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Administration

NHTSA

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CAFE Model Peer Review

Contents

Executive Summary

The Energy Policy and Conservation Act of 1975 (EPCA), as amended by the Energy Independence and Security Act of 2007 (EISA), requires the Department of Transportation (DOT) to set Corporate Average Fuel Economy (CAFE) standards for passenger cars and light trucks at the maximum feasible levels in each model year, and requires DOT to enforce compliance with the standards. The National Highway Traffic Safety Administration (NHTSA), an agency within DOT, carries out these assignments. The Volpe National Transportation Systems Center (Volpe Center), a federal resource within DOT, supports NHTSA in doing so. In particular, the Volpe Center conducts analysis to provide estimates of the impacts of potential future CAFE standards. To conduct much of this analysis, the Volpe Center has developed software referred to here as the CAFE model.

In 2017, the Volpe Center arranged for a formal peer review of the version of the CAFE model released and documented in 2016. Under a contract with the Volpe Center, DIGITALiBiz, Inc. (iBiz) managed the peer review, recruiting and selecting reviewers after assuring against conflicts of interest, providing a peer review charge letter identifying specific questions to be addressed, collected peer reviewers' responses, and provided the Volpe Center with a summary of reviewers' comments and recommendations. NHTSA and Volpe Center staff reviewed these comments and recommendations, and this report provides the staff's responses.

The charge to peer reviewers posed about 20 specific questions spanning five areas:

1. Updates to 2012 Final Rule Version of the CAFE Model: Constraints on the application of technology into manufacturers' fleets
2. Updates to 2012 Final Rule Version of the CAFE Model: CAFE Model use of Argonne National Laboratory (ANL) Autonomie Vehicle Simulation Model
3. Model architectural elements
4. Model operations
5. Overall model assessment

All of the peer reviewers supported much about the model's general approach, and supported many of the model's specific characteristics. Peer reviewers also provided a variety of general and specific recommendations regarding potential changes to the model, inputs, outputs, and documentation.

NHTSA and Volpe Center staff agree with many of these recommendations and have either completed or begun work to implement many of them; implementing others would require further research, testing, and development not possible at this time, but we are considering them for future model versions. When NHTSA and Volpe Center staff disagree with certain general and specific recommendations, we note that often these recommendations appear to involve input values and policy choices external to the model itself, and are therefore beyond the scope of the peer review.

We recognize that the CAFE model is complex, and greatly appreciate the time, careful attention, and thoughtful review provided by the peer reviewers, who are listed below:

Nigel N. Clark, Ph.D., Professor, Mechanical and Aerospace Engineering, West Virginia University

Walter M. Kreucher, B.S.E., M.B.A., Environmental Consultants of Michigan, LLC

José Mantilla, M.S., Director, movendo

Wallace R. Wade, P.E., Ford Motor Company (retired)

The remainder of this report first provides the peer reviewer charge, then provides peer reviewers' comments with responses from NHTSA and Volpe Center staff. An appendix to this report provides peer reviewers' résumés and *Curricula Vitae*.

Peer Review Charge

“CAFE Model”

Introduction

The 1975 Energy Policy Conservation Act (EPCA) requires that the Secretary of the Department of Transportation set Corporate Average Fuel Economy (CAFE) standards for passenger cars, light trucks and medium-duty passenger vehicles at the maximum feasible levels and enforce compliance with these standards. The Secretary has delegated these responsibilities to the National Highway Traffic Safety Administration, an agency of the U.S. Department of Transportation. Another DOT organization, the Volpe National Transportation Systems Center, provides related analytical support.

In 2002 the Volpe Center and NHTSA staff collaborated to develop a modeling system—referred to here as the “CAFE model”—to analyze how manufacturers could comply with potential standards, and estimate the impacts of regulatory alternatives to inform rulemaking actions that establish CAFE standards. Since that time, DOT staff have collaborated to significantly expand, refine, and update the CAFE model, using the model to inform major rules in 2003, 2006, 2009, 2010, 2012, and 2016. To inform the proposed rule announced in August 2018, DOT staff introduced significant new elements to the model, including methods to estimate changes in vehicle sales volumes, vehicle scrappage, and automotive sector labor usage.

Each of these regulatory actions involved consideration of and response to significant public comment on model results, as well as comments on the model itself. In addition to DOT staff’s own observations, these comments led DOT staff to make a wide range of improvements to the model. Insofar as a formal peer review could identify additional potential opportunities to improve the model, DOT sponsored a review of the entire model in 2017. At this time, DOT seeks review of some of the significant new elements added to the model after that review.

Overview of Task

The peer review charge is to identify potential opportunities to improve specific capabilities recently added to the CAFE model. Past comments have sometimes conflated the model with inputs to the model. The peer review charge is limited to the model itself; in particular, rather than addressing specific model inputs which are provided by DOT staff to facilitate review of the model, peer reviewers should address only the model’s application of and response to those inputs. However, an evaluation of new relationships within the model is expected to require evaluation of the model’s characterization of those relationships – through statistical model coefficients, for example. While those enter the model as “inputs” that can be modified by the user, they are a critical component of the relationships in the model. Thus, it is appropriate to evaluate those coefficients – as they relate to the sales response, scrappage response, and employment response on which this review is focused – as part of this review.

Additional Background

CAFE standards determine the minimum average fuel economy levels required of each manufacturer's fleets of vehicles produced for sale in the United States in each model year. The 2007 Energy Independence and Security Act (EISA) amended EPCA such that these standards must be expressed as mathematical functions of one or more vehicle attributes related to fuel economy. DOT must set CAFE standards separately for passenger cars and light trucks, and must set each standard at the maximum feasible level separately for each model year. Compliance is determined separately for fleets of domestic and imported passenger cars, and domestic passenger car fleets are also subject to a minimum standard based on the projected characteristics of the overall passenger car fleet. A fleet that exceeds the applicable standard in a model year earns CAFE "credits," and subject to a range of conditions, manufacturers can use these credits to offset other model year and fleet (including other manufacturer fleets) CAFE "shortfalls." If a fleet does not meet a requirement, and the manufacturer does not obtain and apply enough credit to cover the shortfall, the manufacturer is required to pay civil penalties.

The purpose of the CAFE model is to estimate the potential impact of new CAFE standards specified in an input file that can contain a range of potential regulatory alternatives to be evaluated. The process involves estimating ways each manufacture could (not "should" or "is projected to") respond to standards, and then estimating the range of impacts that could result from those responses. A detailed representation of the current new vehicle market, specified in another input file, describes that current state of fuel economy technology among all new vehicles offered for sale in the model year (the most recent model year characterized in this way is MY2016). A third file houses a range of inputs defining key characteristics of the range of fuel-saving technologies to be considered—characteristics such as the applicability to specific types of vehicles and costs. The fuel economy improvement associated with a given combination of fuel economy technologies (when applied to a particular class of vehicle) is now contained in the CAFE model itself. While it can be viewed, and even modified, by the user, it is not required as an input to the model. A fourth file contains a range of economic and other inputs, such as vehicle survival and mileage accumulation rates (by vehicle age), projected future fuel prices, fuel properties (e.g., carbon content), air pollutant emission factors, coefficients defining potential impact of mass reduction on highway safety, and the social value of various externalities (e.g., petroleum market factors, criteria pollutant and greenhouse gas emissions, and fatalities). Considering each manufacturer's projected production, the CAFE standards under consideration, the projected characteristics of the included fuel-saving technologies, and several other input assumptions (e.g., fuel prices and buyers' effective willingness to pay for fuel economy), the model iteratively applies increasing amounts of fuel-saving technology in response to these inputs, and then calculates impacts such as costs to vehicle purchasers, fuel savings, avoided emissions, and monetized costs and benefits to society.

Several elements that appear in the input files reflect earlier versions of the CAFE model, which relied more heavily on static inputs rather than the endogenous relationships present in the current version. In particular, the input files contain remnants from the now-outdated implementation of both sales and scrappage.

While the market data file still contains a static sales "forecast," it is merely a continuation of MY2016 volumes and is used only computationally (and mostly for testing). Rather, the current model defines sales in a given model year based on a function in the code (and described in the suggested documentation). This model relies on a set of exogenous economic factors (GDP growth rate and labor force participation – in both the current and previous periods) to estimate the total unit sales of new light-duty vehicles in a given model year. That total is then apportioned to body-style groups based on a “dynamic fleet share” model – essentially a series of difference equations that is also present in EIA’s National Energy Modeling System (NEMS), though which we apply slightly differently. Once the share of each vehicle style (car-style or truck-style) is determined, new sales are apportioned to each group and then distributed to each vehicle model based on its relative share of each style in the 2016 new vehicle market. It is worth noting that this does not necessarily preserve the market share of each of NHTSA’s regulatory classes because many vehicle models (over 20% of the current market) have both “car” and “light truck” versions for regulatory purposes. We choose to preserve the market definitions rather than the regulatory definitions in assigning sales.

Similarly, the “parameters” input file contains a set of vehicle survival rates that are also vestigial. Vehicle survival is now determined endogenously within the model run in a way that is responsive to changes in new vehicle prices, cost per mile of travel, and a set of exogenous economic factors. As the model calculates the lifetime mileage accumulation, fuel consumption, fuel expenditures, and various emissions values, it does so using these dynamically defined scrappage rates.

Finally, the employment calculations produced in the CAFE model are not only new in the current version, they are unlike the other two components in this review in that they do not contribute to the benefit cost calculations performed by the model (or subsequently by NHTSA based on changes in employment). The employment calculations are a function of new vehicle sales, as one would expect, but also on technology expenditures by manufacturers that influence upstream employment in the supplier network.

Charge Questions

In your written comments, please provide a detailed response to all of the following questions that are within your area of expertise. Reviewers will be expected to identify additional topics or depart from these examples as necessary to best apply their particular areas of expertise. Comments shall be sufficiently clear and detailed to allow readers to thoroughly understand their relevance to the CAFE model.

1	**Sales Model**
1a	Please comment on the appropriateness of including a sales response model in the CAFE model as a means to estimate differential sales impacts across regulatory alternatives.
e1b	Please comment on the sales model’s specification using an ADRL model time series approach, and comment specifically on the endogeneity of average transaction price.
1c	Please comment on the sales model’s integration in the CAFE model, including interactions with the simulation of multiyear product planning, in combination with the dynamic fleet share model used to allocate total new vehicle sales to the passenger car or light truck market segments.
1d	Please comment on the sales model’s specification as independent of vehicle scrappage, and on the resultant calculation of VMT.
2	**Scrappage Model**
2a	Please comment on the appropriateness of including a scrappage model in the CAFE model as a means to estimate the potential impact of CAFE standards on used vehicle retention.

2b	Please comment on the scrappage model's specification using a form common in the relevant literature. Are there better approaches that allow for both projection (as is necessary in this context) and a focus on new vehicle prices (exclusively).
2c	Please comment on the scrappage model's integration in the CAFE model, addressing the vehicles affected by the scrappage model, and the extent to which changes in expected vehicle lifetimes are consistent with other assumptions.
3	**Labor Utilization Calculations**
3a	Please comment on the inclusion of each source of employment related to automobile production and sales.
3b	Please comment on assumptions regarding labor hours, production location (domestic/foreign), and supplier impacts.
3c	Please comment on methods used to calculate changes across alternatives.

CAFE Peer Review Responses

Review topic
1. Updates to 2012 Final Rule Version of the CAFE Model: Constraints on the application of technology into manufacturers' fleets
1.1. Integration of inheritance and sharing into engines, transmissions, and platforms in a manufacturer's fleet
1.2. Integrated analysis across regulatory vehicle classes, including heavy-duty pickups and vans
1.3. Manufacturer resource constraints modeled on a year-by-year basis using product redesign and refresh schedules (and component sharing) rather than phase-in caps to determine the pace of technology change
1.4. Manufacturer behavior regarding CAFE credits
1.5. The use of technology classes to accommodate different technology-related inputs for different types of vehicles (e.g., small cars, pickup trucks).

Nigel Clark

Reviewer Name:_ Nigel N. Clark

Review Topic Number: 1.1. Integration of inheritance and sharing into engines, transmissions, and platforms in a manufacturer's fleet

Other Review Topic Numbers (if interactive effects are focus of discussions

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   The model chooses technology by considering carefully a pathway, and applying technologies in order, so that a cost-effective yet minimal design solution is adopted. Having engines or platforms that are shared suggests that this carefully ordered approach may not be optimal if production volumes or design costs require the sharing of technology in a platform. Further, there is the need to consider the adoption of new technology by a low volume or high MSRP leader, yielding proven technologies for later application across a number of vehicles. The model does this well. Clearly not all eventualities can be considered, such as the changes to relationships with previous sub-assembly manufacturers, or availability due to mergers, but orderly rules for sharing components or using technology in a refresh or redesign are presented, and refresh/redesign timetables are employed.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   They are, as far as is possible. There could always be factors in a decision – such as (hypothetically) adopting a DOHC engine as a leap over SOHC because DOHC has public appeal and costs little more – that cannot be predicted. (Recall, conversely, how diesel was avoided by consumers after poor car entries in the 70's.) Production changes are also linked to plant changes, and there may be an unwillingness to retire a factory line that is operating efficiently or desire to buy in technology or start a new plant to replace manufacturing that has become burdensome to the OEM. In this way, the manufacturer may use technology that is "next most cost effective" rather than the model prediction to achieve the fuel economy goal, and the whole future pathway for reduction on that vehicle may change. The model cannot search this far upstream or address such complex economics.

   Further, as the TAR observes, bolt-on technologies may be seen as easy targets, and choice between aero (high speeds) and rolling resistance (all speeds) may be driven by this or a choice between a higher CAFE number or higher numbers for real-world freeway use. The same can be said for changing final gear ratio, or trading close ratios against deep overdrive ratios, even though the same transmission may be used. However, the model takes a central approach to economic considerations, by neglecting such pendulum swings.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   No major modifications.

4. Is there an alternative approach you would suggest?

   One possible approach in use is to apply the second most cost-effective option in all or some technology changes as an additional check on sensitivity, and to report this. Also, it may be useful to see how many second-best changes keep the vehicle technology evolution on the same ultimate pathway, possibly due to skipping or delaying a technology, rather than truly changing pathways.

   RESPONSE: Other option selection criteria such as "second-best" or "third-best" approaches could provide important diagnostic insights and will be considered for future development and testing. However, insofar as this approach would be motivated by concern that a manufacturer may have important reasons not to select the "theoretically best" option, the same basic concern can likely be addressed through careful input selection within the model's current framework. For example, if a manufacturer is known to have already made significant recent investments in engine turbocharging, it may be appropriate to specify inputs limiting that manufacturer's tendency to select naturally aspirated high-compression-ratio engines.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   This is an essential part of the model, since CAFE applies to the manufacturer, and not an individual vehicle.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

   Deterioration of fuel efficiency is not central to the model, but low rolling resistance tire benefits are particularly vulnerable in this regard when tires are replaced.

   RESPONSE: By law, CAFE standards apply only to new vehicles at first sale, and not to ongoing fleet fuel economy. While the model does not currently provide means to explicitly estimate owners' possible decision to use replacement tires that are less efficient than tires used for fuel economy certification, it also does not provide means to estimate decisions to use replacement tires that are *more* efficient. Further research could possibly support model changes to account for fuel economy changes over vehicles' useful lives.

Walter Kreucher

[WK PROVIDED A RESPONSE OVERVIEW AND SUMMARY]

The VOLPE CAFE model has been a staple in the regulatory arena for well over a decade and has gone through a number of iterations during that time.

The work VOLPE staff undergoes in preparing the input files is painstaking and time consuming. I congratulate all the dedicated employees who have worked on this model over the years in getting it into its present form.

The input files are a crucial step in the process as these assumptions determine the output and drive a multibillion dollar regulatory compliance strategy for the automobile industry.

I have reviewed the documentation, input and output files, and have drawn the following conclusions. My comments are offered in the spirit of improving the overall quality of the model and continuing to improve the regulatory process.

There are several critical flaws in the input parameters and the way technologies are handled including:

1. **The model seems to have a computational problem. The fuel costs and the other "benefits" are based on the total miles traveled (~250,000 miles). They should be based on the surviving vehicle miles traveled (~150,000 miles).**
2. Input data including technology penetration and fuel economy should be updated to reflect the 2017 model year and it should be verified that the model accurately predicts the base year compliance for each manufacturer.
3. Published data on the ownership and operating costs exhibit substantial differences between conventional gasoline technology and hybrid electric vehicle technology that are not reflected in the model.
4. The "effective cost" for determining the relative attractiveness of different technology applications does not consider all the appropriate factors.
5. The model uses a flat "gap" between Test and On-Road MPG. Published data demonstrates that the gap is not static for a given fuel type but increases as the test fuel economy increases.
6. The model uses a single "gap" between Test and On-Road MPG for all gasoline technologies. Published data demonstrates that there is a substantially larger gap for hybrid electric vehicle (including start/stop) technology compared to conventional vehicle technology.
7. Despite the progress in implementing advanced technology only 19 percent (17% of cars and 23% of trucks) of the models listed in the MY 2017 EPA database met their 2017 model year fuel economy targets. Some models missed their targets by a substantial amount. In fact, only 55 percent (24 of 43) of the hybrid electric vehicles in the EPA report met the MY 2025 fuel economy target (adjusted for AC). Volpe should reassess the cost of technology and the fuel consumption benefits.
8. The model is not complete without an econometric component that considers competitive impacts including changes in employment resulting from the standards.

RESPONSE: Regarding the above numbered comments:

1. **The model uses expected vehicle survival and annual mileage accumulation rates to estimate travel, fuel consumption, and other impacts.**
2. **The model does not prescribe choices regarding the analysis fleet (an input), but NHTSA and Volpe Center staff agree that DOT's analysis should use the most recent fleet that can be practicably applied given other constraints. However, because the model is intended to estimate ways manufacturers *could* (not should or will) respond to standards, we do not expect the model to reproduce manufacturers' *actual* decisions.**
3. **Model inputs provide means to specify technology-specific additional costs.**
4. **The effective cost metric is intended to provide a proxy for estimating manufacturers' decisions. Inputs can be specified to make this metric more responsive or less responsive to fuel economy improvements (and fuel prices). Further research would be required to support simulation that assumes buyers behave as if they actually consider all ownership costs, and that assumes manufacturers respond accordingly.**
5. **As a model input, the model accepts a specified gap between certification and real-world fuel economy. Expressed as a percentage of fuel economy, the magnitude (in mpg) of this gap increases with fuel economy. DOT is not aware of any statistically representative evaluations of the difference between certification and average real-world fuel economy, and further research would be required to determine whether the model should accommodate a functional representation of the gap.**
6. **As model inputs, the model accepts different values for the fuel economy gap when operating on fuels other than gasoline. Further research would be required to determine whether the model should accommodate inputs specifying different gaps for technology combinations involving specific technologies (such as, but perhaps not limited to "lower level" electrification technologies.**
7. **NHTSA and Volpe Center staff review and update model inputs before conducting each new rulemaking analysis.**
8. **Volpe Center staff have updated the model to estimate impacts on new vehicle sales and automotive industry employment. Further research would be required to support inclusion of a vehicle choice model, and the pricing model that could be an important accompaniment.**

REVIEW TOPIC NUMBER 1.1. INTEGRATION OF INHERITANCE AND SHARING INTO ENGINES, TRANSMISSIONS, AND PLATFORMS IN A MANUFACTURER'S FLEET

1. What are the most important concerns that should be taken into account related to the review topic?

   The integration of inheritance and sharing of engines, transmissions, and platforms across a manufacturer's light-duty vehicle fleet and separately across its light-duty truck fleet is standard practice in the industry.

   The problems arise when an engine or transmission is produced at more than one plant. Most of the time a manufacturer will convert only a single plant within a model year. Thus, both the old and the new variants of the engine or transmission will be produced for a finite number of years.

This is dictated by factors not the least of which is the availability of capital to convert multiple facilities.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   (See above.)

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   The VOLPE input file could be modified to add a separate engine (transmission) code for each plant that produces that product. In this way the model could better simulate what is the standard practice within the industry.

   RESPONSE: Thus far, NHTSA and Volpe Center staff have concluded that, especially on a forward-looking industry-wide basis such as for CAFE analysis, plant-level simulation would be unmanageably complex and would likely involve many inputs that cannot be reasonably specified without relying on confidential business information. The CAFE model does, however, accommodate inputs that govern the model's simulation of engine sharing and inheritance, and if sufficient data becomes available, these inputs could possibly be specified in a manner that allows engines to be "split" based on point-of-production. On the other hand, doing so would not guarantee the newly split engines follow the same development path.

Jose Mantilla

Reviewer Name: Jose Mantilla

Review Topic Number: 1.1 – Integration of inheritance and sharing into engines, transmissions and platforms in a manufacturer's fleet

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

The main concerns related to this review topic are the lack of sufficient detail and justification with respect to the approaches for:

- The decision to select " leader" and " follower" vehicles for the application of engines, transmissions, platforms and technologies
- The system's selection of " leader" vehicles for which technology improvements are realized first
- The system's selection of " follower" vehicles that share the leader's platform
- The propagation of specific technologies from leaders to followers
- The determination of technology sharing based on the redesign and/or refresh schedules of leaders and followers

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The main assumptions presented in the draft TAR and Model Documentation with respect to this review topic are:

1. The CAFE model defines an engine or transmission leader as the vehicle with the lowest average sales across all available model years. If there is a tie, the vehicle with the highest average MSRP across model years is chosen.
2. The CAFE model defines a platform leader as the vehicle variant of a given platform that has the highest level of observed mass reduction and aerodynamic technologies present in the analysis fleet. If there is a tie, the CAFE model begins applying aerodynamic and mass reduction technology to the vehicle with the lowest average sales across all available model years. If there remains a tie, the model begins by choosing the vehicle with the highest average MSRP across all available model years.
3. When the system evaluates platform, engine, or transmission-level technologies, since the technology being analyzed directly modifies a shared vehicle

component, the resultant improvements must be considered on all vehicles that utilize a common platform, engine, or transmission simultaneously.

4. During modeling, the system elects a "leader" vehicle, with all technology improvements being realized on that vehicle first, and afterwards, propagated down to the remainder of the vehicles (known as the "followers") that share the leader's platform, engine, or transmission. As such, new technologies are initially evaluated and applied to a leader vehicle during its refresh or redesign year (as appropriate for a specific technology).
5. Any follower vehicles that share the same redesign and/or refresh schedule as the leader apply these technology improvements during the same model year. The rest of the followers inherit refresh-based technologies from a leader vehicle during a follower's respective refresh or redesign year, while redesign-based technologies are inherited on a follower vehicle during its redesign year only.

The general assumptions for the selection of leader and follower vehicles (items 1 and 2 above) seem reasonable as market trends generally indicate that many technologies begin deployment at the high-end, low-volume end of the market. However, no evidence is provided to justify the validity of this assumption for all vehicle manufacturers. Critically, this assumption is fundamental to the application of technologies across vehicles and is likely to have significant impacts on the model outputs.

The documentation provided is not completely clear with respect to the specific aspects considered when applying technologies from leader to follower vehicles based on redesign and/or refresh schedules (items 3-5 above). More specifically, it is not fully clear if specific technologies are applied to follower vehicles only when the redesign/refresh schedule includes the adoption of the specific technology in question, or if technologies implemented in leader vehicles are applied to follower vehicles when the next (concurrent or future) redesign/refresh schedule occurs (even if the redesign/refresh does not necessarily include the application of that specific technology).

The former (application of technologies to follower vehicles only when the redesign/refresh includes update of that specific technology) seems to be the "correct" approach. The latter (application of technologies to follower vehicles in the next redesign/refresh even if it does not include that specific technology) could potentially reduce modeling complexity; however, this approach could result in an overly generous application of technologies to many vehicles that fall into the follower category. Importantly, many of these technologies could have impacts (positive or negative) on fuel economy; as such, the application of technologies to follower vehicles that are not adopting them in the market could result in large errors with respect to estimates of fleetwide fuel economy for a particular manufacturer.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

The following clarifications/modifications are recommended:

- If specific technologies from leader vehicles are applied to follower vehicles only when the redesign/refresh includes update of that specific technology
    - Expand discussion in Model Documentation and draft TAR to clarify this critical aspect of the sharing and inheritance of technologies
- If specific technologies from leader vehicles are applied to follower vehicles even when the redesign/refresh does not include update of that specific technology
    - Consider redefining the propagation of technologies so that they are based on demonstrated application of the specific technologies and not solely on the redesign/refresh schedule. More specifically, the redesign/refresh must include that specific technology.

RESPONSE: Volpe Center staff have updated the model's approach to selecting technology "leaders" and implementing technology inheritance, and have also updated the corresponding model documentation.

4. Is there an alternative approach you would suggest?

The sharing and inheritance of technologies could be defined in the model based on detailed assessments of the engine, transmission, platform and technology redesign/refresh schedules of each vehicle make and model. Aside from potential modeling and computational challenges, this is likely to require a higher level of disclosure from manufacturers with respect to future changes to their vehicle fleets. In addition, it would require periodic (and potentially significant) model updates as redesign/refresh schedules for different manufacturers are developed.

RESPONSE: Because the model is intended to estimate ways manufacturers *could* (not *should* or *will*) respond to standards, we do not expect the model to reproduce manufacturers' *actual* decisions, especially when inputs are not informed by confidential detailed product planning information. While the model already accommodates detailed inputs regarding redesign schedules for specific vehicles, and commercial information sources are available to inform these inputs, further research would be needed to determine whether design schedules for specific engines and transmissions can practicably be simulated.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The review topic is of critical importance to the overall utility and plausibility of the Volpe Model output. As stated in the fraft TAR, previous analyses resulted in the model creating many more unique engines and transmissions that exist in the analysis fleet (or in the market) for a given model year – an undesirable outcome. The inclusion of sharing and inheritance in the current version allows the model creating a more reasonable number and more realistic set of unique engines and transmissions. As such, sharing and inheritance considerations are a positive development of the model.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Wallace Wade

Reviewer Name: Wallace R. Wade

Review Topic Number: 1.1. Integration of inheritance and sharing of engines, transmissions, and platforms in a manufacturer's fleet

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

NHTSA has continued to refine its implementation of an approach accounting for shared platforms between light-duty and heavy-duty products (heavy-duty pickups and vans covered by separate fuel consumption and GHG standards).

Engine and Transmission Sharing and Inheritance:

In the previous Volpe Model, engines and transmissions in individual models were allowed freedom in technology application, which potentially lead to more unique engines and transmissions than would actually exist in the fleet for a given model year. This process failed to account for costs associated with increased complexity and may have represented an unrealistic diffusion of products when manufacturers are consolidating global production with smaller numbers of shared engines and platforms.

In the current Volpe Model, engines and transmissions that are shared between vehicles must apply the same levels of technology, as dictated by "engine or transmission inheritance." The model elects a "leader" vehicle, with all technology improvements being realized on that vehicle first, and afterwards, propagated down to the remainder of the vehicles (the "followers") that share the leader's platform. Any follower vehicles that share the same redesign and/or refresh schedule as the leader apply these technology improvements during the same model year. The rest of the followers apply refresh-based technologies from a leader vehicle during a follower's respective refresh or redesign year. (2016 Draft TAR, p. 13-24, CAFE Model Documentation, p. 17)

<u>Concern 1:</u>
The current Volpe Model with "engine or transmission inheritance" is a significant improvement over the previous model. However, a result of the apparent product simplification, an engine or transmission plant will be required to produce engines or transmissions with the new technology for the leader vehicle, while, at the same time, maintain production of engines or transmissions without the new technology until the follower vehicles' refresh or redesign actions are completed.

Recommendation 1:
Determine if producing engines or transmissions with the new technology for the leader vehicle, while, at the same time, maintaining production of engines or transmissions without the new technology for the follower vehicles incurs a significant incremental cost by manufacturers. If a significant incremental cost is incurred by manufacturers with the improved "engine or transmission inheritance" model, then develop an "incremental (engine or transmission) plant complexity cost." This "incremental plant complexity cost" would be shared by the vehicles receiving the new technologies until the new technology is fully implemented for all applicable vehicle lines, at which time the "incremental plant complexity cost" would be eliminated.

RESPONSE: Further research would be needed to determine whether sufficient data is likely to be available to explicitly specify and apply additional costs involved with continuing to produce an existing engine or transmission for some vehicles that have not yet progressed to a newer version of that engine or transmission. Especially if such costs can reasonably be applied universally, it could be possible to include them using the model's existing input structure (by increasing cost inputs accordingly).

Platforms, Sharing, and Technology:

The Volpe Model was modified so that all levels of mass reduction and aerodynamic improvement are forced, over time, to be constant among variants of a platform. However, because these levels are not concretely defined in terms of specific engineering changes, and the vehicle models in the analysis fleet are not defined in terms of specific engineering content, this aspect of the CAFE model does not mean that every vehicle model on a platform necessarily receives identical engineering changes to attain the same level of aerodynamic improvement or mass reduction. Also, with the application of these improvements tied to vehicle redesign or freshening, some vehicle models on a shared platform may inherit them from platform "leaders." The Volpe Model defines a platform "leader" as the vehicle variant of a given platform that has the highest level of observed mass reduction and aerodynamic technologies present in the analysis fleet.
(2016 Draft TAR, p. 13-25-26)

Concern 2:
The definition of the "leader" needs clarification. Why is the leader defined as the vehicle that already has the "highest" level of technologies present? Should this be re-stated as "the vehicle with the 'highest' potential for improvement with the application of the technologies"?

Recommendation 2:

Clarify the definition of the "leader" of the vehicle variant receiving the "highest" levels of mass reduction and aerodynamic technologies (as possibly the vehicle with the "highest" potential for improvement with the application of the technologies).

RESPONSE: Volpe Center staff have updated the model's approach to selecting technology "leaders" and implementing technology inheritance, and have also updated the corresponding model documentation.

Concern 3:
Forcing the same levels of mass reduction and aerodynamic improvements (where same "level" is implied to be the same percentage reduction) to all variants of a platform may not be realistic. For example, a Ford Focus and Ford Escape are on the same platform, but one is a compact car while the other is an SUV. Active aerodynamics may be more affordable on an Escape than on the Focus. Applying the same level of mass reduction appears to violate NHTSA's guideline for mass reduction shown in Table V-109 of the 2012 FRIA. Table V-109 suggests 0 percent mass reduction for compact cars (i.e., Focus) and up to 20 percent reduction for small light trucks (i.e., Escape SUV).
(NHTSA, "Final Regulatory Impact Analysis - Corporate Average Fuel Economy for MY 2017-MY 2025 Passenger Cars and Light Trucks," August 2012)

Recommendation 3:

Instead of forcing the same levels of mass reduction and aerodynamic improvements to all variants of a platform, consider adhering to the mass reduction guidelines shown in Table V-109 of the 2012 FRIA. Aerodynamic drag reductions should have individual criteria for different vehicles (where a compact car may be near a limit Cd of 0.22 whereas additional opportunities may be available for an SUV).

RESPONSE: Model inputs can likely be used to address the concern prompting this recommendation. Examples such the Escape/Focus platform can be addressed by using model inputs to "split" the platform if doing so would be expected to produce more realistic results. Model inputs can also be used to "tailor" levels of "allowed" mass reduction and aerodynamic improvement to specific "technology classes" and vehicle models. The mass reduction levels showing in Table V-109 of the 2012 FRIA were calibrated to cause the model to produce approximately "safety neutral" fleetwide outcomes. NHTSA and Volpe Center staff review and update model inputs before conducting each new rulemaking analysis.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

Computational methods and assumptions may need to be modified to adopt Recommendations 1-3.

RESPONSE: See above following each of recommendations 1-3.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Suggest implementing Recommendations 1-3. **RESPONSE: See above following each of recommendations 1-3.**

4. Is there an alternative approach that you would suggest?

No. Implementation of Recommendations 1-3 is the suggested approach. **RESPONSE: See above following each of recommendations 1-3.**

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The plausibility of the Volpe Model output would be enhanced if Recommendations 1-3 were adopted to provide more realistic assessments of engine and transmission plant complexity and the resulting impact on product costs. **RESPONSE: See above following recommendations 1.**

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
1. Updates to 2012 Final Rule Version of the CAFE Model: Constraints on the application of technology into manufacturers' fleets
1.1. Integration of inheritance and sharing into engines, transmissions, and platforms in a manufacturer's fleet
1.2. Integrated analysis across regulatory vehicle classes, including heavy-duty pickups and vans
1.3. Manufacturer resource constraints modeled on a year-by-year basis using product redesign and refresh schedules (and component sharing) rather than phase-in caps to determine the pace of technology change
1.4. Manufacturer behavior regarding CAFE credits
1.5. The use of technology classes to accommodate different technology-related inputs for different types of vehicles (e.g., small cars, pickup trucks).

Nigel Clark

Reviewer Name:_Nigel N. Clark

Review Topic Number: 1.2. Integrated analysis across regulatory vehicle classes, including heavy-duty pickups and vans

Other Review Topic Numbers (if interactive effects are focus of discussions: 3.4

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   All vehicles covered by CAFE must be considered in order to compute the weighted average for the manufacturer. A manufacturer considers compliance as a whole, and so the model must address and combine all classes too.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   Yes. The model divides the fleet into classes, allows technology sharing as appropriate between classes, and combines fuel economy for those classes for each manufacturer.

3. What modifications do you suggest to the Volpe Model approach related to the review topic allows for technology sharing between classes?

   None.

4. Is there an alternative approach you would suggest?

   None

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   It governs the CAFE output and highlights trading of technology and fuel economy performance within and between classes for a manufacturer.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

   This topic needs no substantial attention.

Walter Kreucher

REVIEW TOPIC NUMBER 1.2. INTEGRATED ANALYSIS ACROSS REGULATORY VEHICLE CLASSES, INCLUDING HEAVY-DUTY PICKUPS AND VANS

1. What are the most important concerns that should be taken into account related to the review topic?

   The cross integration of technologies between the light-duty truck fleet and the medium-duty or heavy-duty fleets is not as simple as the model protrays. Take for example the six-speed transmission. While both the light-duty version and the heavy-duty version may have the same number of gears, the medium-duty/heavy-duty version would be designed and built with different components that can withstand the higher payloads and durability demands that the MDT/HDT users demand. Thus the spill-over effect may not exist. Great care should be exercised in the integration of inheritance and sharing of engines, transmissions, and platforms across a manufacturer's LDT/MDT/HDT fleets.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   (See above)

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   The default assumption should be no spill-over (i.e., integration of inheritance and sharing of engines, transmissions, and platforms across a manufacturer's fleet) between LDT and MDT or HDT. **This should be reviewed on a case-by-case basis to permit an engine or transmission to flow to a different fleet.**

   RESPONSE: Model inputs can be used to precisely specify the degree of spillover between regulatory classes. If none is expected between light-duty vehicles and heavy-duty pickups and vans, specifying inputs to ensure that no engines, transmissions, or vehicle platforms are shared should prevent any simulated spillover.

Jose Mantilla

Reviewer Name: Jose Mantilla

Review Topic Number: 1.2 – Integrated analysis across regulatory classes, including heavy-duty pickups and vans

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

> No definition is provided with respect to what 'integrated analysis spanning different regulatory classes' involves.
>
> The first reference to this topic in the draft TAR states: "*the current CAFE model provides for integrated analysis spanning different regulatory classes, accounting both for standards that apply separately to different classes and for interactions between regulatory classes.*"
>
> As discussed in item (5) below, the need to integrate the analysis across regulatory classes is not evident. If there is an analytical need, this needs to be fully explained.

RESPONSE: For 2018, model documentation and rulemaking documents include further explanation of integrated analysis. As mentioned above, model inputs can be used to precisely control the degree of estimated spillover between classes.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

> Insufficient information is provided to assess the reasonableness and appropriateness of data, computation methods and assumptions – specifically how integration across regulatory classes has been applied in the model.

RESPONSE: See response to #1 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Pending a satisfactory resolution of the need (or otherwise) to integrate the analysis across regulatory classes, advice can be provided on potential modifications.

4. Is there an alternative approach that you would suggest?

Pending a satisfactory resolution of the need (or otherwise) to integrate the analysis across regulatory classes, advice can be provided on alternative approaches.

RESPONSE: See response to #1 above.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The necessity to assess in an integrated manner the performance of passenger cars and light trucks is questionable – at least within the context of the limitation explanation of its utility. Based on the information provided in the draft TAR and model documentation, the link (and need) is not apparent. More specifically, given that passenger cars and light trucks belong to different regulatory classes, it would seem illogical to fully integrate the two simply because they may share components. The sharing of engines, transmissions and platforms would seem to be important as an input to reduce model complexity and computational needs, but would not seem to be important to analyze the fuel economy the two separate regulatory classes. The same applies to the presumed need to integrate MDHD vehicles in the modeling.

RESPONSE: See response to #1 above. As an example, the two-wheel drive version of the RAV4 is classified as a passenger car, but the four-wheel drive version is classified as a light truck. Insofar as Toyota is unlikely to develop completely different powertrains for these two versions of the same vehicle model, the CAFE model provides means to specify that, for example, they share common engines. Depending on the relative stringency of the passenger car and light-truck standards, this can cause engine technology to spill over from one version to the other in some model years. This means that the response to standards for one regulatory class depends somewhat on standards applicable to the other regulatory class. The model provides the ability to account for these independencies, and model inputs can be used to precisely specify the nature and degree of interdependency.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Wallace Wade

Reviewer Name:_Wallace R. Wade

Review Topic Number: 1.2. Integrated analysis across regulatory vehicle classes, including heavy-duty pickups and vans

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

Passenger Cars and Light Trucks:

Light vehicle CAFE standards are specified separately for passenger cars and light trucks. However, there is considerable sharing between these two regulatory classes – where a single engine, transmission, or platform can appear in both the passenger car and light truck regulatory class. For example, some SUVs are offered in 2WD versions classified as passenger cars and 4WD versions classified as light trucks. Integrated analysis of manufacturers' passenger car and light truck fleets provides the ability to account for such sharing and reduce the likelihood of finding solutions that could involve introducing "impractical levels of complexity" in manufacturers' product lines.
(2016 Draft TAR, p. 13-26)

Concern 1:
A clarification of the statement regarding "impractical levels of complexity" would be helpful. It is likely that an engine/transmission or technology applied in a 2WD SUV will also be applied in the 4WD counterpart in the MY 2015 baseline fleet. Therefore, having a process to preclude the introduction of unique complexities between 2WD and 4WD SUVs is likely to reflect industry practice.

Recommendation 1:

Clarify the statement in the 2016 Draft TAR regarding "impractical levels of complexity" mentioned with respect to the possibility of different engines or transmissions in a 2WD SUV versus a 4WD SUV counterpart. It is likely that an engine/transmission or technology applied in a 2WD SUV will also be applied in the 4WD counterpart in the MY 2015 baseline fleet.

RESPONSE: Updated model documentation and a new Regulatory Impact Analysis (RIA) will clarify complexity as a consideration relevant to the model's representation of shared engines, transmissions, and platforms.

Light-Duty and Medium-Duty Heavy-Duty Classes:

HD pickups and vans are regulated separately from light-duty vehicles. While manufacturers cannot transfer credits between light-duty and MDHD classes, there is some sharing of engineering and technology between light-duty vehicles and HD pickups and vans. For example, some passenger vans with GVWR over 8,500 pounds are classified as medium-duty passenger vehicles (MDPVs) and are thus included in manufacturers' light-duty truck CAFE fleet, while cargo vans sharing the same nameplate are classified as heavy-duty vans. NHTSA has identified several engines that are shared between the light-truck and heavy-duty pickup and van classes.
(2016 Draft TAR, pp. 13-25 to 13-26)

Concern 2:
Several engines and transmissions may be shared between light-duty pickups and heavy-duty vehicles. However, the 2017 Ford light-duty pickup (F150) does not share any of the engines used in the 2017 Ford heavy-duty pickups (F250/350).

RESPONSE: Model inputs can be specified precisely to account for such sharing and lack of sharing. Inputs from the 2016 draft TAR reflected no sharing of engines or transmissions between the Ford light-duty and heavy-duty pickups.

Recommendation 2:

If common engines, transmissions or platforms are found between light and heavy-duty pickups and vans, ensure that a process exists to ensure commonality in the application of technologies. The simultaneous analysis of class 2b/3 trucks and vans with the light-duty CAFE requirements will continue to ensure commonality of technologies in engines, transmissions or platforms shared across the light-duty vehicle fleet and class 2b/3 trucks and vans.

RESPONSE: The model is intended to account for such sharing between regulatory classes, where any instances of sharing are specified as model inputs.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

Computational methods and assumptions are reasonable, but implementation of Recommendations 1- 2 will ensure that common technologies are applied to engines, transmission or platforms shared across regulatory vehicle classes.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Suggest implementing Recommendations 1-2 in the Volpe Model.

RESPONSE: See responses to recommendations 1-2.

4. Is there an alternative approach that you would suggest?

No. Implementing Recommendations 1-2 is the suggested approach.

RESPONSE: See responses to recommendations 1-2.

5. [SKIP FOR REVIEW TOPICS 4.4   4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The plausibility of the Volpe Model would be enhanced by implementing Recommendations 1-2.

RESPONSE: See responses to recommendations 1-2.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
1. Updates to 2012 Final Rule Version of the CAFE Model: Constraints on the application of technology into manufacturers' fleets
1.1. Integration of inheritance and sharing into engines, transmissions, and platforms in a manufacturer's fleet
1.2. Integrated analysis across regulatory vehicle classes, including heavy-duty pickups and vans
1.3. Manufacturer resource constraints modeled on a year-by-year basis using product redesign and refresh schedules (and component sharing) rather than phase-in caps to determine the pace of technology change
1.4. Manufacturer behavior regarding CAFE credits
1.5. The use of technology classes to accommodate different technology-related inputs for different types of vehicles (e.g., small cars, pickup trucks).

Nigel Clark

Reviewer Name:_ Nigel N. Clark

Review Topic Number: 1.3. Manufacturer resource constraints modeled on a year-by-year basis using product redesign and refresh schedules (and component sharing) rather than phase-in caps to determine the pace of technology change

Other Review Topic Numbers (if interactive effects are focus of discussions

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   Manufacturers periodically offer new designs or make major design changes to existing models (refreshing). This activity depends on strength or falloff in sales (ahead of the action - projections) and availability of resources to tackle the engineering and design work. As a result, most of this activity occurs on a cycle, with a fraction of the manufacturer's vehicle lines or classes (or a class leader) receiving attention periodically. Redesign may result in new powertrain technology, and almost always in aerodynamic considerations. New powertrain technology from redesigns may then be applied in a subsequent year to another line's refresh campaign.

   Ultimately this controls the frequency/rate of change of the vehicle technology, subject to demand for performance metrics and tightening emissions or fuel efficiency standards. A redesign will require resources over more than one year, so that the annual release of new designs or refreshed designs by manufacturers can vary in quantity year to year.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   The model takes these design cycles into account. The model appropriately includes anticipated changes in design based on recent design history. The status of current vehicles in the design cycle has been thoroughly addressed for the analysis fleet, including attention to new importation of existing foreign models. Longer term projections require placing vehicles on the redesign/refresh cycle based simply on time/frequency, though the model has the capacity to be updated with real data from future model years.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   None. While seeking deeper information from manufacturers on the cycles may seem attractive, it will control the ability to share the model widely.

4. Is there an alternative approach you would suggest?

   One could develop a model where redesign efforts are assigned as a fraction of redesign in each year, to form a continuum of small technology improvement metrics each year, but this would not capture excess or scarcity of credits (applied technology) associated with a real-world sequence, and would deprive the model of ability to predict credit balances and manufacturer decisions on fines. The current approach is far more realistic and provides better information.

5. SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   This model component is essential if there is interest in the effects of paying fines or carrying credits forward. One must use real estimates within the cadence of design for each manufacturer, or lose manufacturer-specific historical information that drives, in part, manufacturer behavior.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

   None

Walter Kreucher

REVIEW TOPIC NUMBER 1.3. MANUFACTURER RESOURCE CONSTRAINTS MODELED ON A YEAR-BY- YEAR BASIS USING PRODUCT REDESIGN AND REFRESH SCHEDULES (AND COMPONENT SHARING) RATHER THAN PHASE-IN CAPS TO DETERMINE THE PACE OF TECHNOLOGY CHANGE

1. What are the most important concerns that should be taken into account related to the review topic?

   A manufacturer's **overall resource capacity** available for implementing new technologies (such as engineering research and development personnel, and financial resources) is a real constraint for most manufacturers and **must be accounted for somehow in the model**.

   Figure 13.3 in the draft TAR shows the percent of a manufacturer's vehicles that are projected by the model to be redesigned in a single model year. There are 27 instances where more than a third of a manufacturer's vehicles are redesigned in a single year and 9 instances where half, 3 instances where three-quarters, and even 2 instances where essentially the entire fleet is redesigned in a single year.

   One has to question where a manufacturer would get the resources to undertake that level of commitment.

   Each new engine and each new transmission requires millions of miles of durability prove-out under all kinds of environmental and product use conditions. This requires manpower, time, and capital.

   For a full line manufacturer like Ford, or General Motors, the durability cycles required to conduct a thorough failure mode effects analysis are substantially different between their light-duty vehicle and their light-duty truck fleets. Medium duty and heavy-duty procedures are also substantially different. The model asks manufacturers to expend more resources. And not just by a little. **In the case of General Motors the model suggests that the company can implement more fuel economy improvements across their passenger car fleet in 7 of 10 consecutive years than it has ever done in a single year while at the same time implementing more fuel economy improvements in their truck fleet than ever before in two of those demanding years**. This does not seem realistic. (Also see 4.4 below)

   RESPONSE: This may be misunderstanding the purpose of the model. In this case, the model was simply reporting that a manufacturer would, in order to comply with a given schedule of future standards, need to improve fuel economy by reported levels. DOT does not intend that model results, by themselves, suggest the manufacturer can or cannot practicably do so.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The model does not have any resource constraints. This is a serious shortcoming in the model. One that is likely to produce unrealistic results.

RESPONSE: The model accounts for product cadence with a view toward estimating practicable solution, and also accommodates inputs specifying caps on the rates at which specific technologies can be phased in. These caps can be specified based on considerations (e.g., access to capital) not included explicitly in the model. As discussed below, further research would be needed to develop methods and accompanying inputs—perhaps involving significant reliance on confidential business information—to represent various resources constraints explicitly.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   A more realistic approach would be to place a limit on the engineering and product changeover costs as a percentage of revenue. This would require a substantial redesign of the model and would require additional input data.

   RESPONSE: Further research is required to determine how feasible it would be to implement such an approach, which could potentially require explicit accounting (separately) for fixed and variable costs, as well as revenue and perhaps profit projections. As indicated, even if practicable, this would involve a substantial redesign of the model's cost accounting structures. It could also involve considerable information difficult to obtain, especially on a nonconfidential basis.

4. Is there an alternative approach that you would suggest?

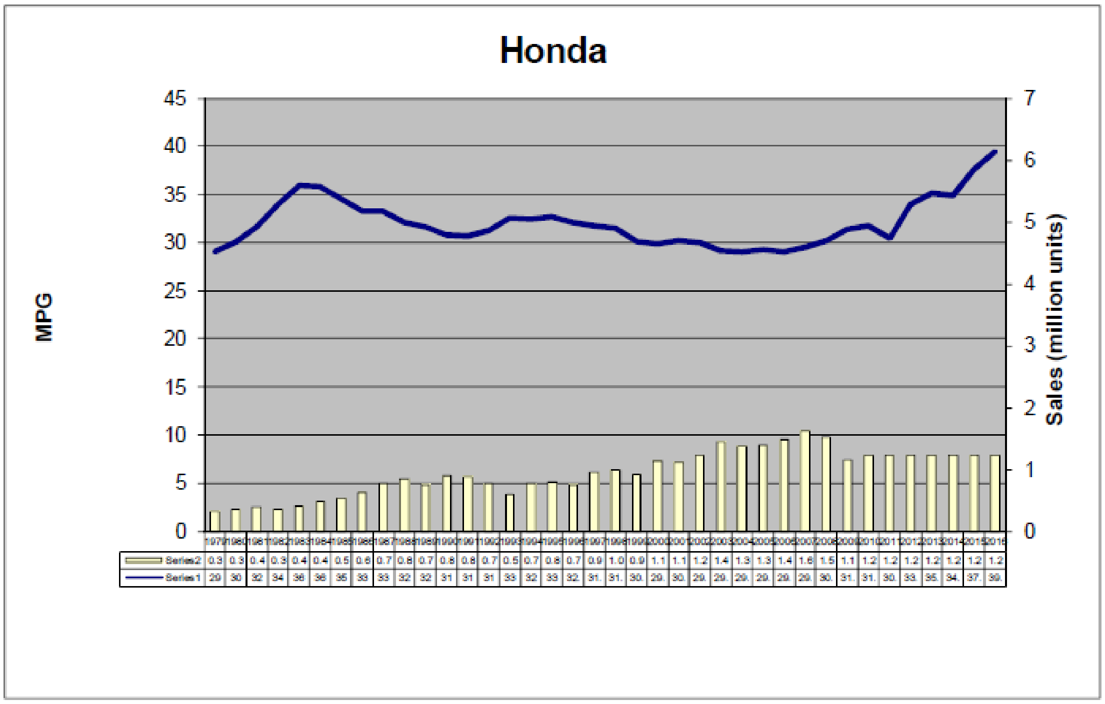
   The simplest solution is to "cap" redesign at some fixed percentage the fleet redesign or **limit the maximum fuel economy improvement in the fleet to the historical average**. This would also necessitate a limit on subsequent year improvements to give a breather.

   RESPONSE: This approach would presume some balancing of the factors involved in determining the maximum feasible stringency of standards. The model already provides the ability to specific a range of potential future standards to be evaluated; if limits such as the above are determined to constitute the proper balancing of factors, the corresponding scenario can be selected. While it would be technically possible to "hard code" a cap on the rate at which the model can increase fuel economy, doing so would require imposing a priori judgment regarding that rate, and defeat part of the model's basic purpose—the exploration of ranges of alternatives, including cases that go beyond historical averages.

5. Provide any additional comments that may not have been addressed above.

   Table 4.42 of the draft TAR shows substantial differences in the redesign cycles between the various manufacturers. At first glance, this may seem odd. The answer as to what may account for the differences lies in the basic definition of a redesign.

Take Honda as an example. When one examines the CAFÉ history of Honda we discover that the company has not made any substantial contribution to improving its fuel economy since the early 1980s. So what is considered a redesign for Honda is not the same as a redesign at Ford, or General Motors, who have substantially increased their CAFÉ performance over this same time frame.



Manufacturer Fleet Average Fuel Economy

Thus, **VOLPE should not assume that a manufacturer can shorten its redesign time by "a year or two"** as is the current practice in the model. Resource constraints and the degree of difficulty in implementing any given technology must be taken into account.

The model should incorporate industry standard timetables based on full line manufacturers for engine, transmission, and vehicle redesign.

RESPONSE: Schedules of estimated future redesigns are specified as model inputs, and recent inputs make no such assumptions. For recent rulemaking analyses, NHTSA and Volpe Center staff have used the best available publicly releasable information to develop these inputs. As discussed above, further research would be needed to determine whether specific resource constraints could practicably be applied as explicit constraints.

Jose Mantilla

Reviewer Name: Jose Mantilla

Review Topic Number: 1.3 – Manufacturers resource constraints modeled on a year-by-year basis using product redesign and refresh schedules (and component sharing) rather than phase-in caps to determine the pace of technology change

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

No evidence is provided for the fundamental assumption (for this review topic) that manufacturers apply multi-year planning – *that is, manufacturers may apply "extra" technology in an early model year with many planned redesigns in order to carry technology forward to facilitate compliance in a later model year with fewer planned redesigns…and to…earn CAFE credits in some model years and use those credits in later model years, thereby providing another compliance option in years with few planned redesigns.* The logic presented in the draft TAR is reasonable but lacks substantiation in terms of the extent to which it occurs across manufacturers, as well as the timing in which it occurs across and within manufacturers.

