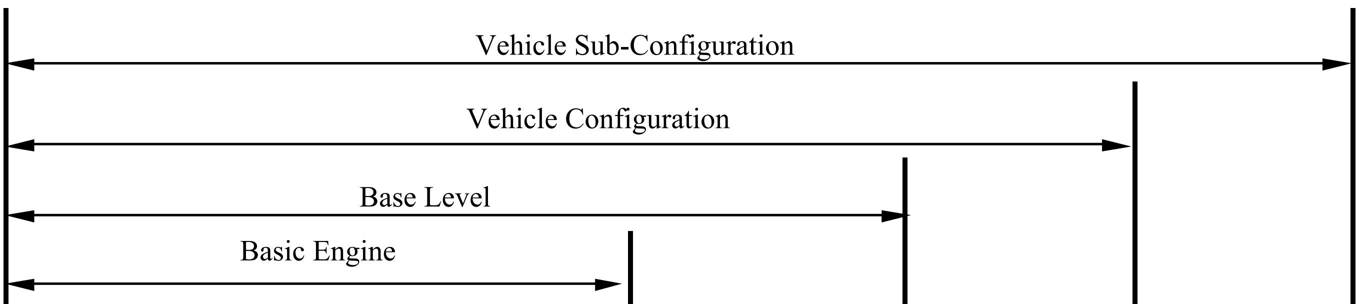
The EPA procedures are illustrated in following flow chart.



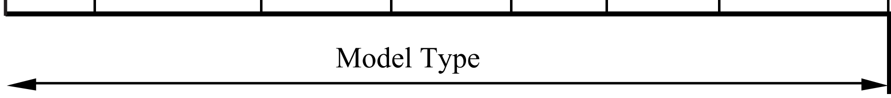
Appendix A. Hierarchy of vehicle categories for CAFE test

- Basic Engine = engine displacement + cylinders + fuel injection + air induction
- Model Type = car line + basic engine + transmission class
- Base Level = basic engine + transmission class + inertial weight class
- Vehicle Configuration = base level + transmission configuration + engine code (engine calibration) + axle ratio
- Vehicle Sub-Configuration = vehicle configuration + equivalent test weight + road-load horsepower (DPA) setting

The figure below illustrates all four levels for dividing vehicles according to CAFE data requirements, specifying what information each level should include.[6]



Car Line	Engine Displacement	No. of Cylinders	Fuel Injection	Intake Boost	Catalyst	Transmission Class	Inertial Weight Class	Calibration	Axle Ratio	Equivalent Test Weight	DPA
Sample	2.3L	4	EFI	TC	B	AT 5	3000	92 kw @5500	3.26	3000	3.0



Abbreviations: Eng Disp = Engine Displacement, No. of Cyls= Number of Cylinders, Fuel Inj.=Fuel Injection System, EFI=Electric Fuel Injection, Intake Boost= Intake Boost System, TC=turbocharger,Trans Class=Transmission Type and Number of Gear Box, IWC=Inertia Weight Class, Calibr.=Calibration, ETW=Equivalent Test Weight, DPA=road-load horsepower setting. See Appendix B for definitions.

6 Figure adapted from lecture notes of Prof. Kanit Wattanavichien http://cu-ocw.eng.chula.ac.th/cu/eng/me/engine-and-emissions-control/lecture-note/

Appendix B. Definition of terms[7]

Model type: a unique combination of car line, basic engine, and transmission class.

Car line: a name denoting a group of vehicles within a make or car division which has a degree of commonality in construction (e.g., body, chassis). Car line does not consider any level of decor or opulence and is not generally distinguished by characteristics as roof line, number of doors, seats, or windows, except for station wagons or light-duty trucks. Station wagons and light-duty trucks are considered to be different car lines than passenger cars.

Basic engine: a unique combination of manufacturer, engine displacement, number of cylinders, fuel system (use of fuel injection), catalyst usage, and other engine and emission control system characteristics. For electric vehicles, basic engine means a unique combination of manufacturer and electric traction motor, motor controller, battery configuration, electrical charging system and energy storage device.

Transmission class: a group of transmissions having the following common features: Basic transmission type (manual, automatic, or semi-automatic); number of forward gears used in fuel economy testing (e.g., manual four-speed, three-speed automatic, two-speed semi-automatic); drive system (e.g., front wheel drive, rear wheel drive; four wheel drive), type of overdrive, if applicable (e.g., final gear ratio less than 1.00, separate overdrive unit); torque converter type, if applicable (e.g., non-lockup, lockup, variable ratio).

Base level: a unique combination of basic engine, inertia weight class and transmission class.

Vehicle configuration: a unique combination of basic engine, engine code, inertia weight class, transmission configuration, and axle ratio within a base level.

Engine code: a unique combination, within an engine-system combination (as defined in part 86 of CFR Title 40), of displacement, carburetor (or fuel injection) calibration, distributor calibration, choke calibration, auxiliary emission control devices, and other engine and emission control system components specified by the Administrator. For electric vehicles, engine code means a unique combination of manufacturer, electric traction motor, motor configuration, motor controller, and energy storage device.

Inertia weight: the class, which is a group of test weights, into which a vehicle is grouped based on its loaded vehicle weight.

Axle ratio: the number of times the input shaft to the differential (or equivalent) turns for each turn of the drive wheels.

7 All definitions are from CFR 40 Part 600.002.93. Online available at http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=a6139ef05cef7597f5e3dc75752ed409&rgn=div8&view=text&node=40:29.0.1.4.42.1.13.7&idno=40

The following chart from CFR40 Part60 Section 89.129.94 illustrates the relation between inertia weight class and test weight.