The main concerns with respect to phase-in caps are whether it is appropriate to reduce the emphasis on manufacturers' resource capacity and to what extent the resource capacity is already captured in the frequency and timing of the redesign/refresh schedules.

RESPONSE: Ample evidence of such planning has been provided to NHTSA in manufacturers' product plans. While such plans are protected confidential business information, some manufacturers' related comments are illustrative.[1] Information regarding manufacturers required and achieved CAFE levels and CAFE credits is publicly available on the Internet at NHTSA's CAFE Public Information Center (https://one.nhtsa.gov/cafe_pic/CAFE_PIC_Home.htm). While the model also accommodates phase-in caps that can, for example, be used to address additional resource constraints not accounted for explicitly by the model, realistic inputs regarding product cadence can also do so.

[1] See, e.g., FCA comments submitted September 26, 2016, to docket number NHTSA-2016-0068 at www.regulations.gov.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

Insufficient information is provided to assess the reasonableness and appropriateness of data, computation methods and assumptions – specifically how the year-by-year analysis integrates the multiyear planning that manufacturers are assumed to engage in. In addition, as discussed in point 1 above, there is no evidence that manufacturers actually engage in the type of multi-year planning that is assumed in the draft TAR, and that is identified as a fundamental component in determining the year-by-year analytical results.

RESPONSE: The model's simulation of multiyear planning builds on past model revisions—responding to manufacturers' past comments from as early as 2002—to account for product cadence. At a general level, the model's simulation of multiyear planning can be assessed by comparing the year-by-year progression of reported required and achieved CAFE levels, and reported levels of credit earning and use. This information is included in the "compliance_report.csv" output file the model produces each time it is executed. The model's specific step-by-step simulation of multi-year planning decisions can be assess by examining the "cf_trace" log file the model records separately for each regulatory scenario.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Pending a satisfactory resolution of the demonstrated practice by manufacturers to engage in the type of multi-year planning assumed in the draft TAR, advice can be provided on potential modifications.

RESPONSE: See response to #1 above.

4. Is there an alternative approach that you would suggest?

Pending a satisfactory resolution of the demonstrated practice by manufacturers to engage in the type of multi-year planning assumed in the draft TAR, advice can be provided on alternative approaches.

RESPONSE: See response to #1 above.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The review topic is of critical importance to the overall utility and plausibility of the Volpe Model output. As stated in the draft TAR, the explicit simulation of multi-year planning (by manufacturers) plays an important role in determining year-by-year analytical results. It is my expectation that the manufacturers' redesign and refresh schedules inherently reflect resource capacity. Accordingly, the increased emphasis on multi-year planning (if it is indeed a common practice) seems appropriate.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Wallace Wade

Reviewer Name:_Wallace R. Wade

Review Topic Number: _1.3. Manufacturer resource constraints modeled on a year-by-year basis using product redesign and refresh schedules (and component sharing) rather than phase-in caps to determine the pace of technology change

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

The Volpe Model includes redesign schedules as an input, and the model limits the introduction of most technologies on a vehicle to major redesign years or refresh years. For every model that appears in the MY 2015 analysis fleet, NHTSA has estimated the model years in which future redesigns (and less significant "freshening," which offer manufacturers the opportunity to make less significant changes to models) will occur, as summarized in Figure13.3, Share of Manufacturer Sales Redesigned in Each Model Year 2016–2030. The model assumes that most technologies will be applied when vehicles are freshened or redesigned, and that manufacturers would sometimes apply technology earlier than "necessary" in order to facilitate compliance with standards in ensuing model years. Each technology considered for application by the Volpe Model is assigned to either a "refresh" or "redesign" that dictates when it can be applied to a vehicle.

Tables 13.3 and 13.4 show the technologies available to manufacturers in the compliance simulation, the level at which they are applied, and whether they available for a refresh or a vehicle redesign only.
(2016 Draft TAR, pp.13-5 to 13-7 and Tables 13.3 and 13.4)

Concern 1:
Although the Volpe Model, as described above, appears to largely reflect industry practice, a significant shortcoming appears to be that the model's current analysis does not account for future new vehicle models or discontinued models. For example, Ford is expected to introduce the EcoSport SUV, Ranger pickup truck, and Bronco SUV in the next few years and discontinue the Lincoln MKS. NHTSA recognizes that some years in which an OEM indicated few redesigns may be years when significant new products are planned to be introduced, but a process for incorporating these new products in the Volpe Model is needed.

Recommendation 1:

Develop a means to recognize and incorporate new vehicle models as well as discontinued models in the Volpe Model. The workload of new vehicle models needs to be recognized together with the impact on current vehicle redesigns (possibly lengthening the period between redesigns) and the estimates of production volumes for the new as well as current vehicle models. Although manufacturers may have been hesitant to provide this information in the past, NHTSA should explain that having this information, as least defined as new offerings by segment, would be beneficial in improving the results from the Volpe Model.

RESPONSE: Design schedules and product offerings are model inputs rather than inherent to the model. Past rulemaking analyses during 2003 to 2009 made direct use of product plans that were typically provided by manufacturers as confidential business information (CBI) and, in some cases, adjusted and corrected in response to NHTSA and Volpe Center staff comments and questions. Those plans reflected new products, discontinued products, gaps in the production of some products, and actual plans to redesign specific vehicles. However, the use of CBI meant that details of the modeling could not be made public. The importance of making details of the modeling public is a policy issue rather than a technical one, and not within the control of Volpe Center staff.

Concern 2:
Table 13.4 shows that most transmissions are applied during redesigns only. However, transmissions can also be applied during a refresh, or even a running change. Recently, the 2017 MY Ford F-150 received a mid-year upgrade with the application of a new 10 speed automatic transmission.

Recommendation 2:
Consider revising Table 3.4 to reflect that transmissions can often be changed during a refresh as well as a redesign. Other technologies should also be reviewed as candidates for application during a refresh.

RESPONSE: The model has been revised to apply transmission changes during either a refresh or a redesign.

The Volpe Model retains phase-in caps that constrain technology application at the vehicle manufacturer level for a given model year. Since the use of phase-in caps has been de-emphasized and manufacturer technology deployment remains tied strongly to estimated product redesign and freshening schedules, technology penetration rates may jump more quickly as manufacturers apply technology to high-volume products in their portfolios.
(2016 Draft TAR, pp. 13-26 to 13-27)

Concern 3:
The expected jump in technology penetration rates, with the de-emphasized phase in caps may result is several issues, even though manufacturers may use low to moderate volumes for the early introductions of new technology to ensure adequacy of the design and system integration.

- For subsequent applications, manufacturers may have limited application engineering resources that need to be recognized with phase-in caps.

- Manufacturing ramp up for the technology may be volume limited and require additional time to achieve manufacturing capability (such as new manufacturing lines or new plants) for higher volumes. Manufacturing volume limitations need to be recognized with phase-in caps.

Recommendation 3:

For the reasons cited in Concern 3, phase-in caps should be retained, but reviewed, and modified as required, to reflect these concerns.

RESPONSE: Phase-in caps are model inputs, with specific values not inherent to the model. Other constraints, especially those involving the model's handling of redesigns, act to limit technology application more than when phase-in caps were introduced as an available model constraint. With phase-in caps set in a non-limiting way (i.e., at 100%), close examination of reported year-by-year technology application can be emphasized in the review of model results. As warranted, "tighter" phase-in caps can be specified.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

Computational methods, assumptions and input data may need to be modified in order to adopt Recommendations 1-3.

RESPONSE: See responses adjacent to recommendations 1-3 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1-3.

RESPONSE: See responses adjacent to recommendations 1-3 above.

4. Is there an alternative approach that you would suggest?

No. Implementation of Recommendations 1-3 is the suggested approach.

RESPONSE: See responses adjacent to recommendations 1-3 above.

5. [SKIP FOR REVIEW TOPICS 4.4   4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The plausibility of the Volpe Model output would be enhanced by implementing Recommendations 1-3.

RESPONSE: See responses adjacent to recommendations 1-3 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
1. Updates to 2012 Final Rule Version of the CAFE Model: Constraints on the application of technology into manufacturers' fleets
1.1. Integration of inheritance and sharing into engines, transmissions, and platforms in a manufacturer's fleet
1.2. Integrated analysis across regulatory vehicle classes, including heavy-duty pickups and vans
1.3. Manufacturer resource constraints modeled on a year-by-year basis using product redesign and refresh schedules (and component sharing) rather than phase-in caps to determine the pace of technology change
1.4. Manufacturer behavior regarding CAFE credits
1.5. The use of technology classes to accommodate different technology-related inputs for different types of vehicles (e.g., small cars, pickup trucks).

Nigel Clark

[NO RESPONSE.]

Walter Kreucher

REVIEW TOPIC NUMBER 1.4. MANUFACTURER BEHAVIOR REGARDING CAFE CREDITS

1. What are the most important concerns that should be taken into account related to the review topic?

   There are a couple of issues with how the model handles credits.

   First, as noted in the TAR, the statute prevents the use of credits in the standard setting process. This begs the question as to why the model even allows the use of credits.

   Second, the cross-manufacture trading provision that was added to the statute in recent years was requested by certain foreign manufacturers so that they could by-pass the “Dingell” provision in the original statute that considered a manufacturer’s domestic and import car fleets to be produced by separate manufacturers (i.e., no credit trading between domestic and import fleets for a given manufacturer).

   When the first Energy Policy Act authorizing CAFÉ standards was being debated in Congress, the United Auto Workers convinced Congressman John Dingell that if stringent CAFÉ standards were enacted, small car production would be shipped overseas costing union workers their jobs in America. In an attempt to prevent domestic manufacturers from shipping jobs overseas, Congressman John Dingell inserted a provision in the statute that deemed vehicles produced with “domestic” content be considered as if they were manufactured by a separate manufacturer than vehicles produced primarily with “import” content.

   Now that credit trading is allowed between manufacturers, Honda for example, can use credits generated in its import car fleet to cover any shortfall in its domestically produced car fleet. The same holds true for other manufacturers.

   Only a few manufacturers are willing to trade credits to competitors.

   There also seems to be an issue with available credits. I have my own spreadsheets that track credits for different manufacturers. I have updated the spreadsheet with the latest CAFE compliance data from NHTSA and compared it to the VOLPE input file. There are substantial differences.

Difference in Banked Credits Available

	PC-2010	PC-2011	PC-2012	PC-2013	PC-2014	LT-2010	LT-2011	LT-2012	LT-2013	LT-2014
BMW	-89%	-61%	-62%	-54%	-47%	-100%	-95%	-99%	-92%	
Daimler	-100%	No Credits Available				-100%	No Credits Available			
FCA	-97%	-43%	-39%	-23%	-81%	-100%	-95%	-100%	-100%	
Ford	-89%	-92%	-93%	-90%	-92%	-94%	-96%	-99%	-97%	-97%
General Motors	-95%	-91%	-96%	-94%	-93%	No Credits Available		-98%	-94%	-76%
Honda	-94%	-100%	-100%	-99%	-100%	-94%	-100%	-100%	-100%	-100%
Hyundai Kia	-90%	-98%	-97%	-96%	-98%	-94%	-96%	-99%	-99%	-99%
Nissan	-100%	-100%	-99%	-99%	-100%	-94%	-100%	-100%	-100%	-100%
TOYOTA	-91%	-99%	-99%	-99%	-100%	-91%	-97%	-100%	-99%	-100%
VWA	-84%	-89%	-91%	-85%	-84%	-75%	-86%	-97%	-87%	-85%

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   No

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   VOLPE should verify the accuracy of banked credits in the input files and delete entirely the 2010MY credits which by regulation cannot be carried forward for cross fleet trading.

   RESPONSE: The model can account for manufacturers' potential application of credits carried forward from prior model years and/or transferred between fleets (such as the Honda example mentioned above), accounting for corresponding statutory limits. Although EPCA required that the determination of the maximum feasible levels of standards be determined without considering the potential to apply CAFE credits in the model years under consideration, Environmental Impact Statements (EISs) required by the National Environmental Policy Act (NEPA) can consider the application of credits. Banked credits are model inputs, values not being inherent to the model itself. Volpe Center staff agree that the banked credit inputs used for the July 2016 analysis should be carefully updated for future analyses. Although NHTSA's CAFE Public Information Center does not provide detailed information regarding specific trades, information submitted by manufactures indicates more trading that some manufacturers' past statements would have suggested. Further research would be required to determine whether, and if so, how it would be practicable to modify the CAFE model to explicitly simulate credit trading.

CARRY BACK OF CREDITS

While the statute prevents the use of credits in standard setting, I noticed that the model sets the carry back of CAFE credits to "FALSE" for the "real-world" scenario. It has been my experience in the corporate compliance world that manufacturers do use carry back. Occasionally a manufacturer will find itself in a situation for various reasons that it misses the standard either by design or through the vagaries of the sales process.

Manufacturers can overshoot in a subsequent year and cover any fine. They will do so as long as applying the technology is the least-cost solution.
I understand that setting the flag to "FALSE" may be an artifact of how the model works. It is just not how the process works in practice.

RESPONSE: Some manufacturers have made occasional use of credit carry-back provisions, although they have repeatedly stated that NHTSA should not assume use of carry-back as a compliance strategy because of the risk in relying on future improvements to cover earlier compliance shortfalls. Thus far, Volpe Center staff have not attempted to include simulation of credit carry-back in the CAFE model, but have provided some of the placeholder material with a view toward potentially doing so in the future if we decide that it is appropriate to consider. Further research would be needed to determine whether it is practicable to do so in a reasonably realistic manner.

CAFE FINES

While we are on the topic of fines, given that NHTSA has collected almost $900 million in fines through the middle of 2014 (based on the most recent publicly available data) this suggests that the models have historically underestimated the cost of technology or overestimated customers willingness to pay for fuel economy. As a result, NHTSA on July 5, 2016,[2] issued an interim final rule that increased the level of fines. This is a reflection of the reality that the cost of compliance was escalating at a rapid pace. This is also a reflection that the cost of technology used in setting the standards grossly underestimated the true cost of compliance as a record number of manufacturers were finding it less expensive to pay the fine.

VOLPE must assess the true cost to implement technology and revise the model inputs accordingly.

> **RESPONSE: The true cost to each manufacturer for each technology and each vehicle model/configuration in each future model year is unknowable. Nevertheless, Volpe Center and NHTSA staff agree that, within the context of any rulemaking analysis that can be practicably implemented, cost (and other) inputs should reflect the best information available when needed to develop these inputs.**

[2] The increased fine of $14 per 0.1 mpg per vehicle produced was to apply to vehicles made since MY 2015. On December 21, 2016, NHTSA postpone implementation of the fines until MY 2019.

Jose Mantilla

Reviewer Name: Jose Mantilla

Review Topic Number: 1.4 – Manufacturer behavior regarding CAFE credits

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

> It is not clear how the past accumulation and use of CAFE credits has been used to inform the model's approach to simulating compliance decisions that account for the potential to earn and use credits.

RESPONSE: See response to #2 below.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

> The use of past trends and patterns is reasonable and appropriate to inform the development of algorithms to estimate credits available, as well as their interaction with the addition of new technologies. However, I am not in a position to comment on the robustness of the algorithms presented in the Model Documentation. Furthermore, there needs to be a detailed explanation of how/why the past data selected is truly representative of 'normal' credit accumulation and technology deployment conditions. In other words, the reader needs to be satisfied that the past data examined was not influenced by unusual circumstances.
>
> The assumptions with respect to the logic to maximize credit carry-forward and application of expiring credits before deploying new technologies in a given model year seems reasonable. However, no evidence is provided to link these assumptions to actual demonstrated behavior by manufacturers.

RESPONSE: Information available through NHTSA's CAFE Public Information Center web site (https://one.nhtsa.gov/cafe_pic/CAFE_PIC_Home.htm) provides some basis for considering manufacturers' past compliance and credit positions. As to whether the past data was influenced by unusual circumstances, or whether "past is prologue," future standards are not known until promulgated, future market trends are not known in advance, so future tendencies toward trading are also uncertain.

Model inputs can be specified to adjust the estimated tendency to maximize (or minimize) credit carry-forward.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Pending a satisfactory resolution of the demonstrated credit carry-forward/use practice by manufacturers, advice can be provided on potential modifications.

RESPONSE: See response to #2 above.

4. Is there an alternative approach that you would suggest?

Pending a satisfactory resolution of the demonstrated credit carry-forward/use practice by manufacturers, advice can be provided on alternative approaches.

RESPONSE: See response to #2 above.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The review topic is of critical importance to the overall utility and plausibility of the Volpe Model output. Manufacturer behavior regarding CAFE credits, and its link to the deployment of new technologies, is fundamental to the model's ability to simulate compliance decisions and addition of technologies. As such, the explicit accounting for CAFE credits in the model is an essential component of the model.

RESPONSE: NHTSA and Volpe Center staff agree that explicit accounting for CAFE credits is an essential component of the model.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Wallace Wade

Reviewer Name: _Wallace R. Wade

Review Topic Number: 1.4. Manufacturer behavior regarding CAFE credits

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

Like previous versions, the current CAFE model can be used to simulate credit carry-forward (a.k.a. banking) between model years and transfers between the passenger car and light truck fleets, but not credit carry-back (a.k.a. borrowing) between model years or trading between manufacturers. Unlike past versions, the current CAFE model provides a basis to specify CAFE credits available from model years earlier than those being simulated explicitly (e.g., credits specified as being available from MY 2014 are made available for use through MY 2019, given the 5-year limit on carry-forward of credits).

Although the model uses credits before they expire if a manufacturer needs to cover a shortfall in achieving compliance with a standard, the model will otherwise carry forward credits until they are within 2 years of expiration, at which point it will use them before adding technology. The model always applies expiring credits before applying technology in a given model year, but attempts to use credits that will expire within the next three years as a means to smooth out technology application over time to avoid both shortfalls and high levels of over-compliance that can result in a surplus of credits.

CAFE credits estimated to be available by manufacturer from 2010 to 2014 are shown in Table 13.2.
(2016 Draft TAR, pp. 13-27 to 13-28)

The final CAFE rule imposes a limit of 2 mpg credit for MY 2018 and beyond that can be transferred between the passenger car fleet and light truck fleet, or vice versa (EPA/NHTSA, 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, August 28, 2012, p. 62648).

Concern 1:
The 2016 Draft TAR in the Accounting for CAFE Credits section does not identify the limit of 2 mpg for MY 2018 and beyond that can be transferred between the passenger car fleet and light truck fleet.

Recommendation 1:

The TAR should mention the limit of 2 mpg credit for MY 2018 and beyond that can be transferred between the passenger car fleet and light truck fleet.

RESPONSE: The 2016 analysis did apply the above-mentioned cap on credit transfers. Volpe Center and NHTSA staff agree that this needs to be evident in future analyses.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The Volpe Model's representation of the CAFE credit provisions appears to be reasonable and represents the methodology that manufacturers would likely followed for credit carry-forward (a.k.a. banking) between model years and transfers between the passenger car and light truck fleets.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

The Volpe Model does not appear to need modifications for modeling credit carry-forward (a.k.a. banking) between model years and transfers between the passenger car and light truck fleets.

Recommendation 1 should be implemented in the TAR.

RESPONSE: See response to recommendation 1 above.

4. Is there an alternative approach that you would suggest?

No. The current approach appears to be suitable.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

The utility of the Volpe Model output should be adequate for modeling credit carry-forward (a.k.a. banking) between model years and transfers between the passenger car and light truck fleets.

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

Review topic
1. Updates to 2012 Final Rule Version of the CAFE Model: Constraints on the application of technology into manufacturers' fleets
1.1. Integration of inheritance and sharing into engines, transmissions, and platforms in a manufacturer's fleet
1.2. Integrated analysis across regulatory vehicle classes, including heavy-duty pickups and vans
1.3. Manufacturer resource constraints modeled on a year-by-year basis using product redesign and refresh schedules (and component sharing) rather than phase-in caps to determine the pace of technology change
1.4. Manufacturer behavior regarding CAFE credits
1.5. The use of technology classes to accommodate different technology-related inputs for different types of vehicles (e.g., small cars, pickup trucks).

Nigel Clark

Reviewer Name:_ Nigel N. Clark

Review Topic Number: 1.5. The use of technology classes to accommodate different technology-related inputs for different types of vehicles (e.g., small cars, pickup trucks).

Other Review Topic Numbers (if interactive effects are focus of discussions)

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   This topic is related to efficiency in operating the model by using lumping of technology rather than more tenuous design associations between separate vehicles. More important, it addresses the fact that a manufacturer is likely to treat a cohort of vehicles (now lumped in the model) in a similar fashion. This could extend to the powertrain language presented below.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   Overall, yes, but there could be granular concerns. The model approach associates vehicles of the same type and purpose, and helps to make them coherent, so that they are treated in an equitable fashion. This is reasonable except in the case where two vehicles in the same class are handled by separate design teams with radically different philosophies (large manufacturer).

   Some specific concerns are:

   - The vehicle technology classes are defined primarily by size, and secondarily by type. The TAR does recognize that in some cases very similar vehicles may be defined differently – one as a car and the other as a truck/SUV. In this way the technology classes may assist the model, but may also invoke the need for exceptions.
   - In one class, say “Medium- to Large Passenger Cars,” there may be substantially different purposes in the design. One model may be a sports car, with a high power-to-weight ratio, another designed for dutiful transportation of people. They will clearly differ in design beyond even power-to-weight ratio. For example, the sports car may sacrifice aero for aesthetics or appealing features, and will certainly have a different driver interface. It is likewise with high MSRP versus utilitarian designs in the same technology class.
   - The era is arriving when complete powertrains are the focus, rather than engines themselves. Seeing the powertrain as the focus allows a conventional package and a hybrid package to be seen more as direct competitors, and recognizes the higher degree of integration now found. This approach would reduce the workload on Autonomie, since Autonomie would no longer handle shifting and certain controls, but rather use a sub-model for the whole powertrain that would require a different, more complex, mapping. Without this “whole powertrain” approach, efforts by manufacturers to

reduce fuel economy through sophisticated controls may not be recognized, and two instances of the same technology change will be ascribed the same benefit by the model, even if the true benefits could differ widely. The manufacturers will know, when they upgrade the gear count of a transmission, that they can use the older, mundane control strategies with the new transmission, or seek to gain more advantage by investing in more joint optimization and innovation of the engine-transmission combination. (In the diesel case, an engine-transmission- aftertreatment combination for management) These assertions may well propel the Volpe model to an unnecessary level of sophistication, though, and adoption of a transmission change with some assumed mid-level commitment to advanced controls would likely suffice. Perhaps this comment is more appropriate for the next evolution of the Volpe model.

- It is likely that some classes are narrowly defined and will catch few vehicles while others are very broad. There is DOHC (broad and large?) but three levels of cooled EGR technology. This will work in the model, but different choices in binning technology (even for pathway definitions) might either improve overall prediction or reduce execution time.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   None to the model, but the documentation could offer a caveat that these technology classes offer a broad approach, and specific vehicle examples within the class could vary in sophistication in a real-world scenario.

   RESPONSE: The model and input file structure have been revised to accommodate a wider range of technology classes, thus providing greater ability to account for significant differences in vehicle performance and/or utility. Regarding future trends in powertrain engineering, as long as the initial fleet used for modeling has diverse combinations of engines and transmissions, inputs to estimate corresponding fuel economy levels will continue to be important.

4. Is there an alternative approach that you would suggest?

   No.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   Definition of pathways (order of technology choices) is critical to the model, to avoid predicting change that is not cost effective to the manufacturer, and hence would not occur. This sector of the model adds confidence in the model's ability to predict outcomes and compliance pathways.

   RESPONSE: We agree. Engineering and other constraints may be such that a manufacturer cannot practicably always make every change that, on a theoretical basis, would be the most

cost effective. Within the context of defined constraints, the model's approach to selecting among available options does seek to minimize "effective costs" (as defined in the model documentation).

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

   None

Walter Kreucher

REVIEW TOPIC NUMBER 1.5. THE USE OF TECHNOLOGY CLASSES TO ACCOMMODATE DIFFERENT TECHNOLOGY-RELATED INPUTS FOR DIFFERENT TYPES OF VEHICLES (e.g.., SMALL CARS, PICKUP TRUCKS).

1. What are the most important concerns that should be taken into account related to the review topic?

   The use of technology classes to accommodate different technology-related inputs for different types of vehicles is both a necessity and appropriate. There are significant differences in the cost and hardware associated with the various technologies across the various vehicle types of vehicles. The simplest example is that of a PHEV50. The battery necessary to power an F150 pickup truck for 50 miles would not be the same size as would be required to power a Fiesta that same distance.

   RESPONSE: This example illustrates part of the motivation for accommodating inputs specific to several differentiated technology classes.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   Yes

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   None

4. Is there an alternative approach that you would suggest?

   No

5. What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   The use of technology classes is of extreme importance.

6. Provide any additional comments that may not have been addressed above.

Jose Mantilla

Reviewer Name: Jose Mantilla

Review Topic Number: 1.5 – The use of technology classes to accommodate different technology-related inputs for different types of vehicles

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.*]

1. What are the most important concerns that should be taken into account related to the review topic?

> The basis for the adoption of seven vehicle technology classes is not provided – are these seven classes sufficient and comprehensively representative of the diversity of light-duty vehicles in the U.S. market?
>
> The basis for the adoption of sixteen engine technology classes is not provided – are these sixteen classes sufficient and comprehensively representative of the diversity of light-duty vehicles in the U.S. market?
>
> **RESPONSE: The model and input file structure have been revised to accommodate a wider range of technology classes, thus providing greater ability to account for significant differences in vehicle performance and/or utility. Further explanation has been provided regarding the model's classification structure.**

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

> Insufficient information is provided to assess the reasonableness and appropriateness of the technology assumptions – specifically how the vehicle and technology classes were determined. The draft TAR and Model Documentation would benefit from providing a simple rationale for the adoption of the vehicle and engine technology classes. More specifically, the criteria used to "condense" or group the spectrum of vehicle and engine technologies needs to be specified. Furthermore, information on the current diversity of vehicle and engine types in the fleet (presumably much larger than seven and sixteen, respectively) should be presented, together with a description of how the criteria enabled the identification of the proposed classification.
>
> **RESPONSE: See response to recommendation #1 above.**

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Pending a satisfactory resolution of the rationale for the identification of vehicle and engine technology classes, advice can be provided on potential modifications.

RESPONSE: See response to recommendation #1 above.

4. Is there an alternative approach that you would suggest?

Pending a satisfactory resolution of the rationale for the identification of vehicle and engine technology classes, advice can be provided on alternative approaches.

RESPONSE: See response to recommendation #1 above.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The review topic is of critical importance to the overall utility and plausibility of the Volpe Model output. The principle of defining vehicle and engine technology classes is a valid approach for logically grouping the application of technologies available on a specified vehicle.

RESPONSE: NHTSA and Volpe Center staff agree that it is important the model accommodate inputs specific to differentiated vehicle and engine technology classes.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Wallace Wade

Reviewer Name: Wallace R. Wade

Review Topic Number: 1.5. The use of technology classes to accommodate different technology-related inputs for different types of vehicles (e.g., small cars, pickups)

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

The Volpe Model defines two types of technology classes: vehicle technology classes and engine technology classes.

Vehicle Technology Classes:

The Volpe Model supports seven vehicle technology classes listed below.

Table 13.5 Vehicle Technology Classes

Class	*Description*
SmallCar	*Small passenger cars*
MedCar	*Medium to large passenger cars*
SmallSUV	*Small sport utility vehicles and station wagons*
MedSUV	*Medium to large sport utility vehicles, minivans, and passenger vans*
Pickup	*Light duty pickups and other vehicles with ladder frame construction*
Truck 2b/3	*Class 2b and class 3 pickups*
Van 2b/3	*Class 2b and class 3 cargo vans*

Concern 1:
The light-duty CAFE requirements apply to new light-duty vehicles, light-duty trucks, and medium-duty passenger vehicles (MDPVs). The descriptions in Table 13.5 are not clear about where MDPVs are binned in the Vehicle Technology categories. Are they binned under "Pickup" as "other vehicles with ladder frame construction"? Since this category may not be all inclusive for MDPVs, where are MDPVs binned with unibody construction (e.g., Ford Transit van)? Are they included under MedSUV as "passenger vans"?

Recommendation 1:
Provide an explanation of where MDPVs are binned in the Vehicle Technology categories shown in Table 13.5 of the 2016 Draft TAR.

RESPONSE: Vehicle-specific inputs are used to assign all vehicles (including MDPVs) to technology classes. For the analysis released in 2016, these inputs were used to assign the included MDPVs to the "Pickup" technology class.

Concern 2:
Including the analysis of Truck 2b3 and Van 2b3 classes in the analysis of the light-duty CAFE requirements appears to be a significant additional task. In addition to ensuring that similar technologies for engines, transmissions or platforms used in Class 2b/3 vehicles will also be applied in the light-duty CAFE applications, is the analysis of Class 2b/3 vehicles also used in the analysis of the medium- and heavy-duty GHG and Fuel Efficiency Standards through 2027?

Recommendation 2:
Provide an explanation of why the significant task of analyzing the Truck 2b3 and Van 2b3 classes was added to the analysis of the light-duty CAFE requirements, when this task appears to exceed what may be required to ensure that similar technologies for engines, transmissions or platforms used in Class 2b/3 vehicles will also be applied in the light-duty CAFE applications.

RESPONSE: The capability to simulate standards and impacts considering the combination of the light-duty and heavy-duty pickup and van fleets was added with a view toward providing the ability to account for any shared platforms or powertrain elements that span these regulatory classes. For example, the analysis released in 2016 used inputs that showed several vehicles (Armada, Frontier, Titan, XTerra, and NV MDPV passenger vans) regulated as light-duty vehicles are offered with the same two engines as Nissan's NV cargo vans regulated as 2b3 trucks. The model can easily be exercised without making use of this capability.

Concern 3:
For the 2012 CAFE rule making, NHTSA identified 12 vehicle classes, but mapped these classes into 6 vehicle classes used by the LPM (Lumped Parameter Model).
(NHTSA. "Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2017-MY2025 Passenger Cars and Light Trucks," 2012, p. 244)

By comparison to NHTSA's 12 vehicle classes, the following classes, previously used by NHTSA, are missing, while the Truck 2b/3 and Van 2b/3 are new additions:

- Subcompact Car
- Large Car
- Minivan
- Small SUV/Pickup/Van
- Med SUV/Pickup/Van
- Large SUV/Pickup/Van

The small and medium pickups may not be adequately handled with the Vehicle Technology Classes shown in Table 13.5.

Recommendation 3:
Provide a discussion of the previously used Vehicle Technology Classes for the 2012 Final Rule and the rationale for the changes in Vehicle Technology Classes shown in Table 13.5 of the 2016 Draft TAR. Determine if the small and medium pickups are adequately handled with the Vehicle Technology Classes shown in Table 13.5.

RESPONSE: The model and input file structure have been revised to accommodate a wider range of technology classes, thus providing greater ability to account for significant differences in vehicle performance and/or utility. Further explanation has been provided regarding the model's classification structure.

Concern 4:
The following issues relate to Vehicle Technology Classes listed in Table 13.5.

- The description of the Small Car class should include: Subcompact and Compact cars.
- Small Station Wagons and Midsize Station Wagons are two separate categories in the EPA Fuel Economy Guide. Since these vehicles are generally derivatives from passenger cars, binning them with Small and Medium Car, respectively, might be more appropriate than binning them with Small SUVs.
- The Pickup category needs to include pickups that might have unibody construction (e.g., Honda Ridgeline).

Recommendation 4:
Consider revisions to the content of the Vehicle Technology Classes shown in Table 13.5 to address the three suggestions listed in Concern 4.

RESPONSE: The model and input file structure have been revised to accommodate a wider range of technology classes, thus providing greater ability to account for significant differences in vehicle performance and/or utility. Further explanation has been provided regarding the model's classification structure.

Engine Technology Classes:

The Volpe Model supports 16 Engine Technology Classes as shown in Table 4. These Engine Technology Classes appear to be more than adequate. It is unlikely that the 2-cylinder and 16-cylinder engines will be important for the analysis of CAFE compliance in the 2022-2025 timeframe.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

Concerns 1-4 address possible issues related to Vehicle Technology Classes and the additional task of including the Truck 2b/3 and Van 2b3 classes in the light-duty CAFE analysis in order to ensure that similar technologies for engines and transmissions used in Class 2b/3 vehicles will also be applied in the light-duty CAFE applications.

The Volpe Model's representation of the Engine Technology Classes appears to be adequate.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1-4.

4. Is there an alternative approach that you would suggest?

No. Implementation of Recommendations 1-4 is the suggested approach.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The utility of the Volpe Model should be adequate for representing Engine Technology Classes, but the Vehicle Technology Classes may be enhanced by implementing Recommendations 1- 4. **RESPONSE: See responses to recommendations 1-4 above.**

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
2. Updates to 2012 Final Rule Version of the CAFE Model: Volpe Model use of Argonne National Laboratory (ANL) Autonomie Vehicle Simulation Model
2.1. Combined impact of applying new technologies simultaneously
2.2. Determining the reference point on which to apply incremental fuel economy improvement
2.3. Calculating the synergy for fuel economy of technology n-tuples
2.4. The models' approaches to estimating the fuel economy level that could be achieved by applying a given combination of technologies to a given vehicle, and the models' approaches to estimating the accompanying costs.

Nigel Clark

Reviewer Name:_ Nigel N. Clark

Review Topic Number: 2.1. Combined impact of applying new technologies simultaneously

Other Review Topic Numbers (if interactive effects are focus of discussions

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   This topic addresses the following need. At a high level, three important issues related to the simultaneous adoption of new technologies, namely

   A. One technology does not allow the other, because there is direct conflict (a trivial example would be applying variable valve timing to a fuel cell vehicle), or
   B. The technologies each offer improvements to fuel efficiency, but the total combined benefit of the technologies is less than the product (as a ratio) or sum (as a percentage) of their individual beneficial effects, or, in fewer cases,
   C. Two technologies may work together to yield more than the sum of their individual effects.

   The model addresses this in detail, relying on the Autonomie simulations to satisfy B.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   Yes. The discussion in the TAR covers the fact that a technology may have differing effects on fuel economy improvement because it is working in synergy with other, different technologies for fuel saving. Of course, it can have differing effects also because it may be better integrated, controlled in a more sophisticated fashion, or applied to different base vehicles – it is not just technology pairs that matter.

   RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   None. The model should be praised for recognizing the more robust approach of using incremental improvement values (differencing) rather than absolute values.

   RESPONSE: NHTSA and Volpe Center staff agree, but also note that incremental improvements are derived from absolute values (i.e., estimated fuel economy levels for specific technology combinations as applied to specific vehicle types), and the latter could also be used directly as model inputs, as long as enough combinations are included to provide the necessary range of “A to B” comparisons.

4. Is there an alternative approach that you would suggest?

   Not needed

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   At a simple level, most practitioners and many lay people appreciate that effects of improvements are not additive. The model clearly addresses this issue. The only caution is that Autonomie predictions can vary due to different calibrations with real world data (that have inherent error) or due to choice of sub-models such as the driver behavior model. It is an art to determine the most faithful prediction of an incremental improvement, and those improvements, as inputs, are critical to model success.

   RESPONSE: Volpe Center and NHTSA staff agree that Autonomie, like any model used to estimate fuel economy, involves underlying inputs subject to uncertainty. Nevertheless, simulation or some other means of estimation is essential, as it would obviously be infeasible to actual build and physical testing even thousands—much less hundreds of thousands—of prospective combinations of technologies and vehicle types. Autonomie is a widely recognized full-vehicle simulation model developed by Argonne National Laboratory over the past 15 years under funding from the U.S. DOE Vehicle Technologies Office. Autonomie has been developed and validated over a very wide range of powertrain configurations and component technologies leveraging vehicle test data from Argonne Advanced Powertrain Research Facility (APRF) and component performance data from the U.S. National Laboratories, including Oak Ridge National Laboratory (ORNL), Idaho National Laboratory (INL), and the National Renewable National Laboratory (NREL). Input data for Autonomie has been created through a combination of benchmarking activities and high-fidelity component modeling. Benchmarking is a commonly used technique that is intended to create a detailed characterization of a vehicle's operation and performance.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

   The volume of documentation is large, and I may have missed discussion on the following. It is important not to use incremental improvement factors for vehicle behavior other than behavior that is relevant to the CAFE city and highway cycles. Cars that offer high city improvement may not offer much sustained highway improvement (as was discovered by the public a decade ago with many hybrid vehicles). In addition, fitting data on hybrids to match the metric gained from conventional 40-year-old cycles will require careful control. However, the documentation suggests that the model authors are aware of such potential pitfalls.

This comment applies broadly to the use of Autonomie. If the models for components in Autonomie do not include specifically the effect of transient behavior, accuracy of the technology increment effect will be adversely impacted. Invariably shifting of gears leads to a loss of efficiency relative to steady-state operation, due to component (certainly for turbochargers) lag times, transmission clutch operation and the manufacturer effort devoted to initial steady-state mapping and optimization. Adoption of an eight-speed transmission, for example, may show high efficiency because the engine can be run more at a "sweet spot." However, if shifts affect efficiency of the powertrain, the addition shifting will erode some of this advantage.

RESPONSE: To prepare inputs for the CAFE model, Autonomie was exercised under city and highway cycles, as well as under other simulated driving conditions. Inputs—including simulated powertrain controls for HEVs—were developed to ensure realistic results under these driving conditions. These inputs are, themselves, complex, and are discussed in documentation of the vehicle simulation effort.

Walter Kreucher

REVIEW TOPIC NUMBER 2. **UPDATES TO 2012 FINAL RULE VERSION OF THE CAFE MODEL: VOLPE MODEL USE OF ARGONNE NATIONAL LABORATORY (ANL) AUTONOMIE VEHICLE SIMULATION MODEL**

1. What are the most important concerns that should be taken into account related to the review topic?

   As a check on the accuracy of the synergistic effects in the model I examined the EPA fuel economy guide data for the 2017 model year. The results were surprising. Manufacturers had already implemented a considerable amount of technology into the fleet. In fact, the average number of forward gears was seven and 36 percent of the models had eight or more

   forward gears. Almost the entire fleet had variable valve timing and four valves per cylinder. Despite the progress in implementing advanced technology Figure 1 shows that only 19 percent (17% of cars and 23% of trucks) of the models listed in the EPA database met their 2017 model year fuel economy target. Some models missed their target by a substantial amount. **In fact, only 55 percent (24 of 43) of hybrid electric vehicles in the EPA report met the 2025 model year fuel economy target (adjusted for AC).**

   This does not bode well for the industry given that the 2025 model year fuel economy standards are 40 percent higher than the standards for the 2017 model year.

   Table 1 shows the number of models with several key technologies and the percent of models represented in the fleet with that technology. Table 2 compares the technology penetration rates in the 2017 MY with that predicted by the VOLPE model for 2017. The manufacturers introduced technology at a higher penetration rate for engine technology and advanced transmissions compared to the penetration rate predicted by the Volpe CAFÉ model. Yet despite the higher penetration rates the vast majority of models did not meet their 2017 model year
   fuel economy targets.

   What is even more disturbing is the fact that the technology penetration rates for the 2017 MY fleet exceed the VOLPE predicted penetration rates for 2025 MY[3] in a number of instances.

   When Manufacturers cannot even meet the 2017 MY standards with a technology penetration that the model says can achieve the 2025 MY standards something must be amiss.

[3] The technology utilization rates in the output file for the augural standards do not match the penetration rates listed in the draft TAR. This may be due to the statutory requirement not to consider credits.

This suggests a fundamental disconnect between the output of the VOLPE model and real-world fuel economy.

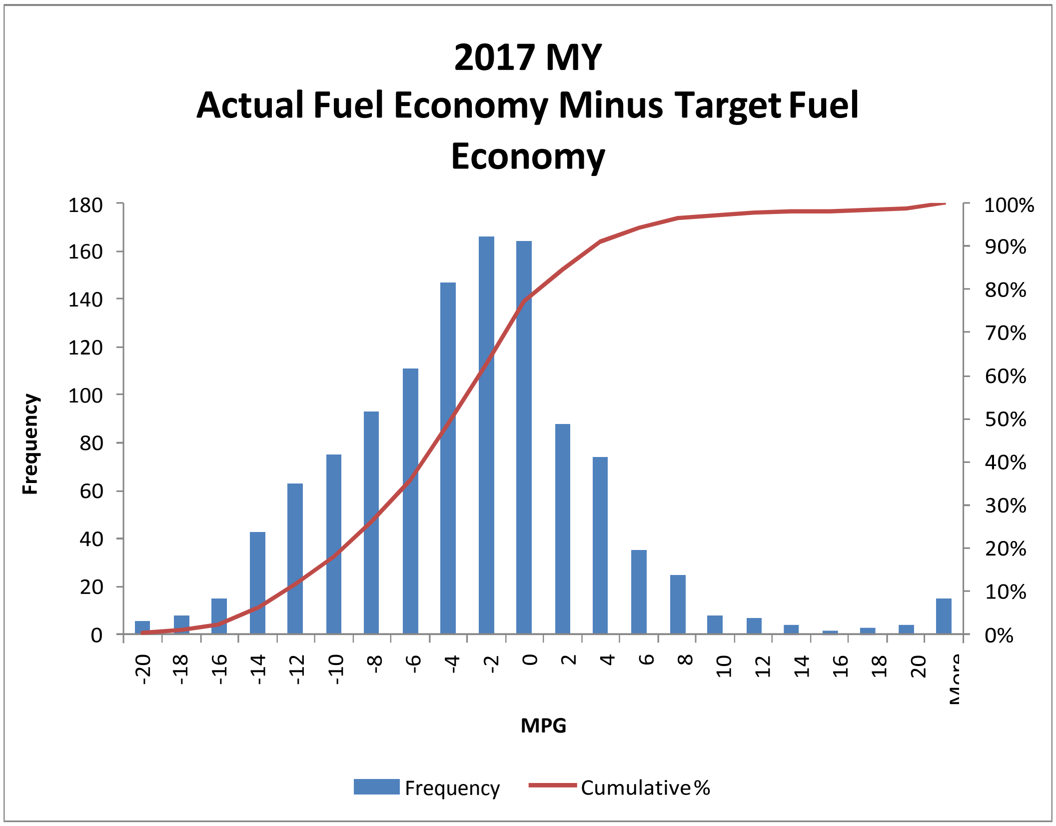
Further this puts an enormous amount of pressure on the fuel pricing assumptions, customers' valuation of fuel economy technology, and other factors outside the control of manufacturers.

Technology Penetration Rates for Key Technology

	2017 Model Year Fleet Based on EPA Data										
	Complies with 2017 standard	Camless Valves	SSV12	DEAC	VVT	VVL	2 Intake Valves	2 Exhaust Valves	8 or more gears	TURBO	HEV
Number of Models	221	40	398	134	1111	329	1056	1050	435	592	36
Percent of Models	19%	4%	35%	12%	97%	29%	92%	92%	36%	52%	3%

92% of HEVs meet the 2017 FE target
6.9 Average number of forward gears
17% of cars comply with the 2017 FE targets
23% of trucks comply with the 2017 FE targets

Technology	Description	Count in VOLPE database	Percent of VOLPE 2015 Models	Percent of EPA 2017 Models	VOLPE 2017 Augural Stds	VOLPE 2025 Augural Stds
SOHC	Single Overhead Camshaft Engine	20	7%		7%	7%
DOHC	Double Overhead Camshaft Engine	258	85%		81%	82%
OHV	Overhead Valve Engine	23	8%		11%	10%
TEFRI	Engine Friction Reduction Improvements (time-based)	-	0%		0%	0%
LUBEFR1	Improved Low Frcition Lubricants and Engine Friction Reduction	291	96%		93%	94%
LUBEFR2	LUBEFR2, Level 2	-	0%		0%	60%
LUBEFR3	LUBEFR2, Level 3	-	0%		0%	19%
VVT	Variable Valve Timing	241	80%	97%	90%	93%
VVL	Variable Valve Lift	63	21%	28%	22%	67%
SGDI	Stoichiometric Gasoline Direct Injection	152	50%	67%	45%	75%
DEAC	Cylinder Deactivation	20	7%	11%	13%	26%
HCR	High Compression Ratio Engine	3	1%		2%	1%
HCRP	High Compression Ratio "Plus" Engine	-	0%		0%	0%
TURBO1	Turbocharging and Downsizing, Level 1 (1.5271 bar)	102	34%	52%	17%	16%
SEGR	Stoichiometric Exhaust Gas Recirculation	2	1%		0%	0%
DWSP	Engine Downspeeding	-	0%		0%	0%
TURBO2	Turbocharging and Downsizing, Level 2 (2.0409 bar)	12	4%		1%	8%
CEGR1	Cooled Exhaust Gas Recirculation, Level 1 (2.0409 bar)	-	0%		2%	28%
CEGR1P	Cooled Exhaust Gas Recirculation, Level 1 "Plus" (2.0409 bar)	-	0%		0%	0%
CEGR2	Cooled Exhaust Gas Recirculation, Level 2 (2.2916/2.301 bar)	-	0%		0%	0%
HCR2	Advanced High Compression Ratio Engine	-	0%		0%	0%
CNG	Compressed Natural Gas Engine	3	1%		0%	0%
ADSL	Advanced Diesel	17	6%	1%	3%	3%
TURBODSL	Improved Diesel Turbocharger	-	0%		1%	3%
DWSPDSL	Diesel Engine Downspeeding with Increased Boost	-	0%		0%	1%
EFRDSL	Diesel Engine Friction Reduction	-	0%		0%	2%
CLCDSL	Closed Loop Combustion Control	-	0%		0%	1%
LPEGRDSL	Low Pressure Exhaust Gas Recirculation	-	0%		0%	1%
DSIZEDSL	Diesel Engine Downsizing	-	0%		0%	0%
MT5	5-Speed Manual Transmission	14	5%	3%	1%	0%
MT6	6-Speed Manual Transmission	47	18%	11%	2%	1%
MT7	7-Speed Manual Transmission	3	1%	1%	0%	2%
TATI	Automatic Transmission Improvements (time-based)	-	0%		0%	0%
AT5	5-Speed Automatic Transmission	15	6%		3%	0%
AT6	6-Speed Automatic Transmission	82	31%	8%	49%	4%
AT6P	6-Speed "Plus" Automatic Transmission	-	0%		1%	7%
AT8	8-Speed Automatic Transmission	46	18%	36%	16%	9%
AT8P	8-Speed "Plus" Automatic Transmission	-	0%	6%	4%	44%
DCT6	6-Speed Dual Clutch Transmission	35	13%	4%	3%	3%
DCT8	8-Speed Dual Clutch Transmission	9	3%	2.4%	1.3%	1.4%
CVT	Continuously Variable Transmission	9	3%	8%	17%	17%
EPS	Electric Power Steering	750	24%		52%	90%
IACC1	Improved Accessories - Level 1	-	0%		30%	89%
IACC2	Improved Accessories - Level 2 (w/ Alternator Regen and 70% Efficient Alternator)	-	0%		30%	89%
SS12V	12V Micro-Hybrid (Stop-Start)	193	6%	35%	15%	44%
BISG	Belt Mounted Integrated Starter/Generator	5	0%		1%	12%
CISG	Crank Mounted Integrated Starter/Generator	3	0%		0%	0%
SHEVP2	P2 Strong Hybrid/Electric Vehicle	23	1%		0%	1%
SHEVPS	Power Split Strong Hybrid/Electric Vehicle	20	1%	4%	2%	9%
PHEV30	30-mile Plug-In Hybrid/Electric Vehicle	9	0%	1.4%	0.8%	0.7%
PHEV50	50-mile Plug-In Hybrid/Electric Vehicle	2	0%		0%	0%
BEV200	200-mile Electric Vehicle	14	0%	2.0%	0.6%	1.2%
FCV	Fuel Cell Vehicle	1	0%	0.2%	0.0%	0.0%
LDB	Low Drag Brakes	-	0%		27%	84%
SAX	Secondary Axle Disconnect	310	10%		22%	37%
ROLL10	Low Rolling Resistance Tires, Level 1 (10% Reduction; Crr 0.0072)	-	0%		61%	99%
ROLL20	Low Rolling Resistance Tires, Level 2 (20% Reduction; Crr 0.0064)	-	0%		36%	94%
MR1	Mass Reduction, Level 1 (5% Reduction in Glider Weight)	383	12%		47%	93%
MR2	Mass Reduction, Level 2 (7.5% Reduction in Glider Weight)	268	8%		25%	71%
MR3	Mass Reduction, Level 3 (10% Reduction in Glider Weight)	222	7%		15%	34%
MR4	Mass Reduction, Level 4 (15% Reduction in Glider Weight)	18	1%		4%	27%
MR5	Mass Reduction, Level 5 (20% Reduction in Glider Weight)	8	0%		4%	18%
AERO10	Aero Drag Reduction, Level 1 (10% Reduction; Cd ~0.2907, varies by class)	133	4%	26%	47%	97%
AERO20	Aero Drag Reduction, Level 2 (20% Reduction; Cd ~0.2584, varies by class)	22	1%	2%	14%	84%



Actual Fuel Economy Minus Target Fuel Economy for 2017 Model Year Vehicles

I would also note that there many inconsistencies in the volume inputs.

Volume Anomolies (VOLPE MINUS NHTSA)				
	PC-2015	PC-2016	LT-2015	LT-2016
BMW	-37%	-6%	-22%	45%
Daimler	0%	-9%	0%	44%
FCA	-2%	-5%	1%	13%
Ford	0%	-6%	1%	26%
General Motors	2%	-9%	2%	24%
Honda	0%	-19%	0%	-8%
Hyundai Kia	0%	-4%	0%	3%
JLR	0%	9%	0%	-15%
Mazda	0%	-35%	0%	-11%
Mitsubishi	113%	127%	32%	-12%
Nissan	0%	-14%	0%	33%
Subaru	0%	4%	0%	80%
Tesla	-8%	-33%		
Toyota	-4%	-1%	-9%	23%
Volvo	0%	9%	0%	-40%
VWA	0%	-5%	0%	33%

REVIEW TOPIC NUMBER 2.1. COMBINED IMPACT OF APPLYING NEW TECHNOLOGIES SIMULTANEOUSLY

1. What are the most important concerns that should be taken into account related to the review topic?

   See discussion above.

   RESPONSE: These comments appear to conflate Autonomie simulation inputs and outputs with CAFE model compliance simulation results. The CAFE model makes use of vehicle-simulation inputs, as well as many other inputs, and is intended to provide means to show realistic ways manufacturers <u>could</u> respond to CAFE standards, not to predict how manufacturers are likely to respond, or to propose how manufacturers should respond. Especially without using manufacturers' actual product and technology planning information (which, being confidential business information, would prevent release of detailed modeling results), the model cannot be used for prediction. Even within a model year, production volumes sometimes change significantly between when midyear and final data are provided to NHTSA. Also, manufacturers often apply specific technologies in ways that do not fully reflect NHTSA's representation (through input choices) of the same technologies.

Jose Mantilla

Reviewer Name: Jose Mantilla

Review Topic Number: 2.1 – Combined Impact of Applying New Technologies Simultaneously

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

The basis for the adoption of true incremental effectiveness of a given technology (with consideration of the underlying technology combinations) has been satisfactorily justified. I have no concerns on this review topic.

RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The rationale and assumptions used to justify the application of technology based on incremental effectiveness values is reasonable. In particular, the design of the CAFE model to 'go beyond' the absolute fuel consumption estimates from the Autonomie simulations seems justified and appropriate.

RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

No modifications are recommended.

RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

4. Is there an alternative approach that you would suggest?

No modifications are recommended.

RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The review topic is of critical importance to the overall utility and plausibility of the Volpe Model output. The approach used has a number of benefits, including: (1) reducing distortions in fuel economy improvement estimates (that would result from the application of absolute fuel consumption estimates); (2) obviating the need to map each vehicle to a point in the Argonne database; and (3) considering technologies not included in the Argonne database.

RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment, but note that there will always be opportunities to refine the CAFE model's application of vehicle simulation results.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Wallace Wade

Reviewer Name:_Wallace R. Wade

Review Topic Number: 2.1. Combined impact of applying new technologies simultaneously

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

In previous versions of the Volpe Model, technology effectiveness values were single values for each technology that were intended to represent the incremental improvement in fuel consumption for that technology. Successive application of new technologies resulted in an improvement in fuel consumption (as a percentage) that was the product of the individual incremental effectiveness of each technology applied. However, this method did not capture interactive effects where a given technology either improves or degrades the impact of subsequently applied technologies. To attempt to account for these situations, synergy factors were defined, in a table format, for a relatively small number of technology pairs (pairwise synergy factors). These pairwise synergy factors used in the Volpe Model for prior rulemakings were based on engineering judgment (2016 Draft TAR, p. 5-458).

The current Volpe Model was modified to accommodate the results of the large-scale vehicle simulation study conducted by Argonne National Laboratory. While Autonomie, Argonne's vehicle simulation model, produces absolute fuel consumption values for each simulation record, the results have been modified in a way that preserves much of the existing structure of the CAFE Model's compliance logic, but still faithfully reproduces the overall simulation outcomes present in the database.
(2016 Draft TAR, p. 13-29 to 13-33)

RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The improvements in the current Volpe Model, based on simulations from Argonne National Laboratory's Autonomie model in place of the pairwise synergy factor approach, are reasonable and are expected to improve the capability of the Volpe Model to reflect the synergy effects of applying a new technology to vehicles already having a variety of fuel consumption reduction technologies.

RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

The current approach using the Autonomie model for accounting for synergy effects is a significant improvement over the pairwise synergy factor approach used previously.

RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

4. Is there an alternative approach that you would suggest?

No. The current approach using the Autonomie model for accounting for synergy effects is the suggested approach.

RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The current improvements using the Autonomie model for accounting for synergy effects are expected to improve the utility and plausibility of the Volpe Model output.

RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

NHTSA has stated that they will continue to refine their approach for accounting for synergy factors. They will consider means to address the application of simulation results for one vehicle to a much wider set of vehicles. Previous analyses and the current approach using the Autonomie model for accounting for synergy effects assume that improvements scale uniformly within a technology class.

RESPONSE: There will always be opportunities to refine the CAFE model's application of vehicle simulation results.

CAFE Peer Review Responses

REVIEW TOPIC
2. Updates to 2012 Final Rule Version of the CAFE Model: Volpe Model use of Argonne National Laboratory (ANL) Autonomie Vehicle Simulation Model
2.1. Combined impact of applying new technologies simultaneously
2.2. Determining the reference point on which to apply incremental fuel economy improvement
2.3. Calculating the synergy for fuel economy of technology n-tuples
2.4. The models' approaches to estimating the fuel economy level that could be achieved by applying a given combination of technologies to a given vehicle, and the models' approaches to estimating the accompanying costs.

Nigel Clark

Reviewer Name:_ Nigel N. Clark

Review Topic Number: 2.2. Determining the reference point on which to apply incremental fuel economy improvement

Other Review Topic Numbers (if interactive effects are focus of discussions): 2.3, 3.1

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   Incremental improvements must be applied to the prior technology combination, and take that prior technology combination into account in assessing the magnitude of the change.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   Yes. The model adds progressively to the technology of the analysis fleet, and employs n-dimensional vectors to describe the reference vehicle to which the technology is added. The analysis fleet, 2015MY, is discussed in Topic 3.1.

   RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   None. See response to topic 2.3. If there is reason to increase the dimension of the vector space in future, that can be accommodated.

   RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

4. Is there an alternative approach that you would suggest?

   No.

   RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   For all analyses that employ incremental differencing it is essential to have a clearly defined starting point. Further, the nature of that starting point must be considered in determining the increment because technologies are not simply additive. The model deals with both these issues capably.

   RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

   None.

Walter Kreucher

REVIEW TOPIC NUMBER 2.2. DETERMINING THE REFERENCE POINT ON WHICH TO APPLY INCREMENTAL FUEL ECONOMY IMPROVEMENT

1. What are the most important concerns that should be taken into account related to the review topic?

   My experience in compliance planning activities suggests that the practice used in the VOLPE model for selecting the "leader" vehicle (or engine) is not in keeping with manufacturer's practice.

   It has been my experience that manufacturers use the "teeter-totter" principle. That is, they select the vehicle farthest below the standard that exerts the most "leverage" (i.e., high volume) on CAFÉ compliance; subject to the constraints of the availability of manpower and capital. This "bottom-up" approach has been employed for a number of years.

   RESPONSE: The model's approach to selecting "leaders" has been revised, as explained in the updated model documentation and a new Regulatory Impact Analysis. Also, while the model assumes engine changes first applied to the identified "lead" vehicle will be subsequently inherited by vehicles sharing the same engine, the model selects among options in a way that, all else being equal, should tend to focus on vehicles that would produce the greatest compliance gains at the lowest effective cost.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   Not always in this case.

   RESPONSE: See response to #1 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   The model should be revised to employ a bottom-up approach. A bottom-up approach has the limitation that certain low volume vehicles (e.g., Dodge Hellcat) will, for marketing reasons, ignore CAFÉ and deploy technology that advances horsepower or some other vehicle attribute desired by consumers.

   I appreciate the fact that the "base case" will always be out of date; however, given that the 2017 model year targets represent a major step change **I would recommend that the model inputs be updated to reflect the 2017 MY (or 2018 if the data is available) prior to any more analysis by VOLPE. The model must also be run so that it can accurately reproduce the manufacturer's CAFÉ for the base year.**

RESPONSE: NHTSA and Volpe Center staff agree that the model should be used with the most current analysis fleet practicably available. Considering confidentiality of product planning information, and considering resources involved with integrating and reviewing fleet and vehicle information from different sources, some "lag" is inevitable (e.g., for analysis published in 2018, 2016 may be the most current model year upon which the model inputs can be practicably based). See also response to #1 above.

4. Is there an alternative approach that you would suggest?

   See answer to question three above.

5. What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   Getting the inputs correct is critical.

Jose Mantilla

Reviewer Name: Jose Mantilla

Review Topic Number: 2.2 – Determining the reference point on which to apply incremental fuel economy improvement

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.*]

1. What are the most important concerns that should be taken into account related to the review topic?

The main concern with this review topic is the absence of:

- Sufficient background information to understand the contents of this section (keeping in mind that this technical document intends to "share with the public the initial technical analyses…");
- Adequate rationale to justify:
  - The assumption that technologies should be considered as part of a tree;
  - The assumption that vehicles move from one technology state to another in order of increasing complexity;
  - The assumption that there is no inherent connection between engine technologies and technologies on other paths of the tree;
  - The determination of the existence of 12 distinct paths that can be traversed by a vehicle to which the model applies technology;
  - The approach used to group the 12 distinct paths into 6 distinct paths – the combination of 'logical sequential paths' is not explained; and
  - The assumption that the reference point for each technology's incremental effectiveness estimate is the logical preceding technology along its path.

RESPONSE: Model documentation will be revised to more fully explain the logical arrangement of technologies into various logical progressions.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

Insufficient information is provided to assess the reasonableness and appropriateness of the model assumptions. The draft TAR and Model Documentation would benefit from providing a simple rationale for determining the reference point on which to apply incremental fuel economy improvements. More specifically, the criteria/approach used to define the technology paths, "condense" or group the technology paths and progress along the technology paths needs to be specified in more detail. Furthermore, information on the current diversity of engines and other technologies should be presented, together with a description of how the criteria enabled the identification of the proposed technology paths.

RESPONSE: See response to #1 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Pending a satisfactory resolution of the rationale for the determination of the reference point on which to apply incremental fuel economy improvement, advice can be provided on potential modifications. Irrespective of that resolution, this section requires the adoption of language that can be more readily understood by the general public, including providing due explanation for terminology that is not broadly understood. For example, Figure 13.20 refers to AERO10 and AERO 20 reductions, for which the only explanation in the Draft TAR is a single row (for each) in Table 13.4 that states that these technologies would result in aero drag reductions of 10 percent and 20 percent, respectively. A description of the types of technologies that would result in these improvements, as well as how these improvements are measured, is required.

RESPONSE: Model documentation will be revised to more fully explain the meaning of each included technology.

4. Is there an alternative approach that you would suggest?

Pending a satisfactory resolution of the rationale for the determination of the reference point on which to apply incremental fuel economy improvement, advice can be provided on alternative approaches.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The review topic is of critical importance to the overall utility and plausibility of the Volpe Model output. The principle of defining technology paths and reference points on which to apply incremental fuel economy improvements is a reasonable approach that would benefit from additional justification and explanation to satisfy readers of its value and validity.

RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment. See also responses to #1-3 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Wallace Wade

Reviewer Name: _Wallace R. Wade

Review Topic Number: _2.2. Determining the reference point on which to apply incremental fuel economy improvement

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

Although engine technologies are related to one another, there is no inherent connection between the engine technologies and technologies on paths of other technology trees. For example, any of the transmissions can be combined with any of the engine technologies. By combining logically sequential technologies into common paths, 6 distinct paths remain.

The "incremental effectiveness" values in the model, used in the fuel consumption calculations when new technology is added to a vehicle, are all based on incremental differences over a single reference point for each technology. Progress along some technology paths is treated as linear (forcing consideration of 6-speed automatic transmission prior to considering application of CVT, for example), and along others as strictly sequential (mass reduction levels must logically be considered in order). Thus, the reference point for each technology's incremental effectiveness estimate is the preceding technology along its path, and the null state along all other paths– where the null state is defined as a vehicle with (only) variable valve timing (VVT), a 5-speed automatic transmission (AT5), no electrification, mass reduction, aerodynamic improvements, and low rolling resistance tires. When considering the incremental impact of applying an 8-speed automatic transmission to a vehicle, the point of reference is the preceding technology on the transmission path (in this case, the 6-speed automatic transmission), and the base engine without any electrification, mass reduction, and improvements in aerodynamics or rolling resistance.

To incorporate the results of the ANL Autonomie database, while still preserving the basic structure of the CAFE model's technology module, it was necessary to translate the points in the database into locations on the technology tree. By recognizing that most of the paths on the technology tree are unrelated, it is possible to decompose the technology tree into a small number of paths and branches by technology type. To achieve this level of linearity, NHTSA defined technology groups, which are: engine cam configuration (CONFIG), engine technologies (ENG), transmission technologies (TRANS), electrification (ELEC), mass reduction levels (MR), aerodynamic improvements (AERO), and rolling resistance (ROLL). The combination of technology levels along each of these paths define a unique technology combination that corresponds to a single point in the database for each technology class.

As an example, a technology combination with a SOHC engine, variable valve timing (only), a 6-speed automatic transmission, a belt-integrated starter generator, mass reduction (level 1), aerodynamic improvements (level 2), and rolling resistance (level 1) is specified as SOHC;VVT;AT6;BISG;MR1;AERO2;ROLL1. By assigning each technology state a vector such as the one in the example, the CAFE model assigns each vehicle an initial state that corresponds to a point in the database. The model then determines a percentage improvement from the database for the new combination of technologies that is applied to each vehicle model and that percentage improvement is applied to the fuel consumption of that vehicle model.
(2016 Draft TAR, pp. 13-33 to 13-35)

Concern 1:
The "null state is defined as a vehicle with (only) variable valve timing (VVT), a 5-speed automatic transmission (AT5), no electrification, mass reduction, aerodynamic improvements, or low rolling resistance tires (top of p. 13-35). The "or" before "low rolling resistance tires" appears incorrect and should be "and", since the null state is defined by "7-tuples".

Recommendation 1:
Change the "or" before "low rolling resistance tires" to "and" where the "null state" is defined in the 2016 Draft TAR (top of p. 13-35).

RESPONSE: Model documentation will be revised to more clearly explain initial mapping of vehicles to specific points in the database of simulation results.

Concern 2:
The difference between the "linear" path (requiring a 6-speed automatic transmission prior to application of CVT) compared to the "sequential" path (where mass reduction levels must be considered in order) is not clear. Both appear to involve the sequential applications of technologies along a specific technology path.

Recommendation 2:
Either clearly differentiate the difference between "linear" path and "sequential" path, or revise the references to paths as "sequential" paths for the application of technology.

RESPONSE: Model documentation will be revised to more clearly explain the "operation" of different technology paths.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The Volpe Model's method for determining the reference point on which to apply incremental fuel economy improvement is well thought out and developed, and is considered reasonable and appropriate.

RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1 and 2 to clarify the definition of the "null state" and to clarify the type of paths for the application of technology.

RESPONSE: See responses to recommendation 1-2 above.

4. Is there an alternative approach that you would suggest?

No. Implementation of Recommendations 1 and 2 is the recommended approach.

RESPONSE: See responses to recommendations 1-2 above.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The modifications made in the current Volpe Model to include the model's method for determining the reference point on which to apply incremental fuel economy improvement will improve the overall utility and plausibility of the model.

Implementation of Recommendations 1 and 2 will assist in clarifying the description of the method for determining the reference point for applying incremental fuel economy improvements.

RESPONSE: Agreed; see responses to #1 and 2 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
2. Updates to 2012 Final Rule Version of the CAFE Model: Volpe Model use of Argonne National Laboratory (ANL) Autonomie Vehicle Simulation Model
2.1. Combined impact of applying new technologies simultaneously
2.2. Determining the reference point on which to apply incremental fuel economy improvement
2.3. Calculating the synergy for fuel economy of technology n-tuples
2.4. The models' approach to estimating the fuel economy level that could be achieved by applying a given combination of technologies to a given vehicle, and the models' approach to estimating the accompanying costs.

Nigel Clark

Reviewer Name:_ Nigel N. Clark

Review Topic Number: 2.3. Calculating the synergy for fuel economy of technology n-tuples

Other Review Topic Numbers (if interactive effects are focus of discussions: 2.1

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   As discussed in 2.1, adding technology to two vehicles with different levels of sophistication or basic design will yield two different relative fuel efficiency improvements – this must be considered in any model.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   Yes, but see comment 3 below. As an alternative, ascribing improvement values (as inputs) to each and every vehicle individually is far too detailed and granular. It is important to maintain some generality in the model to allow updates and reduce the number of inputs. The model includes this generality by including seven separate technology groups, and using a seven-dimensional vector to place a vehicle. Improvements are then quantified relative to this vector. This is a good approach. A comment on level of sophistication and integration is provided below, and is applicable to this and to several other topic areas.

   Use of Autonomie to generate the incremental factors and synergy was a wise move.

   RESPONSE: NHTSA and Volpe Center staff agree, and appreciate the comment, and note that there will always be opportunities to refine the CAFE model's application of vehicle simulation results.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   This comment relates to this topic and several other topics. Improving the performance of a vehicle with software alone has great appeal to a manufacturer, but can have a high up-front cost in test cell time, sub-component characterization, and modeling efforts, followed by design of the controls. Consider a vehicle that may include a reasonably sophisticated engine (perhaps turbocharged) and a dual clutch transmission, but that the transmission is still managed quite conventionally in terms of torque and speed input commands. There will be high potential through more careful engine valve timing management (beyond quasi-steady state), model based controls for powertrain integration, unnecessary shift avoidance algorithms, even GPS-linked predictive control, driver behavior adaptation, and so on to eke out better fuel economy. This is an incremental step (akin to a technology) that is not accounted for in the model. On the one hand, for the model, a “control upgrade” could be accounted for as either a technology or a positive synergy. On the other hand, addition of other subsequent technologies may be less effective without refreshing this sophisticated control, because it is educated to deal with precise hardware: this would make predicting benefit more difficult.

The model should, somehow, include control sophistication or investment in component integration either as part of the n-dimensional space or as an attribute that can affect pathways in terms of cost of change, synergy effects and effectiveness of added technologies.

RESPONSE: Powertrain controls are among the many inputs to full vehicle simulation used, in turn, to produce CAFE model inputs specifying estimated fuel economy for the many “*n*-tuple” combinations of technologies. Increases in the sophistication of such controls could simulated by modifying these full vehicle simulation inputs. However, further research would be required to judge the practicability of representing different levels of control sophistication and, in turn, determining how to “map” each existing vehicle model/configuration to a specific level of control sophistication.

4. Is there an alternative approach that you would suggest?

   No.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   It is essential to account for the fact that multiple treatments are not additive. It adds confidence that this area received very professional attention.

   RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comment, and note that there will always be opportunities to refine the CAFE model’s application of vehicle simulation results.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

   In 2.1 a concern was expressed by this reviewer that incremental factors may not account for transient behavior in some components.

   RESPONSE: See responses to 2.1.

Walter Kreucher

REVIEW TOPIC NUMBER 2.3. CALCULATING THE SYNERGY FOR FUEL ECONOMY OF TECHNOLOGY N-TUPLES

1. What are the most important concerns that should be taken into account related to the review topic?

   Calculating the synergy for fuel economy technology is crucial to the model and subsequently to getting the standards correct. As I stated in the introduction to this line of questioning, there appears to be a disconnect between the application of technologies (which is considerable in the 2017 MY fleet) and the ability of manufacturers to achieve the target fuel economies.
   The gap is widest in the small car fleet. Looking at the 2025 targets versus the 2017 actual the gaps widen. Small cars have the largest gap to overcome. Logically, if this is not corrected, one may expect to see a shift from small cars to medium sized cars, SUVs, and pickups. To some extent this is already happening in the marketplace.

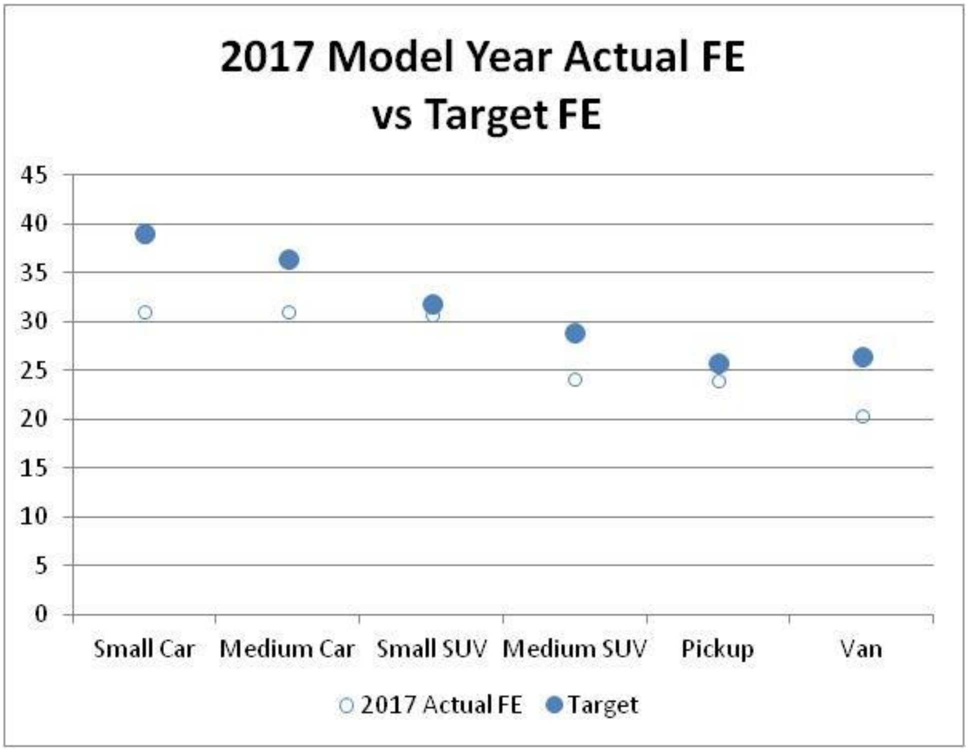
   The reasons for this gap in the small car fleet are many. This category includes many exotic sports cars and some high horsepower products. These products are not marketed for their fuel economy and most of the customers purchasing these products fuel economy is low on their list of priorities.

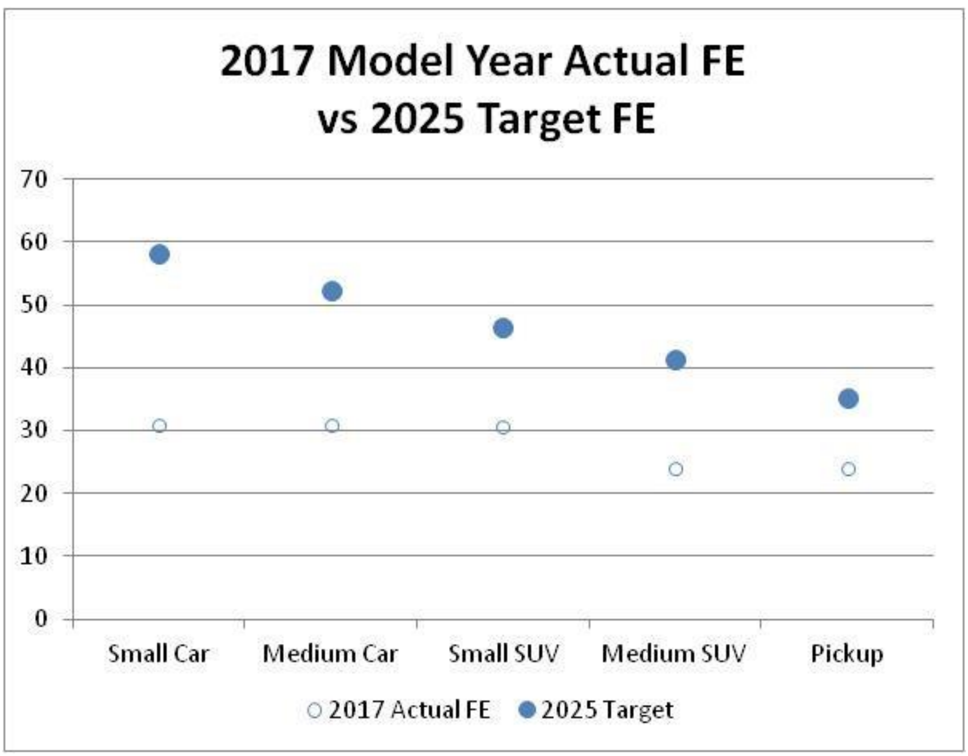
   It should be noted that some of the manufacturers routinely elect to pay CAFE fines and even the gas guzzler penalties in this segment. This behavior is unlikely to change.

   Eliminating the exotic sports cars including Porsche, Lamborghini, and the Bentleys brings the difference between the target and actual into the range of the medium SUV, still on the high side of the categories.

   It is not a lack of technology in the small car segment that accounts for the difference. This class deploys more technology than predicted by the VOLPE model.

	Technology Deployed in Small Car Segment (minus exotic sports cars)														
	SS12V	SHEVP2	VVT	VVL	DEAC	TURBO1	MT5	MT6	MT7	AT5	AT6	AT6P	AT8	AT8P	CVT
VOLPE	6%	1%	80%	21%	7%	34%	5%	18%	1%	6%	32%	0%	18%	0%	13%
EPA 2017	48%	1%	99%	40%	6%	71%	5%	19%	4%	0%	38%	0%	22%	4%	2%


2017 Model Year Actual FE
vs Target FE
45
40
35
30
25
20
15
10
5
0
Small Car
Medium Car
Small SUV
Medium SUV
Pickup
Van
2017 Actual FE
Target


2017 Model Year Actual FE
vs 2025 Target FE
70
60
50
40
30
20
10
0
Small Car
Medium Car
Small SUV
Medium SUV
Pickup
2017 Actual FE
2025 Target

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   It doesn't seem that the computational methods and assumptions are accurate in many of the product segments.

   RESPONSE: The CAFE model is intended to illustrate potential application of fuel-saving technology, not, as this comment suggests, to predict actual technology application. The CAFE model has been revised to accommodate a wider range of technology "classes," thus providing means to differentiate between performance vehicles and other vehicles. Nevertheless, fuel economy standards apply to fleet-level average fuel economy, such that no vehicle is necessarily required to meet its fuel economy target. Also, the model is intended to provide means to show realistic ways manufacturers could respond to CAFE standards, not to predict how manufacturers are likely to respond, or to propose how manufacturers should respond. Especially without using manufacturers' actual product and technology planning information (which, being confidential business information, would prevent release of detailed modeling results), the model cannot be used for prediction. Also, manufacturers often apply specific technologies in ways that do not fully reflect NHTSA's representation (through input choices) of the same technologies. For example, while NHTSA may apply model inputs that represent application of turbocharging and engine downsizing in a way that holds vehicle performance and utility approximately constant, a manufacturer may elect to apply the technology in a way that increases vehicle performance but provides less fuel economy benefit.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   Update the model to reflect the baseline 2017 model year technology state and fuel consumption (FC_0). Revisit the methodologies for calculating synergies that are used as model inputs.

   RESPONSE: NHTSA and Volpe Center staff agree that the model should be used with the most current analysis fleet practicably available, and that model inputs used to determine fuel economy impacts should be based on the best information practicably available. Considering confidentiality of product planning information, and considering resources involved with integrating and reviewing fleet and vehicle information from different sources, some "lag" is inevitable (e.g., for analysis published in 2018, 2016 may be the most current model year upon which the model inputs can be practicably based).

4. Is there an alternative approach that you would suggest?

   Matching the technology and CAFE level in the base year for each manufacturer should be a priority.

When I ran the compliance program at Ford, we used the more conservative financial planning volumes for the initial report to EPA on vehicle certification because this process started well in advance of the model year.

We switched to production planning volumes for the first submission to NHTSA in the pre-model year CAFE report. The mid-model year report was a combination of actual production volumes and updated production planning volumes. The final CAFE report included the final production volumes for the model year.

Thus one of the issues in matching CAFE could be the volume set within the government that VOLPE uses.

There was a time that I needed to create CAFE files for all manufacturers in order to do some advance planning. I used the EPA fuel economy guide and manually matched up volumes obtained from POLK. This process, while painstaking, allowed me to get CAFE estimates on the industry that came within a couple of tenth of a mile per gallon for all the major competitors.

RESPONSE: Volpe Center staff have also made use of volume estimates acquired from Polk, and have found that records often cannot be unambiguously "mapped" to specific model/configurations in CAFE compliance data, especially now that this mapping often involves separate disaggregation by both footprint and fuel economy. Fidelity to actual "base year" characteristics is greatest when the analysis fleet is derived from final CAFE compliance data. However, this data is not available to NHTSA until after the data has been submitted, reviewed, and certified by EPA, a process which can take months if not years from the end of the model year, and moreover is not ready for use in CAFE analysis until additional data elements can be mapped. For example, for analysis to be published spring of 2018, an analysis fleet derived from final compliance data might need to be based on model year 2015. More recently, NHTSA and Volpe Center staff have found it practicable to begin with mid-year compliance data, inviting manufacturers to provide corrections and updates that can later be made public.

5. What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   This is one of the most critical, if not the most critical, components of the model. If the inputs are not correct and this includes the synergies between technologies, then the results are meaningless.

   RESPONSE: We agree, and we wish it was practicable to accommodate inputs that precisely represent every manufacturer's actual experience with every specific actual technology on every specific actual vehicle. Unfortunately, even if this level of precision was technically practicable, it would be wholly dependent on precise confidential information that would prevent release of detailed model inputs and outputs, which has been deemed important to allow the public to replicate our work.

6. Provide any additional comments that may not have been addressed above.

Jose Mantilla

Reviewer Name: Jose Mantilla

Review Topic Number: 2.3 – Calculating the synergy for fuel economy of technology n-tuples

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

The main concerns with this review topic are:

- The text is exceptionally complex – unsuitable for the general public to comprehend
- Absence of sufficient background information to understand the contents
- The text includes multiple obscure references to undefined terms and nomenclature
- Inconsistent and/or confusing terminology used to intermittently refer to the interpretation of the technology tree. For instance, in the section titled "Translating the Technology Tree," there are references to "technology type," "technology groups," "technology levels," "technology state," "technology class," and "technology paths." The relationship between these is unknown.
- It would appear that the "paths" and "groups" refer to the same concept. However, page 13-35 refers to seven groups, while page 13-34 refers to six paths.

RESPONSE: Although the technical complexity of the model limits the ability to easily communicate specific details to the layperson, the model documentation will be revised to more clearly explain terms and provide additional background information.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

Until the definitions, inconsistencies and "obscurity" are clarified, it is not possible to comment on the reasonableness and appropriateness of the data and assumptions.

RESPONSE: See response to #1 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Pending a satisfactory resolution of the concerns raised in item 1, advice can be provided on potential modifications. **RESPONSE: See response to #1 above.**

4. Is there an alternative approach that you would suggest?

Pending a satisfactory resolution of the concerns raised in item 1, advice can be provided on alternative approaches. **RESPONSE: See response to #1 above.**

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The importance of the review topic to the overall utility and plausibility of the Volpe model output cannot be assessed with the information provided. **RESPONSE: See response to #1 above.**

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Wallace Wade

Reviewer Name: _Wallace R. Wade

Review Topic Number: _2.3. Calculating the synergy for fuel economy of technology n-tuples

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

Once a vehicle is assigned a technology state (one of the tens of thousands of unique 7-tuples, defined as CONFIG;ENG;TRANS;ELEC;MR;AERO;ROLL), adding a new technology to the vehicle simply represents progress from one technology state to another. The vehicle's fuel consumption is

$$FC_i = FC_0 \cdot (1 - FCI_i) \cdot S_k / S_0$$

Where:
FC_i = fuel consumption resulting from the application of technology i,
FC_0 = vehicle's fuel consumption before technology i is applied,
FCI_i = incremental fuel consumption (percentage) improvement associated with technology i,
S_k = synergy factor associated with the combination, k, of technologies when the vehicle technology i is applied, and
S_0 = synergy factor associated with the technology state that produced fuel consumption FC_0.

The synergy factor is defined in a way that captures the incremental improvement of moving between points in the database, where each point is defined uniquely as a 7-tuple describing its cam configuration, highest engine technology, transmission, electrification type, mass reduction level, and level of aerodynamic and rolling resistance improvement.

With successive application of technologies, the simple product of the incremental effectiveness associated with those technologies deviates from the magnitude of the improvements determined by Autonomie, as represented in the database. The synergy values correct for this. In the past, synergy values in the Volpe Model were represented as pairs. However, the new values are 7-tuples and there is one for every point in the database. The synergy factors are based (entirely) on values in the Autonomie database, producing one for each unique technology combination for each technology class, and are calculated as

$$S_k = FC_k / FC_0 \cdot \Pi(1 - x_i)$$

Where:
S_k = synergy factor for technology combination k,
FC_0 = fuel consumption of the reference vehicle (in the database),
x_i = fuel consumption improvement of each technology i represented in technology combination k (where some technologies are present in combination k, and some are precedent technologies that were applied, incrementally, before reaching the current state on one of the paths).
(2016 Draft TAR, pp. 13-35 to 13-36)

Concern 1:
The definition of parameters in the above equation (p. 13-36) does not include FC_k.

Recommendation 1:
Provide the definition of the parameter, FC_k, in the above equation on p. 13-36 of the 2016 Draft TAR (The definition is assumed to be as follows: FC_k = fuel consumption of the reference vehicle after application of technology combination k).

RESPONSE: The model's procedures for calculating fuel economy have been revised, and corresponding model documentation has been updated.

Concern 2:
A description of the actual numerical values of the synergy factors, S_k, would be helpful in providing insight into the magnitude of the synergy corrections required. In addition, references for the formats and the actual files containing the synergy factors used in the Volpe Model should be provided.

Recommendation 2:
Provide a description of the formats and actual values for the synergy factors, S_k, in order to provide insight into the magnitude of the synergy corrections required. Provide references for the actual files containing the synergy factors used in the Volpe Model.

RESPONSE: Model documentation has been revised to explain the format and interpretation of the input file containing the database of vehicle simulation results.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The Volpe Model's method for calculating the synergy for fuel consumption reductions of technologies applied to 7-tuple technology states is well thought out and developed, and is considered reasonable and appropriate.

RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comment, and note that there will always be opportunities to refine the CAFE model's application of full vehicle simulation results.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1 and 2.

RESPONSE: See responses to recommendations 1 and 2 above.

4. Is there an alternative approach that you would suggest?

No. Implementation of Recommendations 1 and 2 is the suggested approach.

RESPONSE: See responses to recommendations 1 and 2 above.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The modifications made in the current Volpe Model for calculating the synergy for fuel consumption reductions of technologies applied to 7-tuple technology states will improve the overall utility and plausibility of the Volpe Model output.

Implementation of Recommendations 1 and 2 will enhance the description of the process for calculating the synergy for fuel consumption reductions of technologies applied to 7-tuple technology states.

RESPONSE: We agree; see responses to recommendations 1 and 2 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
2. Updates to 2012 Final Rule Version of the CAFE Model: Volpe Model use of Argonne National Laboratory (ANL) Autonomie Vehicle Simulation Model
2.1. Combined impact of applying new technologies simultaneously
2.2. Determining the reference point on which to apply incremental fuel economy improvement
2.3. Calculating the synergy for fuel economy of technology n-tuples
2.4. The models' approach to estimating the fuel economy level that could be achieved by applying a given combination of technologies to a given vehicle, and the models' approach to estimating the accompanying costs.

Nigel Clark

Reviewer Name:_ Nigel N. Clark

Review Topic Number: 2.4. The models' approach to estimating the fuel economy level that could be achieved by applying a given combination of technologies to a given vehicle, and the models' approach to estimating the accompanying costs.

Other Review Topic Numbers (if interactive effects are focus of discussions)

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   A primary objective of this model is to pair cost and benefit for the application of a technology or a package of technologies, to determine whether they represent a realistic step for the manufacturer to achieve the standard (or else use credits or pay fines).

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   Overall, Yes. The computational philosophy is detailed enough to capture real world practice. The model is constrained by a list of technologies, but major technologies are present, and the model structure allows for addition of more technologies. The technologies are applied in a considered fashion based on technology pathways. Incompatible technologies are prevented from mutual use in the model. Technologies are applied in a pathway order – a sensible approach – starting from the vehicle technology in the analysis fleet. Allowance is made that some technology packages can be added whole to a car, based on prior use of this whole package by the manufacturer. Whether these improvements are used or not, according to the model, is based on the cost, which allows an assessment of the effectiveness of that technology, and whether that cost can be borne.

   RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comment, and note that there will always be opportunities to refine these aspects of the model's operation.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   Estimating the cost, other than for an existing package previously used, is clearly an imprecise art, because there are multiple factors not considered, such as structural redesign needed (or not needed) to accommodate a more advanced powertrain, and because the powertrain controls can be addressed either inexpensively, or with high resources to optimize the system with advanced concepts. The model is capable of a hard-wired sensitivity analysis using a high and low cost, with high and low benefits: Essentially this looks the technology change as two different technology changes as options. The model could use this high-low evaluation more. For example, instead of VVT-VVL-SGDI, there might be VVT- VVT Advanced Controls – VVL –

SGDI. It is not suggested that this is a singular change, but some intermediate levels, where improved controlware competes with additional hardware, may be beneficial and should be considered.

RESPONSE: Beyond the types of sensitivity analyses that can be easily explored by selecting among options provided in the model's graphical user interface (GUI), many other types of sensitivity analyses can be explored by modifying model inputs. For example, sensitivity analyses involving specific combinations of technologies can be explored by modifying the affected portions of the cost inputs and/or the database of vehicle simulations results. To be addressed explicitly, some types of sensitivity analyses (such as those involving powertrain control logic) would need to be addressed upstream of the CAFE model, by modifying inputs to full vehicle simulations. In any event, insofar as including changes in control logic might necessitate characterization of specific vehicles' preexisting control logic, further research would be needed to determine the practicability of this expansion, especially without relying on manufacturers' confidential business information.

4. Is there an alternative approach that you would suggest?

   The approach is good. The point raised in (3) above is a possible embellishment.

   RESPONSE: See response to recommendation 3 above.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   This is key to the cost-benefit analysis of technology change.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

   None.

Walter Kreucher

REVIEW TOPIC NUMBER 2.4. THE MODELS' APPROACH TO ESTIMATING THE FUEL ECONOMY LEVEL THAT COULD BE ACHIEVED BY APPLYING A GIVEN COMBINATION OF TECHNOLOGIES TO A GIVEN VEHICLE, AND THE MODELS' APPROACH TO ESTIMATING THE ACCOMPANYING COSTS.

1. What are the most important concerns that should be taken into account related to the review topic?

   The basic computational approach is sound. The inputs require modification.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   The issue is with the differences between what is actually achieved and what the model predicts.

   RESPONSE: See earlier responses, especially to reviewer's recommendations regarding topics 2.1-2.3.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   Update the model to reflect the MY2017 fuel economy levels and technology.

   RESPONSE: See earlier responses, especially to reviewer's recommendations regarding topics 2.1-2.3.

4. Is there an alternative approach that you would suggest?

   No.

Jose Mantilla

Reviewer Name: Jose Mantilla

Review Topic Number: 2.4 – The model's approach to estimating the fuel economy level that could be achieved by applying a given combination of technologies to a given vehicle, and the model's approach to estimating the accompanying costs

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

The main concerns with this review topic are:

- The apparent contradiction between the two important challenges that NHTSA is attempting to address. The reader is led to believe that the first challenge focuses on the importance of estimating fuel economy improvements in a highly individualized manner, by considering the incremental (rather than absolute) impact of technologies. The second challenge, on the other hand, seems to focus on the opposite: application of simulation results for one vehicle to a much wider set of vehicles. The compatibility and complementarity of these two challenges needs to be better explained.
- My interpretation of challenge two, if correct, is that it would offer an unparalleled and unprecedented ability to derive absolute fuel consumption estimates through simple knowledge of a vehicle's mass and engine power levels. This would avoid the more complex requirement to model the large number of engine and vehicle technology classes, as well as the other elements of the technology tree. However, I am uncertain if my interpretation is correct. If my interpretation is incorrect, the description of challenge two must be better articulated to ensure any reader correctly understands the information being presented.

RESPONSE: While the fuel economy and many other (though not all, and not with unlimited precision) engineering characteristics of specific vehicles in past or current production are knowable and sufficiently available to be included among model inputs, the impacts of potential future technology changes can only be estimated. Estimation involves uncertainty. Also, vehicle simulation inputs fully specific to each individual vehicle model/configuration appear likely to remain impracticable. Past rulemaking analyses have addressed related tradeoffs between precision, practicality, and uncertainty, many of which are based on policy concerns exogenous to the model. Model documentation will be expanded to address these considerations.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

To the extent that the comments made on Review Topics 2.2 and 2.3 are addressed and clarified, the principles of integration of the database into the CAFE model for the purposes of estimating the impact of applying many new technologies simultaneously absolutely sound. Furthermore, if my interpretation of challenge two is correct, the successful development of the functions and coefficients would be a significant enhancement to the predictive power of the mode. **RESPONSE: See responses to recommendation 1 above, and reviewer's recommendations under topics 2.2 and 2.3 above.**

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

No modifications are suggested.

4. Is there an alternative approach that you would suggest?

No alternative approaches are suggested.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The review topic is of critical importance to the overall utility and plausibility of the Volpe Model output.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Wallace Wade

Reviewer Name: _Wallace R. Wade

Review Topic Number: _2.4. The model's approach to estimating the fuel economy level that could be achieved by applying a given combination of technologies to a given vehicle, and the models' approach to estimating the accompanying costs

Other Review Topic Numbers (if interactive effects are focus of discussions):_Topic 4.5________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

Estimating Fuel Economy:

Once a vehicle is assigned a technology state (one of the tens of thousands of unique 7-tuples, defined in the technology input file as CONFIG; ENG; TRANS; ELEC; MR; AERO; ROLL), adding a new technology to the vehicle simply represents progress from one technology state to another. Then the formula to find the increase in vehicle's fuel economy shown in Equation (1) becomes:

$$FE_{new} = FE_{orig} \times \frac{1}{(1-FC_0)} \times \frac{1}{(1-FC_1)} \cdots \times \frac{1}{(1-FC_n)} \times \frac{S_{orig}}{S_{new}} \quad (2$$

Where:

FE_{orig} : the original fuel economy for the vehicle,
$FC_{0,1,\ldots n}$: the fuel consumption improvement factors attributed to the *0-th* to *n-th* technologies,
S_{oirg} : the synergy factor associated with the technology state before application of any of the *0-th* to *n-th* technologies,
S_{new} : the synergy factor associated with the technology state after application of the *0-th* to *n-th* technologies, and
FE_{new} : the resulting fuel economy for the same vehicle.

The synergy factor is defined in a way that captures the incremental improvement of moving between points in the database, where each point is defined uniquely as a 7-tuple describing its cam configuration, highest engine technology, transmission, electrification type, mass reduction level, and level of aerodynamic and rolling resistance improvement.

Model's Approach to Estimating Accompanying Costs:

The costs for engine-level technologies are specified for each engine technology class, while the costs for all other technologies are defined for each vehicle technology class.

The modeling system also incorporates cost adjustment factors to provide accounting corrections for technology costs. Since the Basic Engine path converges from SOHC, DOHC, and OHV technologies, and since the base input costs are defined for the DOHC path, the system necessitates the use of these adjustments in order to offset the costs of some basic engine technologies used on the SOHC and OHV engines.

Along with the base Cost Table, the input assumptions also define the Maintenance Cost Table and the Repair Cost Table. These tables are specified for each model year and account for the learning effect, wherever applicable.

Additionally, the input assumptions include the Stranded Capital Table, which associates a penalty cost for each technology that is replaced (or superseded) prior to fully amortizing the initial investment associated with that technology.

Compliance Simulation Algorithm:

The compliance simulation algorithm begins the process of applying technologies based on the CAFE standards applicable during the current model year. This involves repeatedly evaluating the degree of noncompliance, identifying the next "best" technology available on each of the parallel technology paths mentioned above, and applying the best of these.

Once a manufacturer reaches compliance, the algorithm proceeds to apply any additional technology determined to be cost-effective (as defined below). This process is repeated for each manufacturer present in the input fleet. It is then repeated again for each modeling year until all modeling years have been processed.

Effective cost is used for evaluating the relative attractiveness of different technology applications, not for actual cost accounting. Effective cost obtained from application of a set of one or more candidate technologies on a cohort of vehicles k is defined by the following formula (extracted from NHTSA, "CAFE Model Documentation," July 2016):

$$COST_{eff} = \frac{\sum_{i \in k}\left(\sum_{j=BaseMY}^{j=MY} TECHCOST_{i,j} - TECHVALUE_{i,j} - (VALUE_{FUEL})_{i,j}\right) + \Delta FINE_{MY}}{TOTALSALES} \quad (5)$$

Where:

MY	:	the model year being analyzed for compliance,
$BaseMY$	:	the first model year of the potential application of candidate technologies (can be less than or equal to MY),
$TECHCOST_{i,j}$	:	the total cost off all candidate technologies evaluated on vehicle i in model year j,
$TECHVALUE_{i,j}$	:	the net change in consumer valuation of all candidate technologies evaluated on vehicle i in model year j,
$(VALUE_{FUEL})_{i,j}$	:	the value of the reduction in fuel consumption resulting from application off all candidate technologies evaluated on vehicle i in model year j,
$\Delta FINE_{MY}$	:	the reduction in manufacturer's fines in the analysis year MY (or zero, if the manufacturer prefers not to pay fines or the compliance scenario being evaluated does not allow fine payment for a specific regulatory class), and
$TOTALSALES$	:	the total sales volume of all affected vehicles in cohort k covering model years between $BaseMY$ and MY.

Concern 1:

The definition and units of $COST_{eff}$ are not provided below Equation 5 and the definition of $TECHCOST_{i,j}$ provided below Equation 5 in the CAFE Model Documentation is not clear.

- The units of $COST_{eff}$ are presumed to be "total cost ($s) per affected vehicle," since the equation is divided by total sales of the applicable vehicles.
- The definition of $TECHCOST_{ij}$ is presumed to equal the total cost (direct manufacturing cost x RPE or (1+ICM)) of the technology per applicable vehicle.
- The summation at the beginning of the equation is presumed to indicate a summation of all of the costs per vehicle within the parenthesis and then a summation over all of the affected vehicles. This appears to be required so that $COST_{eff}$ has units of "total cost ($s) per affected vehicle".

Recommendation 1:

Provide the suggested clarifications of Equation 5 identified in Concern 1 regarding: 1) the definition and units of $COST_{eff}$, 2) the definition of $TECHCOST_{ij}$, and 3) the meaning of the first summation of all of the costs within the following parenthesis.

RESPONSE: The model documentation will be expanded to clarify the definition and units of the effective cost metric and the underlying components.

Concern 2:

The parameter, $TECHVALUE_{ij}$, is defined as the "net change in consumer valuation of all candidate technologies…" for equation 5, above. However, further details of the definition are not provided on page 25 of the CAFE Model Documentation where the above equation for $COST_{eff}$ is given. Page 87 of the CAFE Model Documentation states that "consumer valuation" is the "Loss in value to the consumer due to decreased range of pure electric vehicles. This value does not apply if the vehicle is not an EV." If this is the correct interpretation of $TECHVALUE_{ij}$, then this interpretation should be included in the above definition of $TECHVALUE_{ij}$ provided on page 25 of the CAFE Model Documentation.

Recommendation 2:
Provide the appropriate interpretation of the parameter, $TECHVALUE_{ij}$, on page 25 of the CAFE Model Documentation.

RESPONSE: The model documentation will be expanded to clarify the definition and meaning of the consumer valuation variable.

The value of the reduction in fuel consumption achieved by applying a set of candidate technologies in question to a specific vehicle is calculated as follows:

$$VALUE_{FUEL} = \sum_{FT}\left[\left(\sum_{v=0}^{v=PB}\frac{SURV_v \times VMT_v \times (VMT_{GROWTH})_{(MY+v)} \times (PRICE_{FT})_{MY}}{(1-GAP_{FT})\times(1+r)^v}\right)\times\left(\frac{FS_{FT}}{FE_{FT}}-\frac{FS'_{FT}}{FE'_{FT}}\right)\right] \quad (6)$$

Where:

- FT : the fuel type the vehicle operates on (gasoline, e85, diesel, electricity, hydrogen, or CNG),
- PB : a "payback period", or number of years in the future the consumer is assumed to take into account when considering fuel savings,
- $SURV_v$: the probability that a vehicle of a given vintage v will remain in service,
- VMT_v : the average number of miles driven in a year by a vehicle at a given vintage v,
- $(VMT_{GROWTH})_{MY+v}$: the growth factor to apply to the base miles driven in the current model year MY at the given vintage v,
- $(PRICE_{FT})_{MY}$: the price of the specific fuel type in year MY,
- GAP_{FT} : the relative difference between on-road and laboratory fuel economy for a specific fuel type,
- r : the discount rate the consumer is assumed to take into account when considering fuel savings,
- FE_{FT} and FE'_{FT} : the vehicle's fuel economy for a specific fuel type prior to and after the pending application of technology, and
- FS_{FT} and FS'_{FT} : the vehicle's assumed share of operating on a specific fuel type prior to and after the pending application of technology.

Concern 3:
Equation 5 is strongly dependent on $VALUE_{FUEL}$ defined by Equation 6. A critically important parameter in Equation 6 is PB, which is the "payback period," or number of years in the future the consumer is assumed to take into account when considering fuel savings.

(Repeat of Concern 1, Topic 4.5)

The statement on p. 13-99 that "NHTSA applies a one-year payback period in its compliance and technology application analysis" appears to differ from the following comments on page 13-10 (2016 Draft TAR):
"The default assumption in the model is that manufacturers will treat all technologies that pay for themselves within the first three years of ownership (through reduced expenditures on fuel) as if the cost of that technology were negative. This holds true up to the point at which the manufacturer achieves compliance with the standard – after which the manufacturer treats all technologies that pay for themselves within the first year of ownership as having a negative effective cost."

Recommendation 3:
Provide an explanation of how the appropriate value for PB, the payback period, is determined for the Volpe Model. Clarify which of the payback periods described in Concern 3, applies to Equation 6.

RESPONSE: The model documentation will be expanded to clarify how the payback period is applied in calculating the value of avoided fuel consumption. The payback period is a model input that requires explanation in each published analysis.

Concern 4:
Why are technologies that pay for themselves within the first year of ownership applied after compliance has been achieved with the standard? This would appear to result in over-achievement of the standard, but with associated increases in costs to the manufacturer and consumer.

Recommendation 4:
Provide an explanation of why are technologies that pay for themselves within the first year of ownership are applied after compliance has been achieved with the standard. This would appear to result in over-achievement of the standard, but with associated increases in costs to the manufacturer and consumer.

RESPONSE: The model has been revised to first apply any technologies for which the calculated effective cost is negative, and then apply further technologies as may be needed to comply with standards.

Concern 5:
Cost adjustment factors provide accounting corrections for technology costs. Since the Basic Engine path converges from SOHC, DOHC, and OHV technologies, and since the base input costs are defined for the DOHC path, the system necessitates the use of these adjustments in order to offset the costs of some basic engine technologies used on the SOHC and OHV engines. However, these cost adjustment factors are not defined, derived or illustrated in the CAFE Model Documentation.

Recommendation 5:
Provide definitions, derivations and illustrated examples of the cost adjustment factors.

RESPONSE: Model documentation will be revised to more fully explain the model's cost calculations and corresponding inputs.

Concern 6:
The source of the Maintenance Cost Table and the Repair Cost Table, specified for each model year and accounting for the learning effect, wherever applicable, should be provided.

Recommendation 6:
Provide the source of the Maintenance Cost Table and the Repair Cost Table, specified for each model year and accounting for the learning effect, wherever applicable, together with appropriate references.

RESPONSE: These are model inputs that require explanation for each published analysis.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The application of synergy factors, defined in a way that captures the incremental improvement of moving between points in the database, where each point is defined uniquely as a 7-tuple describing its cam configuration, highest engine technology, transmission, electrification type, mass reduction level, and level of aerodynamic and rolling resistance improvement is a significant improvement to the Volpe Model.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implementation of Recommendations 1- 6.

RESPONSE: See responses to recommendations 1-6 above.

4. Is there an alternative approach that you would suggest?

No. Implementation of Recommendations 1- 6 is the suggested approach.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The application of synergy factors, defined in a way that captures the incremental improvement of moving between points in the database, where each point is defined uniquely as a 7-tuple describing its cam configuration, highest engine technology, transmission, electrification type, mass reduction level, and level of aerodynamic and rolling resistance significantly improves the overall utility and plausibility of the Volpe Model output.

Implementing Recommendations 1- 6 to resolve the above concerns with the CAFE Model Documentation will improve the overall utility and plausibility of the model.

RESPONSE: See responses to recommendations 1-6 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
3. Model architectural elements
3.1. Development and use of MY2015 analysis (initialized) fleet (includes vehicle models and their existing technology content characterized by engine, transmission, vehicle attributes, and other technologies)
3.2. Modeling consumer behavior, including willingness to pay for fuel economy and number of miles traveled in new vehicles
3.3. The model's representation of CAFE regulations, including separate passenger car and light truck standards for each model year, minimum standards for domestic passenger cars, the option to carry CAFE credits forward and transfer CAFE credits between fleets, and the civil penalties levied for noncompliance.
3.4. Application of technologies, including interactions, paths and prerequisites of a technology's application (and any logically required exclusions based on the paths and prerequisites) and costs, including learning curves

Nigel Clark

Reviewer Name:_ Nigel N. Clark

Review Topic Number: 3.1. Development and use of MY2015 analysis (initialized) fleet (includes vehicle models and their existing technology content characterized by engine, transmission, vehicle attributes, and other technologies)

Other Review Topic Numbers (if interactive effects are focus of discussions)

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   Since this model is predictive, it must build from a well-documented and representative foundation. Clearly the time needed/taken to develop and verify the model's functionality, and the availability of data (such as synergy quantifiers) preclude the use of the latest model year data. However, it is important that the starting points are not too old in technological terms, especially in an era where criterial pollutant standards, greenhouse gas concerns and fuel efficiency rules are driving very rapid technology change.