Road load power at 50 mi/hour- light duty trucks [123]	Test weight basis [45]	Test equivalent test weight (pounds)	Inertia weight class (pounds)
....	Up to 1062	1,000	1,000
....	1063 to 1187	1,125	1,000
....	1188 to 1312	1,250	1,250
....	1313 to 1437	1,375	1,250
....	1438 to 1562	1,500	1,500
....	1563 to 1687	1,625	1,500
....	1688 to 1812	1,750	1,750
....	1813 to 1937	1,875	1,750
....	1938 to 2062	2,000	2,000
....	2063 to 2187	2,125	2,000
....	2188 to 2312	2,250	2,250
....	2313 to 2437	2,375	2,250
....	2438 to 2562	2,500	2,500
....	2563 to 2687	2,625	2,500
....	2688 to 2812	2,750	2,750
....	2813 to 2937	2,875	2,750
....	2938 to 3062	3,000	3,000
....	3063 to 3187	3,125	3,000
....	3188 to 3312	3,250	3,000
....	3313 to 3437	3,375	3,500
....	3438 to 3562	3,500	3,500
....	3563 to 3687	3,625	3,500
....	3688 to 3812	3,750	3,500
....	3813 to 3937	3,875	4,000
....	3938 to 4125	4,000	4,000
....	4126 to 4375	4,250	4,000
....	4376 to 4625	4,500	4,500
....	4626 to 4875	4,750	4,500
....	4876 to 5125	5,000	5,000
....	5126 to 5375	5,250	5,000
....	5376 to 5750	5,500	5,500
....	5751 to 6250	6,000	6,000
....	6251 to 6750	6,500	6,500
....	6751 to 7250	7,000	7,000
....	7251 to 7750	7,500	7,500
....	7751 to 8250	8,000	8,000
....	8251 to 8750	8,500	8,500
....	8751 to 9250	9,000	9,000
....	9251 to 9750	9,500	9,500
....	9751 to 10250	10,000	10,000
....	10251 to 10750 ..	10,500	10,500
....	10751 to 11250 ..	11,000	11,000
....	11251 to 11750 ..	11,500	11,500
....	11751 to 12250 ..	12,000	12,000
....	12251 to 12750 ..	12,500	12,500
....	12751 to 13250 ..	13,000	13,000
....	13251 to 13750 ..	13,500	13,500
....	13751 to 14000 ..	14,000	14,000

Appendix C. Definition of harmonic average

Fuel economy is defined as miles divided by gallons. The average fuel economy value of two or more vehicles is computed by dividing the total number of miles traveled by the total amount of fuel consumed. This approach is used when averaging mpg values. **For fuel consumption or CO_2 emission metric like liters/100km or g/km, simple sales-weighted averaging should apply.** This result obtained from harmonic averaging is different from that from simple (arithmetic) averaging, which computes the average by dividing the sum of the fuel economy values of all the vehicles by the number of vehicles as shown in the following example.

Consider a vehicle manufacturer selling two vehicles:

One inefficient car "A" at 20 miles per gallon (mpg)

One efficient car "B" at 40 mpg

If these two vehicles each drive the same amount of miles (100 miles)…

Total fuel = $Fuel_A + Fuel_B$ = 100 mi/(20mi/gal) + 100mi/(40mi/gal) = 7.5 gal.

Total miles = $Miles_A + Miles_B$ = 200 miles

Average fuel economy ($FE_{average}$) = 200 miles/7.5 gal = 26.7 mpg

By using simple average fuel economy evaluation:

$FE_{average}$ = (20+40)/2 = 30 mpg

The simple average of fuel economy computation is incorrect. Simple averages will always give a result higher than the arithmetic average.

The harmonic average approach can be used to calculate the average fuel economy of a group of vehicles with different fuel economy values. For instance, for a fleet of 1,000 vehicles, if the fuel economy of 200 vehicles is 20 mpg and the fuel economy of 800 vehicles is 40 mpg, and if each vehicle is driven the same amount of miles (100 miles), the harmonic average fuel economy of the fleet is:

$$\text{Total fuel} = 200 \times \frac{100\text{ mi}}{20\text{ mi/gal}} + 800 \times \frac{100\text{ mi}}{40\text{ mi/gal}} = 3{,}000\text{ gal.}$$

Total miles = 100 mi x 200 + 100 mi x 800 = 100,000 miles

FEaverage = 100,000 miles/3,000 gal = 33.3 mpg

In general, weighted harmonic average fuel economy of a fleet of two groups of vehicles with different fuel economy can be presented as:

$$FE_{average} = \frac{\text{Total miles}}{\text{Total fuel}} = \frac{Miles_A \times \#veh_A + Miles_B \times \#veh_B}{\frac{Miles_A \times \#veh_A}{FE_A} + \frac{Miles_B \times \#veh_B}{FE_B}}$$

where

Milesi = miles driven by group i

#vehi = number of vehicles in group i

FE i = fuel economy of group i

About the Authors

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Fung and He's work focuses on policies to reduce greenhouse gas emissions and conventional pollutants from light- and heavy-duty vehicles, with an emphasis in China.

About the International Council on Clean Transportation
The International Council on Clean Transportation (ICCT), a nonprofit organization, is a central actor in efforts to reduce the negative impacts from all transportation sectors. Our goal is to protect public health, minimize climate change and improve quality of life for billions of people as the world's transportation infrastructure grows. Our work, focused in the top ten largest motor vehicle markets globally, falls into four general categories: (1) producing reports that identify international best practices, (2) working with consultants and organizations to lay the technical groundwork for future regulations, (3) working with government agencies directly to provide technical assistance in the drafting of regulatory documents and data collection and analysis, (4) holding public workshops as well as invite-only meetings among key regulators.

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