   The prediction extends for more than a decade, but it is important to recognize as early as possible if this initial MY fleet may not be representative even of the fleet at the time that the predictive model is released. In other words, if there has been recent disruptive, rather than steady, change, it would be inappropriate to continue with the prior fleet data as a foundation.

   The TAR provides good argument for the redesign and refresh table that was adopted: this is important for near- and mid-term prediction.

   The TAR presents the technologies as finite steps with a single attribute, except for continuous variables such as mass reduction. However, it is evident that some of these technologies are also symbolic, in that they bring other technology advances along with them. For example, use of an 8-speed transmission is likely to have an association with a greater control of shift patterns (more intelligent shifting) than a prior transmission, and more integrated engine and transmission controls that offer further fuel efficiency gains. In this way one could have a modest benefit from just using an 8-speed transmission, or a greater benefit from using the 8-speed transmission with superior integration and controls. It is not clear whether the Argonne simulation reported one or the other. More cryptically, some technologies proposed will have true causal benefit, and some correlational benefit in addition: This is a different issue than synergy as it is presented in the TAR. Two MY2015 vehicles with the same attributes may be very different in design sophistication.

   RESPONSE: NHTSA and Volpe Center staff agree that inputs defining the analysis fleet should be as current as practicable. Further research would be needed to determine the practicability

of explicitly accounting for powertrain controls, especially considering the potential to—without confidential business information—precisely characterize controls on existing vehicles.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   Yes. The model developers are critically aware of the disruptive change concern and allude to history. They write "For example, in the 2012-2016 Final Rule the 2008 Model Year fleet was used, while for the 2017-2025 Final Rule both the 2008 and 2010 Model Year fleets were used. In addition to reflecting the near dissolution of Chrysler due to market turmoil in that year, the 2008-based fleet included a significant proportion of models and brands discontinued between 2008 and 2010."

   The 2015 MY was chosen, with that MY carried to completion to include total sales by vehicle, with full vehicle attributes known.

   The NHTSA decision to use MY2015 data is wise. In the TAR they point out that a MY2016 foundation would require the use of confidential data, which is less desirable. Clearly they would also have a qualitative vision of the MY2016 landscape while employing MY2015 as a foundation. Although MY2015 data may still be subject to minor revision, this is unlikely to impact the predictive ability of the model. The TAR also points out that MY2015 was a year of great technology change, so that new technology and vehicles were captured: this is supported by a table.

   RESPONSE: NHTSA and Volpe Center staff agree that inputs defining the analysis fleet should be as current as practicable.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

4. Is there an alternative approach that you would suggest?

   Most likely not. A more complex alternative approach might be to employ some 2016 changes in technology, and attempt a blend of MY2015 and MY2016, while relying of estimation gained from only MY2015 for sales. This approach may add some relevancy in terms of technology, but might introduce substantial error in terms of sales. The TAR, early in Chapter 4, discusses in detail the decision not to use MY2015 mid-year data when considering the MY2014 baseline: a similar issue. And MY2014 to MY2015 linear extrapolation to estimate MY2016 would be dangerous, noting that sales are driven by changing fuel prices.

YEAR	2013	2014	2015	2016
GASOLINE PRICE	3.575	3.437	2.520	2.250

   The model developers should explore some additional technologies, but it is appropriate not to guess at these technologies until they are firmly in the manufacturer's plans. Most of the technologies chosen are fairly obvious and appropriate, and many were already being applied in the MY2015 fleet. Some, such as fuel cell pathways, are aspirational at this time, but have been in the public eye for decades. As the model is applied in future years, additional technologies can be added. There is feedback between the model, standards and the technologies employed. Tough standards will stretch the need for advanced technologies, which can be incorporated into the model, and then used to demonstrate the practicality of the standards: this cycle is well known.

RESPONSE: The development of the analysis fleet involves tradeoffs between precision, certainty, resources (including available time), and opportunity for public disclosure. Setting aside direct use of manufacturers' confidential product planning information to develop the analysis fleet, Volpe Center and NHTSA staff consider the best option to be one that makes use of the most recent model year for which the production volumes, fuel economy ratings, and engineering characteristics of all specific vehicle model/configurations are both reasonably defined and able to be made public at the time a given analysis is to be released. In any event, choices regarding these model inputs are explained in the documentation (e.g., in a Regulatory Impact Analysis) of each published analysis.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   This review topic is pivotal to the model output because it is a foundation. The model's utility could be marred by other factors, such as unexpected changes in fuel price or battery price, or socioeconomic factors, but the utility cannot be defended without a good foundation.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

   The TAR would serve some readers better by addressing in more detail the test schedules or cycles used, as in the Autonomie simulations. It is clear that CAFE standards are bound by the original EPA city & highway schedules, and that this can result in designing to the cycle more or less. Presumably the Argonne simulations were similarly restricted to these cycles, but results could differ based on both driving style and selection of powertrain controls to favor either the test cycles or overall anticipated on-road performance.

   RESPONSE: Test schedules are inputs to full vehicle simulation tools. The CAFE model, though not a full vehicle simulation tool, makes use of model inputs developed by exercising a full vehicle simulation tool (currently Autonomie). CAFE model documentation will be expanded to discuss the model's current assumption that inputs defining the fuel economy impacts of specific technology combinations reflect current fuel economy test procedures, including the long-standing city and highway driving cycles.

Walter Kreucher

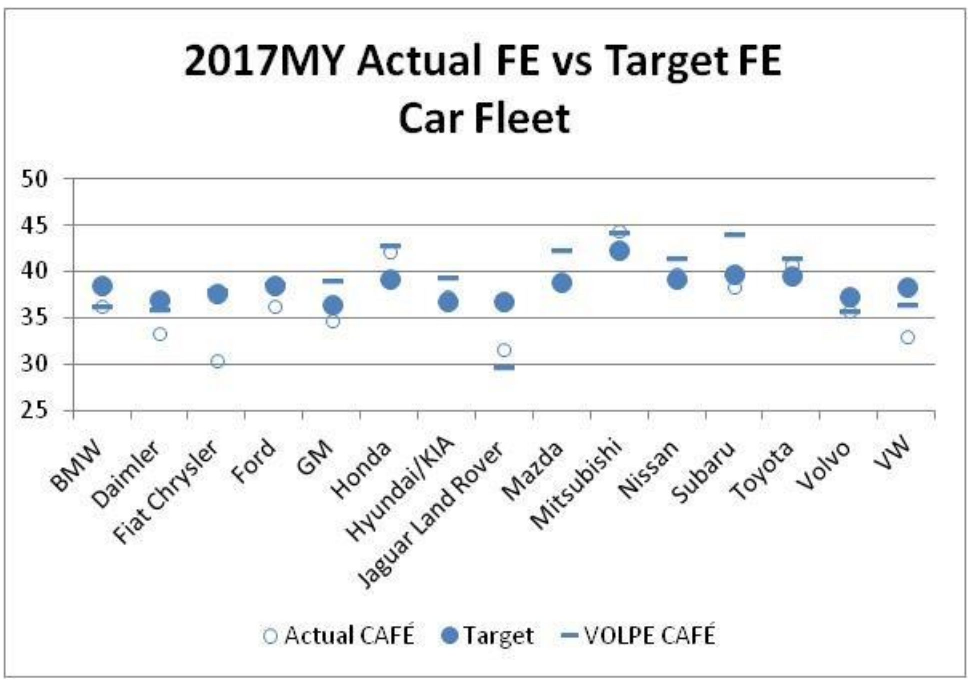
REVIEW TOPIC NUMBER 3.1. DEVELOPMENT AND USE OF MY2015 ANALYSIS (INITIALIZED) FLEET (INCLUDES VEHICLE MODELS AND THEIR EXISTING TECHNOLOGY CONTENT CHARACTERIZED BY ENGINE, TRANSMISSION, VEHICLE ATTRIBUTES, AND OTHER TECHNOLOGIES)

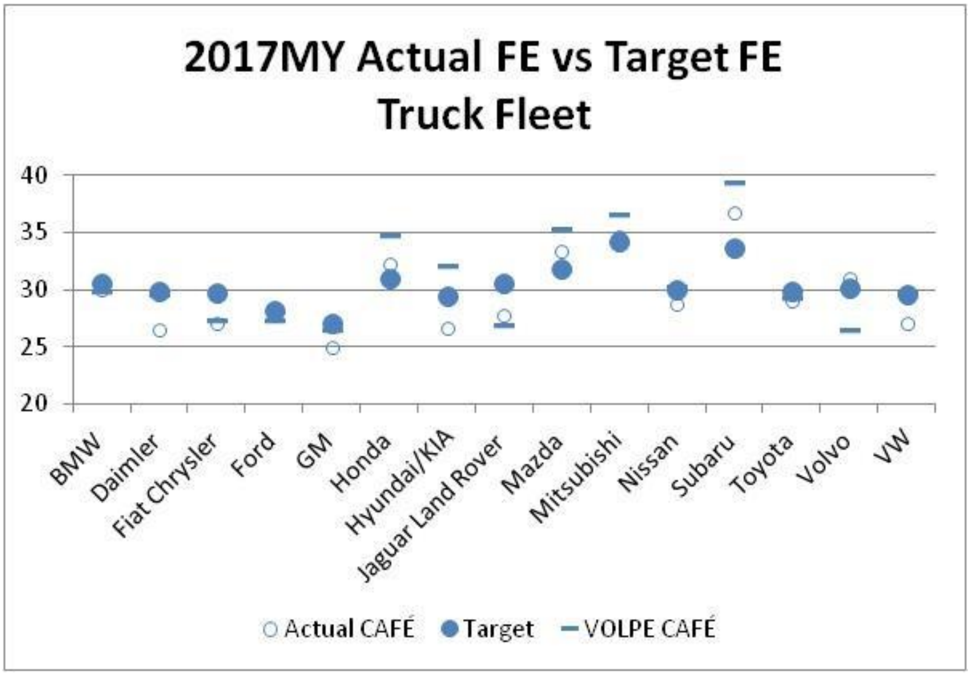
There seems to be some inconsistencies in the application of the MY2015 Analysis Fleet. For example, I counted over 280 line items that met the VOLPE definition of AERO10 yet did not have the technology marked as USED. (Also see 4.4 below)

I did not attempt to check all the technologies against the EPA data set.

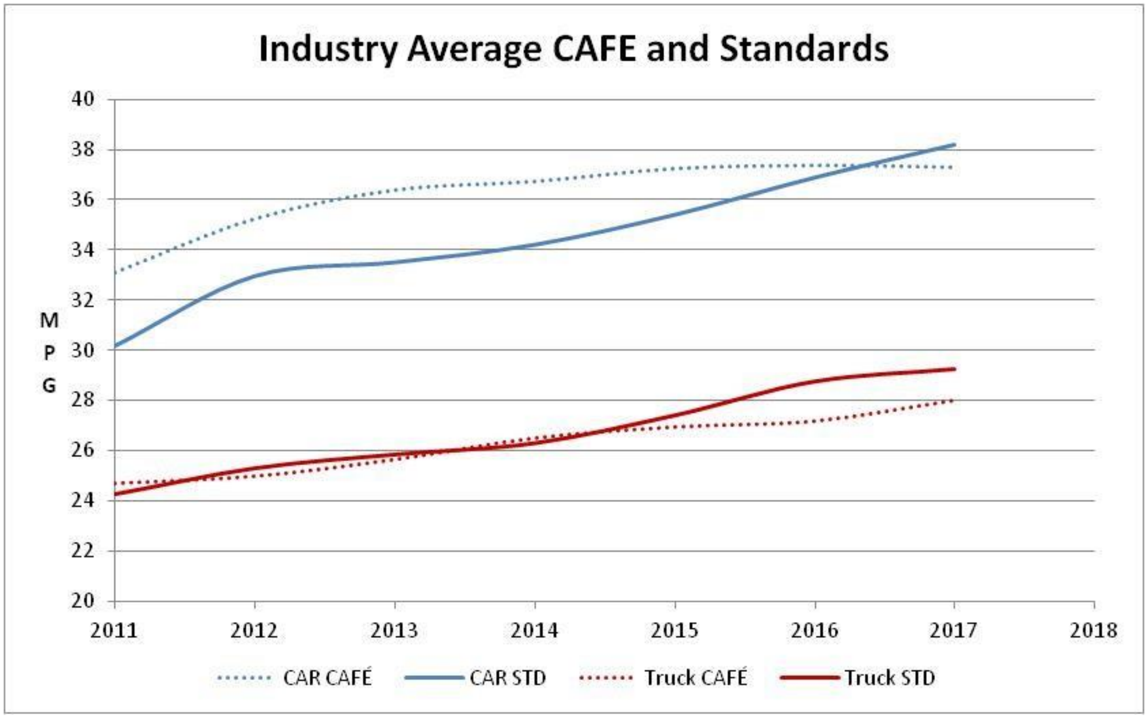
1. What are the most important concerns that should be taken into account related to the review topic?

   The choice of model year as the Analysis Fleet presents the modelers with a dilemma. On the one hand they want to use the most recent year in order to get the fleet as accurate as possible. The downside is that by the time the internal review process is complete the data is already one or even two model years old.





Having outdated data presents a risk to manufacturers. As can be seen from the above two figures, the 2017 MY information on the mid-model year CAFE compared to the target fuel economy shows a substantial number of manufacturers that are not in compliance.



In fact, both the car and the truck fleets are projected to miss the CAFE targets for 2017. The truck fleet has missed the target since 2015.

The concern is that if the model is not predicting with any accuracy the capabilities of the fleet two model years in advance there is little hope that it will accurately predict the future ten years down the road.

RESPONSE: The model is intended to illustrate a potential response to CAFE standards, not, *per se*, to be predictive. At the reviewer appears to recognize, the development of the analysis fleet involves tradeoffs between precision, certainty, resources (including available time), and opportunity for public disclosure. Setting aside direct use of manufacturers' confidential product planning information to develop the analysis fleet, Volpe Center and NHTSA staff consider the best option to be one that makes use of the most recent model year for which the production volumes, fuel economy ratings, and engineering characteristics of all specific vehicle model/configurations are both reasonably defined and able to be made public at the time a given analysis is to be released. In any event, choices regarding these model inputs are explained in the documentation (e.g., in a Regulatory Impact Analysis) of each published analysis.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   The data, computational methods, and/or assumptions do not appear to be reasonable. One of the weaknesses in the methodology is the NHTSA assumption that the IHS/Polk data “necessarily includes their assumptions about what decisions manufacturers will have to make in order to comply with the standards.”

CAFE is enormously complicated and few, even within the automotive companies, truly understand just how complicated it is. It is not reasonable that an outside firm would have any basis on which to make valid assumptions.

Going back to Figure 3, for example, would HIS/Polk even take this differential segment gap in into account? Or know that it exists? If you do not account for the greater stringency in a subcategory you will inevitably make the wrong assumptions going forward. It may be less expensive to delete a small car (or ship manufacturing overseas to avoid the minimum domestic production target) then it would be to add technology to achieve compliance. This is especially true in the small car segment that is the most sensitive to price. It is the law of unintended consequences.

RESPONSE: While manufacturers’ actual plans reflect intentions to discontinue some products and introduce others, those plans are considered confidential business information (CBI). Further research would be required in order to determine whether and, if so, how it would be practicable to simulate such decisions, especially without relying on CBI. A new Regulatory Impact Analysis will discuss the related tradeoffs.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   Herein lies the dilemma. NHTSA can ask for manufacturers to provide information but NHTSA cannot publish the manufacturers’ information as it is confidential for future model years.

   NHTSA can use the manufacturers’ plans as a check on the model and revise the input assumptions in an attempt to match the plans.

   RESPONSE: The development of the analysis fleet involves tradeoffs between precision, certainty, resources (including available time), and opportunity for public disclosure. Setting aside direct use of manufacturers’ confidential product planning information to develop the analysis fleet, Volpe Center and NHTSA staff consider the best option to be one that makes use of the most recent model year for which the production volumes, fuel economy ratings, and engineering characteristics of all specific vehicle model/configurations are both reasonably defined and able to be made public at the time a given analysis is to be released. In any event, choices regarding these model inputs are explained in the documentation (e.g., in a Regulatory Impact Analysis) of each published analysis.

4. Is there an alternative approach that you would suggest? All the inputs should be revised.

   RESPONSE: See responses to recommendations 2 and 3 above.

Jose Mantilla

[NO RESPONSE.]

Wallace Wade

Reviewer Name:_Wallace R. Wade

Review Topic Number: _3.1. Development and use of MY 2015 analysis (initialization) fleet (includes vehicle models and their technology content characterized by engine, transmission, vehicle attributes, and other technologies)

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.*]

1. What are the most important concerns that should be taken into account related to the review topic?

2015 MY Fleet:

The fleet used for analysis in the 2016 Draft TAR is the set of vehicles offered for sale in MY 2015, with individual vehicle models described by attributes like vehicle specifications, technology features, and sales volumes. Once the analysis fleet is defined, NHTSA estimates how each manufacturer could potentially deploy additional fuel-saving technology in response to a given series of attribute-based standards.

Engine/Electrification Technologies:

The Volpe Model does not allow technology to be added to a vehicle already equipped with that technology. Table 4.43 shows the estimated prevalence of major technologies, by sales volume weighting, in the MY 2015 light duty analysis fleet. The major technologies include Diesel, DOHC, VVT, VVL, SGDI, Cylinder Deactivation, and Turbo- or Super-Charging. Table 4.44 shows the prevalence of electrified technologies.

Concern 1:
Significantly more information about the specific types and levels of technologies applied to each vehicle type in the MY 2015 fleet is required than illustrated in Tables 4.43 and 4.44 as indicated by the examples below:

1. For engine technologies: VVL needs to be defined as discrete or continuous; turbocharging needs to be defined as Level 1 (18 bar BMEP), Level 2 (24 bar BMEP), CEGR1 (24 bar BMEP), or CEGR2 (27 bar BMEP).
2. Additional information is required for transmission type, including levels of High Efficiency Gearbox (HEG1 or HEG2) and the extent of Shift Optimization (SHFTOPT).
3. Vehicle information, often lacking from EPA certification data, is required to fully define the technologies in the MY 2015 fleet. Vehicle information includes: Level of tire rolling resistance reduction, Level of aerodynamic drag reduction, Level of mass reduction, Level of improved accessories, presence of Low drag brakes and Secondary axle disconnect.
4. Details of the electrified technologies (SS12V, BISG/CISG (Belt/Crank Integrated Starter/Generator), SHEV, PHEV, EV) in the MY 2015 fleet need to be defined.

(Ref: NHTSA, Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2017-MY2025 Passenger Cars and Light Trucks, 2012)

Recommendation 1:

The 2016 Draft TAR should be modified to address Concern 1 regarding the need for significantly more information about the specific types and levels of technologies applied to each vehicle type in the MY 2015 fleet than illustrated in Tables 4.43and 4.44. It is likely that the Volpe Model correctly handles the specific types and levels of technologies applied to each vehicle type in the MY 2015 fleet. However, if there any deficiencies relative to Concern 1, then modifications should be made to the input data for the Volpe Model to correct the deficiencies.

RESPONSE: Following the 2016 analysis, inputs defining the analysis fleet have been updated, and levels of already-present technology have been specified as precisely as practicable, as documented in a new Regulatory Impact Analysis.

Mass Reduction and Aerodynamic Drag:

NHTSA recognizes that manufacturers have already implemented mass savings technologies and drag reductions on many of their MY 2015 products. As a result, not all vehicles in the 2015 fleet have the same opportunities to further reduce mass and improve aerodynamic drag in future years. To account for the diverse progress on mass reduction and aerodynamics among the fleet, NHTSA assigned each vehicle a level of mass reduction and aerodynamic treatment relative to a baseline case. NHTSA has adopted a relative performance approach to assess the application of mass reduction and aerodynamic technologies.

Mass Reduction of Baseline Fleet:

The 2016 Draft TAR addresses the level of mass reductions in the MY 2015 fleet on pages 4-65 to 4-73. NHTSA developed regression models to estimate curb weights based on other observable attributes, listed in Table 4.47, Regression Statistics for Curb Weight. Based on the actual curb weights relative to predicted curb weights, NHTSA/Volpe assigned platforms (and the associated vehicles) a MY 2015 mass reduction level. Table 4.49 shows examples of the mass reduction levels (MR1 through MR5) assigned to the specific platforms/vehicles in the MY 2015 fleet. Table 4.50 summarizes the initial levels of mass reduction assigned for each manufacturer's MY 2015 light-duty fleet. With these “MR” assignments, additional weight savings opportunities will have different starting points, so that vehicles may face incrementally higher or lower costs for these additional weight savings.

In addition, pages 4-73 to 4-79 address NHTSA/Volpe’s finding of significant deviations of trends in (1) Mass Reduction Residual Analysis for Footprints under 41 square feet, (2) High and Low Price Platforms, and (3) Company Heritage, the results of which are summarized in Table 4.51 (two smallest vehicles were the most overweight), Table 4.53 (accounting for premium content is not needed to correct for predicted weight bias among high priced vehicles), and Table 4.54 (Asian parent companies demonstrate a residual skew towards lightweight designs, while European heritage exhibit a modest skew towards heavier designs).

Comment 2:

The mass reduction starting point for the baseline fleet has been an ongoing concern since the publication of the 2012 TSD, as discussed in Finding 6.8 (p. 242) of the 2015 NRC Report (NRC, Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles, 2015). NHTSA's technique for determining the mass reduction level starting points for the MY 2015 baseline fleet is a good beginning for resolving this concern. However, the following issues with NHTSA's technique will need to be addressed to improve the process for determining the mass reduction starting point for the baseline fleet:

- The introduction to the Mass Reduction section of the 2016 Draft TAR (p. 4-65) states that "NHTSA developed cost curves for glider weight savings on baseline sedans and pick-ups," but the remainder of the section addresses curb weight. Clarification of where glider weight is addressed with respect to mass reduction in needed. Why and how was glider weight determined, and how was it used in the analysis that appears to be based on curb weight?
- Table 4.49 showing examples of the mass reduction levels (MR1 through MR5) assigned to the specific platforms/vehicles in the MY 2015 fleet, has the following concerns:
    - The F150 with an all-aluminum body shows a -8.2 percent MR residual, whereas the steel GMC Canyon shows a – 9.3 percent MR residual. This demonstrates an insufficient recognition of other independent variables in the regression analysis, such as material usage in the vehicles.
    - The suggested requirement to recognize material usage in the baseline fleet vehicles is consistent with the 2015 NRC Report's Recommendation 6.3 for a "materials based approach…to better define opportunities…for implementing lightweighting techniques."
- Consideration should be given to developing a separate regression for premium cost vehicles, such as the Lamborghini Veneno Roadster, Porsche 918 Spyder and BMW i8.
- NHTSA found significant deviations from the curb weight regression trends for 1) Footprints under 41 square feet, 2) High and Low Price Platforms, and 3) Company Heritage. These deviations need to be addressed and incorporated in the analysis of the mass reduction starting point for the baseline fleet.

Recommendation 2:

Address and resolve the issues identified in Concern 2 regarding NHTSA's technique for determining the mass reduction starting point for the baseline fleet and make appropriate modifications to the TAR and input for the Volpe Model.

RESPONSE: Following the 2016 analysis, inputs defining levels of already-present mass reduction have been updated, as documented in a new Regulatory Impact Analysis.

Aerodynamic Drag:

Similar to mass reduction, NHTSA used a relative performance approach to assign the current aerodynamic technology level to a vehicle. The 2016 Draft TAR describes this approach on pages 4-80 to 4-82 which is summarized in Table 4.56 showing Levels of aerodynamic application by manufacturer as a percent of MY 2015 sales.

NHTSA/Volpe computed an average coefficient of drag (Cd) for each body style segment in the MY 2015 analysis fleet from drag coefficients published by manufacturers. NHTSA calculated the average Cd for each body style by grouping vehicles by body style and then averaging the manufacturer reported or publicly available drag coefficients for each group.

In order for a vehicle to achieve AERO10, for example, the aerodynamic drag coefficient needed to be at least 10 percent below the calculated average drag coefficient for the body style. No aerodynamic application was assumed for vehicles with no manufacturer reported Cd.

Comment 1:

The aerodynamic drag starting point for the baseline fleet has been an ongoing concern since the publication of the 2012 TSD, as discussed on page 208 of the 2015 NRC Report (NRC, "Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles, 2015). However, NHTSA's technique for determining the aerodynamic drag starting points for the MY 2015 baseline fleet goes a long way in resolving this concern.

Concern 3:

The validity and consistency of using manufacturer reported or publicly available aerodynamic drag coefficients may be a concern due to different measurement techniques and test facility differences.

Recommendation 3:

To improve the validity and consistency of the aerodynamic drag coefficients, NHTSA should consider inferring aerodynamic drag from the chassis dynamometer settings used in EPA's certification process (by using coefficient C, which represents aerodynamic effects that are a function of vehicle speed squared).

RESPONSE: Following the 2016 analysis, inputs defining levels of already-present aerodynamic drag performance have been updated, as documented in a new Regulatory Impact Analysis.

Technology Cost Class:

Technology Cost Class accounts for costs that vary by engine configuration (e.g. SGDI, VVT), and therefore provides a code for the number of cylinders, banks, and whether or not a vehicle uses an OHV valve train configuration. NHTSA seeks comment on this approach to grouping specific vehicles for these different analytical requirements.

(2016 Draft TAR, p. 4-65)

Comment 2:

Using Technology Cost Class to account for costs that vary by engine configuration appears to be required to ensure that appropriate costs are assigned to the technologies applied to specific engine types. For example, the cost of VVT using cam phasers for a V6 engine (with 4 camshafts) will be significantly more expensive than VVT for a 4 cylinder engine (with 2 camshafts).

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

Since the 2016 Draft TAR does not provide adequate information regarding the specific types and levels of technologies applied to each vehicle type in the MY 2015 fleet, an assessment of whether the assumptions are reasonable cannot be made.

Identifying mass reduction starting points and aerodynamic drag starting points for the baseline MY 2015 fleet are significant improvements relative to the analysis for the 2012 Final Rule, but several issues identified with NHTSA's technique will need to be addressed to improve the process for determining the mass reduction starting point for the baseline fleet.

RESPONSE: See responses to recommendations 1-3 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1- 3.

4. Is there an alternative approach that you would suggest?

No. Implementation of Recommendations 1- 3 is the suggested approach.

RESPONSE: See responses to recommendations 1-3 above.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

Implementing Recommendations 1- 3 regarding how the Volpe Model handles the specific types and levels of technologies applied to each vehicle type in the MY 2015 fleet and a possible improvement in the validity and consistency of the aerodynamic drag coefficients will enhance the utility and plausibility of Volpe Model.

RESPONSE: See responses to recommendations 1-3 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

NHTSA should consider upgrading the baseline fleet from the MY 2015 to the MY 2016 or even MY 2017 so that it is closer to the midterm review period of MYs 2022 to 2025 together with the recently added MY 2021. Changing to the MY 2016 or even MY 2017 baseline is important to address automobile manufacturers' concerns that NHTSA's analysis through the MY 2025 may not adequately recognize and account for the technologies already applied and included on current models.

RESPONSE: The analysis fleet has been updated to reflect model year 2016. The development of the analysis fleet involves tradeoffs between precision, certainty, resources (including available time), and opportunity for public disclosure. Setting aside direct use of manufacturers' confidential product planning information to develop the analysis fleet, Volpe Center and NHTSA staff consider the best option to be one that makes use of the most recent model year for which the production volumes, fuel economy ratings, and engineering characteristics of all specific vehicle model/configurations are both reasonably defined and able to be made public at the time a given analysis is to be released. In any event, choices regarding these model inputs are explained in the documentation (e.g., in a Regulatory Impact Analysis) of each published analysis.

CAFE Peer Review Responses

REVIEW TOPIC
3. Model architectural elements
3.1. Development and use of MY2015 analysis (initialized) fleet (includes vehicle models and their existing technology content characterized by engine, transmission, vehicle attributes, and other technologies)
3.2. Modeling consumer behavior, including willingness to pay for fuel economy and number of miles traveled in new vehicles
3.3. The model's representation of CAFE regulations, including separate passenger car and light truck standards for each model year, minimum standards for domestic passenger cars, the option to carry CAFE credits forward and transfer CAFE credits between fleets, and the civil penalties levied for noncompliance.
3.4. Application of technologies, including interactions, paths and prerequisites of a technology's application (and any logically required exclusions based on the paths and prerequisites) and costs, including learning curves

Nigel Clark

[NO RESPONSE.]

Walter Kreucher

REVIEW TOPIC NUMBER 3.2. MODELING CONSUMER BEHAVIOR, INCLUDING WILLINGNESS TO PAY FOR FUEL ECONOMY AND NUMBER OF MILES TRAVELED IN NEW VEHICLES

1. What are the most important concerns that should be taken into account related to the review topic?

   Modeling consumer behavior is an issue that has never been addressed by the model. It is also one that must be addressed.
   Predicting consumer behavior is the central focus of every manufacturer. If a manufacturer does not produce models that customers are welling to purchase at a price they are willing to pay, they will not be in business in the long term.

   RESPONSE: Prior to 2016 NHTSA sponsored academic research to estimate a choice model that, among other things, differentiated among specific market segments. Volpe Center staff integrated this choice model into an experimental version of the CAFE model, but determined that further research would be needed before applying a choice model outside the experimental context. The CAFE model does not apply a "dynamic fleet share" model that estimated the overall relative market shares of passenger cars and light trucks, as discussed in updated model documentation and a new Regulatory Impact Analysis.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   No. Payback period is defined in the model as the number of years of the accumulated dollar value of fuel savings needed to recover the additional cost of technology included in the purchase price of a new vehicle. This definition only covers part of the cost that the customer would pay. It neglects the increase in insurance, maintenance, repairs, taxes and fees, and the change in value associated with a technology.

   RESPONSE: As applied by the model in the technology application context, the payback period is intended to provide means to simulate the potential that a manufacturer's decisions to increase fuel economy may proceed as if the manufacturer expects to be able to price vehicles as if buyers are willing to pay for fuel savings accrued during the indicated period. This is not intended as full actuarial representation of the payback period, or as an assertion that customers' purchase decisions actually reflect a full accounting of all costs of vehicle ownership. Even if purchase decisions actually do so, the simulation of technology application involves representing <u>manufacturers'</u> decisions.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?
   Revise the "effective cost" to include "tech value."

“Consumer valuation” appears in the “technology” input file but is blank for all technologies. “Tech Value” as used in equation 5 (in the documentation) must include the increase in insurance, maintenance, repairs, taxes and fees, and the change in value associated with a technology. This is especially critical in the case of HEVs, PHEVs, and BEVs which show a substantial difference in depreciation compared to gasoline or diesel technology. (See below for details)

RESPONSE: The model does calculate and report additional costs (e.g., sales taxes), applying corresponding model inputs. The model also applies any “consumer valuation” estimates included as model inputs. Past analyses applied a negative value for electric vehicles with limited (80 mile) range. The 2016 analysis considered electric vehicles with longer driving range. Volpe Center staff have since revisited and expanded these estimates to include a wider range of hybrid and battery-only electric vehicles.

Jose Mantilla

[NO RESPONSE.]

Wallace Wade

Reviewer Name:_Wallace R. Wade

Review Topic Number: _3.2. Modeling consumer behavior, including willingness to pay for fuel economy and number of miles traveled in new vehicles

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

Modeling Consumer Behavior:

The current CAFE analysis lacks consumer dynamic demand response to the simulated changes in vehicle attributes – which include fuel economy, price, electrification level, and curb weight – that occur as manufacturers add technology to new vehicles to comply with standards. Currently, sales volumes at the model/variant level, for all future model years, are an input to the Volpe model and do not respond to simulated changes in vehicle attributes. Therefore, when a range of regulatory alternatives is examined, all alternatives are assumed to have the same total number and sales mix of vehicle models, regardless of the stringency of the alternative considered.

NHTSA purchased a commercial forecast from IHS/Polk that includes their assumptions about decisions manufacturers will have to make in order to comply with standards through MY 2021, which influenced the production volumes used in this forecast. However, any volume changes that would occur as a result of post-2021 standards would not be captured by the current approach.

NHTSA has not been able to resolve the following issues with discrete choice models:

- There is not an obvious definition of price that fits all purchases.
- Manufacturers may employ pricing strategies that often cross subsidize vehicles in one class.
- Manufacturers may prefer to apply technology to improve other vehicle attributes (e.g., vehicle size, power) that consumers value if their compliance position is favorable and if that affordable technology is available

The default assumption in the Volpe Model is that manufacturers will treat all technologies that pay for themselves within the first three years of ownership (through reduced expenditures on fuel) as if the cost of that technology were negative. This holds true up to the point at which the manufacturer achieves compliance with the standard – after which the manufacturer treats all technologies that pay for themselves in the first year of ownership as having a negative effective cost.
(2016 Draft TAR, pp. 13-8 to 13-10)

Concern 1:

The 2015 NRC Report (NRC, Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles, 2015) has the following comments regarding consumer behavior:

> An economic behavioral model would be useful for predicting the effects of the standards on the fleet. Examples of concerns that an economic behavior model could address include the following:
>
> - As the fuel economy standards are made more stringent over time, what is the relative shift in the marginal costs for vehicles of different sizes and how would those changes affect purchase decisions across the fleet?
> - Are the proportionate changes in small car costs greater than large car costs, as might be expected?
> - What is known about the elasticities of demand for vehicles of different sizes and market segments? This question is relevant for predicting how difficult it will be to pass costs forward in different model segments.

Although not noted in the 2016 Draft TAR, MSRP (manufacturers suggested retail price) or a derivative of MSRP (e.g., transaction price), is not always the price that the consumer evaluates. Often, the consumer considers the monthly payment or monthly lease fee, rather than MSRP or derivative, in their purchase decision.

Recommendation 1:

Because of the impact of an economic behavioral model on demand for vehicles of different sizes and market segments, NHTSA should continue to develop, resolve previous issues, and validate an economic behavioral model for eventual incorporation in the Volpe Model. The price that the consumer evaluates in their purchase decision, such as MSRP, monthly payment, and/or monthly lease fee, will need to be determined for a successful economic behavioral model.

RESPONSE: Prior to 2016, NHTSA sponsored academic research to estimate a choice model that, among other things, differentiated among specific market segments. Volpe Center staff integrated this choice model into an experimental version of the CAFE model, but determined that further research would be needed before applying a choice model outside the experimental context. The CAFE model does not apply a "dynamic fleet share" model that estimated the overall relative market shares of passenger cars and light trucks, as discussed in updated model documentation and a new Regulatory Impact Analysis.

Concern 2:

What is the rationale and basis for treating all technologies that pay for themselves within the first three years of ownership (through reduced expenditures on fuel) as if the cost of that technology were negative and then, after achieving compliance with the standard, treating all technologies that pay for themselves within the first year of ownership as having a negative effective cost. How is this assessment of technologies used?

Recommendation 2:

Provide the rationale and basis for the time frames (3 years until compliance with the standard, 1 year after compliance with the standard) for treating technologies that pay for themselves as having negative effective costs. Explain how negative effective costs are used in the Volpe Model (Are negative costs only a means of identifying technologies that are cost effective?).

RESPONSE: The model documentation will be revised to explain that these model inputs provide the ability to accommodate different assumptions about manufactures' technology application decisions "before" and "after" achieving compliance, and to explain the meaning and modeling implications of negative "effective costs." The two payback periods can be set to the same level.

Vehicle Miles Traveled:

To develop new mileage accumulation schedules for vehicles regulated under the CAFE program, NHTSA purchased a data set of vehicle odometer readings from IHS/Polk (Polk). Polk collects odometer readings from registered vehicles when they encounter maintenance facilities, state inspection programs, or interactions with dealerships and OEMs. In contrast, the basis for estimated travel demand in the 2012 Final Rule was developed using self-reported odometer data in the 2009 National Household Travel Survey (NHTS).

Table 13.1 provides a comparison of lifetime VMT for current and previous schedules by vehicle class. Compared to the previous schedule, the current schedule shows approximately 100,000 miles (or approximately 30%) lower lifetime VMT for car, van, SUV, and pickup classes.

Table 13.1

	Lifetime VMT		
	Current	Previous	% difference
Car	204,233	301,115	32.2%
Van	237,623	362,482	34.4%
SUV	237,623	338,646	29.8%
Pickup	265,849	360,982	26.4%
2b/3	246,413	270,662	9.0%

Source: 2016 Draft TAR

<u>Concern 3:</u>

The current Lifetime VMTs, which are approximately 30 percent lower than the previous schedule, is a concern, particularly considering that the average age of cars on the road has been increasing (and is currently over 11 years). The steep decline in average annual mileage accumulation after vehicles have been in operation for 6 years should also be re-examined.

Recommendation 3:

The approximately 30 percent lower lifetime VMT used in the current Volpe Model, relative to the 2012 Final Rule, is a concern and should be re-examined, particularly with respect to the steep decline in average annual mileage accumulation after vehicles have been in operation for 6 years.

RESPONSE: The comparisons shown above use cumulative values that do not reflect estimated vehicle survival rates. Vehicle mileage accumulation rates are model inputs, and have been revised. The model's approach to vehicle survival has also been revised. These changes are discussed in updated model documentation and a new Regulatory Impact Analysis.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

Implementing Recommendations 1-3 will ensure that the data, computational methods and assumptions are reasonable and appropriate.

RESPONSE: See responses to recommendations 1-3 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1-2 so that, if the issues can be resolved, the best available economic behavioral models could be validated and incorporated in the Volpe Model to reflect the impact on demand for vehicles of different sizes and market segments.

Implement Recommendation 3 to confirm the lower Lifetime VMT results used in the current Volpe Model and make adjustments, if appropriate.

RESPONSE: See responses to recommendations 1-3 above.

4. Is there an alternative approach that you would suggest?

No. Implementing Recommendations 1-3 is the suggested approach.

RESPONSE: See responses to recommendations 1-3 above.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

Implementing Recommendations 1-3 will enhance the utility and plausibility of the Volpe Model output.

RESPONSE: See responses to recommendations 1-3 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
3. Model architectural elements
3.1. Development and use of MY2015 analysis (initialized) fleet (includes vehicle models and their existing technology content characterized by engine, transmission, vehicle attributes, and other technologies)
3.2. Modeling consumer behavior, including willingness to pay for fuel economy and number of miles traveled in new vehicles
3.3. The model's representation of CAFE regulations, including separate passenger car and light truck standards for each model year, minimum standards for domestic passenger cars, the option to carry CAFE credits forward and transfer CAFE credits between fleets, and the civil penalties levied for noncompliance.
3.4. Application of technologies, including interactions, paths and prerequisites of a technology's application (and any logically required exclusions based on the paths and prerequisites) and costs, including learning curves

Nigel Clark

[NO RESPONSE.]

Walter Kreucher

REVIEW TOPIC NUMBER 3.3. THE MODEL'S REPRESENTATION OF CAFE REGULATIONS, INCLUDING SEPARATE PASSENGER CAR AND LIGHT-TRUCK STANDARDS FOR EACH MODEL YEAR, MINIMUM STANDARDS FOR DOMESTIC PASSENGER CARS, THE OPTION TO CARRY CAFE CREDITS FORWARD AND TRANSFER CAFE CREDITS BETWEEN FLEETS, AND THE CIVIL PENALTIES LEVIED FOR NONCOMPLIANCE.

1. What are the most important concerns that should be taken into account related to the review topic?

   I note that the Augural Standards show that it is less expensive for manufacturers to pay fines than it is to add technology. This seems to be a fundamental flaw in the standard setting process.

   It is unclear if the problem is the model or the policy decisions that are driving the input assumptions.

   If it is less expensive to pay a fine this is an indication that the cost of the technology minus any consumer payback is greater than the rate of the fine in the eyes of manufacturers.

   RESPONSE: The model's purpose is to estimate ways manufacturers could respond to standards at different levels, not to determine what levels of standards should be promulgated. Depending on the rates at which civil penalties are levied for failures to comply with CAFE standards, paying civil penalties can be less expensive for manufacturers than complying by adding technology to vehicles.

Jose Mantilla

[NO RESPONSE.]

Wallace Wade

Reviewer Name:_Wallace R. Wade

Review Topic Number: _3.3. The model's representation of CAFE regulations, including separate passenger car and light truck standards for each model year, minimum standards for domestic passenger cars, the option to carry CAFE credits forward and transfer CAFE credits between fleets, and the civil penalties levied for noncompliance.

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.*]

1. What are the most important concerns that should be taken into account related to the review topic?

Separate Passenger Car and Light Truck Standards:

Table 29 in the CAFE Model Documentation lists only the Passenger Car and Light Truck regulatory classes for the light duty CAFE requirements, but adds the Truck 2b3 regulatory class for medium- and heavy-duty CAFE requirements.

Table 29. Regulatory Classes

Reg. Class	Includes
Passenger Car	All passenger automobiles
Light Truck	Class 1 and class 2a trucks
Light Truck 2b/3	Class 2b and class 3 trucks

Concern 1:
The Regulatory Classes listed in Table 29 may be confusing without additional clarification as follows:

- The passenger car standards apply individually to the Import and Domestic Passenger Car fleets.
- The 2017 and Later Model Year Light-Duty Vehicle CAFE standards apply to (1) passenger cars, (2) light-duty trucks, and (3) medium-duty passenger vehicles (MDPV).
  (EPA/NHTSA, 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, October 15, 2012)
- The light duty CAFE standards do not apply to the Class 2b/3 Trucks and Vans, although the Volpe Model runs the analysis of these classes to evaluate compliance with the medium- and heavy-duty CAFE requirements.
  - Allowing simultaneous analysis of light duty and medium duty fleets accounts for potential interaction between shared platforms, engines, and transmissions.
  (CAFE Model Documentation, pp. 1-2)

Recommendation 1:
Modify Table 29 to include a description of the complexity of the classes analyzed within the Volpe Model, as outlined in Concern 1.

RESPONSE: The model has been revised to account for the requirement that domestic passenger car fleets and imported passenger car fleets comply separately with passenger cars standards, and that the former comply with a minimum standard. These changes are discussed in updated model documentation, as is the more general treatment of boundaries between regulatory classes versus shared platforms, engines, and transmissions.

Concern 2:
The Volpe Model does not appear to analyze the Passenger Car Standards as they apply individually to the Import and Domestic Passenger Car fleets.

Recommendation 2:
Assess the need to analyze the Passenger Car Standards as they apply individually to the Import and Domestic Passenger Car fleets, and, if necessary, implement the capability to include the analysis of Import and Domestic Passenger Car fleets.

RESPONSE: See response to recommendation 1 above.

Minimum Standards for Domestic Passenger Cars:

The minimum CAFE standard that each manufacturer must attain, specified as a flat-standard in miles/gallon, or 0 if not applicable, is shown as input for each regulatory class on the scenario worksheet shown in Table 30 of the CAFE Model Documentation.

The minimum domestic passenger car standard was added to the CAFE program through EISA, when Congress gave NHTSA explicit authority to set universal standards for domestically manufactured passenger cars at the level of 27.5 mpg or 92 percent of the average fuel economy of the combined domestic and import passenger car fleets in that model year, whichever was greater (EPA/NHTSA, “2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards”, August 28, 2012, p. 63020.

Carry CAFE Credits Forward and Transfer Between Fleets:

The Runtime Settings Panel (Figure 17) provides additional modeling options, including allowing credit trading. This option specifies whether the model should allow manufacturers to transfer credits between passenger car and light truck fleets and to carry-forward credits from previous model years into the analysis year. (CAFE Model Documentation, p. 97)

Civil Penalties:

The Volpe Model finds the best next applicable technology in each of the technology pathways, and then selects the best among these. If a manufacturer is assumed to be unwilling to pay CAFE civil penalties, then the algorithm applies the technology to the affected vehicles. Afterwards, the algorithm reevaluates the manufacturer's degree of noncompliance and continues application of technology. Once a manufacturer reaches compliance (i.e., the manufacturer no longer pays CAFE civil penalties), the algorithm proceeds to apply any additional technology determined to be cost-effective. Conversely, if a manufacturer is assumed to prefer to pay CAFE civil penalties, the algorithm only applies technology if it is cost-effective to do so. (CAFE Model Documentation, p. 23)

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The Volpe Model appears to handle the various regulatory classes properly, including:

- 1) Passenger Cars, 2) Light-Duty Trucks, and 3) Medium-Duty Passenger Vehicles.
- However, the Volpe Model does not appear to handle the Passenger Car Standards as they apply individually to the Import and Domestic Passenger Car fleets.
- The Volpe Model also runs the analysis of Class 2b3 Trucks and Vans to evaluate compliance with the Medium- and Heavy-Duty CAFE requirements to account for potential interaction between shared platforms, engines, and transmissions.

The Volpe Model has appropriate provisions to account for input of minimum standards for domestic passenger cars, provides input for carrying CAFE credits forward and transfers between car and truck fleets, and specifies if a manufacture is willing to pay civil penalties.

RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comment, and note that the CAFE model now explicitly accounts for the statutory requirement that domestic and imported passenger car fleets comply separately with CAFE standards.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1 and 2. The Volpe Model does not appear to have provisions to account for the Domestic and Imported Passenger Car regulatory classes. If this is correct, then assess the need, and implement, if necessary the capability to analyze passenger car standards as they apply individually to the Import and Domestic Passenger Car fleets.

RESPONSE: See response to recommendations 1-2 above.

4. Is there an alternative approach that you would suggest?

No. Implementation of Recommendations 1 and 2 is the preferred approach.

RESPONSE: See response to recommendations 1-2 above.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

Implementation of Recommendation 1 and 2, as well as having the capability to input minimum standards for domestic passenger cars, input for carrying CAFE credits forward and transfer between car and truck fleets, and capability to specify if a manufacturer is willing to pay civil penalties contribute to the utility and plausibility of the Volpe Model output.

RESPONSE: See response to recommendations 1-2 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

Review topic
3. Model architectural elements
3.1. Development and use of MY2015 analysis (initialized) fleet (includes vehicle models and their existing technology content characterized by engine, transmission, vehicle attributes, and other technologies)
3.2. Modeling consumer behavior, including willingness to pay for fuel economy and number of miles traveled in new vehicles
3.3. The model's representation of CAFE regulations, including separate passenger car and light truck standards for each model year, minimum standards for domestic passenger cars, the option to carry CAFE credits forward and transfer CAFE credits between fleets, and the civil penalties levied for noncompliance.
3.4. Application of technologies, including interactions, paths and prerequisites of a technology's application (and any logically required exclusions based on the paths and prerequisites) and costs, including learning curves

Nigel Clark

Volpe Model Review Template

Reviewer Name:_ Nigel N. Clark

Review Topic Number: 3.4. Application of technologies, including interactions, paths and prerequisites of a technology's application (and any logically required exclusions based on the paths and prerequisites) and costs, including learning

Other Review Topic Numbers (if interactive effects are focus of discussions)

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   I view this as a request to reiterate the primary inputs needed for reasonably accurate fuel economy prediction. First, the technologies that can be employed to improve fuel efficiency, over and above those already in place in the analysis fleet, must be identified. Some of these technologies are applicable only to selected powertrain philosophies (or overall configurations), so that facilities for technology inclusion or exclusion are needed in the model.

   For a single technology used, there must be a fuel efficiency effect, and for each combination of technologies, there must be a combined fuel efficiency effect.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   In general, they are appropriate and address (1) above. The model seeks to be general, and it is already large and granular. It seeks to predict "tomorrow's weather from today's weather," which is a stable approach. One could argue that the model should consider in more detail the exact effect of new technologies and their synergies precisely for each separate vehicle, due to varying power to weight ratios or varying control sophistication (and more factors too), but the model would devolve into a multidimensional lookup table, lose its generality, and be over-educated by the immediate fleet's properties. The model is appropriately proportioned. Sufficient additional error will arise due to design variations, technology and societal disruptions, the economy, and so on, that increased specificity is not warranted.

   The model does include some assumptions (such as how to choose GVW in the face of mass reduction – just one example) that could be posed to yield different outcomes, but a different choice would not affect significantly the overall outcome or lead to an incorrect conclusion to the overall questions of fuel efficiency improvement.

   RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comment, and note that limited information has thus far been available regarding specific powertrain control algorithms already in place for each specific vehicle model/configuration.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

None that would make a substantial difference to the outcome, except perhaps addition of some technology that is neglected, such as shift patterns adaptive to terrain (predictive control). However, my instinct is that there are measurable variations, not taken into account, which could be ascribed to factors such as:

- Design toward the CAFE cycles fuel economy versus toward the sticker fuel economy versus toward some in-use application, based on value. These three targets vary in sympathy for some tools (low rr tires), and not for others. This is akin to willingness to pay fines, which is handled in the model, but far more complex to consider. Pricing to manage sales mix is also a factor here.
- As in the point above, but where the manufacturer is considering factors such as durability or performance weighed against the CAFE fuel economy performance. In other words, other constraints affect the economy optimization. This is recognized in the TAR, but almost impossible to treat generally for prediction.
- Degree of sophistication of controls, use of adaptive controls, and degree of integration of overall powertrain management. This can be lumped with the adoption of some advanced technologies, just due to correlation: for example, an 8-speed transmission is more likely to be associated with other sophistication (not listed as a technology option) than a 5-speed. But the extent to which a named/chosen technology is symbolic of (or implies) other advanced tools will vary, and is unclear. High level engine and transmission integration of controls could be associated with an 8-speed transmission, or variable valve duration or lift, or both. This could imply positive synergy in some cases, rather than a double dip of claims. The model could just use a number of technology steps instead of naming each step with a specific item of technology, but the model's current approach is likely more understandable to users.
- An unrealistic driver simulation in the Autonomie runs, or variability in the driver simulation. Note that the same PID approach might not be applicable to, or appropriate for, two diverse vehicles. If the Autonomie run data are calibrated against some real-world data, then it is important to avoid having any real-world error enter into determining the difference between "with" and "without a technology" runs. This also relates to the degree that the current incremental improvements used by the Volpe model developers take into account effect of test cycle transient behavior. Some of these benefits may inherently assume a more steady-state advantage.

The model already addresses some decisions that might defy the careful progression order of the technology by considering technology or platform or engine sharing.

This approach is good, but as with all predictions, the exact weights in equations could be changed to yield different outcomes.

RESPONSE: NHTSA and Volpe Center staff agree that while many of these items would, in principle, provide for more precise full vehicle simulations, there are important practical limitations on the prospects to include all of them, especially without relying on confidential business information (regarding, e.g., powertrain control algorithms). These recommendations apply primarily to the Autonomie full vehicle simulations conducted to

develop CAFE model inputs. These simulations, in turn, use inputs—such as powertrain control algorithms—that, though realistic, cannot practicably represent every specific technology as it might be applied by every specific manufacturer to every specific vehicle configuration. Because the CAFE model's foundational objective is to estimate manufacturers' potential responses to CAFE standards, the model applies the 2-cycle portion of the Autonomie results. However, to ensure that technologies are simulated in a way that assumes the simulated would perform satisfactorily under real-world driving conditions, the Autonomie simulations also include driving conditions (high speeds, hard acceleration, towing, etc.) not represented by the 2-cycle driving cycles.

4. Is there an alternative approach that you would suggest?

   There are clearly genetic algorithms and artificial neural networks that might allow a non-classical model to be fed less orderly data for prediction, but the anticipated sales would be too hard to model this way. There is mention of a Monte-Carlo option, but that is just likely to yield near-identical outputs with the sales volume anticipated.

   The model should strive as far as possible to use differences rather than absolute values for inputs and outputs. It does appear to do so. Many of these fuel efficiency effects are small and masked by small percentage errors in absolutes. Even the analysis fleet data will include measurement variability that is of the same order as the effect of some technologies.

   Some vehicle classes (such as those with V12 engines) could be lumped with no loss of overall accuracy.

   RESPONSE: The model's approach to handling fuel consumption calculations has been revised to use inputs that are more transparently relatable to underlying full vehicle simulation results. Future uncertainty analyses could potentially be expanded to accommodate uncertainty in the initial fuel economy values. However, insofar as uncertainty analyses already address uncertainty in fuel economy values after additional technology application, and within the context of actual CAFE compliance enforcement, compliance fuel economy values are treated as known, it is not clear that this expansion of the uncertainty analysis would be additionally informative.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   This topic addresses major factors governing the output.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

   None

Walter Kreucher

REVIEW TOPIC NUMBER 3.4. APPLICATION OF TECHNOLOGIES, INCLUDING INTERACTIONS, PATHS AND PREREQUISITES OF A TECHNOLOGY'S APPLICATION (AND ANY LOGICALLY REQUIRED EXCLUSIONS BASED ON THE PATHS AND PREREQUISITES) AND COSTS, INCLUDING LEARNING CURVES

1. What are the most important concerns that should be taken into account related to the review topic?

   The "effective cost" for determining the relative attractiveness of different technology applications does not consider all the appropriate factors.

   The "effective cost" includes a provision for "tech value" but the term is not defined for anything other than BEVs and appears only in the "output" files. "Consumer Valuation" does appear in the "technology" file but is blank for all technologies. "**Tech Value" as used in equation 5 (in the VOLPE documentation) must include the increase in insurance, maintenance, repairs, taxes and fees, and the change in value associated with a technology.** This is especially critical in the case of HEVs, PHEVs, and BEVs which show a substantial difference in depreciation compared to gasoline or diesel technology.

   RESPONSE: Equation 5, which defines the "effective cost" used to estimate manufacturers' potential decisions among available fuel-saving technologies, is not intended to provide a complete actuarial accounting of all costs of vehicle ownership. While such an accounting could be important if manufacturers are expected to act as if buyers' purchase decisions actually and explicitly consider and weigh all ownership costs, it is not at all clear that this is the case, and in any event, incomplete inputs (e.g., regarding maintenance costs) could cause an otherwise complete accounting to have unintended biases. Equation 5 only provides a proxy for manufacturers' decisions that, especially without extensive confidential business information, cannot be fully known or anticipated. Model inputs such as payback periods can be adjusted based on expectations. Equation 5 does include the "Tech Value" term that applies inputs specifying estimated technology-specific changes in value. Estimates for HEVs, PHEVs, and BEVs are documented in a new Regulatory Impact Analysis.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   No. the model needs to be revised to include additional costs beyond those currently considered.

   RESPONSE: See response to 1 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   Revise the “effective cost” used in equation 5 to include “tech value.”

   “Consumer valuation” appears in the “technology” input file but is blank for all technologies. “Tech Value” as used in equation 5 must include the increase in insurance, maintenance, repairs, taxes and fees, and the change in value associated with a technology. This is especially critical in the cage of HEVs, PHEVs, and BEVs which show a substantial difference in depreciation compared to gasoline or diesel technology.

   RESPONSE: See response to 1 above.

Jose Mantilla

[NO RESPONSE.]

Wallace Wade

Reviewer Name: _Wallace R. Wade

Review Topic Number: _3.4. Application of technologies, including interactions, paths and prerequisites of a technology's application (and any logically required exclusion based on the paths and prerequisites) and costs, including learning curves

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.*]

1. What are the most important concerns that should be taken into account related to the review topic?

Technology Pathways:

The modeling system defines technology pathways for grouping and establishing a logical progression of technologies on a vehicle. As the model traverses each path, the costs and improvement factors are accumulated on an incremental basis with relation to the preceding technology. The system stops examining a given path once a combination of one or more technologies results in a "best" technology solution for that path. After evaluating all paths, the model selects a most cost-effective solution among all pathways.

"Best" is defined from the manufacturers' perspective as the technology pathways that minimizes effective costs, which include:
(a) vehicle price increases associated with added technologies,
(b) for manufacturers that prefer to pay civil penalties, reductions in civil penalties owed for noncompliance with CAFE standards,
(c) the value vehicle purchasers are estimated to place on fuel economy, and
(d) any changes in consumer valuation attributed to the added technologies.
(CAFE Model Documentation, p. 11)

The modeling system incorporates thirteen technology pathways for evaluation as shown in Table 5.

Table 5. Technology Pathways

Technology Pathway	Application Level
Basic Engine Path	Engine
Turbo Engine Path	Engine
Advanced Engine Path	Engine
Diesel Engine Path	Engine
Manual Transmission Path	Transmission
Automatic Transmission Path	Transmission
Electrification Path	Vehicle
Hybrid/Electric Path	Vehicle
Advanced Hybrid/Electric Path	Vehicle
Dynamic Load Reduction Path	Vehicle
Low Rolling Resistance Tires Path	Vehicle
Mass Reduction Path	Platform
Aerodynamic Improvements Path	Platform

The technologies that comprise the four Engine-Level paths available within the model are shown in Figure 2.

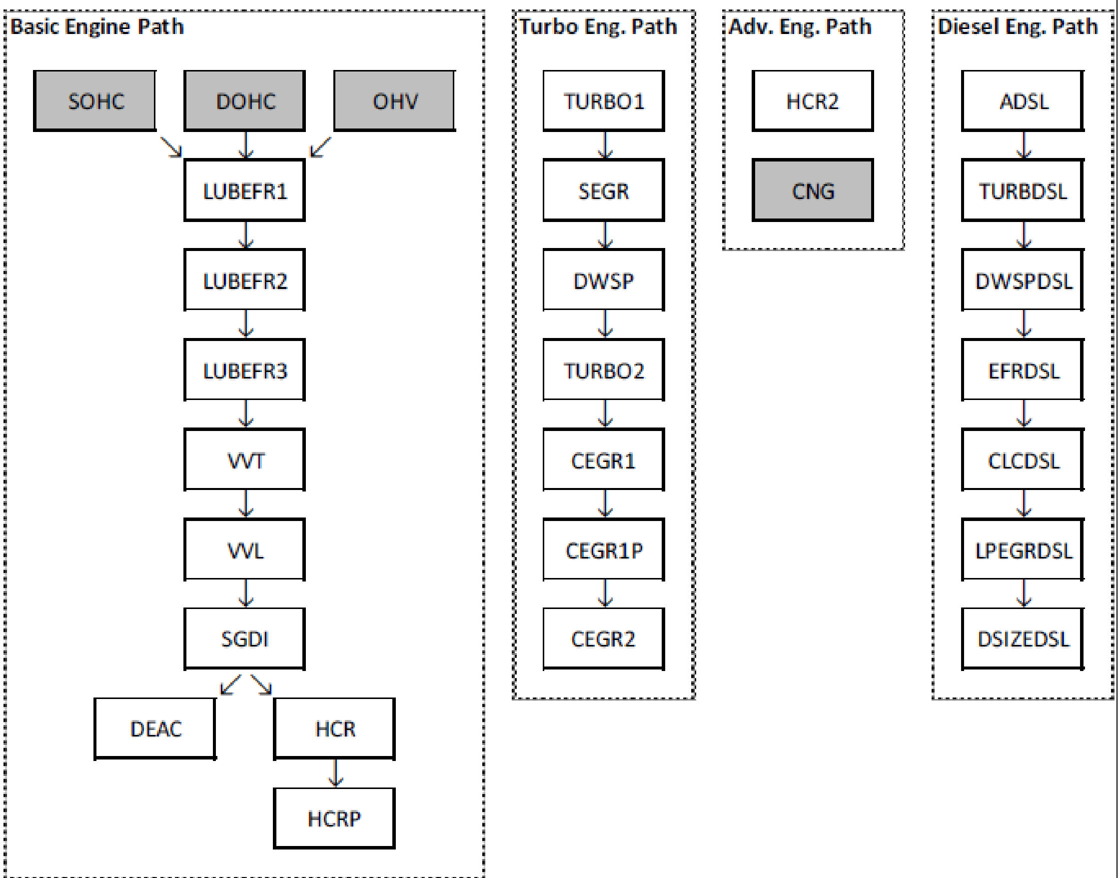


Figure 2. Engine-Level Paths

Concern 1:

The following technologies are not shown in the Engine level paths:

- Non-HEVAtkinson-2 cycle engines (ATK2), described in detail in the 2016 Draft TAR (ATK2: pp. 5-29 to 5-33 and 5-280 to 5-283);
- MILLER cycle engines described in the 2016 Draft TAR (pp.5-33 to 5-36 and p. 5-289)

Non-HEVAtkinson-2 cycle engines (ATK2) and Miller cycle engines (MILLER) are listed in Table 12.20, Technology Code Definitions used in Technology Penetration Tables, and Table 12.41, Summary of Absolute Technology Penetrations in the MY2025 Control Case.

The technologies that make up the two Transmission-Level paths defined by the modeling system are shown in Figure 3.

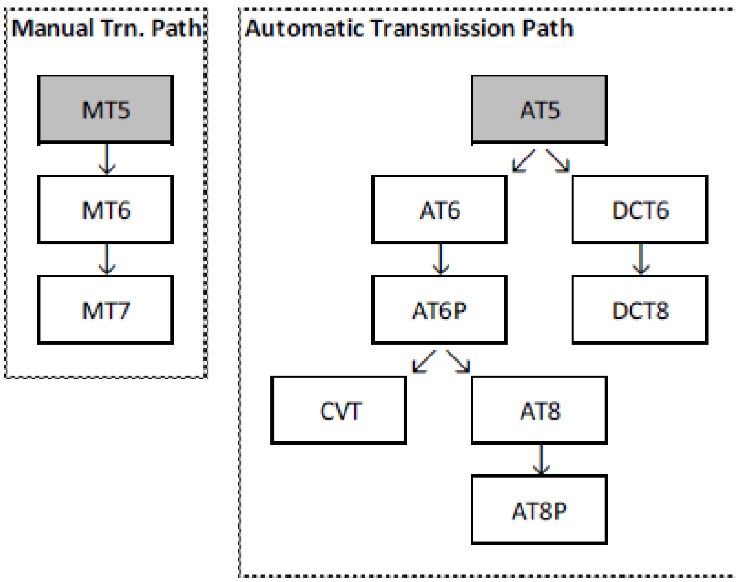


Figure 3. Transmission-Level Paths

Concern 2:

The new transmission terminology, TRX11, TRX12, TRX21, TRX22 is not used in Figure 3. In the "TRX" numbering system the first digit specifies the number of gears in the transmission and the second digit specifies the HEG level (high-efficiency gearbox). A "1" in the first digit represents a 6-speed transmission (as shown in Table 5.78, but incorrectly described as an 8-speed in the text (p. 5-297, line 6)) and a "2" in the first digit represents an 8-speed. Similarly, a "1" in the second digit represents HEG1 and a "2" in the second digit represents HEG2.
(2016 Draft TAR, p.5-297)

Concern 3:

The specific technical content of the high-efficiency gearboxes, Level 1 and 2 (HEG1 and HEG2), are not clearly defined in the 2016 Draft TAR although the efficiency levels are listed in Table 5.80.

Concern4:
Nine and 10-speed transmissions are currently applied in production vehicles and should be recognized in the TAR, the CAFE Model Documentation, and the new transmission terminology (e.g., TRX31 and TRX32).

Recommendations 1- 4:
Revise the Engine Level Paths (Figure 2) and Transmission Level Paths (Figure 3) to include the new engine and transmission technologies and the new transmission terminology introduced in the 2016 Draft TAR.

RESPONSE: Model documentation will be updated to reflect all changes to engine and transmission paths, and corresponding documentation.

Concern 5:
Figure 3 shows that the DCT path ends at DCT8 without being able to return to the AT or CVT path. However, some current DCT applications are likely to revert to an AT8 or a CVT with a future redesign, to resolve drivability issues with the DCT, particularly those using dry clutches.

Recommendation 5:
Revise the Transmission Level Paths (Figure 3) to show that a DCT path, at any point, could revert to the AT or CVT path.

RESPONSE: The transmission path reflects an assumption that, having made investments to—presumably successfully—replace a given AT with a DCT, the manufacturer would be most likely to continue with the DCT technology rather than reverting to an AT. Model inputs could be adjusted to force the model to simulate other assumptions (e.g., by setting the model to "skip" DCT options for specific transmissions).

The technologies that compose the two Platform-Level paths provided by the model are displayed in Figure 4

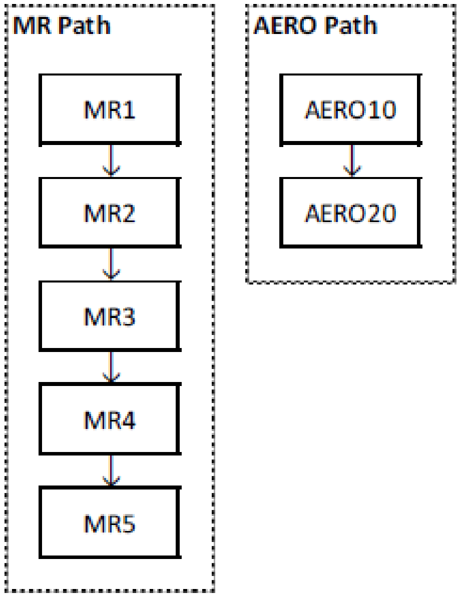


Figure 4. Platform-Level Paths

Concern 6:
The 2016 Draft TAR shows the different MR (Mass Reduction) levels and AERO (aerodynamic drag reduction) levels for the MY 2015 baseline fleet, as described in Tables 4.49 and 4.50 for mass reductions and Table 4.56 for aerodynamic drag reduction levels. However, an explanation of how the baseline MR and AERO levels are incorporated in the Volpe Model is not provided in this section of the CAFE Model Documentation.

Recommendation 6:
Provide an explanation of how the baseline MR and AERO levels, described in Tables 4.49 and 4.50 for mass reduction and Table 4.56 for aerodynamic drag reductions, are incorporated in the Volpe Model after the discussion of Figure 4. (The MR Levels and AERO Levels of the baseline vehicles are required input to Table 9, Vehicles Worksheet). Define where/how the mass reduction cost curves are entered for the variety of different baseline MR levels shown in Table 4.49.

RESPONSE: As for other inputs, specific input values indicating estimated levels of mass reduction and aerodynamic improvement already present on the analysis (aka baseline) fleet will be discussed in the Regulatory Impact Analysis. The model documentation will remain focused on how inputs are interpreted and applied.

Concern 7:
The CAFE Model Documentation (p. 17) states that the "user determines which technologies are initially present in the input fleet, given the characteristics of each vehicle, engine, and transmission" and inputs this information in the "market data input file." However, an explanation of where/how the user inputs this information is not provided, but a brief comment on the Vehicles, Engines and Transmissions worksheets would be informative in this section of the CAFE Model Documentation. A related concern is that Table 11, Transmission Worksheet, uses different and confusing

terminology (e.g., AT12 together with AT6 and AT8), rather than the new terminology, TRX21, indicating number of gears and HEG level.

RESPONSE: The model documentation will be revised to more clearly explain the interpretation and application of model inputs specifying the technologies present on specific vehicle model/configurations.

Recommendation 7:
Provide an explanation of how the technologies existing on the 2015 baseline vehicles are provided as input to the Volpe Model is this section of the CAFE Model Documentation by referring to the Vehicles, Engines and Transmissions worksheets. Resolve the inconsistencies shown in Table 11, Transmission Worksheet, which uses different and confusing terminology (e.g., AT12 together with AT6 and AT8), rather than the new terminology, TRX21, indicating number of gears and HEG level.

RESPONSE: See response to recommendations 1-4 above.

Concern 8:
Table 9, Vehicles Worksheet, lists input for fuel economy which is specified as the CAFE fuel economy rating of the vehicle, but Footnote 21 indicates that this information is “not used by the modeling system.” The comment that this information is “not used by the modeling system” is not clear. To be consistent with the adoption of the MY 2015 as the baseline for the analysis, the EPA certification data base fuel economy (uncorrected) for MY 2015 appears to be the required baseline fuel economy used the Volpe Model for adding technologies to provide improvements over the baseline fuel economy to achieve CAFE compliance.

Recommendation 8:
Provide clarification of Footnote 21 in Table 9, Vehicles Worksheet, which indicates that the CAFE fuel economy rating of the vehicle is “not used by the modeling system.” To be consistent with the adoption of the MY 2015 as the baseline for the analysis, the EPA certification data base fuel economy (uncorrected) for MY 2015 appears to be the required baseline fuel economy used the Volpe Model for adding technologies to provide improvements over the baseline fuel economy to achieve CAFE compliance.

RESPONSE: Model documentation will be revised to update text and footnotes regarding the model’s handling of the primary and secondary fuel types and fuel economy values.

Prerequisites:

For all pathways, the technologies are evaluated and applied to a vehicle in sequential order, as shown, from top to bottom. If the modeling system applies a technology that resides later in the pathway, it will “backfill” anything that was previously skipped in order to fully account for costs and improvement factors.

Required Exclusions:

The thirteen technology pathways present in the model are logically linked for incremental technology progression as illustrated in Figure 6.

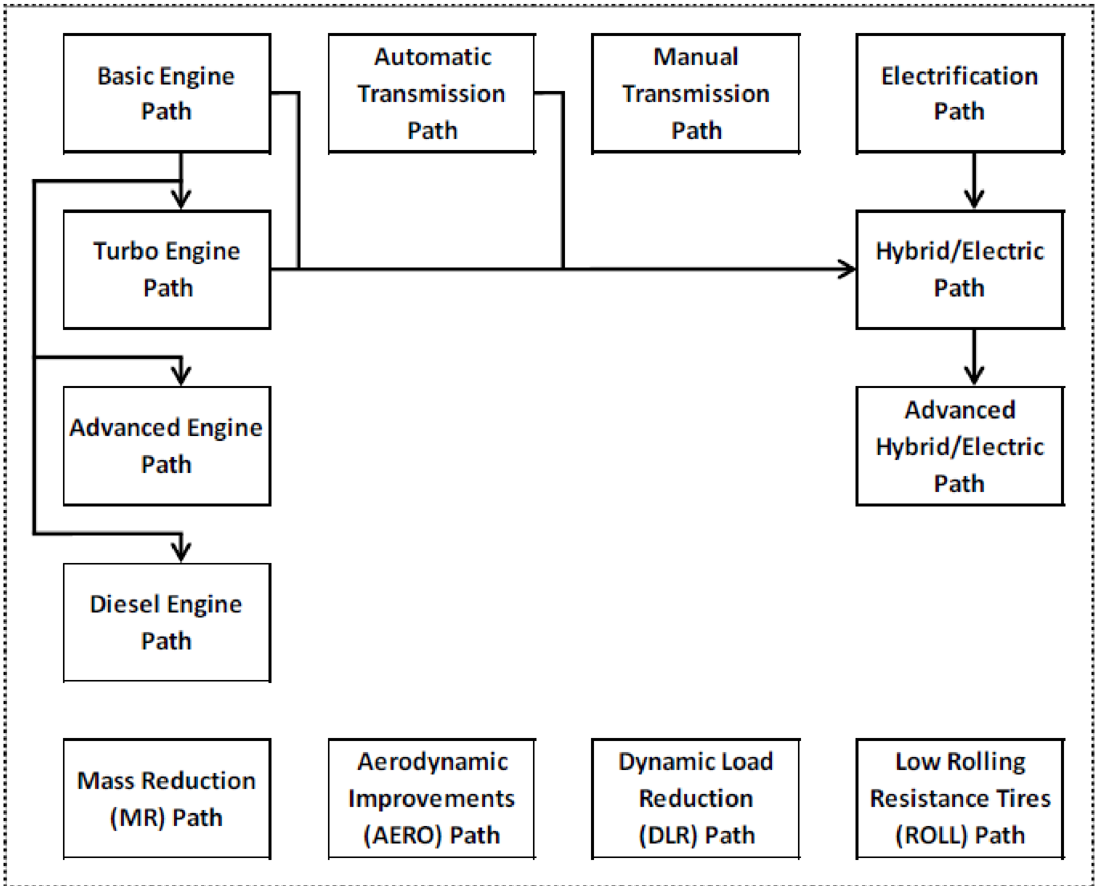


Figure 6. Technology Pathways Diagram

Some of the technology pathways, as defined in the CAFE Model and shown in Figure 6, may not be compatible with a vehicle given its state at the time of evaluation. For example, a vehicle with a 6-speed automatic transmission will not be able to get improvements from a Manual Transmission path. Therefore, the system explicitly disables certain paths whenever a constraining technology from another path is applied on a vehicle.

Learning Curves:

NHTSA applies estimates of learning curves to the various technologies that will be used to meet CAFE standards. Learning curves reflect the impact of experience and volume on the cost of production.

Concern 9:
In contrast to NHTSA's comment that learning curves reflect experience and volume, Table 5.183, Learning Schedules by Model Year Applied to Specific CAFE Technologies,

indicates that the learning curves, applied to direct manufacturing costs, are a function only of time, and are not a function of production volume.

The 2015 NRC Study recommended that NHTSA and EPA "should assess whether and how volume-based learning might be better incorporated into their cost estimates, especially for low volume technologies. The agencies should also continue to conduct and review empirical evidence for the cost reductions that occur in the automobile industry with volume, especially for large-volume technologies that will be relied on to meet the CAFE/GHG standards."
(NRC, Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles 2015, Finding and Recommendation 7.2, p. 259)

Recommendation 9:
Provide a discussion on whether and how volume-based learning might be better incorporated into cost estimates, especially for low volume technologies. Provide an update on empirical evidence of the cost reductions that occur in the automobile industry with volume, especially for large-volume technologies that will be relied on to meet the CAFE/GHG standards.

RESPONSE: Further research, development, and testing would be required to determine whether the model could practicably be revised to dynamically account for volume-based learning effects, considering the possible need to iteratively seek convergence toward a solution that is stable in a multiyear planning context. The Regulatory Impact Analysis will discuss these considerations.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The Volpe Model's input data, computations, and assumptions appear to be reasonable, but could be enhanced, or clarified, by implementing Recommendations 1- 9, above.

RESPONSE: See responses to recommendations 1-9 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1-9, above.

RESPONSE: See responses to recommendations 1-9 above.

4. Is there an alternative approach that you would suggest?

No. Implementation of Recommendations 1-9 is the suggested approach.

RESPONSE: See responses to recommendations 1-9 above.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The application and use of technology pathways, prerequisites, required exclusions and learning curves in the Volpe Model, together with the implementation of Recommendations 1- 9, enhance the overall utility and plausibility of the model's output.

RESPONSE: See responses to recommendations 1-9 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
4. Model operations
4.1. Dynamic application of technology to each manufacturer's fleet to minimize effective costs based on the CAFE standards for the current model year, defined as the difference between the incremental cost of a technology and the value of fuel savings produced by the technology over three years of vehicle ownership (iterative process until the most effective technology is found) by manufacturer and model year
4.2. Approach to estimating vehicle survival and use (i.e., vehicle miles traveled), including the model's application of the input defining a rebound effect
4.3. Approach to estimating total emissions of criteria pollutants (e.g., nitrogen oxides) and greenhouse gases (e.g., methane) other than carbon dioxide.
4.4. Model results for industry response to CAFE Standards
4.5. Estimation of consumer impacts from CAFE standards
4.6. Model results for social, economic and environmental effects of CAFE standards (costs, benefits, and quantities)
4.7. Sensitivity of augural standards net benefits to high and low value assumptions of factors such as fuel price, rebound, etc.

Nigel Clark

Reviewer Name:_ Nigel N. Clark

Review Topic Number: 4.1. Dynamic application of technology to each manufacturer's fleet to minimize effective costs based on the CAFE standards for the current model year, defined as the difference between the incremental cost of a technology and the value of fuel savings produced by the technology over three years of vehicle ownership (iterative process until the most effective technology is found) by manufacturer and model year

Other Review Topic Numbers (if interactive effects are focus of discussions):

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   The model should check compliance of each manufacturer with standards realistically. This involves making technology choices based on investment and reward from using a technology or technologies, and assembling all the manufacturer's choices to reach an overall metric, mimicking the pathways most likely chosen by the manufacturers.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   Yes. The model adds progressively to the technology of the analysis fleet.

   RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comment, and note that manufacturers' have choices (e.g., shifting fleet mix) beyond those the CAFE model attempts to simulate.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   No model change, but additional application. A high-level concern addresses technology costs that affect the technology pathways that are chosen. For example, as considered in the supplied material, lower battery costs may swing the fleet in the direction of hybrid electric or all-electric technology. This could occur due to future supply changes, but a pathway bifurcation could also occur due to even modest overestimation or underestimation of a current technology cost. Clearly sensitivity analysis is needed, of the kind that will express the net cost increase when one forces some alternate pathways. The overall manufacturer solution might have high technology difference for modest cost difference. Stringency of standards will also affect this kind of sensitivity analysis. The TAR mentions differences in prior pathway solutions between agencies, and so the modelers are aware of this issue. For example, some may ask, "If we were to force deeper hybrid vehicle penetration in the fleet, would cost-benefit change much?"

RESPONSE: These are good points, and model inputs are capable of being adjusted to explore myriad scenarios, including cases that force or otherwise emphasize specific technologies, such as hybrid electric vehicles, in order to examine the potential consequences of doing so. Such scenarios can be included as part of the sensitivity analysis typically included in the Regulatory Impact Analysis accompanying any given CAFE rulemaking.

4. Is there an alternative approach that you would suggest?

   No.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   It is the major summary output.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

   None.

Walter Kreucher

REVIEW TOPIC NUMBER 4.1. DYNAMIC APPLICATION OF TECHNOLOGY TO EACH MANUFACTURER'S FLEET TO MINIMIZE EFFECTIVE COSTS BASED ON THE CAFE STANDARDS FOR THE CURRENT MODEL YEAR, DEFINED AS THE DIFFERENCE BETWEEN THE INCREMENTAL COST OF A TECHNOLOGY AND THE VALUE OF FUEL SAVINGS PRODUCED BY THE TECHNOLOGY OVER THREE YEARS OF VEHICLE OWNERSHIP (ITERATIVE PROCESS UNTIL THE MOST EFFECTIVE TECHNOLOGY IS FOUND) BY MANUFACTURER AND MODEL YEAR

1. What are the most important concerns that should be taken into account related to the review topic?

   (See above discussion)

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   The current method is not reasonable. The model needs to be revised to include additional costs beyond those currently considered.

   RESPONSE: The model accommodates inputs specifying several different categories of costs, such as marked-up direct costs, stranded capital costs, maintenance and repair costs, taxes and fees, and insurance. Additional data would be required to make fuller use of all of these inputs. If not already able to be represented in one of these categories (e.g., in marking up direct costs), some types of costs to manufacturers may require explicit separate accounting for fixed and variable costs. Additional research and data is required to determine whether separate accounting for fixed and variable costs could be practicably implemented, especially without relying extensively on confidential business information that could be difficult to obtain and impossible to make public.

Jose Mantilla

[NO RESPONSE.]

Wallace Wade

Reviewer Name: _Wallace R. Wade

Review Topic Number: _4.1. Dynamic application of technology to each manufacturer's fleet to minimize effective costs based on the CAFE standards for the current model year, defined as the difference between the incremental cost of a technology and the value of fuel savings produced by the technology over three years of vehicle ownership (iterative process until the most effective technology is found) by manufacturer and model year

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.*]

1. What are the most important concerns that should be taken into account related to the review topic?

The Volpe Model estimates each manufacturer's potential year-by-year application of fuel-saving technologies to each engine, transmission, and vehicle. Subject to a range of engineering and planning-related constraints, the model attempts to apply technology to each manufacturer's fleet in a manner that minimizes "effective costs."

The effective cost represents the difference between the incremental cost of the technologies and the value of fuel savings to a buyer over the first three years of ownership. This construction allows the model to choose technologies that both improve a manufacturer's CAFE compliance position and are most likely to be attractive to its consumers.

The use of effective cost means that different assumptions about future fuel prices will produce different rankings of technologies when the model evaluates available technologies for application. For example, in a high fuel price regime, an expensive but very efficient technology may look attractive to manufacturers because the value of the fuel savings is sufficiently high to both counteract the higher cost of the technology and, implicitly, satisfy consumer demand to balance price increases with reductions in operating cost.
(2016 Draft TAR, p. 13-49)

Concern 1:
Effective cost is calculated using Equation 5 (CAFE Model Documentation, p.25):

$$COST_{eff} = \frac{\sum_{i \in k}\left(\sum_{j=BaseMY}^{j=MY} TECHCOST_{i,j} - TECHVALUE_{i,j} - (VALUE_{FUEL})_{i,j}\right) + \Delta FINE_{MY}}{TOTALSALES} \quad (5$$

The premise that higher fuel prices may make "expensive, but very efficient technology" look attractive may not follow from this equation, as explained below:

- A vehicle will have a specific fuel economy improvement required to achieve a specified CAFE target.

- One approach to achieving the required fuel economy improvement would be to use a group of the lowest cost technologies that, combined, will provide the specific fuel economy improvement.
- Another approach, suggested in the 2016 Draft TAR, is to apply one expensive technology (assumed to be more expensive than the group of lowest cost technologies) in a high fuel price regime.
- Subtracting the value of the fuel savings from the technology cost is indicative of the effective cost. However, in the high fuel price regime, the group of lowest cost technologies will still result in a lower effective cost than with the one expensive technology.
- The disadvantages of using one expensive technology are:
    - The effective cost, based on equation 5, will be higher for the one expensive technology since the value of the fuel savings will be the same in both cases for a specific fuel price regime.
    - The cost to the manufacturer and to the consumer will be significantly greater with the one more expensive technology.
- The only way that applying one more expensive technology could provide a lower effective cost to the consumer would be if the perceived value of the technology compensated for the higher cost of the technology, but this appears to be unlikely.

The 2015 NRC report found that "consumers do not fully account for the expected present discounted value of fuel-saving technologies when they purchase new vehicles". "Manufacturers perceive that consumers require relatively short payback periods of 1 to 4 years." "Consumers' responses vary from requiring payback in only 2 to 3 years to almost full lifetime valuation of fuel savings."
(NRC, Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles, 2015, p. 331)

The report commented that "if consumers are myopic when it comes to fuel savings in purchasing new or used cars, the more fuel-efficient cars may be perceived as more expensive. A new fuel-efficient car that costs even 6 percent more may appear to be less affordable than an alternative used car or no vehicle purchase at all…. "
(2015 NRC, p. 332)

<u>Recommendation 1-1:</u>
Consider revising the following comment in the 2016 Draft TAR (p. 13-49), "in a high-fuel-price regime, an expensive but very efficient technology may look attractive to manufacturers because the value of the fuel savings is sufficiently high to both counteract the higher cost of the technology and, implicitly, satisfy consumer demand to balance price increases with reductions in operating cost," after consideration of Concern 1.

RESPONSE: Staff will update discussion of the influence of fuel prices on the model's simulation of manufacturers' technology decisions.

<u>Recommendation 1-2:</u>
Consider adding to the comment regarding "in a high fuel price regime" (in Recommendation 1-1), the following qualification discussed in Concern 1 regarding consumers' valuation of fuel saving technologies: "if consumers are myopic when it

comes to fuel savings in purchasing new or used cars, the more fuel-efficient cars may be perceived as more expensive. A new fuel-efficient car that costs even 6 percent more may appear to be less affordable than an alternative used car or no vehicle purchase at all … ." (2015 NRC, p. 332)

RESPONSE: See response to recommendation 1-1 above.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The computations in the model are reasonable for the assumptions stated. However, the assumptions should be qualified, and possibly modified, as indicated by Recommendations 1-1 and 1-2.

RESPONSE: See responses to recommendations 1-1 and 1-2 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Incorporate Recommendations 1-1 and 1-2.

RESPONSE: See responses to recommendations 1-1 and 1-2 above.

4. Is there an alternative approach that you would suggest?

No. Including Recommendations 1-1 and 1-2 is the suggested approach.

RESPONSE: See responses to recommendations 1-1 and 1-2 above.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

Including Recommendations 1-1 and 1-2 will enhance the utility and plausibility of the Volpe Model output.

RESPONSE: See responses to recommendations 1-1 and 1-2 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
4. Model operations
4.1. Dynamic application of technology to each manufacturer's fleet to minimize effective costs based on the CAFE standards for the current model year, defined as the difference between the incremental cost of a technology and the value of fuel savings produced by the technology over three years of vehicle ownership (iterative process until the most effective technology is found) by manufacturer and model year
4.2. Approach to estimating vehicle survival and use (i.e., vehicle miles traveled), including the model's application of the input defining a "rebound" effect
4.3. Approach to estimating total emissions of "criteria" pollutants (e.g., nitrogen oxides) and greenhouse gases (e.g., methane) other than carbon dioxide.
4.4. Model results for industry response to CAFE Standards
4.5. Estimation of consumer impacts from CAFE standards
4.6. Model results for social, economic and environmental effects of CAFE standards (costs, benefits, and quantities)
4.7. Sensitivity of augural standards net benefits to high and low value assumptions of factors such as fuel price, rebound, etc.

Nigel Clark

[NO RESPONSE.]

Walter Kreucher

REVIEW TOPIC NUMBER 4.2. APPROACH TO ESTIMATING VEHICLE SURVIVAL AND USE i.e., VEHICLE MILES TRAVELED), INCLUDING THE MODEL'S APPLICATION OF THE INPUT DEFINING A REBOUND EFFECT

1. What are the most important concerns that should be taken into account related to the review topic?

   The new approach to vehicle survival and use is appropriate with the exception of ZEVs. The survival rate of ZEVs is greater than that of cars and the miles driven[4] is also greater than all other classes except pickups. **There is no discussion in the draft TAR to justify this assumption.** If the model is to rely on this level of use and survivability, then the maintenance cost of ZEVs must be increased substantially to account for replacement batteries.

   Tesla provides premium ZEVs warrants the battery for 5 years or 100,000 miles, whichever comes first. In a scenario where a ZEV survives 37 years this would require six replacement batteries at substantial cost.

   RESPONSE: Model inputs underlying the 2016 analysis included structure to incorporate new EV-specific estimates based on registration and other data available at that time. However, that structure was not used in support of the TAR. The values appearing in those tables for ZEVs are merely placeholders. The model's approach to representing vehicle survival has been updated.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   The assumptions related to ZEV survivability and miles driven do not appear to be realistic.

   RESPONSE: See response to 1 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   Revise the input assumptions for HEVs, PHEVs, and BEVs to include several battery replacements.

   RESPONSE: As for the 2016 analysis, anticipated battery replacement costs can be embedded in technology costs. These costs could also be represented as maintenance or repair costs. Further research could support expansion of inputs addressing not just battery replacement costs, but also maintenance, repair, and replacement costs for other technologies.

[4] ZEV miles driven is set at the average of all Class 1 and 2 trucks.

4. Is there an alternative approach that you would suggest?

   Revise the model to limit the survivability of HEVs, PHEVs, and BEVs to 10 years and 100,000 miles.

   RESPONSE: Further research and data would be required to support technology-specific vehicle survival rates.

Jose Mantilla

[NO RESPONSE.]

Wallace Wade

Reviewer Name:_Wallace R. Wade

Review Topic Number: _4.2. Approach to estimating vehicle survival and use (i.e., vehicle miles traveled), including the model's application of the input defining a "rebound" effect

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

Vehicle Survival/Lifetimes:

The number of vehicles of a specific model and model year that remains in service during each subsequent calendar year is calculated by multiplying the number originally produced by estimates of the proportion expected to remain in service at each age up to an assumed maximum lifetime. Separate survival rates by age of vehicle were developed for passenger automobiles, light trucks (class 1 and 2a), and medium-duty trucks (class 2b and 3), where light trucks are further separated into vans, SUVs, and pickups. Based on analysis of recent registration data, the maximum ages of passenger automobiles and light and medium-duty trucks are estimated to be 30 years and 37 years, respectively.
(CAFE Model Documentation, p.32)

Vehicle lifetime survival rates and total vehicle miles traveled (VMT) are provided in Tables 10.5 and 10.6, respectively. The updates in these tables were made in order to align the 2016 Draft TAR analysis with inputs developed in conjunction with the EPA MOVES 2014a model, which has integrated new activity and population data sources from R. L. Polk, FHWA, and the EIA Annual Energy Outlook.
(2016 Draft TAR, p. 10-6 to 10-8)

Concern1:
Table 10.5, Updated Vehicle Survival Rates (from MOVES 2014a), extends to 31 years, instead of the maximum 30 years stated for passenger cars, and it does not extend beyond 31 years to the maximum 37-year lifetime for light- and medium-duty trucks. A similar issue exists for Table 10.6, 2011 Mileage Schedule (from MOVES 2014a).

Table 10.6 is labeled as 2011 Mileage Schedule, but the text indicates that total vehicle miles traveled were updated after the 2012 FRM (and assumed to be for the 2016 Draft TAR).

Recommendation 1:

Table 10.5, Updated Vehicle Survival Rate, should be revised to show a maximum 30-year lifetime for passenger cars, and a maximum 37-year lifetime for light- and medium-duty trucks.
Table 10.6 should be revised to show the mileage schedules for the same respective lifetime years for passenger cars and trucks. Table 10.6 is labeled as 2011 Mileage Schedule, but the 2011 date should be updated, according to the text of the 2016 Draft TAR.

RESPONSE: The model's approach to vehicle survival has been updated.

Rebound Effect:

The rebound effect generally refers to the additional energy consumption that may arise from the introduction of a more efficient, lower cost energy service which offsets, to some degree, the energy savings benefits of the efficiency improvement.

"The elasticities of vehicle use with respect to fuel efficiency or per-mile fuel costs (or fuel prices) are given as the percentage increase in vehicle use that results from a doubling of fuel efficiency (e.g., 100 percent increase), or a halving of fuel consumption or fuel price. For example, a 10 percent rebound effect means that a 20 percent reduction in fuel consumption or fuel price (and the corresponding reduction in fuel cost per mile) is expected to result in a 2 percent increase in vehicle use."
(2016 Draft TAR, p. 10-9)

<u>Concern 2:</u>
The above description of the rebound effect in the 2016 Draft TAR is confusing. Eliminating the reference to "doubling of fuel efficiency (e.g., 100 percent increase)" would be helpful since Footnote D (p. 10-9) describes the source of the confusion: "Vehicle fuel efficiency is more often measured in terms of fuel consumption (gallons per mile) rather than fuel economy (miles per gallon) in rebound estimates."

Eliminating reference to fuel efficiency would also ensure that the definition of the rebound effect is consistent with EPA's definition that is based on fuel consumption.

The 2016 Draft TAR (p. 10-9) continues with a numerical example that is consistent with EPA's definition: "a 10 percent rebound effect means that a 20 percent reduction in fuel consumption or fuel price is expected to result in a 2 percent increase in vehicle use".

EPA's definition of the rebound effect is shown below:

Percent difference in VMT =
rebound effect * (FC reference case – FC policy case)/FC reference case)

EPA provides an example for a 10 percent rebound effect as follows: a 30 percent change in fuel costs, multiplied by a 10 percent rebound effect would result in 3 percent additional driving. EPA describes this as "an elasticity of annual vehicle use with respect to fuel cost per mile driven of -0.10."
(EPA, Regulatory Impact Analysis, 2012, p. 4-119, Footnote xxx)

Recommendation 2:
The rebound effect should be defined using EPA's equation from the 2012 EPA RIA for consistency and to avoid confusion resulting from the reference to fuel efficiency, as indicated in Footnote D in the 2016 Draft TAR (p.10-9), as discussed in Concern 2.

RESPONSE: Discussion of the rebound effect has been updated.

Rebound Effect Used in the 2016 Draft TAR:

There is a wide range of estimates for both the historical magnitude of the rebound effect and its projected future value, and there is some evidence that the magnitude of the rebound effect appears to be declining over time. The 10 percent value was not derived from a single point estimate from a particular study, but instead represents a reasonable compromise between historical estimates of the rebound effect and forecasts of its projected future value, based on an updated review of the literature on this topic. (2016 Draft TAR, p.10-19 to 10-20)

The elasticity of vehicle use (ε), equal to the rebound effect, is used in equation 15 to calculate the average number of miles driven by a surviving vehicle model, i, produced in model year MY, during calendar year CY

$$MI_{i,MY,CY} = VMT_{C,a} \times (1+r)^{CY-BaseCY} \times \left[1 + \varepsilon \times \left(\frac{CPM_{i,MY,CY}}{CPM_{H,a,BaseCY}} - 1\right)\right] \qquad \textbf{(15)}$$

Concern 3:
The elasticity of vehicle use (ε) in Equation 5 appears to be equivalent to the "rebound effect" discussed in Concern 2.

Recommendation 3:
Provide a brief discussion in the CAFE Model Documentation and/or TAR indicating that the elasticity of vehicle use (ε) in Equation 15 appears to be equivalent to the rebound effect discussed in Concern 2 according to EPA's definition of the rebound effect.

RESPONSE: Discussion of the rebound effect has been updated.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The computational methods are reasonable and the assumptions for the rebound effect appear to be the best available after NHTSA's extensive literature review.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1-3. **REPONSE: See responses to recommendations 1-3 above.**

4. Is there an alternative approach that you would suggest?

No. Implementing Recommendations 1-3 addressing VMT and the rebound effect in the Volpe Model is the suggested approach. **REPONSE: See responses to recommendations 1-3 above.**

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

Including Recommendations 1-3 addressing the effects of VMT and the rebound effect in the Volpe Model will enhance its overall utility and plausibility. **REPONSE: See responses to recommendations 1-3 above.**

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
4. Model operations
4.1. Dynamic application of technology to each manufacturer's fleet to minimize effective costs based on the CAFE standards for the current model year, defined as the difference between the incremental cost of a technology and the value of fuel savings produced by the technology over three years of vehicle ownership (iterative process until the most effective technology is found) by manufacturer and model year
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4.4. Model results for industry response to CAFE Standards
4.5. Estimation of consumer impacts from CAFE standards
4.6. Model results for social, economic and environmental effects of CAFE standards (costs, benefits, and quantities)
4.7. Sensitivity of augural standards net benefits to high and low value assumptions of factors such as fuel price, rebound, etc.

Nigel Clark

Reviewer Name:_ Nigel N. Clark

Review Topic Number: 4.3. Approach to estimating total emissions of criteria pollutants (e.g., nitrogen oxides) and greenhouse gases (e.g., methane) other than carbon dioxide. **Other Review Topic Numbers (if interactive effects are focus of discussions):**

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   Since the model assembles a predicted fleet, it is of interest to predict criteria pollutants and GHG pollutants as well as fuel used by the fleet

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   Yes for GHG. Given the fuel used, and fuel carbon content, with assumed high combustion efficiency, carbon dioxide tailpipe production can be calculated with good accuracy, as described in the model documentation. Methane, the other measureable GHG contributor, cannot be calculated readily, because the tailpipe concentrations vary widely, depending on engine load and speed, and catalyst efficiency (design and temperature effects).

   No, for criteria pollutants - or currently the criteria pollutant models are at best simplistic. The model structure is fine, but emissions factors are not constant, and depend on speed, load, technology deterioration and more. Although per mile emissions factors have been used in CARB and EPA models, those models are either load-based using short time windows, or employ speed correction factors (that imply some average load for flat terrain or terrain with undefined gradients).

   RESPONSE: The CAFE model is intended to provide estimates of national-scale impacts. At this scale, average emission factors are necessary and appropriate. Other models can be used to estimate highly-localized criteria pollutant emissions.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   No modifications are suggested, since this is not the primary mission of the model. The fleet, of known technology and defined activity, could be estimated by EPA MOVES instead. If the modelers wish to incorporate criteria pollutant or methane emissions, it will be necessary to determine the type of vehicle activity to be considered, or whether CAFE cycle emissions levels are to be considered. More rigorous methodologies will then be needed to formulate the factors.

   RESPONSE: See response to 1 above. The CAFE model accommodates MOVES-based emission factors.

4. Is there an alternative approach that you would suggest?

   Use the Volpe model data to feed a dedicated emissions model.

   RESPONSE: While NHTSA and Volpe Center staff consider the CAFE model's national-scale estimation of criteria emissions appropriate for characterizing the impacts of potential CAFE standards, CAFE model outputs could likely be used as inputs to a dedicated criteria pollutant emissions model.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

   This adds little to the model benefit, but may provide a coarse estimate of emissions as a talking point. Vehicle count and activity data could be processed in other ways to yield emissions factors.

7. Provide any additional comments that may not have been addressed above.

   It should be made very clear to the reader which outputs are based on the precise data from the CAFE cycles, and which output data seek to represent real world activity.

   RESPONSE: Model documentation will be updated to clarify the nature of the model's criteria pollutant calculations.

Walter Kreucher

REVIEW TOPIC NUMBER 4.3. APPROACH TO ESTIMATING TOTAL EMISSIONS OF CRITERIA POLLUTANTS (e.g., NITROGEN OXIDES) AND GREENHOUSE GASES (e.g., METHANE) OTHER THAN CARBON DIOXIDE.

1. What are the most important concerns that should be taken into account related to the review topic?

   The classic approach used by the model is appropriate until such time as the criteria pollutants are revised.

Jose Mantilla

Reviewer Name: Jose Mantilla

Review Topic Number: 4.3 – Approach to estimating total emissions of criteria pollutants and greenhouse gases other than carbon dioxide

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.*]

1. What are the most important concerns that should be taken into account related to the review topic?

> The methodology for the calculation of emissions of criteria pollutants has been satisfactorily justified. I have no major concerns on this review topic.
>
> **RESPONSE: NHTSA and Volpe Center agree, appreciate the comment, and note that recent model revisions refine the representation of future emission rates for upstream processes.**

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

> Insufficient information is provided to assess the reasonableness and appropriateness of data, computation methods and assumptions – specifically the assumptions and methodology for the estimation of emission rates for each pollutant for each vehicle. Similarly, the assumptions and methodology for the estimation of fuel production/distribution emissions rates are not presented. These are (perhaps the most) critical inputs to the calculation of criteria air pollutant emissions; as such, additional information should be provided in the Model Documentation with respect to the sources and methods used to derive these rates. In addition, a discussion of the differences in real-world versus rated emission levels should be presented.
>
> **RESPONSE: Emission factors and supporting documentation have been updated.**

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

> No modifications on the approach for estimating criteria air pollutants are recommended.

4. Is there an alternative approach that you would suggest?

No alternative approaches for estimating criteria air pollutants are recommended.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The review topic is of critical importance to the overall utility and plausibility of the Volpe Model output. The potential reduction in criteria air pollutants (and greenhouse gas emissions) is a fundamental aspect of (and reason for) the implementation of CAFE standards.

RESPONSE: In terms of monetized costs and benefits of CAFE standards, inputs applied for recent analyses indicate that technology costs and avoided fuel consumption are especially important, that the importance of avoided GHG emissions is heavily dependent on a comparatively uncertain rate of valuation, and that increases and decreases in criteria pollutant emissions are, by comparison, small.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Wallace Wade

Reviewer Name:_Wallace R. Wade

Review Topic Number: _4.3. Approach to estimating total emissions of "criteria" pollutants (e.g., nitrogen oxides) and greenhouse gases (e.g., methane) other than carbon dioxide

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

Criteria Pollutants Emitted by Vehicles:

Criteria pollutants that are emitted in significant quantities by motor vehicles include carbon monoxide, various hydrocarbon compounds, nitrogen oxides, sulfur dioxide, and fine particulate matter.

The Volpe Model calculates emissions of criteria pollutants resulting from vehicle operation by multiplying the number of miles driven by vehicles of a model year during each year they remain in service by per-mile emission rates for each pollutant, which are listed in the parameters input file by model year and vehicle age. These emission rates differ among passenger cars, light trucks, and class 2b/3 trucks when operating on different fuel types. The CAFE modeling system accepts emission rate tables defined for gasoline and diesel fuel types, where the gasoline rates are also used for vehicles operating on E85. Additionally, vehicles operating on electricity (PHEVs and EVs), hydrogen (FCV), and CNG are assumed to generate no emissions of criteria air pollutants during vehicle use.
(CAFE Model Documentation, p. 44)

Concern 1:
The above documentation states that the CAFE modeling system accepts emission rate tables defined for gasoline and diesel fuel types, but does not define the emission rate tables. No reference was given for the emission rate tables, but they appear to refer to Table 28, Tailpipe Emissions Worksheets. However, Table 28 does not define the content of the emission rate tables.

Recommendation 1:
Provide clarification of what emission rates are actually used in the CAFE modeling. For example:

- Are the emission rates simply the regulatory standards, or,
- As Table 28 suggests, are the emissions rates defined as increasing with mileage (Table 28 and equation 36 refer to "vehicle age"), finally reaching the actual

emission standard, within a specified statistical margin required for compliance, at the specific mileage for the emission standard?

RESPONSE: The model documentation explains the interpretation and application of different types of model inputs, not specific input values. The model documentation will be updated to clarify that inputs choices are explained in published analysis, such as in the Regulatory Impact Analysis accompanying any given rulemaking. The model documentation will be updated to clarify this point, and any RIA will clarify the basis for emission factor input choices.

Total emissions of any given criteria air pollutant, from the use of all surviving vehicle models produced during model year MY, during calendar year CY is defined as follows:

$$E_{MY,CY}^{veh} = \frac{\sum_i \sum_{FT} MI'_{i,MY,CY} \times FS_{i,MY,FT} \times E_{i,MY,a,FT}}{1e6} \quad \textbf{(36)}$$

Where:
MI = the number of miles driven in a year by all surviving vehicles of model i produced in model year MY during calendar year CY,
FS = the percentage share of miles a vehicle model i produced during model year MY travels when operating on a specific fuel type FT,
E = the per-mile rate at which vehicles of model i and model year MY emit a given pollutant at age a when operating on a specific fuel type FT,

Criteria Pollutants During Production and Distribution of Fuel Types:

Emissions of criteria air pollutants that occur during production and distribution of various fuel types are estimated. The model uses aggregate estimates of emissions of criteria air pollutants from all stages of fuel production and distribution, which are specified in the parameters input file and are weighted by the user-defined fuel import assumptions.
(CAFE Mode Documentation, p. 44-45)

Concern 2:
The CAFE Model Documentation states that the model uses aggregate estimates of emissions of criteria air pollutants from all stages of fuel production and distribution, which are specified in the parameter input file (apparently referring to Table 7), but does not define the source of the data for the parameter input file (CAFE Mode Documentation, p. 44).
No reference was given for the emission rate tables, but they appear to refer to Table 27, Upstream Emissions Worksheets, but Table 27 does not define the source of input for this table.

Recommendation 2:
Provide references for the parameter input file (e.g., Table 7) and for the source of the emission rates of criteria air pollutants from all stages of fuel production and distribution that are required in Table 27, Upstream Emissions Worksheets.

REPONSE: See response to 1 above.

The total emissions of any given criteria air pollutant, from producing and distributing of fuel consumed by all surviving vehicle models of model year MY, during calendar year CY is:

$$E_{MY,CY}^{ref} = \frac{\sum_{FT}\left(QUADS_{MY,CY,FT} \times E_{FT} \times 1e9\right)}{1e6} \quad \textbf{(38)}$$

Where:
E = the total emissions of a specific pollutant resulting from the production and distribution of various fuel types is equal to the
QUADS = the amount of quadrillion BTUs of energy consumed in a year by all surviving vehicle models produced in model year MY during calendar year CY, for a specific fuel type FT
E_{FT} = overall emissions of a given pollutant from all stages of feedstock production and distribution of fuel type FT

Total emissions of each criteria pollutant over the lifetimes of all vehicles of a model year are the sum of emissions that occur as a result of their lifetime use, and emissions from producing and distributing the fuel they consume over their lifetimes,

Total lifetime emissions of each criteria air pollutant by all vehicles produced during a future model year will differ between the baseline CAFE standard and any alternative standard that is specified. The model calculates the effect of imposing a higher CAFE standard on emissions of criteria air pollutants by taking the difference between lifetime emissions by all vehicle models produced during a model year the new CAFE standard takes effect and those vehicles' emissions under the baseline standard.
(CAFE Model Documentation, pp. 45-46)

Greenhouse Gases Except Carbon Dioxide:

The most recent U.S. GHG emission inventory includes seven greenhouse gases: carbon dioxide (CO_2), methane (CH4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3).

CO_2 emissions represent 96 percent of total mobile source GHG emissions.
(2016 Draft TAR, p. 1-21)

<u>Concern 3:</u>
Neither the 2016 Draft TAR nor the CAFE Model Documentation provides an explanation of how non-CO_2 emissions are estimated.

<u>Recommendation 3:</u>
Provide an explanation of how non-CO_2 emissions are estimated and used in the Volpe Model.

REPONSE: See response to 1 above. Also, model documentation will be updated to explain how non-CO_2 emissions are calculated.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The computational methods used for calculating total emissions of any given criteria air pollutant from vehicles and total emissions of any given criteria air pollutant from producing and distributing fuel consumed appear to be reasonable and appropriate.

However, Recommendations 1-3, above, regarding the emission rates actually used in the CAFE modeling, estimates of emissions of criteria air pollutants from all stages of fuel production and distribution, and how non-CO_2 emissions are estimated should be implemented.

RESPONSE: See responses to recommendations 1-3 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1-3, above, are suggested.

RESPONSE: See responses to recommendations 1-3 above.

4. Is there an alternative approach that you would suggest?

No. Implementation of Recommendations 1-3 is the suggested approach.

RESPONSE: See responses to recommendations 1-3 above.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

Implementation of Recommendations 1-3, above, regarding the emission rates which are actually used in the CAFE modeling, estimates of emissions of criteria air pollutants from all stages of fuel production and distribution, and how non-CO_2 emissions are estimated should be addressed to enhance the overall utility and plausibility of the Volpe Model output.

RESPONSE: See responses to recommendations 1-3 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

Review topic
4. Model operations
4.1. Dynamic application of technology to each manufacturer's fleet to minimize effective costs based on the CAFE standards for the current model year, defined as the difference between the incremental cost of a technology and the value of fuel savings produced by the technology over three years of vehicle ownership (iterative process until the most effective technology is found) by manufacturer and model year
4.2. Approach to estimating vehicle survival and use (i.e., vehicle miles traveled), including the model's application of the input defining a "rebound" effect
4.3. Approach to estimating total emissions of criteria pollutants (e.g., nitrogen oxides) and greenhouse gases (e.g., methane) other than carbon dioxide.
4.4. Model results for industry response to CAFE Standards
4.5. Estimation of consumer impacts from CAFE standards
4.6. Model results for social, economic and environmental effects of CAFE standards (costs, benefits, and quantities)
4.7. Sensitivity of augural standards net benefits to high and low value assumptions of factors such as fuel price, rebound, etc.

Nigel Clark

[NO RESPONSE.]

Walter Kreucher

REVIEW TOPIC NUMBER 4.4. MODEL RESULTS FOR INDUSTRY RESPONSE TO CAFE STANDARDS

1. What are the most important concerns that should be taken into account related to the review topic?

   This is a difficult question. No single model can accurately predict the industry response to CAFÉ standards. And this model is no exception.

   The unintended consequences of any policy are enormous. When the first CAFÉ standards were enacted there were five domestic automobile companies. American Motors went out of business (only the Jeep brand survived). Navistar (then called International Harvester) voluntarily left the light duty business rather than comply with the standards. Chrysler went bankrupt not once but twice, and was sold three times (and is currently on the market again as it struggles to survive). General Motors went bankrupt once. Of the five domestic companies that existed prior to CAFÉ, only Ford has so far managed to keep its head above water.

   So the track record of the policy is poor when it comes to the domestic automobile industry.

   The primary reason for all this was that the flat standards enacted at the time targeted domestic companies. Foreign companies either elected to pay fines (in the case of the European companies) or did not have to make any changes (in the case of the Japanese companies). In fact, many of the Japanese companies actually decreased their fleet average fuel economy for several years while building bigger and more profitable automobiles (and taking market share from the domestic companies).

   So the simple answer to this question is that **the model does not accurately predict the industry response to the CAFÉ standards.**

   This is evident in the 2017MY data set that shows manufacturers not able to achieve the CAFÉ standards despite implementing more technology than predicted by the model.

   The tables below show the major changes in fuel economy predicted by the model. Those highlighted in **bold red** represent fuel economy increases greater than the manufacturer has achieved in any single year since 2001. The red values that are not bolded represent differences of greater than a half mile per gallon from that actually achieved by the manufacturer.

VOLPE Predicted Versus Actual Fuel Economy																
	PC-AVE	PC-MAX	PC-2015 ACT	PC-2016 ACT	PC-2017 ACT	PC-2015 VOLPE	PC-2016 VOLPE	PC-2017 VOLPE	PC-2018 VOLPE	PC-2019 VOLPE	PC-2020 VOLPE	PC-2021 VOLPE	PC-2022 VOLPE	PC-2023 VOLPE	PC-2024 VOLPE	PC-2025 VOLPE
BMW	0.7	3.1	34.8	34.0	36.3	33.3	34.8	35.5	37.6	37.8	38.0	38.5	40.2	41.1	41.8	42.5
Daimler	0.7	2.7	34.1	34.4	33.3	33.0	33.9	35.2	36.6	37.7	37.8	40.4	**44.0**	44.2	45.6	45.6
FCA	0.2	2.1	33.3	31.6	30.5	32.2	32.2	**37.2**	38.6	**41.2**	**47.3**	**49.6**	51.3	52.5	52.3	52.2
Ford	0.5	3.0	35.6	36.0	36.3	34.4	36.7	37.9	38.9	**41.9**	**46.3**	49.2	50.0	50.0	50.4	52.9
General Motors	0.4	1.5	34.8	34.9	34.8	33.0	**35.0**	**38.3**	**40.6**	41.4	**44.7**	**47.9**	48.0	**49.9**	50.6	**52.6**
Honda	0.6	2.1	41.2	42.2	42.2	40.4	41.2	41.9	43.3	43.9	44.4	45.3	**49.1**	**51.9**	53.6	54.3
Hyundai Kia	0.4	2.0	35.2	37.3	36.1	34.8	**37.1**	38.6	39.9	40.8	**43.1**	**45.8**	**50.3**	50.9	51.7	53.1
JLR	0.8	4.3	27.6	27.3	31.6	26.4	28.5	29.3	29.2	30.7	30.7	31.6	32.0	31.9	32.0	32.0
Mazda	0.9	4.1	42.0	41.8	39.0	41.5	41.2	41.4	43.9	44.0	48.0	48.0	50.3	53.3	53.7	53.8
Mitsubishi	1.2	8.2	39.3	36.2	44.4	40.8	43.6	43.1	43.2	43.8	**56.9**	55.3	56.7	57.2	57.5	57.3
Nissan	0.7	3.9	41.0	40.9	39.7	40.6	40.5	40.5	42.7	43.7	43.7	**48.4**	50.1	51.5	54.0	54.3
Subaru	0.6	5.0				38.0	38.7	43.0	43.8	44.3	44.0	**50.4**	52.2	54.4	55.1	54.9
Toyota	0.6	4.2	39.9	39.9	40.9	39.5	40.5	40.6	43.8	44.6	46.2	48.0	49.1	50.5	53.0	54.8
Volvo	1.1	4.6	35.1	35.3	35.7	34.9	34.9	35.2	35.2	**40.9**	41.0	41.0	41.0	41.5	41.5	41.9
VWA	0.3	2.1	36.7	32.9	33.0	35.8	35.5	35.8	**38.4**	39.4	40.3	41.1	42.5	43.4	44.0	44.7

Note: without AC adjustment
Max . mpg Y-O-Y Change 2001-
2017 Ave . mpg Y-O-Y Change
2001-2018

VOLPE Predicted Versus Actual Fuel Economy																	
	LT-AVE	LT-MAX	LT-2015 ACT	LT-2016 ACT	LT-2017 ACT	LT-2015 VOLPE	LT-2016 VOLPE	LT-2017 VOLPE	LT-2018 VOLPE	LT-2019 VOLPE	LT-2020 VOLPE	LT-2021 VOLPE	LT-2022 VOLPE	LT-2023 VOLPE	LT-2024 VOLPE	LT-2025 VOLPE
BMW	0.7	2.9	28.5	28.8	30.0	28.9	28.9	29.5	30.4	31.8	32.1	32.5	33.2	33.2	34.9	35.0
Daimler	0.6	2.8	26.9	27.3	26.5	26.5	29.1	29.1	31.0	31.3	31.3	32.3	32.3	33.1	34.0	34.0
FCA	0.4	1.2	26.4	26.5	27.1	25.2	25.1	**26.9**	**35.0**	35.0	35.8	**37.3**	38.3	38.3	38.7	39.3
Ford	0.5	2.0	25.9	25.7	27.7	25.2	26.3	27.0	27.4	28.2	28.2	**33.6**	33.9	34.6	34.7	35.6
General Motors	0.3	1.9	23.7	23.8	25.3	24.2	25.8	26.1	27.3	28.5	**30.4**	31.7	31.7	**33.6**	34.6	35.4
Honda	0.4	1.5	31.3	30.9	32.3	31.3	32.7	34.2	34.1	34.3	34.7	**37.4**	**40.0**	40.2	40.5	**42.5**
Hyundai Kia	0.2	3.4	27.3	26.7	26.7	27.3	29.9	31.6	32.1	**36.0**	36.0	36.1	37.8	40.9	41.7	42.7
JLR	0.9	3.2	25.9	24.9	27.8	24.9	24.9	26.5	27.6	28.3	29.5	30.5	30.9	31.3	31.3	33.8
Mazda	0.9	3.1	31.2	34.3	33.4	31.2	**34.7**	34.7	37.6	37.6	37.6	38.0	38.1	**45.3**	45.3	45.3
Mitsubishi	0.9	3.9	34.1	33.9	34.6	34.6	35.9	35.9	35.9	37.5	**43.4**	43.4	43.4	43.4	44.4	46.9
Nissan	0.5	2.7	28.6	30.7	28.7	28.6	29.0	29.8	31.4	**35.0**	35.1	37.7	38.5	39.4	40.2	41.0
Subaru	0.8	2.8	36.5	36.4	36.8	36.5	36.5	38.7	38.8	38.8	38.8	**45.2**	45.6	45.6	46.6	46.7
Toyota	0.4	2.3	26.4	26.7	29.0	25.7	**28.6**	28.9	30.8	**34.3**	**37.1**	38.5	38.6	39.3	39.6	39.6
Volvo	1.1	3.5	26.2	29.7	31.0	26.2	26.1	26.1	26.1	**32.5**	32.5	32.6	32.6	32.6	32.6	32.7
VWA	0.4	4.3	28.3	27.8	27.1	27.3	28.1	29.4	31.3	31.2	31.4	31.5	32.9	32.9	35.9	35.9

Note: without AC adjustment
Max . mpg Y-O-Y Change 2001-
2017 Ave . mpg Y-O-Y Change
2001-2018

The competitive impacts of the model are staggering. When the regulatory costs are assessed on a competitive basis there are enormous costs.

For example, based on the augural standards in the 2025 MY, the average Ford vehicle will be at a $2,000 competitive disadvantage to the average Toyota (and almost $1,000 versus Honda and VW). **This large price gap will impact sales due to demand elasticity.** There are similar disadvantages for General Motors and other manufacturers. Toyota seems to be the big winner in the model. This may be due to their leadership in the preferred technology.” Ford and GM must add 300,000 to 400,000 SHEVPSs to their fleets in 2025 MY.

	Regulation Cost per Vehicle		
	Augural Standards 2025		
	vs Honda	vs Toyota	vs VW
BMW	$ 135	$ 1,518	$ (105)
Daimler	$ (50)	$ 1,333	$ (289)
FCA	$ (1,204)	$ 179	$ (1,443)
Ford	$ 961	$ 2,344	$ 721
General Motors	$ 830	$ 2,213	$ 591
Honda	$ -	$ 1,383	$ (240)
Hyundai Kia	$ 690	$ 2,073	$ 451
JLR	$ (111)	$ 1,273	$ (350)
Mazda	$ (821)	$ 562	$ (1,061)
Mitsubishi	$ 281	$ 1,664	$ 41
Nissan	$ (484)	$ 899	$ (724)
Subaru	$ (1,280)	$ 103	$ (1,519)
Tesla	$ (3,339)	$ (1,956)	$ (3,579)
Toyota	$ (1,383)	$ -	$ (1,623)
Volvo	$ 71	$ 1,454	$ (168)
VWA	$ 240	$ 1,623	$ -

The differential competitive impact is the primary reason why the traditional Big Three routinely oppose CAFÉ standards and the Japanese companies support them. **The Japanese companies use CAFÉ as a predatory tactic.**

The total regulatory costs per manufacturer also present an enormous hit to the bottom line of the manufacturer. Ford and GM will undergo **a four to five BILLION dollar hit to profitability vis a vis competition**. Not all of this will be recoverable in the marketplace and there will be lost sales, lost jobs, and other unintended consequences as we have seen in the past. Somehow the model and the standard setting process must assess this impact.[5,6]

RESPONSE: The CAFE model has been revised to estimate impacts on industry sales volumes and employment. However, the model is not intended as, *per se*, a predictive model, but rather to indicate pathways manufacturers <u>could</u> potentially take in response to standards. Therefore, especially when the model is exercised using inputs that can be made available to the public, differences between model-estimated outcomes and actual outcomes are inevitable. The model is also intended only to estimate potential impacts of standards, not to determine at what levels standards should be set.

[5] If VOLPE does not have the expertise to do this kind of update, I suggest you contact Dr. Martin Zimmerman, clinical professor emeritus of business economics and public policy, Ross School of Business, University of Michigan.

[6] Carley, S., Duncan, D., Esposito, D., Graham, J. D., Siddiki, S., & Zirogiannis. (2016, February). Rethinking auto fuel economy policy: Technical and policy suggestions for the 2016-17 midterm reviews. Bloomington, IN: Indiana University School of Public and Environmental Affairs. Available at https://spea.indiana.edu/doc/research/working-groups/fuel-economy-policy-022016.pdf

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   The methods and assumptions are not capable of predicting the industry response. **Too few factors are considered and the model is limited in predicting how the industry might respond.**

   The fact that sales are constrained is just one example of an unrealistic assumption.
   RESPONSE: See response to 1 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   Add features that consider the cost and availability of capital, competitive impacts, and changes in sales as a result of CAFE. Short of that, I do not see anything that can improve the performance of the model in predicting the industry response.

   RESPONSE: See response to 1 above. Further research, development, and testing would be required before adopting explicit accounting for fixed and variable costs, such as might be needed to explicitly address any specific expected limits on the availability of capital.

4. Is there an alternative approach that you would suggest?

   Alternative solutions to a complete redo of the model to account for economic factors are not modeling solutions but policy ones. NHTSA could abandon CAFÉ (and EPA could abandon GHG standards). A much simpler approach would be to increase fuel taxes. This would prompt consumers to purchase energy efficient products. A better option would be to move to low or zero carbon fuels.

   RESPONSE: The purpose of the CAFE model is to provide means to show ways manufacturers could potentially respond to CAFE standards, and to estimate various impacts of these responses. The reviewer is correct that broader policy solutions are not within the purview of Volpe Center staff responsible for building and operating the CAFE model.

Jose Mantilla

[NO RESPONSE.]

Wallace Wade

Reviewer Name:_Wallace R. Wade

Review Topic Number: _4.4. Model results for industry response to CAFE standards

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

CAFE Compliance Capability:

Table 13.8 summarizes the actual CAFE requirement for each manufacturer in MY2015; the estimated CAFE requirement in MY 2021 through which CAFE standards are final; and the estimated CAFE requirement in MY 2030, when NHTSA modeling indicates that the Augural Standards would produce a fully stable fleet. The Augural Standards are assumed to remain constant at the MY 2025 level through MY 2030. Due to credit carry-forward, trading between fleets, and product cadence considerations, NHTSA estimates that some manufacturers will be taking actions to reach compliance with MY 2025 standards for several model years thereafter.

Conclusions from Table 13.8 and Figure 13.29 include:

- Between MY 2015 and MY 2030, manufacturers as a group will be required to increase required vehicle fuel economy levels by more than 50 percent for passenger cars and 40 percent for light trucks.
- The analysis assumes an increase in NHTSA's CAFE non-compliance fine rate from $55 per mpg under the required level per vehicle sold to $140 per mpg. As a result, the modeling indicates that many fine-paying manufacturers will respond more aggressively to CAFE requirements than in previous analyses.
- A few manufacturers (e.g., JLR, Volvo) could find the option of paying fines attractive enough to fall well short of one or both standards by MY 2030.
- By MY 2030, all manufacturers assumed to be averse to paying CAFE fines (e.g., Ford, GM, and FCA) are estimated to be able to reach compliance without the use of credits.
- Total industry average CAFE level and standard are lower using the MY 2015 fleet in the current analysis than they were using the MY 2010 fleet in the Final Rulemaking, largely attributable to the shifts in sales between light trucks and passenger cars.
- The 2016 Draft TAR states "manufacturers achieving CAFE levels close to the requirements, albeit generally closer for the passenger cars than the light trucks.

(2016 Draft TAR, pp.13-57 to 13-60)

Concern1:
Regarding Figure 13.29 and the last bullet point, above, some manufacturers (e.g., BMW, Daimler) are shown to miss the 2025 CAFE standard by over 5 mpg. An explanation of what resulted in under achieving the CAFE standard would be informative. An explanation would be particularly helpful since both manufacturers are shown with significant numbers of downsized, turbocharged engines and over 60 percent strong hybrids in trucks and over 50 percent hybrids in cars. This suggests that there were still technologies that these manufacturers could have applied, unless these manufacturers are also in the group who find the option of paying fines attractive enough to fall well short of one or both standards by MY 2030.

Recommendation 1:

Add a statement that some manufacturers (e.g., BMW, Daimler) are shown to miss the 2025 CAFE standard by over 5 mpg and provide an explanation of what resulted in this underachievement.

RESPONSE: DOT's published 2016 analysis used inputs treating BMW and Daimler as treating payment of civil penalties as an economic choice, and treated most other manufacturers as treating payment of civil penalties as something to be avoided at all costs. The draft TAR presented a highly-summarized single-chapter summary of the analysis. A fuller Regulatory Impact Analysis will discuss manufacturers' estimated responses to potential new standards.

Concern 2:

No reference or estimated effective date is provided for the increase in NHTSA's CAFE non-compliance fine rate from $55 per mpg under the required level per vehicle sold to $140 per mpg.

Recommendation 2:

Provide a reference and estimated effective date for the increase in NHTSA's CAFE non-compliance fine rate from $55 per mpg under the required level per vehicle sold to $140 per mpg.

RESPONSE: A new Regulatory Impact Analysis will discuss input values specifying projected civil penalty rate.

Technology Penetration Rates:

Figure 13.30 through Figure 13.33 show passenger car technology penetration rates for engine, transmission, electrification, and load reduction technologies, respectively. Figure 13.34 through 13.37 present comparable analyses for light trucks.

(2016 Draft TAR, pp. 13-61 to 13-72)

Concern 3:

Notably missing from Figures 13.30 and 13.33 are the Atkinson 2-cycle (non-hybrid) and Miller cycle engines. This is particularly notable since EPA's analysis indicates a 44 percent penetration for Atkinson 2-cycle engines by 2025 (Table 12.45, p. 12-35).

Recommendation 3:

Add an explanation of 1) why Atkinson 2-cycle engines do not appear in Figures 13.30 and 13.33, or modify Figures 13.30 and 13.33 appropriately, and 2) the significant differences with EPA's projection of 44 percent penetration of Atkinson 2-cycle engines.

RESPONSE: The 2016 Draft TAR presented a highly-summarized single page discussion of DOT's 2016 analysis, which showed limited application of HCR2 (a.k.a. "Akinson 2") engines. A new Regulatory Impact Analysis will more fully discuss input assumptions and model results for specific technologies.

Projected Compliance Costs:

Table 13.9, showing average per vehicle cost for the primary analysis using RPE to mark up direct costs, has three columns, the first of which shows costs added with stringency increases through 2016.

(2016 Draft TAR, pp. 13-72 to 13-74)

Concern 4-1:

The explanation of Table 13.9 is not clear for several reasons.

The text on p. 13-72 comments that the first column shows the "investments" manufacturers would have to make to comply with current standards through 2016. However, Table 13.9 is labeled "costs" rather than "investments."

Recommendation 4-1:

Since Table 13.9 is believed to show total costs (direct manufacturing costs x RPE), the text should be changed from "investment" to "total cost."

RESPONSE: A new Regulatory Impact Analysis will better differentiate between investments and costs.

Concern 4-2:

The first column labeled “Costs added with stringency increases through 2016” needs further explanation with respect to the time period. Are these costs that have been added for the 2012 through the 2016 time period?

Recommendation 4-2:

Clarify the first column of Table 13.9 with respect to the time period for the “costs added with stringency increases through 2016” (e.g., such as 2012 through 2016).

RESPONSE: A new Regulatory Impact Analysis will more fully explain the modeled timing of compliance costs.

Concern 4-3:

The “Total Costs” shown in the last column labeled “Total Costs” generally appear to equal the total of the previous 3 columns for each row. However, this is not always the case. For example:

- The 2017 total is 410 compared to 400 shown in the last column; and
- The 2019 total is 840 compared to 830 shown in the last column.

Recommendation 4-3:

An explanation should be added that the “Total costs” shown in the last column are the total of the adjacent 3 columns for each row (if this is correct). Appropriate numerical corrections should be made to Table 13.9.

RESPONSE: These differences are attributable to rounding in the tabulation of costs. A new Regulatory Impact Analysis will present updated results and discuss any rounding.

Concern 4-4:

The text states that, in NHTSA’s modeling, manufacturers begin investing in compliance with the Augural Standards as early as 2017, redesigning vehicles that will continue to be built in 2022 and beyond. However, it likely that not all of the costs for 2017 – 2021 can be assigned to the Augural Standards in the MY 2022 – 2025 time period.

Recommendation 4-4:

The text should clarify which costs can be assigned to the Augural Standards. Although the

"Additional costs under MYs 2022-2025 Augural Standards" (Column 3) can be assigned to the Augural Standards, an explanation of what part of the costs labeled "Additional costs with stringency increases through 2021" (Column 2) can be assigned to the Augural Standards should be provided.

RESPONSE: The third column "Additional Costs under MYs 2022-2025 Augural Standards" attempted to do this. A new Regulatory Impact Analysis will present updated results, and will explain attribution of costs to different model years' standards.

Concern 4-5

Figure 13.38 shows the rate at which average regulatory costs increase relative to the required and achieved CAFE levels for the industry. The (assumed "cumulative") cost by 2030 is shown as $1,250. However, Table 13.9 would suggest that this cost might be the sum of $660 (or a part of $660 related to MYs 2022-2025) and $1,240, or $1,900, but this cost from Table 13.9 is inconsistent with the $1,250 shown in Figure 13.38.

Recommendation 4-5:

Add the label "cumulative (if correct) to the right-hand y axis of Figure 13.38. Add an explanation of how this "cumulative" cost of $1,250 is related to the costs shown in Table 13.9 (specifically the sum of $660 (or the part of $660 related to MYs 2022-2025) in Column 2 and $1,240 in Column 3, or $1,900).

RESPONSE: The right-hand *y* axis of Figure 13.38 in the 2016 Draft TAR correctly identifies the costs (shown as a dashed line) as being the average additional costs beyond those occurring under the "no action alternative." These are aligned with the third column "Additional Costs under MYs 2022-2025 Augural Standards" shown in Table 13.9. A new Regulatory Impact Analysis will present updated estimates of costs, explaining attribution to the no-action and other regulatory alternatives.

Concern 5:

Table 13.10, showing average per vehicle cost and production volume in MY 2025, provides additional information on the distribution of projected sales and compliance costs for each manufacturer. The industry average cost of $2,070, which is assumed to be the sum of the previous 3 columns, agrees with Table 13.9 for MY 2025. However, the 3 previous columns only add to $$2,060, rather than $2,070.

(2016 Draft TAR, pp.13-75 to 13-76)

Recommendation 5:

Resolve the difference between the industry average of $2,070 and sum of the 3 previous columns, which only equals $2,060 (370 + 670 + 1,020) in Table 13.10.

RESPONSE: These differences are attributable to rounding in the tabulation of costs. A new Regulatory Impact Analysis will present updated results and discuss any rounding.

Concern 6:

The $$2,480 shown for the 2012 Final Rule in Table 13.10 is significantly different from the current analysis showing a cost of $2,070. The following explanation is provided for this difference: “Notably, drops in overall costs for compliance through 2016, relative to analysis in the 2012 final rule, reflect, among other things, choices that manufacturers across the sector have made since 2010 (the model year providing the foundation for NHTSA’s 2012 analysis) with respect to applying technology and to achieving compliance in the early years.” This explanation is vague, non-quantitative, and unclear.

Recommendation 6:

Provide a clear explanation, with a quantitative illustration, for the difference between the $2,070 total cost for the 2025 standards in the current analysis and the $2,480 cost for the 2025 standards shown for the 2012 Final Rule in Table 13.10. The difference is significantly greater than the difference between 2013$s used for the current analysis and 2010$s used for the Final Rulemaking.

RESPONSE: These differences are attributable to rounding in the tabulation of costs. A new Regulatory Impact Analysis will present updated results and discuss any rounding.

Comparison to No-Action Alternative:

Table 13.11 shows estimated model year 2028 CAFE levels under the No-Action Alternative and the Augural Standards. On an industry-wide basis, the Augural Standards are estimated to improve average fuel consumption by about 14 percent.

Table 13.12 shows the estimated average additional cost in MY 2028 (compared to the No-Action Alternative) of fuel-saving technologies producing these incremental fuel consumption improvements under the Augural Standards. On an industry-wide basis, these estimated incremental costs for the Augural Standards average $1,175 for the combined fleet.

(2016 Draft TAR, pp. 13-77 to 13.79)

Concern 7:

The difference between the estimated incremental costs of $1,174 for MY 2028 for the combined fleet for the Augural Standards shown in Table 13.12 and the $1,250 cost for the Augural Standards shown in Table 13.9 is not explained in the 2016 Draft TAR.

Recommendation 7:

An explanation of the difference between the $1,175 for MY 2028 for the combined fleet for the Augural Standards shown in Table 13.12 and the $1,250 shown in Table 13.9 for the Augural standards should be provided. Include an explanation of the role of the $660 (or the part of $660 related to MYs 2022-2025) as related to the $1,250 shown in Table 13.9 (see Recommendation 4-5).

RESPONSE: In the 2016 Draft TAR, the text preceding Table 13.12 indicates that table shows costs that "excluding any estimated civil penalties." Costs shown in Table 13.9 included civil penalties. A new Regulatory Impact Analysis will present updated results and discuss the scope of costs presented.

Sensitivity to Key Inputs:

NHTSA examined how alternative assumptions about critical inputs to the simulation would change outcomes of interest.

The two bar plots in Figure 13.39 and Figure 13.40, show the percentage change in regulatory costs (technology costs plus fines) under the high and low case assumptions for a variety of sensitivity assumptions.

Figure 13.40 showing the sensitivity of total regulatory costs (MY2016 - MY2030) to alternative assumptions has several key observations:

- The highest influence on total cost is product cadence, where design cycles 2 years longer limit manufacturers' choices and lead to cost increases approaching 30 percent over the design cycles used in the central analysis.
- Battery costs are second in importance and total costs decrease 7 percent when battery costs are reduced to $100/kWh.
- Mass reduction is third in importance and total cost could increase by 4 percent if the MR1 limit for passenger cars is replaced with no restrictions in mass reduction.

(2016 Draft TAR, p.13-92)

Concern 8:

The explanation of why extending product cadence by 2 years results in cost increases approaching 30 percent is not provided. Why does extending the product cadence limit the manufacturers' choices?

Recommendation 8:

Provide an explanation, with examples, of why extending product cadence by 2 years results in cost increases approaching 30 percent. Explain why extending the product cadence limits the manufacturers' choices.

RESPONSE: A new Regulatory Impact Analysis will present an updated sensitivity analysis and will more fully discuss cases involving changes to estimated cadence.

RPE vs. ICM:

NHTSA also conducted a sensitivity case analysis using indirect cost multiplier (ICM) in place of retail price equivalent (RPE) which was used for the primary analysis. Table 13.23, showing a comparison of cost estimates using retail price equivalent and indirect cost multiplier mark up, show that the average per-vehicle cost in MY 2025 is $2,065 using RPE and $1,859 using ICM.

(2016 Draft TAR, pp. 13-90-13-94)

Concern 9:

In Table 13.23, NHTSA shows that the use of ICM in place of RPE leads to different average per-vehicle costs for MY 202. However, the 2016 Draft TAR makes the statement that "The ICM estimates used in this draft TAR, (is) consistent with the FRM."

(2016 Draft TAR, p. 5-238)

Recommendation 9:

NHTSA should provide insight into whether the RPE or ICM method will be used for the average per-vehicle cost for 2025 MY. This appears to be an important decision since EPA and NHTSA were evaluating both methods in the 2016 Draft TAR.

RESPONSE: An updated Regulatory Impact Analysis will discuss how cost input values reflect NHTSA's approach to "marking up" estimated direct costs.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The data, computational methods and assumptions are likely reasonable and appropriated, but Recommendations 1-9 need to be addressed. **RESPONSE: See responses to recommendations 1-9 above.**

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1-9. **RESPONSE: See responses to recommendations 1-9 above.**

4. Is there an alternative approach that you would suggest?

No. Implementation of Recommendations 1-9 is the suggested approach. **RESPONSE: See responses to recommendations 1-9 above.**

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

The output of the Volpe Model is critical in setting the CAFE standards by ensuring that they are cost effective to the consumer. Ensuring cost effective CAFE standards increases the likelihood that the vehicles will continue to be attractive to the consumers. Implementing Recommendations 1- 9 will enhance the utility and plausibility of the Volpe Model output. **RESPONSE: See responses to recommendations 1-9 above.**

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
4. Model operations
4.1. Dynamic application of technology to each manufacturer's fleet to minimize effective costs based on the CAFE standards for the current model year, defined as the difference between the incremental cost of a technology and the value of fuel savings produced by the technology over three years of vehicle ownership (iterative process until the most effective technology is found) by manufacturer and model year
4.2. Approach to estimating vehicle survival and use (i.e., vehicle miles traveled), including the model's application of the input defining a "rebound" effect
4.3. Approach to estimating total emissions of "criteria" pollutants (e.g., nitrogen oxides) and greenhouse gases (e.g., methane) other than carbon dioxide.
4.4. Model results for industry response to CAFE Standards
4.5. Estimation of consumer impacts from CAFE standards
4.6. Model results for social, economic and environmental effects of CAFE standards (costs, benefits, and quantities)
4.7. Sensitivity of augural standards net benefits to high and low value assumptions of factors such as fuel price, rebound, etc.

Nigel Clark

[NO RESPONSE.]

Walter Kreucher

REVIEW TOPIC NUMBER 4.5. ESTIMATION OF CONSUMER IMPACTS FROM CAFE STANDARDS

1. What are the most important concerns that should be taken into account related to the review topic?

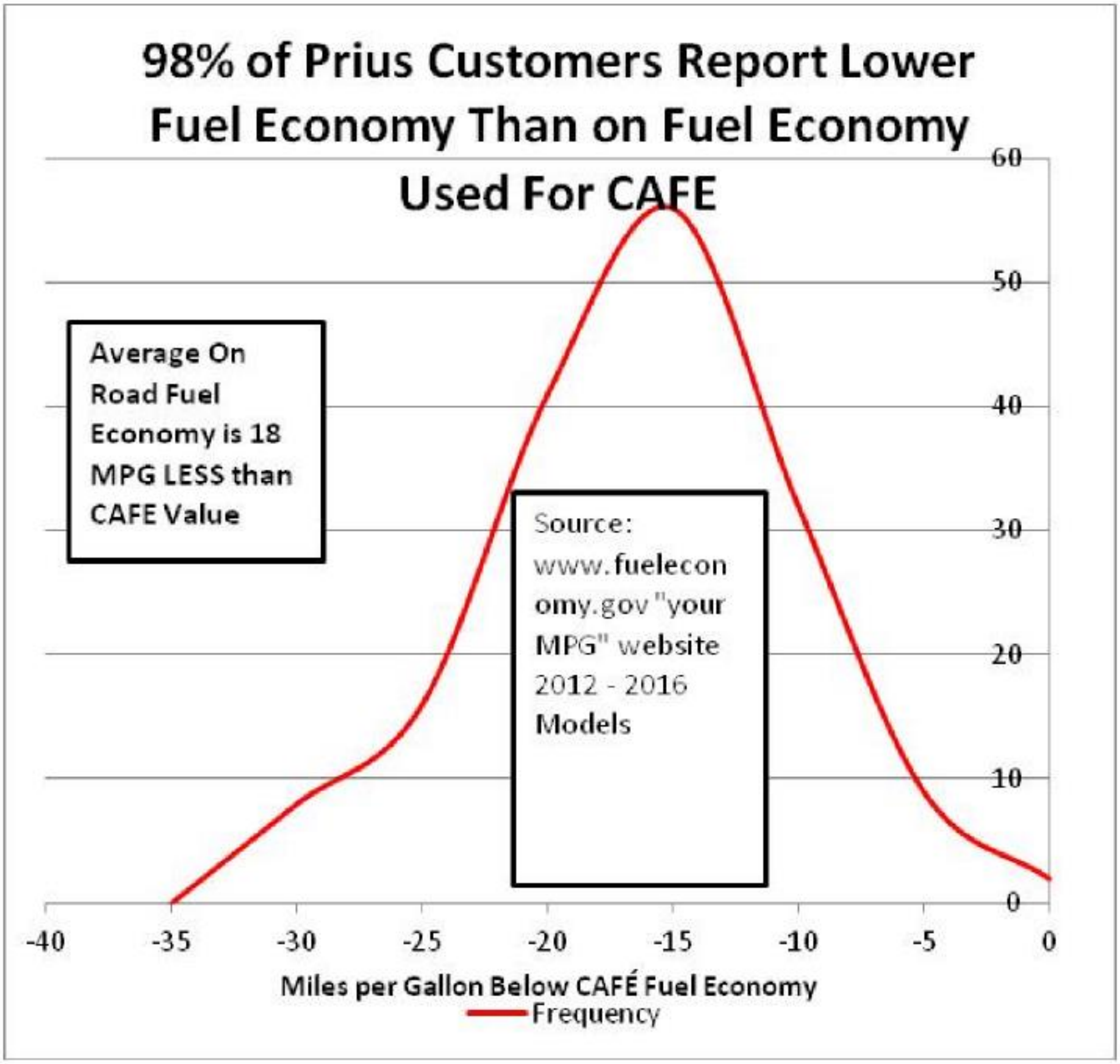
   The existence of the "Energy Paradox"[7] is well documented. It may not be as confounding as the proponents of CAFE believe.

   Consumers are smarter than CAFE proponents. They look at the totality of costs including "real world" fuel economy, maintenance, and depreciation. One of the things that should be corrected is the lack of a battery replacement over the useful life for HEVs, PHEVs, and BEVs.

   Another item that the model misses is the differential depreciation rates for HEVs, PHEVs, and BEVs.

   A third item is to update the model to plug in realistic inputs for the gap between test fuel economy and real-world fuel economy for HEVs, PHEVs, and BEVs.

[7] Committee on the Assessment of Technologies for Improving Fuel Economy of Light-Duty Vehicles, Phase 2. (2015). *Cost, effectiveness, and deployment of fuel economy technologies for light-duty vehicles*. Washington, DC: National Academies Press.



There is considerable evidence that hybrid electric vehicles operate differently on the road compared to gasoline vehicles.

RESPONSE: Expectations regarding manufacturers' apparent judgments regarding buyers' willingness to pay for fuel economy are reflected in the "payback period" values specified when running the model. A new Regulatory Impact Analysis will discuss updated values used for NHTSA's analysis Other model inputs can be used to specify differences between "laboratory" and "real-world" energy consumption, and to specific different values for operation on gasoline and operation on electricity.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

OWNERSHIP AND OPERATING COSTS

The ownership and operating cost data used in the report is limited and outdated. Several companies, Edmunds, Kelley Blue Book, and others regularly publish these values for every vehicle on the market.

Hybrid electric vehicle technology has been on the market for almost two decades. During that time a substantial body of data has been collected on the ownership and operating cost of this technology compared to conventional gasoline technologies.

	Depreciation	Financing	Taxes and Fees	Insurance	Maintenance	Repairs	Fuel
Gasoline	$13,391	$2,959	$2,298	$4,726	$4,087	$772	$6,894
Hybrid Electric	$17,317	$3,567	$2,745	$5,106	$4,147	$812	$4,794
Difference	$3,926	$609	$447	$380	$60	$40	-$2,100

The table above shows a sampling of data from the 15 highest selling HEVs compared with their gasoline counterparts.[8] The ownership and operating costs are substantially higher for the hybrid electric vehicle. This data must be reflected in the technology input files. The higher costs are due to the added complexity and cost of a second powertrain.

As a percentage of the MSRP, the values are relatively consistent with the exception of depreciation. Hybrid electric vehicles depreciate faster and in most cases the resale vehicles are actually below that of the comparable gasoline vehicles in less than 7 years despite the fact that the HEV starts out at a price premium. **The model must reflect the lower resale value of hybrid electric vehicles.**

I would point out that the fuel savings in the above table may not be realistic as it reflects the EPA label fuel economy information. EPA made the strategic decision almost ten years ago at the urging of Honda and a few other hybrid manufacturers to lump hybrids in with conventional gasoline vehicles for fuel economy labeling purposes even though EPA had knowledge as far back as 1998[9] that hybrids operated differently on test cycles than they did on the road. (see next item for details).

Of the top 25 HEVs on the market in 2017, only 5 have a 5-year cost of ownership that is lower than the gasoline counterpart (even assuming the EPA fuel economy value is accurate). In those cases where the HEV is cheaper to own it is because the manufacturer made the strategic decision to spread the cost of the hybrid technology across the entire platform.

[8] I can provide the raw data if you need it but it is all available online.

[9] Evaluation of a Toyota Prius Hybrid System; EPA420-R-98-006; August 1998; Karl Hellman et al.

While the strategy of platform pricing works on a limited basis, it is not the foundation of a long-term business strategy.

RESPONSE: As will be discussed in a new Regulatory Impact Analysis, model input values have been updated to reflect a new analysis of hybrid and electric vehicle resale value.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

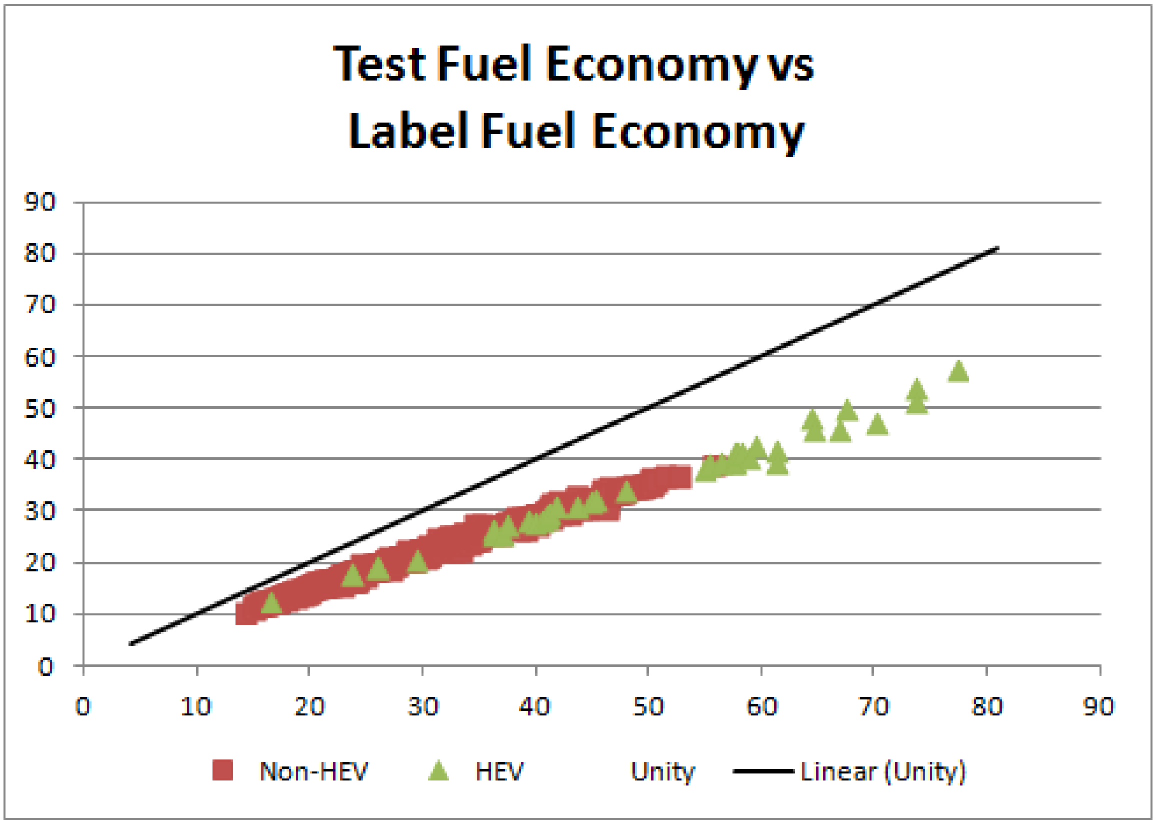
Update the input files to reflect realistic assumptions for the true cost of ownership.

RESPONSE: See response to 1 and 2 above.

GAP BETWEEN TEST AND ON-ROAD MPG

The Environmental Protection Agency since the beginning of the fuel economy labeling program has discounted the test fuel economy. In the years following the introduction of hybrid electric vehicles and conventional vehicles with higher fuel economy, the Agency received a substantial increase in complaints from consumers indicating that they could not achieve the fuel economy that was listed on the Monroney label.

The Agency conducted a substantial investigation into this phenomenon and published a revised rule that changed the way fuel economy labels were calculated. In this rule, the Agency changed from a "static" adjustment factor to a "dynamic" adjustment factor. The higher the test fuel economy the larger the adjustment EPA applied to the fuel economy label.



The figure above is a plot of the fuel economy test data from the 2017 EPA database comparing the unadjusted combined fuel economy with the EPA adjusted combined fuel economy. The data shows two things. First, the gap between test fuel economy and label fuel economy is not "static" as EPA had assumed prior to the 2008 model year but is dynamic in that as the test fuel economy increases EPA applies a larger adjustment factor to the value.

The adjustment that EPA applies ranges from 18 percent on the low end up to 29 percent at the higher fuel economy.

In order to understand how this came about, a bit of history is necessary.

In 1998 EPA conducted an evaluation of the Toyota Prius Hybrid System.[10] Toyota loaned EPA a vehicle certified to the Japanese standards. Based on these tests, EPA concluded:

Because the Prius had regenerative braking on only the front wheels (the wheels used on the dynamometer for the official EPA test) the vehicle over charged the battery during official testing with the result that fuel economy measured by EPA "may be too high compared to what actually happens on the road, and it could be conjectured that the **resulting mpg from the chassis dynamometer will be inappropriately high** (and the vehicle would emit more greenhouse gases when driven on the road)." This conjecture was validated with vehicle test data in the report.[11]

The state of charge impacted vehicle fuel economy and greenhouse gas emissions. This may explain in part why HEVs lose fuel economy as the hybrid battery deteriorates over its life.

Highway fuel economy was approximately 7 percent different depending on state of charge of the battery. **Thus a short highway trip may result in lower fuel economy as the engine works harder to recharge the battery.**

EPA conducted a "Bag 1"[12] Federal test procedure (FTP) and noticed significantly higher hydrocarbon and oxide of nitrogen emissions and significantly lower fuel economy (25%) when the battery was fully discharged. The effect over the entire FTP was an 11 percent difference in fuel economy and carbon dioxide.

The Toyota hybrid system shuts off the engine at idle, during decelerations and during low speed driving when the air conditioning and cabin heat are in the off position. **When the air conditioning or cabin heat is in the on position the engine is turned on and fuel economy is reduced.**

The nature of current hybrid technology – the addition of a battery as a second source of on-board power, sophisticated control systems, and sometimes a smaller engine – makes a hybrid's fuel economy more sensitive to certain factors, such as colder weather and air conditioning use.

Cold temperatures cause the battery to discharge faster. EPA testing shows that the vehicle loses 50 percent of its charge in two weeks while stored at 20 °F. **This results in lower fuel economy and higher greenhouse gas emissions when the vehicle is operated following a period of inactivity**.

[10] Evaluation of a Toyota Prius Hybrid System; EPA420-R-98-006; August 1998; Karl Hellman et al.
[11] EPA uses a "k" factor developed by Toyota to factor in the state of charge.
[12] Bag 1 is the first third of the EPA standard city test.

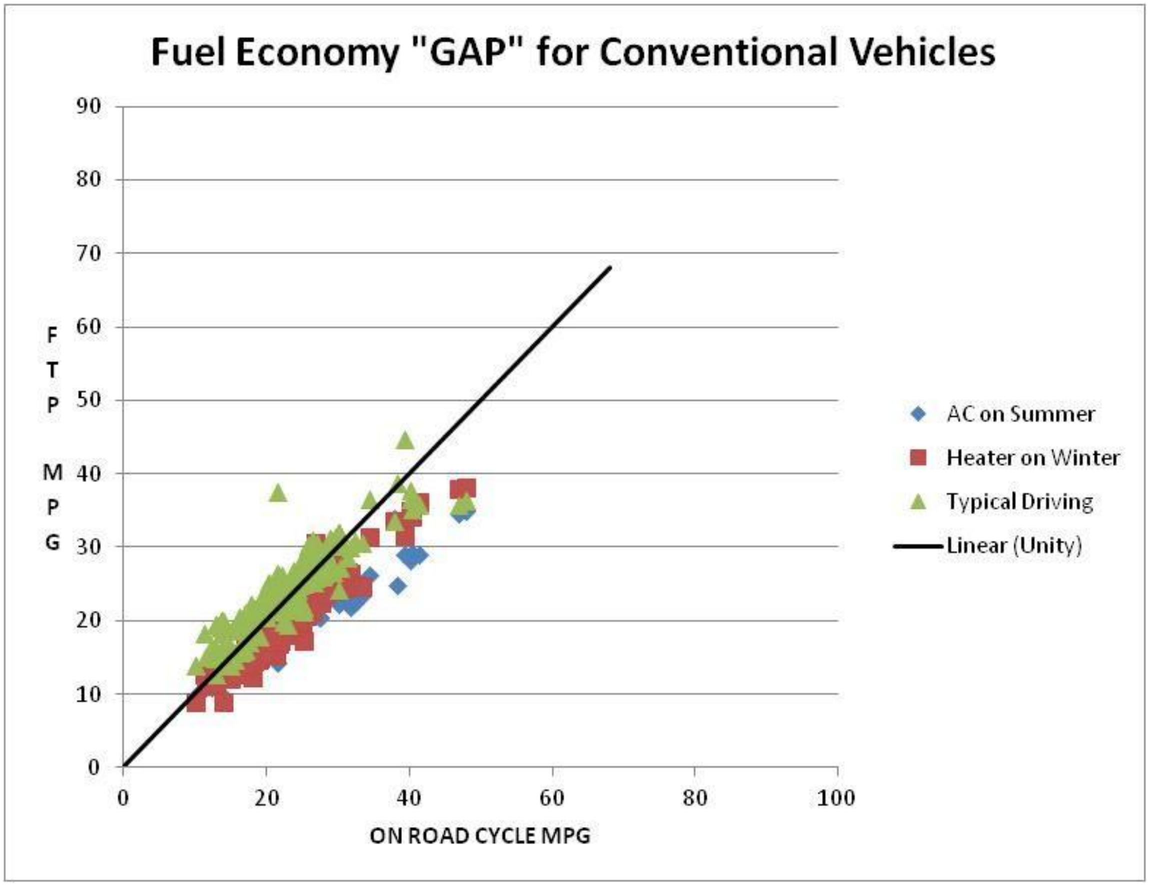
EPA conducted an additional study in 2006[13] confirming that HEVs operate substantially differently on the road than they do during official testing. Based on a 2006 review of several independent studies EPA concluded:

1. Hybrid vehicles showed a slightly greater impact of **aggressive driving** on fuel economy than conventional gasoline vehicles (**33% lower fuel economy versus 29% lower fuel economy for a conventional vehicle**).
2. Hybrid vehicles tended to show greater sensitivity to air conditioning operation than conventional vehicles. **The effect of air conditioning operation reduced hybrid fuel economy by 31 percent, compared to the 20 percent impact on conventional vehicle fuel economy.**
3. Overall, conventional gasoline vehicles averaged a **cold temperature effect of about 11 percent lower fuel economy, while the impact on hybrid vehicles averaged about 32 percent lower fuel economy.**
4. The Cold Federal Test Procedure fuel economy with the heater/defroster on was significantly lower than that with the heater/defroster off, ranging from 5.8 percent lower fuel economy (~1 mile per gallon lower on a non-hybrid vehicle) to 18.4 percent lower fuel economy (~8 miles per gallon lower on a hybrid vehicle). Note the fuel economy tests used by EPA for the original fuel economy labels were conducted with the air conditioning, heater and defrosters all switched to the off position.

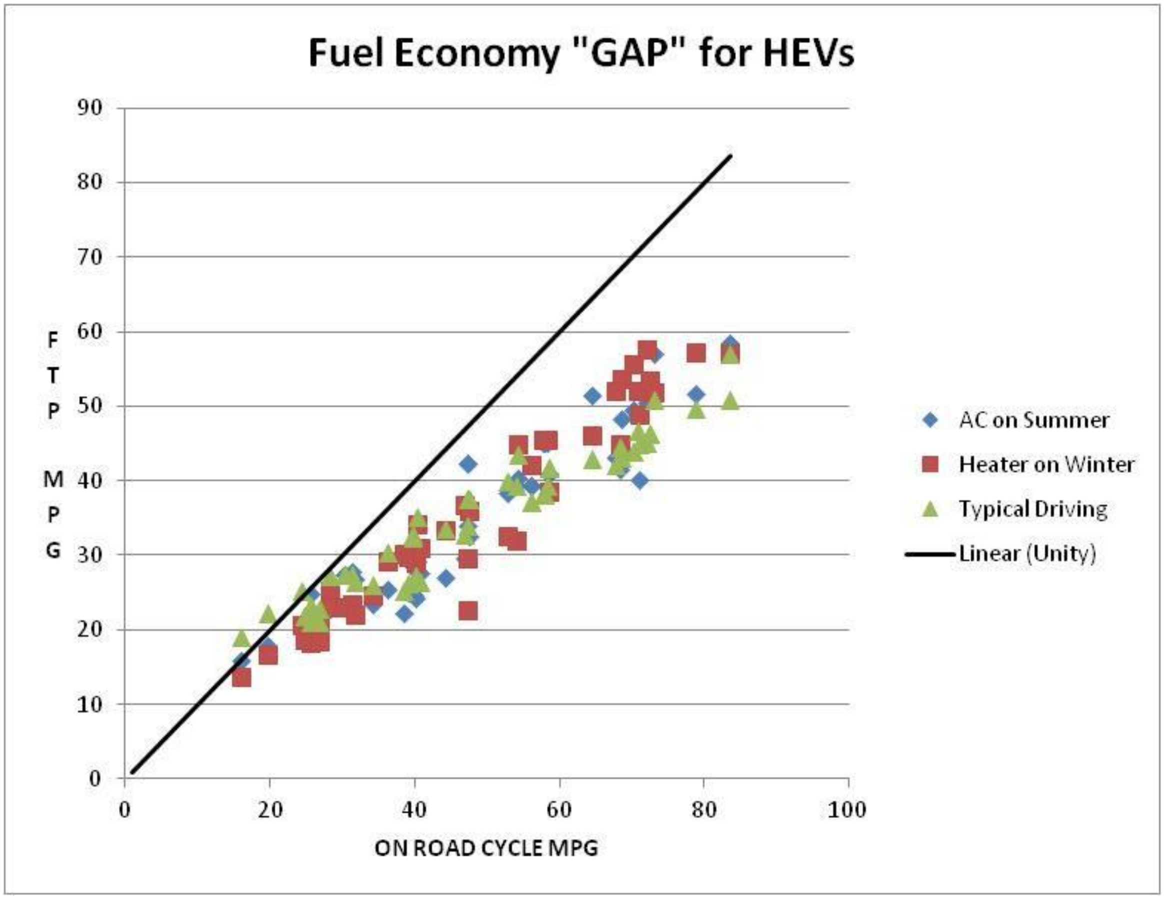
The Agency promulgated new rules effective in 2008 for fuel economy labels. These new fuel economy label requirements ***recommended*** that manufacturers conduct testing using a five-cycle test sequence (few of the producers of HEVs chose this option).

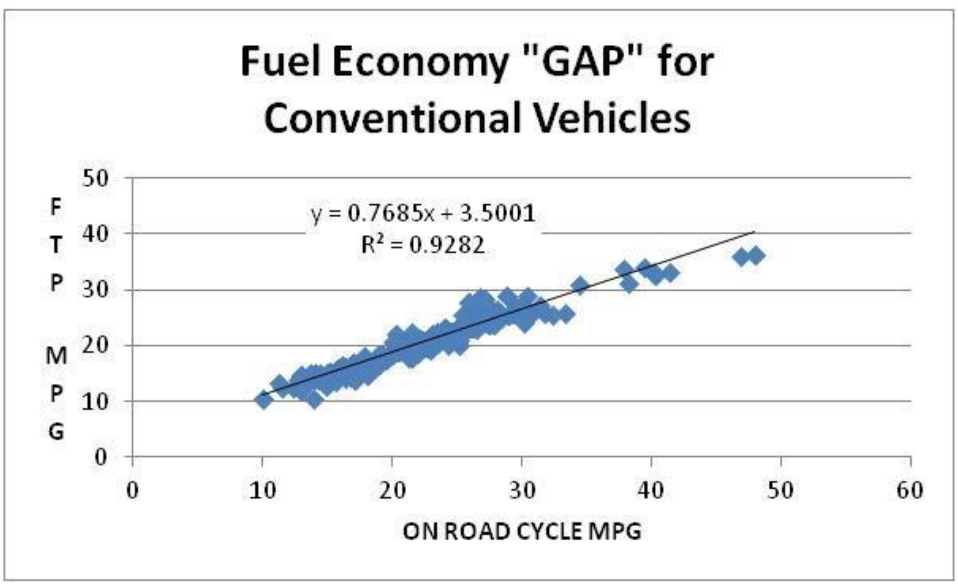
Manufacturers were given the option to conduct the full test and use the vehicle specific data to adjust their fuel economy data or were permitted to use generic fuel economy adjustment values. The Agency permitted hybrid vehicles to use the gasoline vehicle adjustment equation even though all indications at the time were that hybrid vehicles were more sensitive to these real-world driving conditions.

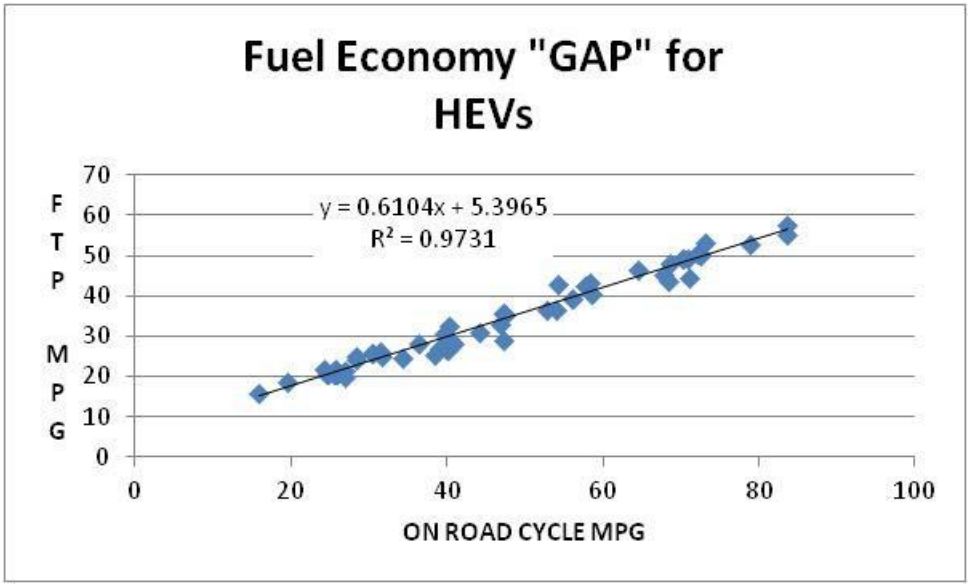
[13] Draft Technical Support Document; Fuel Economy Labeling of Motor Vehicles: Revisions to Improved Calculation of Fuel Economy Estimates; EPA420-D-06-002; January 2006



Fuel Economy "GAP" for Conventional Vehicles
FTP MPG
ON ROAD CYCLE MPG
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
AC on Summer
Heater on Winter
Typical Driving
Linear (Unity)


Fuel Economy "GAP" for HEVs
FTP MPG
ON ROAD CYCLE MPG
AC on Summer
Heater on Winter
Typical Driving
Linear (Unity)
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100


Fuel Economy "GAP" for Conventional Vehicles
FTP MPG
ON ROAD CYCLE MPG
y = 0.7685x + 3.5001
R² = 0.9282
0
10
20
30
40
50
0
10
20
30
40
50
60



For purposes of this analysis, I combined the data[13] from three of the "on road" test cycles (SCO3 – AC on Summer, US06 – typical driving, and the Cold CO – Heater on Winter) that EPA uses in into a single gap. The values of the gap range from 0 to 19 percent for conventional technology and from 3 percent to 33 percent for hybrid electric vehicle technology with the gap increasing as the test fuel economy increases.

Based on this, **the CAFE model must be revised to reflect a dynamic gap and the gap must be technology-specific.**

4. Is there an alternative approach that you would suggest?

Add a provision to the model that allows a technology specific gap. This is critical for start- stop technologies, HEVs, PHEVs, and BEVs. Start-stop technologies behave in a similar manner to HEVs when the air conditioning and/heater are operational.

RESPONSE: Model inputs can be used to specify differences between laboratory and real-world energy consumption, and to specific different values for operation on gasoline and operation on electricity Inputs to NHTSA's 2016 analysis reflected expectations that this gap would be greater for electricity than for gasoline. Additional research and data is required in order to determine whether it would be practicable to accommodate technology-specific gaps, especially considering that gaps could vary between <u>combinations</u> of technologies.

5. What is your assessment of the utility of the output of the model for setting CAFE standards?

See discussion below. I would recommend that the consumer cost be revised to reflect the loss of utility and the loss of value.

[13] The data is contained in the EPA test car data sets.

Jose Mantilla

[NO RESPONSE.]

Wallace Wade

Reviewer Name:_Wallace R. Wade

Review Topic Number: _4.5 Estimation of consumer impacts from CAFE standards

Other Review Topic Numbers (if interactive effects are focus of discussions):_Topic 2.4_____

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

Although the CAFE model does not currently estimate a potential market response to changes in vehicle prices, it does contain data on initial purchase cost (2015 MSRP reported by the manufacturer) and final vehicle purchase cost (defined as 2015 MSRP plus added technology cost to meet the applicable standard) for each specific vehicle model These estimates provide a general indication of the price range of particular models, and give some indication of the starting point for manufacturer's consumer price optimization decisions.

By the time the fleet reaches a stable compliance level in MY 2028, both passenger car and truck classes of vehicles are projected to incur over $2,000/vehicle in compliance costs relative to the MY 2015 vehicle (assuming RPE methodology) Of the $2,000 cost increase, NHTSA's modeling suggests that Augural Standards will increase average vehicle technology costs by about $1,000 per vehicle relative to the average price of a new vehicle under continuation of the MY 2021 standard.

However, NHTSA cannot predict the extent to which each manufacturer will choose to mix price increases, other cost reductions, and reduced margins in the aggregate, or how these decisions will be distributed across the vehicles in each manufacturer's fleet.

To the extent that new vehicle cost increases are passed on to consumers, other consumer cost elements that scale with purchase price, including interest on car loans, insurance, and some taxes and fees would also increase. NHTSA's analysis includes estimates of some of these types of impacts.

While new car buyers are likely to pay more to purchase, register, and insure their new vehicles under the CAFE standards, they will pay less to operate them. Consumers might consider the "payback period" for incremental technology, which is defined as the number of years of the accumulated dollar value of fuel savings needed to recover the additional cost of technology.

The payback period associated with the technology cost increases for new cars and trucks for the 2021 baseline standards, the Augural standards and the total 2025 standards, using the same projected fuel prices, based on the EIA's Annual Energy Outlook, are shown in Figure 13.41and indicate the following:

- Payback periods under all three scenarios are generally longer for cars than for trucks. Passenger cars have comparable average per-vehicle costs under the total program, but start from higher fuel economy levels Improving the fuel economy of the less efficient trucks, which are driven more miles leads to greater savings and shorter payback periods.
- The payback period for the Augural Standards is longer than either the baseline standards or the combined total 2025 standards, for much the same reason as above.
- By MY 2030, the payback period for cars is about 4.4 years and for trucks is about 3.1 years.

NHTSA applies a one-year payback period in its compliance and technology application analysis (and assumes manufacturers will recoup all direct and indirect costs and realize normal levels of profit). This one-year payback assumption attempts to address the possible concerns with assuming either that new car and truck buyers place no value on fuel economy or place a sufficiently high value on additional fuel economy to contradict historical observations of preferences in the new car market (where trends toward smaller, more fuel efficient vehicles under high fuel price scenarios have typically retreated as the fuel price fell).
(2016 Draft TAR, pp. 13-93 to 13-99)

Concern 1:
The statement on p. 13-99 that "NHTSA applies a 1-year payback period in its compliance and technology application analysis" appears to differ from the following comments on page 13-10 (2016 Draft TAR):
"The default assumption in the model is that manufacturers will treat all technologies that pay for themselves within the first 3 years of ownership (through reduced expenditures on fuel) as if the cost of that technology were negative. This holds true up to the point at which the manufacturer achieves compliance with the standard – after which the manufacturer treats all technologies that pay for themselves within the first year of ownership as having a negative effective cost."

Recommendation 1:
The payback periods used in the Volpe Model should be clearly explained, particularly with respect to when the three year payback period is used and when the one year payback period is used In addition, the comment that "manufacturers will treat all technologies that pay for themselves within the first three years of ownership (through reduced expenditures on fuel) as if the cost of that technology were negative" needs to be explained. (Is this applied only in the technology selection process rather than in the calculation of initial cost increases? Are the negative costs calculated using Equation 5 for effective cost [p. 25])?

RESPONSE: The reference to "negative costs" refers to negative values obtained when calculating the "effective cost" by applying the equation 5 from the model documentation The model documentation will more fully explain the meaning and application of these payback periods, and a new Regulatory Impact Analysis will more fully explain corresponding input values applied by NHTSA. Some manufacturers' comments support applying payback period of 2 to 3 years.

Concern 2:
It is not clear if the payback periods discussed in Concern1 apply to 1) the entire list of technologies used to meet the MY 2025 CAFE standard, or 2) the incremental list of technologies used to meet the Augural CAFE standards, or 3) to each incrementally added technology for any to the CAFE standard scenarios?

Recommendation 2:
Clarify when the various payback periods (one year, three years) apply. For example, explain whether the payback periods apply to: 1) the entire list of technologies applied to meet the MY 2025 CAFE standard, or 2) the incremental list of technologies used to meet the Augural CAFE standards, or 3) to each incrementally added technology for any to the CAFE standard scenarios.

RESPONSE: The payback period is an input that determines the quantity of fuel savings to be included when calculating the "effective cost" (shown as equation 5) of each potential application of technology See also response to recommendation 1 above.

Concern 3:
EPA and NHTSA assumed a short-run demand elasticity of -1 to convert a change in price into a change in quantity demanded of vehicles (EPA RIA, 2012) An elasticity of -1 means that a 1 percent increase in price leads to a 1 percent reduction in quantity sold (EPA, Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, August 2012, p. 8-1)

With an average vehicle price of $34,000, the estimated $2,000 increase for the MY 2025 standards would result in a 5.9 percent increase in vehicle price If the estimated price elasticity of demand of -1 is correct, then a 5.9 percent decline in sales might result (1 x $2,000/$34,000 x 100).

Recommendation 3:
Address the impact of the possible 5.9 percent decline in sales on the economy and the automotive industry in the TAR and /or other appropriate documentation.

RESPONSE: The model has been revised to estimate impacts on industry sales and employment.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The assumptions regarding the application of payback periods are not clear, as explained in Concerns 1 and 2, above The impact of the estimated price elasticity of demand of around - 1 and the associated impact on the decline in sales, as explained in Concern 3, need to be addressed.

RESPONSE: See responses to recommendations 1-3 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1-3, together with any appropriate modifications to the model and the model documentation that may result.

RESPONSE: See responses to recommendations 1-3 above.

4. Is there an alternative approach that you would suggest?

No. Implementation of Recommendations 1-3, together with any appropriate modifications to the model that may result, is the suggested approach.

RESPONSE: See responses to recommendations 1-3 above.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

Implementation of Recommendations 1-2 together with any appropriate modifications to the model that may result, will enhance the utility and plausibility of the Volpe Model output Implementation of Recommendation 3 addressing the impact of the estimated 5.9 percent decline in sales on the economy and the automotive industry in the TAR and /or other appropriate documentation will also enhance the utility and plausibility of the Volpe Model output.

RESPONSE: See responses to recommendations 1-3 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
4. Model operations
4.1. Dynamic application of technology to each manufacturer's fleet to minimize effective costs based on the CAFE standards for the current model year, defined as the difference between the incremental cost of a technology and the value of fuel savings produced by the technology over three years of vehicle ownership (iterative process until the most effective technology is found) by manufacturer and model year
4.2. Approach to estimating vehicle survival and use (i.e., vehicle miles traveled), including the model's application of the input defining a "rebound" effect
4.3. Approach to estimating total emissions of "criteria" pollutants (e.g., nitrogen oxides) and greenhouse gases (e.g., methane) other than carbon dioxide.
4.4. Model results for industry response to CAFE Standards
4.5. Estimation of consumer impacts from CAFE standards
4.6. Model results for social, economic and environmental effects of CAFE standards (costs, benefits, and quantities)
4.7. Sensitivity of augural standards net benefits to high and low value assumptions of factors such as fuel price, rebound, etc.

Nigel Clark

Reviewer Name:_ Nigel N. Clark

Review Topic Number: 4.6. Model results for social, economic and environmental effects of CAFE standards (costs, benefits, and quantities)

Other Review Topic Numbers (if interactive effects are focus of discussions):

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   The CAFE model purpose is supported by reporting the real world fuel economy benefits arising from enforcement of the standard.

   RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comment, and note that manufacturers have choices (e.g., adjusting fleet mix) beyond those currently simulated by the CAFE model.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   The model employs a defensible methodology, but reliable/accurate input data are hard to define. Vehicle survival rates vary regionally and by owner type, and hence the miles that they are driven are difficult to identify. Driving schedules and terrain play a major role. Older vehicles, as one example, will deteriorate in efficiency, often with higher rolling resistance tires in place, and poor combustion left uncorrected. It is well known that the CAFE standards themselves are not a good indicator. But an approximate number can be projected.

   RESPONSE: Consistent with 49 U.S.C. 32902 and 32904, the CAFE model's compliance calculations assume fuel consumption inputs reflect the test procedure used for fuel economy certification. The model also accommodates inputs estimating differences between laboratory and real-world conditions, and uses these adjustments when estimating impacts on national fuel consumption.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   None. To increase accuracy would need the addition of a substantial module and new input data to the model.

4. Is there an alternative approach that you would suggest?

   No.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

   An approximate quantification of fuel saved, projected by the model, will serve to promote the national benefit of the standards.

7. Provide any additional comments that may not have been addressed above.

   If these output benefit calculations become a major thrust, they will require additional resources to increase their real-world accuracy.

   RESPONSE: See response to 1 above.

Walter Kreucher

REVIEW TOPIC NUMBER 4.6. MODEL RESULTS FOR SOCIAL, ECONOMIC AND ENVIRONMENTAL EFFECTS OF CAFE STANDARDS (COSTS, BENEFITS, AND QUANTITIES)

1. What are the most important concerns that should be taken into account related to the review topic?

   The model does not seem to account for lost jobs or sales transfers. I raise this as an issue because in a number of cases the model results in setting standards that demand year-over-year changes higher than the manufacturer has ever accomplished. (see 4.4 above)

   RESPONSE: The model has been revised to estimate impacts on sales and employment.

Jose Mantilla

Reviewer Name: Jose Mantilla

Review Topic Number: 4.6 – Model results for social, economic and environmental effects of CAFE standards

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.*]

1. What are the most important concerns that should be taken into account related to the review topic?

The methodologies for the calculation of fuel consumption, greenhouse gas emissions and emissions of criteria pollutants are reasonable. However, the fundamental components of the estimations have not been properly discussed. In addition, the respective interactions between the different factors of relevance to the calculation of fuel consumption, greenhouse gas emissions and criteria pollutants are not properly discussed. As such, the reader is left with the need to 'fully trust' the information presented rather than being able to critically evaluate it.

RESPONSE: Sections 3-5 of the model documentation describe the methodologies applied in order to calculate fuel consumption, greenhouse gas emissions, and criteria pollutant emissions, with the structure of relevant model inputs described in Appendix A (Section A.3). Specific values used as inputs are determined when the model is exercised, and methods and data involved in developing these inputs are explained in the Regulatory Impact Analysis accompanying any given rulemaking. Insofar as these inputs are developed using other models (e.g., EPA's MOVES model, Argonne's GREET model), they are documented by the organization that develop and maintain these models. We are not certain what further steps the reviewer would deem necessary for a "proper discussion."

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

Insufficient information is provided to assess the reasonableness and appropriateness of data, computation methods and assumptions – specifically the assumptions and methodology for the estimation of emission rates for each criteria pollutant for each vehicle. Similarly, the assumptions and methodology for the estimation of fuel production/distribution emissions rates are not presented. These are (perhaps the most) critical inputs to the calculation of criteria air pollutant emissions; as such, additional information should be provided in the Model Documentation with respect to the sources and methods used to derive these rates.

RESPONSE: See response to 1 above.

A detailed discussion of the differences in real-world versus rated fuel efficiency and emission levels should be presented. This should be accompanied by a discussion of the effects on overall (by vehicle and fleetwide) estimates.

The information presented in the Draft TAR is potentially technically sound and valid; however, it has been presented in a manner that appears unnecessarily confusing and could be significantly enhanced and clarified. For example, I make reference to the following paragraph on page 13-100:

> *Of particular note in Figure 13.42 is the magnitude of the difference in emissions savings for the conventional tailpipe pollutants (NOx and PM). Since the 2012 final rule analysis was conducted, additional tailpipe standards have been implemented that reduce the long-term emissions of these pollutants, and the increase in total VMT relative to the 2012 analysis increases the opportunity to reduce emissions. While the additional VMT associated with the rebound effect does increase the emissions of conventional pollutants from vehicle tailpipes, the reduction in upstream emissions from avoided fuel consumption is significantly larger - and produces social benefits.*

On first reading, this paragraph implies that an increase in VMT produces social benefits. I understand that the document is discussing the relative magnitudes of changes in emissions from vehicle use and fuel refining/distribution. However, while an increase in fuel efficiency will indeed result in a reduction in upstream emissions on a per mile basis, an increase in VMT will necessarily imply more upstream emissions. As such, I deem this paragraph to be potentially technically incorrect, poorly written, potentially contradictory and/or overwhelmingly confusing.

RESPONSE: This paragraph attempted to communicate four factors influencing total future NOx and PM emissions: (a) "organic" VMT growth, (b) reduced fuel consumption resulting from increasing fuel economy, (c) additional VMT attributable to the rebound effect also resulting from increased fuel economy, and (d) tighter tailpipe emissions standards. It also attempted to communicate that total future NOx and PM emissions reflect the sum of tailpipe and upstream emissions. Since 2016, the model has been revised to provide means to estimate impacts on sales, fleet composition, and fleet turnover, all of which impact total emissions. Corresponding portions of the Regulatory Impact Analysis will reflect these changes and attempt to more clearly explain the several factors that influence calculated total emissions.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Pending a satisfactory resolution of the need for a more detailed discussion of the rationale for the determination of the fuel consumption and emission factors, and the way in which real-world vs rated levels are considered, advice can be provided on potential modifications. **RESPONSE: See response to 1 above.**

4. Is there an alternative approach that you would suggest?

Pending a satisfactory resolution of the need for a more detailed discussion of the rationale for the determination of the fuel consumption and emission factors, and the way in which real-world vs rated levels are considered, advice can be provided on alternative approaches. **RESPONSE: See response to 1 above.**

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

The review topic is of critical importance to the overall utility and plausibility of the Volpe Model output. The potential changes in fuel consumption and emissions are a fundamental aspect of (and reason for) the implementation of CAFE standards. The methodologies used for estimating fuel consumption and emissions are reasonable but would benefit from additional justification and explanation. **RESPONSE: See responses to 1 and 2 above.**

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Wallace Wade

Reviewer Name:_Wallace R. Wade

Review Topic Number: _4.6. Model results for social, economic and environmental effects of CAFE standards (costs, benefits, quantities)

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.*]

1. What are the most important concerns that should be taken into account related to the review topic?

Criteria Pollutants and Greenhouse Gas Emissions:

In addition to conserving the nation's energy, two significant benefits of CAFE standards are the reduction in criteria pollutants that affect individual health and the reduction in greenhouse gas emissions that affect climate change.

Figure 13.42 shows that "the savings in emissions, fuel gallons, and fuel quads of total energy consumption are generally larger under the draft TAR analysis than the 2012 analysis." The significant reduction in criteria pollutants is primarily the result of additional tailpipe standards that have been implemented since the 2012 analysis although VMT increased.

Concern 1:
The 2016 Draft TAR states that, although VMT associated with the rebound effect increases the emissions of conventional pollutants from vehicle tailpipes, the reduction in upstream emissions from "avoided fuel consumption" is significantly larger - and produces social benefits. This observation appears to contradict Figure 13.42 which shows that the gallons of fuel saved relative to the 2012 analysis is slightly negative, implying an increase in fuel consumption instead of the stated "avoided fuel consumption." It is not clear why the "significant reduction in conventional pollutants" from vehicle tailpipes with Tier 3 emission requirements was not large enough to offset the rebound effect of increased VMT.

Recommendation 1:
Review, clarify, and modify as appropriate, the 2016 Draft TAR comments regarding Figure 13.42 with particular attention to:

- The slightly negative savings in gallons of fuel consumed (implying an increase in gallons of fuel consumed) and reconcile with the comment regarding "avoided fuel consumption" (implying a decrease in fuel consumption).
- Why the significant reduction in conventional pollutants with Tier 3 requirements from vehicle tailpipes was not large enough to offset the rebound effect of increased VMT, which was modest.

RESPONSE: Since 2016, the model has been revised to provide means to estimate impacts on sales, fleet composition, and fleet turnover, all of which impact total fuel consumption and emissions. Model documentation has been updated to discuss how the model preforms these calculations, and the Regulatory Impact Analysis discusses how they interact and combine to produce estimates of total fuel consumption and emissions.

Societal Safety:

NHTSA's analysis indicates that the amount of mass reduction applied to passenger cars has been limited to achieve overall neutral societal safety, thus showing a pathway manufacturers could use to comply with the Augural Standards that has small net reductions in fatalities over the period when considering both mass reduction and increased VMT.

Overall Benefits:

Table 13.25 summarizes the costs and benefits associated with the implementation of the Augural Standards for MYs 2022 – 2025, relative to the continuation of the MY 2021 standard over the same period (through MY 2028). Highlights of Table 13.25 are:

- The primary benefit of CAFE standards accrue as a result of avoided fuel expenditures by new car and truck buyers. This single category of benefits is sufficient to ensure that the Augural Standards result in net benefits, both to society and to buyers of new vehicles.
- Other significant social benefits are the value of time savings associated with less frequent refueling events and the value of additional travel with more efficient vehicles.
- Energy security represents reduction in the economic risk associated with dependence on oil and exposure to price shocks.
- The social cost of carbon emissions represents estimates of the reduction in long-term economic impact of global climate change.
- Conventional pollutant category represents the health savings from reducing exposure to conventional pollutants.

(2016 Draft TAR, pp. 13-99 to 13-103)

<u>Concern 2:</u>

The 2016 Draft TAR concludes that "While the sum of benefits accruing to buyers of new cars and trucks significantly exceeds the additional cost of new technology borne by those consumers, the benefits associated with 'social externalities' (only) do not. This was true for the analysis supporting the 2012 final rule CAFE standards as well." The comment that "the benefits associated with social externalities (only) do not" exceed the additional cost (implied) is not clear, and requires an explanation of the specific social externalities that are referred to and the relevant additional costs which are not exceeded.

(2016 Draft TAR, p. 13-102)

Recommendation 2:

Provide an explanation of the comment in the 2016 Draft TAR (p. 13-102) that "the benefits associated with social externalities (only) do not" have benefits that exceed the additional costs, and provide an explanation of the specific social externalities that are referred to in this comment and the relevant additional costs which are not exceeded.

RESPONSE: The 2016 Draft TAR presented a highly summarized discussion of impacts. The Regulatory Impact Analysis accompanying the proposed rule provides a fuller description of the various components included in private and social costs and benefits. Model documentation has also been updated.

Concern 3:

The Social Benefits from the Augural CAFE standards are listed in Table 13.25. The value of the first benefit, (1) Fuel Savings, can be calculated from the sum of fuel savings associated with all the vehicles analyzed. However, the calculations of the economic benefits of the other Social Benefits, including: (2) Refueling Time Savings, (3) Energy Security, (4) Social Cost of Carbon Emissions, (5) Increased Mobility, and (6) Conventional Pollutants) are not apparent and need further explanation.

Brief explanations of how costs are assigned to each of these Social Benefits are provided in the CAFE Model Documentation starting on page 49 and are summarized below (where the headings from the CAFE Model Documentation are shown in parentheses following the headings from Table 13.25):

1) Pre-Tax Fuel Savings (Value of Fuel Savings):
The economic value of fuel savings to buyers of new vehicle models whose fuel economy is improved by applying the forecast (an input to the model) of future retail fuel prices to each year's estimated fuel savings for those models. The total annual fuel savings for a model during each year of its lifetime in the vehicle fleet is multiplied by the number of those initially sold that are expected to remain in use during that year.

2) Refueling Time Savings (Extended Refueling Range):
The CAFE model calculates the reduction in the annual number of required refueling cycles that results from improved fuel economy.

3) Energy Security (Reduced Petroleum Imports):
The reduction in petroleum imports resulting from higher CAFE standards is estimated by assuming that the resulting savings in gasoline use during each future year is translated directly into a corresponding reduction in the annual volume of U.S. oil imports during that same year. The value to the U.S. economy of reducing

petroleum imports – in the form of lower crude oil prices and reduced risks of oil supply disruptions – is estimated by applying the sum of the previously reported estimates of these benefits to the estimated annual reduction in oil imports.

4) Social Cost of Carbon Emissions:
The model estimates changes in damage costs caused by carbon dioxide emissions by multiplying the magnitude of the change in emissions by the estimated value of damages per unit of emissions.

5) Increased Mobility (Additional Driving):
The benefits from this additional travel exceed the costs drivers and their passengers incur in making more frequent or longer trips. The amount by which the additional travel exceeds its cost represents the increase in consumer surplus associated with additional rebound effect driving. The system estimates the value of these benefits using the conventional approximation of one half of the product of the decline in fuel cost per mile driven and the resulting increase in the annual number of miles driven.

6) Conventional Pollutants (Changes in Environmental Impacts):
The CAFE modeling system estimates the economic value of the net change in emissions of criteria pollutants using estimates of the economic damage costs per ton of emissions of each of these pollutants.

Recommendation 3-1:

Make appropriate revisions to the Social Benefit names so that they are consistent between Table 13.25 in the 2016 Draft TAR and the CAFE Model Documentation (where the headings from the CAFE Model Documentation are shown in parentheses following the headings from Table 13.25 in the above listing of the Social Benefits).

RESPONSE: Model documentation will be updated to make nomenclature and treatment more consistent with external analysis of model-estimated components of private and social costs and benefits.

Recommendation 3-2 (Social Benefit 2):

Explain how the annual number of required refueling cycles is converted into costs shown in Table 13.25.

RESPONSE: Section S7.4 of the model documentation will be revised to more fully explain how these costs are calculated.

Recommendation 3-3 (Social Benefit 3):

Explain how "the sum of the previously reported estimates of lower crude oil prices and reduced risks of oil supply disruptions" are derived (and converted to consistent units of value), and then the sum is applied to the "estimated annual reduction in oil imports" to calculate the value of reduced petroleum benefits. Explain the sources of the information needed for these calculations.

RESPONSE: Relevant model inputs are listed in Appendix A.3.4 to the model documentation. Section S7.6.2 will be updated to more fully explain how these inputs are applied. As indicated, these are all applied on a dollar per gallon basis. The development of specific values used as model inputs will be discussed in the Regulatory Impact Analysis.

Recommendation 3-4 (Social Benefit 4):

Explain how the damage costs caused by carbon dioxide emissions are estimated.

RESPONSE: Section S7.6.3 of the model documentation explains how these damage costs are calculated. Specific values used as model inputs will be explained in the Regulatory Impact Analysis.

Recommendation 3-5 (Social Benefit 5):

Explain the source and derivation of the "conventional approximation" of one half of the product of the decline in fuel cost per mile driven and the resulting increase in the annual number of miles driven for calculating the value of increased mobility.

RESPONSE: The Regulatory Impact Analysis will provide a fuller discussion of the estimated value of the benefits of additional driving.

Recommendation 3-6 (Social Benefit 6):

Explain the source and derivation of the estimates of the economic damage costs per ton of emissions of each of the criteria pollutants.

RESPONSE: The Regulatory Impact Analysis will provide a fuller discussion of these input values.

Recommendation 3-7:

Provide appropriate references for the explanations of the derivations of the cost savings associated with each of the Social Benefits discussed above (Recommendations 3-2 to 3-6).

RESPONSE: The Regulatory Impact Analysis will provide a fuller discussion of these input values.

Concern 4:

The footnote to "Social Cost of Carbon Emissions" in Table 13.25 states "Social cost of carbon to be added." This is confusing since Table 13.25 already has cost entries for all columns associated with "Social Cost of Carbon Emissions."

Recommendation 4:

Resolve the concern regarding the footnote to "Social Cost of Carbon Emissions" in Table 13.25 which states "Social cost of carbon to be added" since the table already has cost entries for all columns associated with "Social Cost of Carbon Emissions."

RESPONSE: The Regulatory Impact Analysis will provide a fuller discussion of the various components of estimated private and social costs and benefits.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

Concerns 1-4 above need to be addressed to ensure that the computational methods and assumptions are reasonable.

RESPONSE: See responses to recommendations 1-4 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implementation of Recommendations 1-4 is the suggested approach and is expected to result in modifications to the Volpe Model documentation.

RESPONSE: See responses to recommendations 1-4 above.

4. Is there an alternative approach that you would suggest?

No. Implementation of Recommendations 1- 4 is the suggested approach. **RESPONSE: See responses to recommendations 1-4 above.**

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

With the resolution of Concerns 1-4 by the implementation of Recommendations 1-4, the utility of the output of the Volpe Model for setting CAFE standards will be enhanced. **RESPONSE: See responses to recommendations 1-4 above.**

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
4. Model operations
4.1. Dynamic application of technology to each manufacturer's fleet to minimize effective costs based on the CAFE standards for the current model year, defined as the difference between the incremental cost of a technology and the value of fuel savings produced by the technology over three years of vehicle ownership (iterative process until the most effective technology is found) by manufacturer and model year
4.2. Approach to estimating vehicle survival and use (i.e., vehicle miles traveled), including the model's application of the input defining a "rebound" effect
4.3. Approach to estimating total emissions of "criteria" pollutants (e.g., nitrogen oxides) and greenhouse gases (e.g., methane) other than carbon dioxide.
4.4. Model results for industry response to CAFE Standards
4.5. Estimation of consumer impacts from CAFE standards
4.6. Model results for social, economic and environmental effects of CAFE standards (costs, benefits, and quantities)
4.7. Sensitivity of augural standards net benefits to high and low value assumptions of factors such as fuel price, rebound, etc.

Nigel Clark

Reviewer Name:_ Nigel N. Clark

Review Topic Number 4.7. Sensitivity of augural standards net benefits to high and low value assumptions of factors such as fuel price, rebound, etc.

Other Review Topic Numbers (if interactive effects are focus of discussions):

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   There is a natural inclination to inquire about the robustness of the model in the face of changing external factors. This analysis helps to address that inquiry.

   RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comment, and note that sensitivity analysis using the CAFE model can help to understand the robustness of different model results.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   Yes. The model itself is likely to be reasonably reliable. It can be used to determine benefits that occur as a variety of factors is changed. Data are credible, although no high battery cost case appears in the report.

   RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comment, and note that cost inputs can be adjusted to examine alternative estimates. A new Regulatory Impact Analysis will discuss cases included in an updated sensitivity analysis.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   None to the model, but sensitivity analysis by perturbing inputs is valuable. Addition of some runs with high and low costs for some technology implementations would also be valuable. Low rolling resistance tires tend to lose their relative benefit against baseline tires as both wear. This (including tire replacement with regular tires) would be another topic to examine through sensitivity.

   RESPONSE: The sensitivity analysis included in the Regulatory Impact Analysis accompanying the proposed rule explores a wider range of options than the 2016 analysis. The model does not currently accommodate inputs that would handle changes in fuel economy over the course of the vehicle's useful life, such as would occur as components wear and/or are replaced with components other than those used for vehicle certification, in part because this is not a central concern of the CAFE program according to Congress. The model does,

however, apply inputs specifying the expected (relative) difference between laboratory and real-world (a.k.a. “on road”) fuel economy, and the RIA includes cases exploring the sensitivity of results to changes in this input value.

4. Is there an alternative approach that you would suggest?

   None offered.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

   This is very useful in presenting the model, and discussing its application amidst future uncertainty.

   RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comment, and note that model inputs can be adjusted to examine sensitivity of results to a wide range of alternative estimates and assumptions.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

   None.

Walter Kreucher

REVIEW TOPIC NUMBER 4.7. SENSITIVITY OF AUGURAL STANDARDS NET BENEFITS TO HIGH AND LOW VALUE ASSUMPTIONS OF FACTORS SUCH AS FUEL PRICE, REBOUND, ETC.

1. What are the most important concerns that should be taken into account related to the review topic?

   It strikes me as odd that the sensitivity runs impact manufactures in different directions.

Sensitivity Runs PC (Sensitivity Run FE- Actual FE) A positive number means the case evaluated is higher than actual as measured in MPG - 2017 MY Results																
	BMW	Daimler	Fiat Chrysler	Ford	GM	Honda	Hyundai/KIA	Jaguar Land Rover	Mazda	Mitsubishi	Nissan	Subaru	TESLA	Toyota	Volvo	VW
VOLPE Base	(0.8)	1.9	6.8	1.6	3.5	(0.3)	1.3	(2.3)	2.4	(1.3)	0.8	4.7	(122.0)	(0.3)	(0.5)	2.8
dBase Tech	(1.6)	1.3	4.3	0.0	2.5	(1.4)	1.0	(2.4)	2.3	(2.1)	0.7	3.7	(122.0)	(0.4)	(0.5)	1.9
High VMT	(1.5)	1.3	4.4	0.0	2.3	(1.5)	0.9	(2.3)	2.3	(2.0)	0.7	3.7	(122.0)	(0.4)	(0.5)	1.9
Cost Markup ICM	(1.6)	1.3	5.9	0.7	6.0	(3.9)	(8.0)	9.7	3.4	(3.9)	1.8	207.1	(326.9)	(5.7)	(0.7)	9.4
Low Battery Cost	(1.5)	1.4	4.1	0.0	2.3	(1.5)	0.9	(2.2)	2.3	(2.0)	0.7	1.6	(122.0)	(0.4)	(0.5)	1.9
Very High SCC	(1.5)	1.3	4.4	0.0	2.3	(1.5)	0.9	(2.3)	2.3	(2.0)	0.7	3.7	(122.0)	(0.4)	(0.5)	1.9
Longer Product Cadence	(2.0)	0.3	4.5	(0.2)	(0.4)	(1.8)	(0.3)	(4.6)	3.2	(0.7)	1.3	(0.5)	(122.0)	(0.9)	(0.6)	1.5
Low Oil Price	(1.7)	1.1	4.4	0.0	2.2	(1.5)	0.8	(2.3)	2.3	(2.1)	0.9	1.9	(122.0)	(0.4)	(0.5)	1.7

Sensitivity Runs LT (Sensitivity Run FE- Actual FE) A positive number means the case evaluated is higher than actual as measured in MPG - 2017 MY Results																
	BMW	Daimler	Fiat Chrysler	Ford	GM	Honda	Hyundai/KIA	Jaguar Land Rover	Mazda	Mitsubishi	Nissan	Subaru	TESLA	Toyota	Volvo	VW
VOLPE Base	(0.5)	2.6	(0.2)	(0.7)	1.1	1.9	4.9	(1.3)	1.3	1.3	1.1	1.9	0.0	(0.1)	(4.9)	2.3
dBase Tech	(0.5)	2.7	(0.2)	(1.2)	1.1	1.1	3.7	(1.3)	1.0	1.3	1.1	1.4	0.0	(0.0)	(4.9)	2.3
High VMT	(0.5)	2.7	(0.1)	(1.2)	1.1	0.9	3.8	(1.3)	1.0	1.3	1.1	1.4	0.0	(0.1)	(4.9)	2.3
Cost Markup ICM	(0.5)	2.8	(0.2)	(1.1)	1.1	0.9	3.8	(1.2)	0.6	1.3	1.1	1.2	0.0	(0.1)	(4.9)	2.3
Low Battery Cost	(0.5)	2.7	(0.2)	(1.2)	1.1	0.9	3.8	(1.3)	1.0	1.3	1.4	0.5	0.0	(0.1)	(4.9)	2.3
Very High SCC	(0.5)	2.7	(0.2)	(1.2)	1.1	0.9	3.8	(1.3)	1.0	1.3	1.1	1.4	0.0	(0.1)	(4.9)	2.3
Longer Product Cadence	(0.3)	0.8	0.6	(1.2)	(0.6)	(0.3)	3.2	(1.9)	1.3	1.3	(0.5)	(0.3)	0.0	(1.8)	(5.0)	0.7
Low Oil Price	(0.5)	2.6	(0.2)	(1.0)	1.1	1.0	3.8	(1.4)	1.3	1.3	0.9	0.6	0.0	(0.1)	(4.9)	2.0

Sensitivity Runs PC (Sensitivity Run Regulatory Costs) A positive number means the case evaluated is higher than the base case for Augural Standards 2025 - in $Million																
	BMW	Daimler	Fiat Chrysler	Ford	GM	Honda	Hyundai/KIA	Jaguar Land Rover	Mazda	Mitsubishi	Nissan	Subaru	TESLA	Toyota	Volvo	VW
dBase Tech	$ -	($2.8)	($262.0)	($169.9)	$27.1	$157.5	($56.5)	$ -	($42.1)	($5.2)	$239.4	$9.8	$ -	($289.8)	$ -	$ -
High VMT	$ -	$0.1	($222.8)	($107.4)	($169.1)	$196.8	($79.7)	$ -	($103.1)	($8.8)	$61.7	$10.6	$ -	($552.6)	$ -	$ -
Cost Markup ICM	$8.5	$7.8	($265.2)	($80.4)	($135.1)	$36.1	($166.7)	$ -	($154.4)	($29.7)	$192.5	($7.2)	$ -	($559.4)	$ -	$ -
Low Battery Cost	($44.3)	($71.3)	($393.7)	($447.9)	($459.9)	$196.8	($514.5)	($0.9)	($115.4)	($19.9)	$241.6	$23.0	$ -	($551.7)	$ -	($30.7)
Very High SCC	$ -	($2.8)	($223.2)	($135.4)	($138.3)	$196.8	($72.8)	$ -	($105.8)	($5.2)	$241.6	$10.4	$ -	($551.7)	$ -	$ -
Longer Product Cadence	$ -	($12.4)	($426.4)	($1.8)	($553.4)	($123.8)	($1,313.1)	$ -	($107.1)	($5.1)	$257.1	$59.1	$ -	($697.5)	$ -	$ -
Low Oil Price	($28.2)	($38.7)	($285.4)	($325.4)	($303.7)	$73.9	($139.1)	($2.2)	($132.1)	($14.7)	$58.8	($4.0)	$ -	($400.3)	($4.2)	($62.4)

Sensitivity Runs LT (Sensitivity Run Regulatory Costs) A positive number means the case evaluated is higher than the base case for 2025 - in $Million																
	BMW	Daimler	Fiat Chrysler	Ford	GM	Honda	Hyundai/KIA	Jaguar Land Rover	Mazda	Mitsubishi	Nissan	Subaru	TESLA	Toyota	Volvo	VW
dBase Tech	$4.0	$4.5	($976.3)	$44.1	($771.6)	$181.8	($23.1)	$ -	($4.5)	$14.6	($66.8)	($2.5)	$ -	($1,107.8)	$ -	$0.0
High VMT	$2.0	$41.7	($1,191.9)	$91.3	($1,526.7)	$122.5	($27.7)	$ -	($75.7)	$7.0	($140.3)	($15.5)	$ -	($1,149.1)	$ -	$0.0
Cost Markup ICM	($2.6)	$ -	($1,295.9)	($132.4)	($1,723.0)	$4.4	($25.5)	$ -	($98.0)	($4.9)	($49.5)	($28.7)	$ -	($1,173.4)	$ -	($43.1)
Low Battery Cost	$31.5	$8.7	($1,190.3)	($535.3)	($1,840.9)	$122.5	($156.4)	($3.2)	($75.7)	$4.1	($110.1)	$27.2	$ -	($1,154.1)	$ -	$5.6
Very High SCC	$2.0	$4.5	($734.5)	($44.3)	($1,562.3)	$122.5	($27.7)	$ -	($75.7)	$16.8	($72.6)	($2.5)	$ -	($1,154.1)	$ -	$0.0
Longer Product Cadence	($1.6)	$16.5	($295.2)	($1,245.5)	($984.8)	($168.5)	($81.2)	$ -	($88.6)	($0.1)	$206.5	$413.5	$ -	($889.6)	$ -	($43.1)
Low Oil Price	$18.7	$18.7	($1,162.5)	$292.8	($1,302.4)	$192.9	$47.2	$7.2	($66.9)	$20.8	$234.5	$19.5	$ -	($435.6)	$4.7	($25.1)

It is not clear why the longer product cadence would lower regulatory costs (technology cost plus fines) when the standards remain the same.

RESPONSE: Except for cases involving changes only to inputs involving economic externalities, all sensitivity analysis cases are likely to impact specific manufacturers in different ways. In some cases, these differentiated impacts arise through indirect effects that may be difficult to intuit; for example, a case involving higher VMT will change the valuation of avoided fuel consumption, which will impact manufacturer-specific estimates of technology choices and

degrees of under- or over-compliance. Page 13-104 of the 2016 Draft TAR explains the case there presented involving product cadence:

> ***"As we also saw in the discussion of sensitivity to industry outcomes, product cadence may play an important role. The figure shows that a longer assumed cadence, which has the potential to reduce manufacturers' opportunities to comply with an increase in standards during the year in which it occurs, is likely to result in additional technology into products redesigned in earlier model years. Similarly, shorter cadence increases the opportunities for manufacturers to respond to increasingly stringent standards in the model years where the increases occur – forcing more of the technology cost, and fuel savings benefit, into the model years covered by the Augural Standards."***

Also, at a manufacturer-specific level, if longer cadence results in less technology being applied in early model years, this could result in less technology being carried forward into future model years, and inherited by other vehicles on shared platforms and/or sharing engines or transmissions. The directions and magnitudes of these incremental effects should depend on other inputs, such as those defining the stringency of the standards, the manufacturer's willingness to treat civil penalties as an economic choice, the regulatory rate (e.g., $5.5 per 0.1 mpg) of civil penalties, and the payback period.

The Regulatory Impact Analysis will discuss cases included in an updated sensitivity analysis.

Jose Mantilla

[NO RESPONSE.]

Wallace Wade

Reviewer Name: _Wallace R. Wade

Review Topic Number: _4.7. Sensitivity of augural standards net benefits to high and low value assumptions of factors such as fuel price, rebound, etc.

Other Review Topic Numbers (if interactive effects are focus of discussions):_Topic 4.5___

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

Figure 13.44 shows the sensitivities of the augural standards net benefits when the assumptions are ranked by their degree of influence on an outcome. It illustrates the change in net benefits attributable to the Augural Standards that results from using the alternative assumptions described in Table 13.22.

Concern 1:
The x axis of Figure 13.44 is not labeled. The figure caption implies the x axis is "Percent Change in Influence on Net Benefits Attributable to Augural Standards." The 0 percent point should be clarified, but is presumed to be the $85 billion net benefits over the lifetimes of MYs 2016-2028 vehicles using 3 percent discount rate (in 2013 dollars) as shown in Table 13.25.

Recommendation 1:
Provide a label for the x axis of Figure 13.44 and explain the 0 percent point (presumed to the $85 billion net benefits over the lifetimes of MYs 2016-2028 vehicles using 3 percent discount rate (in 2013 dollars) as shown in Table 13.25).

RESPONSE: As implied by the figure title, the x axis for this figure is in percentage change in net benefits. A new Regulatory Impact Analysis will label axes of included graphs.

Highlights from Figure 13.44 are:

- Assumed Fuel Prices have the largest influence on the net benefits attributable to the Augural Standards. The low fuel price case reduces net social benefits by nearly 30 percent, while the high fuel price case increases net benefits by over 80 percent.
- Assuming no Rebound effect increases net benefits by about 15 percent, and assuming a high rebound effect reduces them by 30 percent.
- Increasing the Demand for Fuel Economy with a payback period of 36 months increases the net benefits by about 5 percent, while decreasing the payback period to 0 months decreases the net benefits by over 35 percent.
- A longer assumed cadence by 2 years, which has the potential to reduce manufacturers' opportunities to comply with an increase in standards during the year in which it occurs, will likely result in additional technology into products redesigned in earlier model years, which decreases net benefits by 12 percent. Shorter cadence increases the opportunities for manufacturers to respond to

increasingly stringent standards in the model years where the increases occur, forcing more of the technology cost, and fuel savings benefit, into the model years covered by the Augural Standards (which increases net benefits by 20%).

- Including up to 20 percent mass reduction for passenger cars reduces net benefits by about 20 percent due to the impact on overall societal safety. In contrast, allowing no mass reduction on passenger cars results in a 2 percent increase in net benefits.
- Lower battery costs (at $100/kWh) and mass reduction costs (at a fraction of the NAS costs) will increase net benefits by about 18 and 14 percent respectively.

Recommendation 2-1:

Table 13.22, Definition of Sensitivity Cases Considered for Draft TAR, should include the range of actual fuel prices for the low and high cases. The range of fuel prices for the baseline case should also be clearly described.

RESPONSE: Input files used for each case in the sensitivity analysis were released with the 2016 Draft TAR, and will be released with the new Regulatory Impact Analysis. The RIA will provide summarized information regarding the fuel prices defining the low and high oil price cases.

Recommendation 2-2:

The baseline case for Demand for Fuel Economy should be clearly described as a specific payback period in months, which can be compared to the high 36-month value and low 0 month value shown in Table 13.22. Concern 1 and Recommendation 1 in the Review of Topic 4.5 addresses the payback period assumptions for the baseline case (i.e., Is it 12 months or 36 months until after compliance with the CAFE standard when it decreases to 12 months?).

RESPONSE: See responses to cited recommendation under Topic 4.5. The Regulatory Impact Analysis discusses updated sensitivity analysis cases involving the payback period.

Recommendation 2-3:

The specific increases or decreases in net benefits for the high and low cases for Product Cadence should be provided in the text on p. 13-104 (the specific changes in benefits for the high and low cases are provided in the above discussion of highlights of Figure 12.44).

RESPONSE: Compared to 2016 Draft RIA's single-chapter summary of DOT's modeling results, the Regulatory Impact Analysis will provide a fuller review of all results, including cases included in the sensitivity analysis.

Recommendation 2-4:

A consistent description for the low Mass Reduction case should be provided. The text on p. 13-105 indicates the low case is “no mass reduction on passenger cars.” However, Table 13.22 shows the low case is “All PCs stop at MR1 (unless they already have > MR1).” The baseline case should also be provided, as described in Table 4-52 (assuming this correctly defines the baseline case).

Table 4.52 Criteria for Limiting Additional Application of Mass Reduction Technology in the CAFE Analysis

Platforms with a sales weighted average of less than 2800 lbs. may not apply more mass reduction technology.
SmallCar vehicles may not add new MR technology to proceed past MR2.
MediumCar vehicles may not add new MR technology to proceed past MR2.

RESPONSE: The Regulatory Impact Analysis will discuss changes to model inputs defining estimated initial levels of mass reduction, and defining the availability of additional mass reduction included in the reference case and in cases included in the sensitivity analysis.

<u>Recommendation 2-5:</u>

Specify the quantitative value of the “Fraction of the NAS costs” for the low case of Mass Reduction costs.

RESPONSE: The Regulatory Impact Analysis will discuss the definition and specification of cases included in an updated sensitivity analysis.

<u>Recommendation 2-6:</u>

Revise Table 13.22 to include a column showing the “baseline case” for all sensitivities studied.

RESPONSE: Compared to 2016 draft RIA’s single-chapter summary of DOT’s modeling results, the Regulatory Impact Analysis will provide a fuller review of all results, including the baseline case included in the sensitivity analysis.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

Although the data, computational methods and assumptions are likely reasonable, Recommendations 1 and 2-1 to 2-6 should be implemented to ensure that the data and assumptions are clearly stated.

RESPONSE: See responses to recommendations 1 and 2-1 to 2-6 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1 and 2-1 to 2-6 to ensure that the data and assumptions are clearly stated. **RESPONSE: See responses to recommendations 1 and 2-1 to 2-6 above.**

4. Is there an alternative approach that you would suggest?

No. Implementing Recommendations 1 and 2-1 to 2-6 is the suggested approach. **RESPONSE: See responses to recommendations 1 and 2-1 to 2-6 above.**

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

Implementing Recommendations 1 and 2-1 to 2-6 will enhance the utility and plausibility of the Volpe Model output. **RESPONSE: See responses to recommendations 1 and 2-1 to 2-6 above.**

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

CAFE Peer Review Responses

REVIEW TOPIC
5. Overall model assessment
5.1. The organization, readability, accuracy, and clarity of the model documentation.
5.2. The organization, structure, and clarity of the model input files.
5.3. The organization, structure, and clarity of the model output files
5.4. The model's ease and clarity of operation.
5.5. Any other comments you may have on the CAFE model.

Nigel Clark

Reviewer Name:_ Nigel N. Clark

Review Topic Number: 5. Overall model assessment

Other Review Topic Numbers (if interactive effects are focus of discussions):

Provide an objective assessment of the Volpe Model approach for the review topic:

1. What are the most important concerns that should be taken into account related to the review topic?

   The model should be defensible, and the accompanying material should be thorough and readable.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

   The model is impressive in its detail, and in the completeness of the input data that it uses. Although the model is complex, the reader is given a clear account of how variables are variously divided and combined to yield appropriate granularity and efficiency within the model. The model tracks well a simplified version of the real-world and manufacturing/design decisions. The progression of technology choices and cost benefit choices is clear and logical. In a few cases, the model simply explains a constraint, or a value assigned to a variable, without defending the choice of the value or commenting on real-world variability, but these are not substantive omissions. The model will lend itself well to future adaptation or addition of variables, technologies and pathways. Kudos to the model developers and technical experts involved.

   RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comments, and note that with every release of a new version of the model accompanying a CAFE rulemaking analysis, the Notice of Proposed Rulemaking (NPRM) is followed by a comment period that provides opportunity for all stakeholders and the public to review and formally comment on the model

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

   My version of the model required .xls input files rather than .xlsx - the user instructions presented .xlsx - but this was a small issue. The model, and its substantial input files, will be readily employed by anyone but a complete novice to the area.

   RESPONSE: We thank the reviewer for noting this issue; the model documentation will be updated to clarify hardware and software requirements, and file formatting.

4. Is there an alternative approach that you would suggest?

   No.

5. [SKIP FOR REVIEW TOPICS 4.4 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

   None.

Walter Kreucher

REVIEW TOPIC NUMBER 5.1. THE ORGANIZATION, READABILITY, ACCURACY, AND CLARITY OF THE MODEL DOCUMENTATION.

1. What are the most important concerns that should be taken into account related to the review topic?

   The documentation is clear and for the most part covers the current version. There are anomalies that are likely the result of model changes that do not appear in the current version of the documentation. (See issues in the comment section below)

REVIEW TOPIC NUMBER 5.2. THE ORGANIZATION, STRUCTURE, AND CLARITY OF THE MODEL INPUT FILES.

2. What are the most important concerns that should be taken into account related to the review topic?

   Inputs are logically laid out and clear.

   RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comment, and note that this review has identified several opportunities to further clarify the interpretation and application of model inputs.

REVIEW TOPIC NUMBER 5.3. THE ORGANIZATION, STRUCTURE, AND CLARITY OF THE MODEL OUTPUT FILES

3. What are the most important concerns that should be taken into account related to the review topic?

   The “raw” output files are a handful.

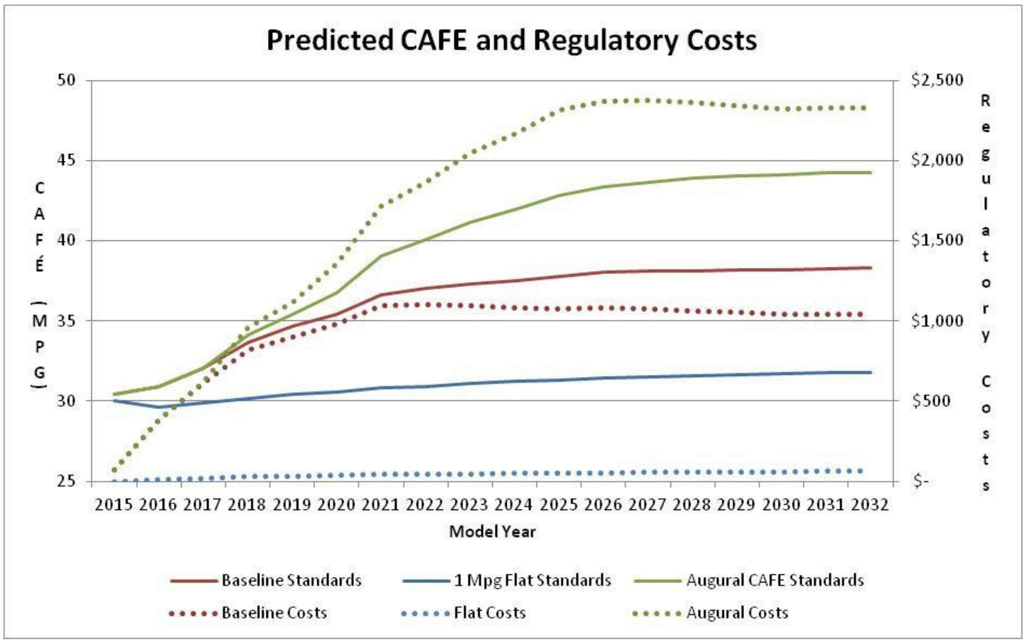
   There is no clear way to wade through the output files in any expeditious manner that would facilitate an easy review by anyone who didn’t build the model.

   I suspect that there is a mechanism that VOLPE uses to take the output files and condense them into a manageable format for review by the policymakers and management. This element should be added to the program for ease of use.

   I would recommend adding a file that shows the bottom line in terms of costs and benefits. A figure or two would also facilitate the review and understanding the results.

   RESPONSE: While Volpe Center staff will continue to explore ways to make output files easier to review, much of the output files’ scale and complexity is unavoidable if the model is to provide detailed transparency. Past versions of the model produces Excel-formatted output files. More recently versions produce text-formatted output files that can be examined in Excel, but can also be examined with other analytical software. Excel’s auto-filtering

capability is useful for reviewing these files. Volpe Center staff will consider posting other “off-model” tools Volpe Center staff have developed to analyze and summarize model output files, even though these tools are not intended for wider use. Past versions of the CAFE model produced output files that compared aggregated costs to aggregated benefits. More recent versions have deemphasized these aggregations, because various monetized impacts could be characterized as either costs or, with a change in sign, benefits. A new Regulatory Impact Analysis will discuss NHTSA’s approach to treating various monetized impacts as costs or benefits. Volpe Center staff will revisit the potential to also include these total values in model output files.



The “Costs” in this figure are the total costs to achieve the fuel economy level (the compliance model shows the incremental cost over the baseline).
I was shocked to see there was so much technology still around in the out years that the model predicted manufacturers were willing to add in the absence of additional regulations (over seven miles per gallon).

The compliance files also show that the “standard” in 2032 is higher than it is in 2016 even though the scenario input file shows no change in the standard and the footprint change (0.6) does not account for the large difference in stringency. This does not seem realistic. What is driving the increase in standards in the baseline case?

RESPONSE: Model inputs underlying the published 2016 analysis indicated that, beyond the MY 2015-level technology present in the analysis fleet, considerable technology could be available through 2032 that would quickly “pay back” and therefore be attractive even absent regulation. Different inputs would have shown different results. The baseline scenario (specified in the “scen_baseline” worksheet of the “scenarios” input file released in 2016) involves standards that continue to increase in stringency through MYH 2021, and then continue at 2021 levels through 2032.

All	Augural Standards 2022 - 2025	
Social Costs		
Technology Cost	$ 63,826,305,569	from Compliance Report
Fines	$ 4,866,639,022	from Compliance Report
Maintenance Cost	$ 2,215,857,356	from Compliance Report
Crashes, Fatalities, Congestion, Noise	$ 8,381,169,736	From Annual Societal Cost Report
Taxes & Fees	$ 3,750,634,774	from Compliance Report
Financing	$ 10,523,759,111	from Compliance Report
Insurance	$ 13,209,653,246	from Compliance Report
Relative Value Loss	$ 1,500,548	from Compliance Report
Lost Fuel Tax Revenue	$ 22,148,109,750	From Annual Societal Cost Report
Social Benefits		
Pre Tax Fuel Savings	$ 166,413,218,334	From Annual Societal Cost Report
Refueling Time Savings	$ 8,393,530,671	From Annual Societal Cost Report
Energy Security	$ 12,076,148,095	From Annual Societal Cost Report
Social Cost of Carbon Emissions	$ 36,970,592,098	From Annual Societal Cost Report
Increased Mobility	$ 12,661,524,286	From Annual Societal Cost Report
Conventional Pollutants	$ 51,618,000,938	From Annual Societal Cost Report
Net Benefit/(Cost)	$ 159,209,385,309	

PC	Augural Standards 2022 - 2025	
Social Costs		
Technology Cost	$ 28,435,589,258	from Compliance Report
Fines	$ 3,484,000,114	from Compliance Report
Maintenance Cost	$ 736,652,526	from Compliance Report
Crashes, Fatalities, Congestion, Noise	$ 13,037,325,315	From Annual Societal Cost Report
Taxes & Fees	$ 1,744,722,301	from Compliance Report
Financing	$ 4,895,447,921	from Compliance Report
Insurance	$ 6,144,873,599	from Compliance Report
Relative Value Loss	$ 1,500,548	from Compliance Report
Lost Fuel Tax Revenue	$ 6,651,754,474	From Annual Societal Cost Report
Social Benefits		
Pre Tax Fuel Savings	$ 49,831,205,820	From Annual Societal Cost Report
Refueling Time Savings	$ 3,024,833,024	From Annual Societal Cost Report
Energy Security	$ 3,624,733,207	From Annual Societal Cost Report
Social Cost of Carbon Emissions	$ 11,067,157,279	From Annual Societal Cost Report
Increased Mobility	$ 3,789,594,116	From Annual Societal Cost Report
Conventional Pollutants	$ 15,639,046,708	From Annual Societal Cost Report
Net Benefit/(Cost)	$ 21,844,704,099	

LightTruck	Augural Standards 2022 - 2025	
Social Costs		
Technology Cost	$ 34,740,458,985	from Compliance Report
Fines	$ 1,382,638,908	from Compliance Report
Maintenance Cost	$ 1,481,377,826	from Compliance Report
Crashes, Fatalities, Congestion, Noise	$ (3,676,965,688)	From Annual Societal Cost Report
Taxes & Fees	$ 1,970,408,424	from Compliance Report
Financing	$ 5,528,691,767	from Compliance Report
Insurance	$ 6,939,735,162	from Compliance Report
Relative Value Loss	$ -	from Compliance Report
Lost Fuel Tax Revenue	$ 15,250,456,797	From Annual Societal Cost Report
Social Benefits		
Pre Tax Fuel Savings	$ 114,783,926,069	From Annual Societal Cost Report
Refueling Time Savings	$ 5,304,650,445	From Annual Societal Cost Report
Energy Security	$ 8,319,633,499	From Annual Societal Cost Report
Social Cost of Carbon Emissions	$ 25,502,751,457	From Annual Societal Cost Report
Increased Mobility	$ 8,694,625,098	From Annual Societal Cost Report
Conventional Pollutants	$ 35,417,465,902	From Annual Societal Cost Report
Net Benefit/(Cost)	$ 134,406,250,289	

Looking at the costs and the benefits from the Compliance Report file and the Annual Societal Cost Report, the costs are not offset by the benefits.

RESPONSE: A new Regulatory Impact Analysis will review updated model estimates of the various components of estimated costs and benefits, and resultant estimates of net benefits for various regulatory alternatives.

REVIEW TOPIC NUMBER 5.4. THE MODEL'S EASE AND CLARITY OF OPERATION.

1. What are the most important concerns that should be taken into account related to the review topic?

   (See below)

REVIEW TOPIC NUMBER 5.5. ANY OTHER COMMENTS YOU MAY HAVE ON THE CAFE MODEL.

1. I see that the "SUM" column in the "upstream emissions" worksheet of the "parameters" file is blank for electricity, hydrogen, and compressed natural gas. Does the program pick up these parameters from elsewhere in the program or does it ignore these emissions?

   RESPONSE: The model's input structure for upstream emissions has been revised to accommodate (and apply) values that change over time. Model documentation will be updated accordingly.

2. Are the values used based on the latest GREET program? If not they should be updated.

   RESPONSE: See response to 1 above. A new Regulatory Impact Analysis will discuss the basis for specific input values.

3. In the "Market Data" file, FCA is listed as NOT preferring fines yet the NHTSA data shows they routinely pay fines. This parameter should be set to "Y" for the real-world scenarios.

   RESPONSE: In fact, FCA has only rarely paid civil penalties for non-compliance over the history of the CAFE program, and their relative readiness to pay those penalties represents a more recent phenomenon. See NHTSA's CAFE Compliance website at https://onewww.nhtsa.gov/cafe_pic/CAFE_PIC_Home.htm. A new Regulatory Impact Analysis will discuss input values specifying manufacturers' anticipated willingness to treat civil penalties as an "economic option" rather than as something to be avoided at all costs.

4. Regulatory Class and Technology Class should be defined. The model works in EPA "space" when it looks at carbon dioxide emissions and in NHTSA "space" when dealing with fuel economy. The two agencies use different definitions for what constitutes a car and a truck. Does the Vehicle Worksheet of the Market Data Workbook use "regulatory class" to refer to the categorization for CAFE purposes (NHTSA definitions)? Or for emission purposes (EPA definitions)?

   RESPONSE: The model documentation discusses the difference between regulatory and technology classes, but the corresponding section of the table in the appendix will be revised to emphasize this difference. Regulatory classification specifies a given vehicle model/configuration's treatment for regulatory purposes, and technology classification directs the model toward the most appropriate set of technology-related inputs. As discussed in footnote 9: *"Such groups [of vehicles impacted by a specific technology application] can span regulatory classes. For example, if the algorithm is evaluating a potential upgrade to a given engine, that engine might be used by a station wagon, which is regulated as a passenger car, and a minivan, which is regulated as a light truck. If the manufacturer's passenger car fleet complies with the corresponding standard, the algorithm accounts for the fact that upgrading this engine will incur costs and realize fuel savings for both of these vehicle models, but will only yield reductions of CAFE fines for the light-truck fleet."* The same principle applies to technology classes; for example, 2WD and 4WD versions of a given small SUV would be classified, respectively, as a passenger car and light truck, even though both would be classified as a small SUV for purposes of technology application.

5. The model only recognizes .xls files and not the later version .xlsx.

   RESPONSE: Agreed; the model documentation will be updated to clarify hardware and software requirements, and file formatting.

6. The model should have a failsafe cap on annual spending per manufacturer set at a rate of 2% of the US automotive revenue.

   RESPONSE: The reviewer has not provided a citation or basis for this specific of a recommendation. While past versions of the model provided means to have the model "seek" stringency levels that satisfied user-specified criteria, including limits on costs, more recent versions of the model simply evaluate specific user-specified scenarios. If the reviewer is suggesting that industry should not be required to spend more than 2% of "U.S. automotive revenue" to meet CAFE standards, that would be a policy goal rather than an analytical one. The determination of what levels of CAFE standards would be maximum feasible is an exercise conducted outside the model itself, and involves consideration of all the relevant factors, with costs entering into the consideration of economic practicability.

7. When adding SHEVP2 or SHEVPS to a class 2 truck, there should be some loss of utility in terms or space available, trailer towing, and payload capacity (i.e., customer valuation?). Also, the technology cost seems unrealistic. The technology is shown as less expensive than the cost of the technology for a medium size passenger car. A system that would work in a Fusion would not be nearly durable enough or powerful enough to work in an F250. The scale is wrong.

   RESPONSE: The model has been revised to accommodate inputs for a wider range of technology "classes." Because costs are specified on an incremental basis relative to preceding technologies, incremental cost input values for any specific technology may not be easily comparable across technology classes. A new Regulatory Impact Analysis will discuss inputs specific to towing-capable pickup trucks.

8. Selection of "Leader" vehicle platform seems counter-intuitive. My experience working in industry is that CAFE planners will select the "Leader" as the vehicle with the highest CAFE leverage. The planner will look at the vehicle (or engine) that is furthest below the standard neglecting low volume applications. From this point, the planner will determine what changes can be made that will have the greatest impact on fleet fuel economy at the lowest cost.

   RESPONSE: The model's approach to identifying specific vehicle model configurations as leaders has been revised, and corresponding model documentation has been updated.

9. If the model assumes a 30-year life for a hybrid electric vehicle, or an electric vehicle then it must account for at least one traction battery replacement and probably two replacements during the useful life. This also brings up the subject of disposal of the batteries that contain hazardous waste. How are these costs factored into the equation?

   RESPONSE: The model applies inputs defining expected vehicle survival and mileage accumulation as functions of vehicle age. Inputs from 2016, and more recently, reflect a small share of vehicles (about 2% of cars and about 10% of light trucks) still in service after 30 years of operation. The model also applies any input value for the (differential) consumer value attributable to hybrid or electric vehicles (or any other technology); updates to these values will be discussed in a new Regulatory Impact Analysis, and the used car value data used to develop these inputs likely reflects, among other things, the value implications of battery replacement.

10. The “USED” technology filter for AERO1 and AERO2 do not reflect the current C_d values for the vehicles in the “Market Data” workbook. EPS and other technologies also seem to be out of date.

    RESPONSE: Model input values indicating estimated initial levels of aerodynamic performance, and presence of specific technologies (e.g., EPS) have been updated, as discussed in a new Regulatory Impact Analysis.

11. The “USED” technology filter for MR1 should be added across the board as manufacturers have already implemented substantial mass reductions just to offset the mass of NHTSA safety regulations. An alternative is to increase the cost of the technology.

    RESPONSE: Model input values indicating estimated initial levels of mass reduction have been updated, as discussed in a new Regulatory Impact Analysis.

12. The report uses the same descriptors to mean two different things. “Consumer Costs” and “Societal Costs” have different definitions depending on which output file you are reviewing. This can lead to confusion when discussing the output of the report.

    RESPONSE: Model documentation will be updated to more clearly differentiate between consumer and societal costs.

13. The lost fuel tax revenue from the higher standards must be added to the cost of compliance.

    RESPONSE: Fuel taxes are among the costs calculated and reported by the model. Avoided fuel taxes are appropriately counted as benefits to consumers, but being transfers, not as costs to society. A new preamble and Regulatory Impact Analysis will seek comment on implications for the Highway Trust Fund.

14. The model appears to have imbedded in it historical data that appears in some of the output files. This should be specified in the documentation.

    RESPONSE: This historical data is among the set of information in the input files. Documentation of these input values will be included in the input files and, as appropriate, in a new Regulatory Impact Analysis.

Total Social Cost

Compliance Report

The total social costs accumulated by the manufacturer for a specific model year and regulatory class. The social costs are the sum of: discounted technology costs, maintenance costs, repair costs, loss of value, and relative loss of value.

Societal Cost Report

Total social costs accumulated by the industry for a specific model year, regulatory or vehicle class, and fuel type. The social costs are the sum of: pre-tax fuel costs, drive surplus, refueling surplus, market externalities, congestion costs, accident costs, noise costs, fatality costs, and emissions damage costs (CO, VOC, NO_x, SO_2, PM, CO_2, CH_4, and N_2O).

Total Consumer Cost

Compliance Report

The total consumer costs accumulated by the manufacturer for a specific model year and regulatory class. The consumer costs are the sum of: discounted technology costs, fines, taxes & fees, financing costs, insurance costs, maintenance costs, repair costs, loss of value, and relative loss of value.

Societal Cost Report

Total consumer costs accumulated by the industry for a specific model year, regulatory or vehicle class, and fuel type. The consumer costs are the sum of: retail fuel costs, drive surplus, and refueling surplus.

Note: since the costs to the manufacturer are typically passed on to the consumer, the total consumer costs in the societal cost report should also reflect technology costs, fines, taxes and fees, financing costs, insurance costs, maintenance costs, repair costs, loss of value, and relative loss of value.

RESPONSE: A new Regulatory Impact Analysis will discuss NHTSA's reconsideration of assignment of various types of costs to total consumer and/or social, and these will be reflected in future model and documentation revisions.

OTHER ISSUES/COMMENTS

1. Why do all manufacturers (except Tesla) have FFV credits?

   RESPONSE: These model inputs can be specified at any value. The published 2016 analysis reflected the assumption that all manufacturers (except Tesla, whose business model does not include production of non-EVs) could improve their respective compliance positions by earning the maximum available quantity of FFV credit.

2. Pursuant to regulations, credits cannot be carried forward from the 2010MY for use against the cross fleet trading program.

   RESPONSE: Inputs specifying banked credits from model years prior to 2016 have been updated, as discussed in a new Regulatory Impact Analysis.

3. There seems to be some discrepancies in the availability of credits in the input file. They do not appear to match those available pursuant to NHTSA reports.

   RESPONSE: Inputs specifying banked credits from model years prior to 2016 have been updated, as discussed in a new Regulatory Impact Analysis.

4. How is compliance with the minimum Domestic Production requirement handled in the model?

   RESPONSE: The model has been updated to account for the requirement that domestic and imported car fleets comply separately. Inputs are used to assign each passenger car vehicle model/configuration to either the domestic or imported fleet. The model applies these values, but does not assign them

5. The fine changed in 2019 not 2014MY

   RESPONSE: Inputs specifying the civil penalty rate have been updated, as discussed in a new Regulatory Impact Analysis.

6. The models use of rounding is incorrect. The regulations specify the number of decimal places for calculating CAFÉ and determining fines.

   RESPONSE: The model uses different levels of rounding for different purposes. For "rolling" calculations of fuel economy ratings, CAFE levels, and civil penalties, the model uses unrounded calculations. For compliance calculations, the model uses rounded values. Model documentation will be revised to discuss rounding.

7. The volumes are off by a substantial amount (more than ten percent) in a third of the car fleet and the majority of the truck fleet.

   RESPONSE: The analysis published in 2016 mainly addressed impacts estimated to occur after MY 2020. For the MY 2020 fleet, engineering characteristics and final production volumes will not be known until 2022. For the 2016 analysis, model inputs specified an "analysis fleet" that was based on the estimated characteristics and production volumes of vehicles in the MY 2015 fleet. These inputs were developed before final MY 2015 volumes were known. Basing these inputs on an older fleet (e.g., 2014) would have omitted technical progress first observed in the 2015 fleet (e.g., the redesigned Ford F-150). In NHTSA's judgment, the more recent fleet provided a better basis for estimating impacts 5 to 15 years into the future.

8. It is not clear how the model is used to determine the level of stringency in the standard. The model responds to inputs (including a set of standards), how is the choice of equations made?

   RESPONSE: The model is neither intended nor used to determine stringency. The model estimates impacts of standards specified as model inputs. Choices about the form and stringency of standards are made outside the model.

9. The definitions in the documentation for the Compliance Report say that the "Regulatory Cost" is the sum of the "Technology Cost" and "Fines." When I looked at the file, this did not seem to be the case. If the definition is wrong then it must be changed. If the model is wrong it must be changes.

   RESPONSE: The model distributes civil penalties across the manufacturer's total production, such that penalties incurred by one fleet (e.g., imported cars) may be partially passed along to vehicles in other fleets (e.g., light trucks). Model documentation will be updated to clarify the model's approach to allocating penalties and reporting total regulatory costs.

10. It is not clear what the High Cost ICM sensitivity case is representing. The case does not seem to be defined.

    RESPONSE: Page 13-92 of the 2016 Draft TAR discussed evaluation of a side case applying EPA's "ICM" approach to "marking up" direct costs. A new Regulatory Impacts Analysis will discuss calculation of costs, and related cases included in a new sensitivity analysis.

11. The language in some of the output files is imprecise. The consumer costs and societal costs are not "<u>accumulated by the manufacturer</u>" rather they are "the total consumer costs accumulated <u>are reported on a</u> manufacturer basis for a specific model year and regulatory class."

    RESPONSE: An new Regulatory Impact Analysis will discuss NHTSA's reconsideration of assignment of various types of costs to total consumer and/or social, and these will be reflected in future model and documentation revisions.

12. Why doesn't the model record the total value of fuel saved?

    RESPONSE: The model calculates changes in fuel costs and taxes, reporting results in the "Societal Costs Report."

13. The footnotes in the Appendix do not seem to be defined.

    RESPONSE: Model documentation will be updated to ensure that footnotes are displayed correctly after conversion to Adobe Acrobat (PDF) format.

14. The columns in the output tables do not match those in the current version of the documentation.

    REPONSE: Model documentation will be updated to match output tables.

15. Are the fuel share ratios used in the output reports for primary and secondary fuels the same as used in CAFÉ compliance?

    REPONSE: The shares of operation on primary and secondary fuels can differ between the compliance context and the real-world. In particular, for a manufacturer producing FFVs, the adjustment to CAFE levels may reflect levels of E85 use unlikely to occur in the real-world. Model documentation will be updated to clarify this distinction.

16. The cost of an extra set (or two) of low rolling resistance tires is not included in the lifetime repair costs. The report acknowledges they wear out faster than regular tires but there is no added cost. Edmunds.com in their true cost to own description states that low rolling resistance tires last 10,000 miles less than their conventional counterparts this means one extra set of tires over the useful life (more if the model is really using 250,000 miles as the vehicle miles travelled see number 18 below).

    RESPONSE: Inputs to the 2016 Draft TAR analysis included values reflecting estimated increases in costs for replacement tires. For each technology class, these values appear in the "Maint. Table" section of the "Technology" input file.

17. The lost highway tax revenue resulting from the higher fuel economy should be added as a "cost" of the regulation.

    RESPONSE: See response to comment 12 above. Fuel tax revenues are treated as a cost to consumers. Calculation of social costs and benefits does not include fuel tax revenues, as these revenues are considered economic transfers.

18. The model seems to have a computational problem. The fuel costs and the other “benefits” are based on the total miles traveled (~250,000 miles). They should be based on the surviving vehicle miles traveled (~150,000 miles).

    RESPONSE: To calculate fuel costs and driving-related benefits, the model applies estimates of vehicle survival and mileage accumulation, including estimates of additional driving attributable to the “rebound effect.” A new version of the model also accounts for the estimated potential that changes in the prices and fuel economy of new vehicles could impact survival and use of older vehicles.

19. Given VWs trouble with diesels, is the technology cost of diesels still viable to meet the current emission standards?

    RESPONSE: For diesel engines, the 2016 Draft TAR analysis applied model inputs reflecting costs that included the cost to comply with future criteria pollutant emissions standards.

20. A number of the VOLPE technologies are not defined.(e.g., how do the modelers define low drag brakes?).

    RESPONSE: A new Regulatory Impact Analysis will discuss the definition of various modeled technologies, and model documentation will be updated accordingly.

Jose Mantilla

5. Overall model assessment

My review of the CAFE model is intended to provide an independent perspective and technical opinion by an expert who is knowledgeable in the subject area and competent with respect to the specific nature of the CAFE model. My review is not intended to be a technical critique of the validity and robustness of the predictive tools that have been utilized in the model; of the technical inputs, data sources/acquisition processes and methodologies used; or of the mathematical accuracy of the calculations and results presented. Rather, in accepting the appropriateness of the underlying analytics my review focuses on two aspects:

- The utility of the model for gauging the impacts of proposed CAFE standards for MY 2022-25
- Ability of the Draft TAR and Model Documentation to appropriately address the necessary public information requirements – "…*share with the public the initial technical analyses of the technical issues relevant to GHG emissions and augural CAFE standards for MY 2022-25*."

5.1. The organization, readability, accuracy, and clarity of the model documentation.

The model documentation is well organized and for the most part presented in a logical sequence. However, the readability and accuracy of the documentation is variable. In many instances, better language could be utilized, the structure of specific topics be made clearer, the identification of key assumptions be made more explicit, and explanations of key model components enhanced to provide readers with an unequivocal and unambiguous appreciation of the model's functionalities and accomplishments, as well as of the interaction between model components and the application of inputs and derivation of outputs.

In particular, the purpose and application of many model components remains unclear, as they are presented using obscure and "difficult-to-understand" principles. Examples include aspects such as the approach to model manufacturers' behavior regarding multi-year planning and CAFE credits, the determination of the reference point on which to apply incremental fuel improvements, and the calculation of the synergy for fuel economy of technology 7-tuples.

In practice, readers are left to interpret for themselves much of the meaning of key model components. The explanations provided for the various model topics would benefit from explicit explanation of their significance, as well as of the approaches used for the 'calculations'.

RESPONSE: Model documentation will be revised to better communicate the meaning, purpose, and implementation of various model components. The significance of any given component typically depends on specified input values (e.g., fuel prices) that are not inherent to the model. A new Regulatory Impact Analysis will present an updated sensitivity analysis that illustrates the significance of different aspects of the model and inputs.

5.2. The organization, structure, and clarity of the model input files.

The model input files seem to be clearly identified, well organized and logically structured.

RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comment, and note that this review has identified several opportunities to further clarify the interpretation and application of model inputs.

5.3. The organization, structure, and clarity of the model output files

The model output files seem to be clearly identified, well organized and logically structured.

RESPONSE: NHTSA and Volpe Center staff agree, appreciate the comment, and note that this review has identified several opportunities to further clarify the interpretation and application of model outputs.

5.4. The model's ease and clarity of operation.

Model operation is not easy and requires significant effort and an understanding of complex technical matters and advanced mathematical techniques. The information presented in many sections assumes a high level of technical proficiency and knowledge of a wide range of technology, economics, and environmental matters. In many of these instances, succinct and simple explanations may suffice to reduce the level of 'assumed knowledge' and enhance readability and interpretation of the model's operation.

RESPONSE: As practicable as possible without detracting from its "operational" aspects, model documentation will be revised to expand the explanation of underlying concepts, many of which are discussed at greater length in Regulatory Impact Analyses.

5.5. Any other comments you may have on the CAFE model.

I note that there are a lot of new components and capabilities embedded in the CAFE Model that were not previously available in "older" versions. This provides a more robust and comprehensive modelling framework. However, the rationale for those improvements, the assumptions underlying the updates and the manner in which they have been incorporated would benefit from additional explanation.

The CAFE model documentation (included in the draft TAR and Model Documentation) provides a significant body of detailed information and analysis with respect to the key topics associated with the model. It is my view that the CAFE model is generally suitable to gauge the impacts of proposed CAFE standards for MY 2022-2025, subject to some clarification and refinement as outlined in my detailed review of topics 1 and 2 (and my preliminary comments on topic 4).

RESPONSE: To date, model documentation has emphasized "what the model does," "how the model does it," and "how to use the model," with much of the discussion of "why the model does these things" appearing in Regulatory Impact Analyses. Volpe Center staff will explore and pursue opportunities to include more of the "why" in the model documentation without detracting from the "what" and "how."

Wallace Wade

Reviewer Name:_Wallace R. Wade

Review Topic Number: _5.1. The organization, readability, accuracy, and clarity of the model documentation

Other Review Topic Numbers (if interactive effects are focus of discussions):_Topics 2.4, 3.3, 4.6

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

Compliance simulation in the Volpe Model begins with a detailed initial forecast, provided by the user, of the vehicle models offered for sale during the simulation period. The compliance simulation then attempts to bring each manufacturer into compliance with CAFE standards defined in an input file developed by the user; for example, CAFE standards that increase in stringency by 4 percent per year for 5 consecutive years, and so forth. The model sequentially applies various technologies to different vehicle models in each manufacturer's product line in order to simulate how a manufacturer might make progress toward compliance with CAFE standards. Subject to a variety of user-controlled constraints, the model applies technologies based on their relative cost-effectiveness, as determined by several input assumptions regarding the cost and effectiveness of each technology, the cost of CAFE-related civil penalties, and the value of avoided fuel expenses.
(CAFE Model Documentation, p.3)

The CAFE Model Documentation is well developed and provides clear and accurate information on the important content in the model and operation of the model. Brief explanations on how the model handles some of the more complex issues are provided, but additional details are suggested in the Recommendations, below, to enhance the understanding of how the model handles these complex issues.

Concern 1:
The "detailed initial forecast, provided by the user, of the vehicle models offered for sale during the simulation period" is not clearly explained. The 2016 Draft TAR states, "To support the Draft TAR, NHTSA purchased a commercial forecast from IHS/Polk that necessarily includes their assumptions about decisions manufacturers will have to make in order to comply with standards through MY 2021, as does the AEO 2015, which also informed the production volumes used in this analysis."
(CAFE Model Documentation, p. 3) (2016 Draft TAR, p. 13-75)

"…such an analysis fleet… may not reflect…manufacturers' plans to change product offerings by introducing some vehicles and brands and discontinuing other vehicles and brands."

(2016 Draft TAR, p. 4-54)

Recommendation 1:
An explanation of the detailed forecast should be provided. Although it appears to start with the actual MY 2015 sales of vehicle models, additional explanations would be helpful in the following areas:

1. How was the forecast developed for each future MY?
2. What kind of assumptions about decisions manufacturers will have to make in order to comply with standards through MY 2021are included in the forecast?
3. How was the IHS/Polk forecast used in conjunction with the AEO (Annual Energy Outlook) 2015 forecast?
4. AEO should be defined in the Abbreviations section (p. viii) of the CAFE Model Documentation.
5. How did the forecast handle vehicle models that are discontinued and new vehicle models that are introduced in the years after MY 2015 (such as the retirement of the Lincoln MKS or the introduction of the Ford EcoSport, Ford Ranger and Bronco)? Explain if and how these types of actions are included in the forecast, or the resulting errors by not including these actions.

RESPONSE: Model documentation will be revised to include "AEO" in the list of abbreviations. Model documentation will also be expanded to discuss recent revisions to the model's approach to "extrapolating" from the analysis fleet defined in model inputs. The development of these inputs will be discussed in a new Regulatory Impact Analysis.

Concern 2:

The CAFE Model Documentation describes "CAFE standards that increase in stringency by 4 percent per year for 5 consecutive years." In contrast to this statement, the CAFE standards are defined by CAFE target curves versus vehicle footprint for each model year.

(CAFE Model Documentation, p. 3)

Recommendation 2:
Provide an explanation of what target each vehicle is required to achieve in the Volpe model. Clarify whether the (rounded) target percentages, as mentioned in the CAFE Model
Documentation, or the actual footprint target curves are used for achieving compliance on a year by year basis. Include an explanation of how changes in wheelbase for a specific vehicle line are handled.

RESPONSE: Because Corporate Average Fuel Economy (CAFE) compliance is determined at the level of total production for sale in the United States, no vehicle need actually meet its specific fuel economy target. Model documentation will be revised to emphasize this point. A new Regulatory Impact Analysis will discuss development of inputs specifying each standard in each model year.

Concern 3:
The CAFE Model Documentation (p. 3) states, "the model applies technologies based on their relative cost-effectiveness." Is "relative cost-effectiveness" assessed based on the "effective cost" which is defined by Equation 5 (p. 25)?

Recommendation 3:
Provide a footnote on page 3 of the documentation to clarify that "relative cost-effectiveness" is assessed based on "effective cost" which is defined by Equation 5 (p. 25) (if this is the correct assumption).

RESPONSE: Model documentation will be revised to clarify the definition of the "effective cost" metric used by the model to weigh options.

Concern 4:
The CAFE Model Documentation does not appear to describe whether a certain model can be allowed to under achieve its CAFE standard while another model can compensate by over achieving its CAFE standard.

Recommendation 4:
Provide an explanation of whether a certain model can be allowed to under achieve its CAFE standard while another model can compensate by over achieving its CAFE standard.

RESPONSE: See response to recommendation 2 above.

At the conclusion of the compliance simulation for a given model year, the system contains a new fleet of vehicles with new prices, fuel types, fuel economy values, and curb weights that have been updated to reflect the application of technologies in response to CAFE requirements. For each vehicle model in this fleet, the system then estimates the following: lifetime travel, fuel consumption, and carbon dioxide and criteria pollutant emissions. After aggregating model-specific results, the system estimates the magnitude of various economic externalities related to vehicular travel (e.g., noise) and energy consumption (e.g., the economic costs of short-term increases in petroleum prices). (CAFE Model Documentation, p.3)

Initial State of the Fleet:

Concern 5:
Figure 1shows the basic structure of the input file defining the fleet's initial state. However, the example is restricted to one engine /transmission per vehicle model.

Recommendation 5:
Figure 1 should be revised to depict the more complex case where, for example, Vehicle 3 would have two different engines and /or transmissions.

RESPONSE: Model documentation will be expanded to provide figures that illustrate cases involving vehicle models offered with multiple engines and/or transmissions.

Vehicle Technology Application:

Concern 6:
Table 1, which shows CAFE Model Technologies, does not include Atkinson 2-cycle (non-hybrid) or Miller cycle engines.

Recommendation 6:
Revise Table 1 to include Atkinson 2-cycle (non-hybrid) or Miller cycle engines as candidate technologies.

RESPONSE: Model documentation will be updated such that figures illustrating technology pathways reflect all modeled technologies.

Concern 7:
Table 2, which shows CAFE Model Technologies, does not include 9- and 10-speed Automatic Transmissions or High Efficiency Gearboxes (HEG1 and HEG2).

Recommendation 7:
Revise Table 2 to include 9- and 10-speed Automatic Transmissions and High Efficiency Gearboxes (HEG1 and HEG2) as candidate technologies.

RESPONSE: See response to recommendation 6 above.

Technology Classes:

In 2014 the system was adapted and expanded to perform analysis in support of the medium duty rulemaking. As such, a new regulatory class, covering class 2b and class 3 pickups and vans, was introduced into the modeling system. In 2016 the modeling system was further refined to allow simultaneous analysis of light-duty and medium-duty fleets, accounting for potential interaction between shared platforms, engines, and transmissions.

Concern 8 (Adapted Extracts from Topic 3.3, Concern 1):
Table 3, which shows Vehicle Technology Classes, includes Class 2b and 3 trucks and vans.
(CAFE Model Documentation, p. 10).

Several issues exist regarding the Vehicle Technology Classes listed in Table 3 that may be confusing and need to be clarified:

- The 2017 and Later Model Year Light-Duty Vehicle CAFE standards apply to (1) Passenger Cars, (2) Light-Duty Trucks, and (3) Medium-Duty Passenger Vehicles.
  (EPA/NHTSA, 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, October 15, 2012)

- The light duty CAFE standards do not apply to the Class 2b/3 Trucks and Vans, although the Volpe Model runs the analysis of these classes to evaluate their compliance with the Medium- and Heavy-Duty Fuel Efficiency Standards.

  (EPA/NHTSA, "Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles – Phase 2," August 2016
  - Allowing simultaneous analysis of light duty and medium duty fleets accounts for potential interaction between shared platforms, engines, and transmissions.

    (CAFE Model Documentation, pp. 1-2)

Recommendation 8:
Provide an explanation of how the light-duty CAFE model interacts with the medium-duty fleet analysis in order to allow "simultaneous analysis of light-duty and medium-duty fleets." Explain that both fleets are required to be analyzed simultaneously to account for the potential interaction, but this simultaneous analysis significantly increases the complexity of analyzing the light-duty CAFE fleet.

RESPONSE: Model documentation will be updated to clarify interactions between different regulated fleets based on specified model inputs.

Technology Pathways:

Concern 9:
Figure 3, which shows the Transmission-Level Paths, does not include a 10-speed automatic transmission. It also does not show a possible path from a 6-speed or 8-speed DCT to an 8-speed automatic transmission (possibly due to drivability concerns with the DCT).

Recommendation 9:
Add a 10-speed automatic transmission to Figure 3. Add a possible path from a 6-speed or 8-speed DCT to an 8-speed or 10-speed automatic transmission, and explain how such a path is handled in the Volpe Model.

RESPONSE: See response to recommendation 6 above. The model does not simulate the potential that, having invested to apply DCTs—presumably successfully—to a specific vehicle model, a manufacturer would revert to applying ATs. A new Regulatory Impact Analysis will invite comment on whether and, if so, the model should be revised to accommodate reversion to prior transmission types.

Synergies:

For some technologies, the modeling system may convert a vehicle or a vehicle's engine from operating on one type of fuel to another. For example, application of Advanced Diesel (ADSL) technology converts a vehicle from gasoline operation to diesel operation. In such a case, the Equations (1) and (2) still apply, however, in each case, the FE new value is assigned to the vehicle's new fuel type, while the fuel economy on the original fuel is discarded.
(CAFE Model Documentation, p. 20)

Concern 10:
The above description of process for changing from a gasoline engine to a diesel engine is not clear. Figure 2, showing Engine-Level Paths, indicates that the Diesel Engine Path is an independent path from the Basic Engine Path. This appears to be a significant change from the 2012 FRIA where the Diesel Engine was in the last branch of the Engine Technology Decision Tree, shown in Figure V-29 (2012 FRIA). The comment that "the FE new value is assigned to the vehicle's new fuel type, while the fuel economy on the original fuel is discarded" needs to be explained.

For example, will the fuel consumption reduction of the diesel now be referenced to the null gasoline vehicle (where the diesel provides 28.4 to 30.5 percent reduction in fuel consumption (2012 TSD), rather than to the end of the gasoline engine pathway (where Table V-126 of the 2012 FRIA shows the diesel provides 5.53 percent reduction in fuel consumption relative to the last step in the gasoline engine pathway)?
(NHTSA, "Final Regulatory Impact Analysis Corporate Average Fuel Economy for MY 2017-MY 2025 Passenger Cars and Light Trucks," 2012)
(EPA/NHTSA, "Joint Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards," August 2012)

Recommendation 10:
Provide a clear description of the process and impact of the change from a gasoline engine to a diesel engine on page 20 of the CAFE Model Documentation. Provide an explanation of the reference point for diesel engine fuel consumption reduction, and contrast this with the reference point used in the 2012 FRIA. Extend the explanation to non-liquid fuel types, such as CNG, electricity, and hydrogen.

RESPONSE: Model documentation will be revised to clarify updated procedures for calculating changes in fuel consumption, including those involved with switching from gasoline to other fuels.

Technology Cost Tables:

The modeling system also incorporates cost adjustment factors to provide accounting corrections for technology costs. Since the Basic Engine path converges from SOHC, DOHC, and OHV technologies, and since the base input costs are defined for the DOHC path, adjustments are needed to offset the costs of some basic engine technologies used on the SOHC and OHV engines.

Concerns 11, 12, and 13:
The "cost adjustment factors," "Maintenance Cost Table and Repair Cost Table, and "Stranded Capital Table" should have additional explanations together with references.

Recommendation 11: Provide an explanation of how the cost adjustment factors to offset the cost of some basic technologies used on the SOHC and OHV engines are derived and where they can be found. Describe what are "some basic technologies" (CAFE Model

Documentation, p. 21). Explain whether the cost adjustment factors are actually factors (multiplicative) or incremental costs (additive or subtractive).

RESPONSE: Model documentation will be updated to clarify how these adjustment factors are applied, and a new Regulatory Impact Analysis will discuss the basis for specific input values.

Recommendation 12: Provide an explanation of the source of the "Maintenance Cost Table and the Repair Cost Table."
(CAFE Model Documentation, p. 21)

RESPONSE: A new Regulatory Impact Analysis will discuss the basis for specific input values for maintenance and repair costs.

Recommendation 13: Provide a reference for the derivation of the "Stranded Capital Table."
Explain how the "Stranded Capital Table" includes the effects of previously invested capital that is terminated prior to full useful life and how the "stranded" part of this capital is appropriated across future vehicle production, on a per vehicle coast basis.
(CAFE Model Documentation, p. 21)

RESPONSE: A new Regulatory Impact Analysis will discuss the basis for specific input values for stranded capital costs.

Compliance Simulation Loop:

The algorithm first finds the best next applicable technology in each of the technology pathways, and then selects the best among these.

The effective cost, defined by Equation 5, is used for evaluating the relative attractiveness of different technology applications.

$$COST_{eff} = \frac{\sum_{i \in k}\left(\sum_{j=BaseMY}^{j=MY} TECHCOST_{i,j} - TECHVALUE_{i,j} - (VALUE_{FUEL})_{i,j}\right) + \Delta FINE_{MY}}{TOTALSALES} \qquad (5)$$

(CAFE Model Documentation, p. 23- 25)

Concern 14 (Same as Concern 1, Topic 2.4):
The units of $COST_{eff}$ and the definition of $TECHCOST_{i,j}$ provided below Equation 5 in the CAFE Model Documentation are not clear.

- The units of $COST_{eff}$ are presumed to be "total cost (dollars) per affected vehicle," since the equation is divided by total sales of the applicable vehicles.
- The definition of $TECHCOST_{i,j}$ is presumed to equal the total cost (direct manufacturing cost x RPE or (1+ICM)) of the technology per applicable vehicle.
- The summation at the beginning of the equation is presumed to indicate a summation of all the costs per vehicle within the following parenthesis over all of

the affected vehicles. This appears to be required so that $COST_{eff}$ has units of "total cost (dollars) per affected vehicle."

Recommendation 14 (Same as Recommendation 1, Topic 2.4):
Provide the suggested clarifications of Equation 5 identified in Concern 14 regarding: 1) the units of $COST_{eff}$, 2) the definition of $TECHCOST_{i,j}$, and 3) the meaning of the first summation of all of the costs within the following parenthesis.

RESPONSE: Model documentation will be updated to clarify the definition and units of the "effective cost" metric.

Concern 15 (Same as Concern 3, Topic 2.4):
Equation 5 is strongly dependent on $VALUE_{FUEL}$ defined by Equation 6. A critically important parameter in Equation 6 is PB, which is the "payback period," or number of years in the future the consumer is assumed to take into account when considering fuel savings.

Recommendation 15 (Same as Recommendation 3, Topic 2.4):
Provide an explanation of how the appropriate value for PB, the payback period, is determined for the Volpe Model. Explain if PB is 3 years ("the value of fuel savings to a potential buyer over the first three years of ownership" or 1 year (""payback period," assumed to be 1 year for all manufacturers in this analysis"), since both payback periods are mentioned in the same paragraph on p. 13-49 of the 2016 Draft TAR.

RESPONSE: The strength of this dependence depends on several inputs. In addition to the payback period, other inputs—notably fuel prices—can strongly influence the calculated value of the reduction in fuel consumption. A new Regulatory Impact Analysis will discuss input values specifying payback periods (and other inputs), and will present an updated sensitivity analysis considering other possible values for these inputs (e.g., shorter or longer payback periods, lower or higher fuel prices).

Concern 16:
Figure 8, Determination of "Best Next" Technology Application, suggests that only technologies that can be considered are those which are cost effective (i.e., effective cost < 0, where effective cost represents the difference between the incremental cost and the value of fuel savings to a potential buyer over the first three years of ownership).

Recommendation 16:
Explain whether Figure 8 implies that only groups of technologies (i.e., "Tech Solution") that are cost effective can be considered, or does it imply that individual technologies which are not cost effective cannot be considered.

RESPONSE: In Figure 8, "solution" refers to the application of a specific technology to a specific set of vehicles that would be affected by a single application of the technology (e.g., changes to a single engine could simultaneously impact a range of specific vehicle models). Model documentation will be updated to clarify this point.

Vehicle Use and Total Lifetime Mileage:

The average number of miles driven by a surviving vehicle model i produced in model year MY, and belonging to VMT category C, during calendar year CY is given by Equation 15, where "ε" is defined as the elasticity of annual vehicle use with respect to fuel cost per mile.
However, an explanation of how "ε" is determined is not available.

<u>Recommendation 17:</u>
Provide an explanation of how "ε," defined as the elasticity of annual vehicle use with respect to fuel cost per mile, is determined. Provide a reference for this explanation.

RESPONSE: Model documentation will be updated to more clearly relate this elasticity with the rebound effect input listed in appendix A. A new Regulatory Impact Analysis will discuss specific values for the rebound effect.

Vehicle Safety Effects:

Total fatalities attributed to vehicle use for vehicles of model year MY, belonging to safety class SC and weight threshold T are computed using Equation 42. Key parameters in Equation 42 include:

> $BASE_{SC, T}$: the measure of base fatalities per billion miles for vehicles within a safety class SC and weight threshold T.
> $FMVSS_{SC,T}$: an adjustment for new Federal Motor Vehicle Safety Standards (FMVSS) for vehicles within a safety class SC and weight threshold T.

<u>Concern 18:</u>
The source of the vehicle safety effects data for $BASE_{SC,T}$ and $EFFECT_{SC,T}$ in Equation 42 should be explained with references provided.

<u>Recommendation 18:</u>
Explain the source of the vehicle safety effects data for $BASE_{SC,T}$ and $EFFECT_{SC,T}$ used in Equation 42 to calculate total fatalities attributed to vehicle use for vehicles of model year MY, belonging to safety class SC and weight threshold T.
(CAFE Model Documentation, p. 47)

RESPONSE: Model procedures and inputs for calculating safety effects have been revised to account for a wider range of underlying factors. Model documentation will be updated to reflect these new procedures, and a new Regulatory Impact Analysis will discuss specified input values

Private versus Social Costs and Benefits:

See Topic 4.6, Model results for social, economic and environmental effects of CAFE standards (costs, benefits, and quantities).

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

> Implementation of Recommendations 1- 18 will ensure that the data, computational methods and assumptions are reasonable and appropriate.
>
> **RESPONSE: See responses to recommendations 1-18 above.**

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

> Implement recommendations 1- 18.
>
> **RESPONSE: See responses to recommendations 1-18 above.**

4. Is there an alternative approach that you would suggest?

> No. Implementation of Recommendations 1- 18 is the suggested approach.
>
> **RESPONSE: See responses to recommendations 1-18 above.**

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

> Implementation of Recommendations 1- 18 will enhance the overall utility and plausibility of the Volpe Model output.
>
> **RESPONSE: See responses to recommendations 1-18 above.**

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Reviewer Name: _Wallace R. Wade

Review Topic Number: _5.2. The organization, structure, and clarity of the model input files

Other Review Topic Numbers (if interactive effects are focus of discussions):_Topic 2.3___

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

Manufacturers Worksheet (Table 8):

Concern 1:
The Manufacturers Worksheet (Table 8) requires input of the manufacturer's discount rate and payback period. Although these parameters are required in the Manufacturers Worksheet, they appear to refer to the manufacturer's assumption of the consumer's discount rate and payback period.

Recommendation 1:
Specify that the Manufacturers Worksheet (Table 8) refers to the manufacturer's assumption of the consumer's discount rate and payback period (if this is the correct interpretation).

RESPONSE: Model documentation will be revised to clarify that inputs specifying payback periods and discount rates represent estimates of manufacturers' apparent expectations regarding buyers' willingness to pay for fuel economy improvements.

Concern 2:
This worksheet requires percentage of manufacturer's ZEV credits assumed to be generated in California and S177 states. Table 24, ZEV Credit Values Worksheet, also requires similar input.

The handling of the ZEV mandate needs to be explained in the CAFE Model Documentation and in the TAR. The following questions should be addressed:

- Table 8 requires "The percentage of manufacturer's ZEV credits assumed to be generated in California and S177 states" while Table 24 requires the "Minimum and Maximum percentage of zero emission vehicle (ZEV) credits that a manufacturer must generate in order to meet the ZEV requirement in each specified model year." An explanation of these two tables (similarities and differences) with respect to ZEV credits would be helpful. How are the ZEV credits related to the minimum and maximum ZEV credits?
- Do the percentages of manufacturer's ZEV credits assumed to be generated in California and S177 states refer to the MY 2015 baseline or to each of the years through 2025?

- What assumptions are made regarding ZEV credits (e.g., Are the mandates met each year in California and S177 states without regard for effective cost and other constraints (such as caps) applied for modeling CAFE compliance?)
- Are the costs of meeting the ZEV mandates included in the overall costs reported by NHTSA for the 2025 CAFE standards, or have they been subtracted out of the costs?
- Is NHTSA's approach consistent with EPA's analysis for the ZEV mandate, which is stated on p. ES-10, Footnote 3 of the 2016 Draft TAR as follows: "In EPA's modeling, the California Zero Emission Vehicles (ZEV) program is considered in the reference case fleet; therefore, 3.5 percent of the fleet is projected to be full EV or PHEV in the 2022-2025 timeframe due to the ZEV program and the adoption of that program by nine additional states"?

Recommendation 2:
Provide an explanation of how the ZEV mandate is handled in the CAFE Model. Include responses to the five questions listed in Concern 2. An explanation of how the ZEV mandate is handled should be included in the TAR.

RESPONSE: The 2016 Draft TAR analysis did not apply the model's ability to simulate compliance with states' "Zero Emission Vehicle" mandates. These model capabilities and inputs will be documented if applied toward any published analysis.

Vehicles Worksheet (Table 9):

Recommendation 3:
The input for the CAFE fuel economy rating of the vehicle for each fuel type should specify the uncorrected 2-cycle fuel economy from EPA certification test data.

Recommendation 4:
Explain the source of the input for "Employment Hours per Vehicle" and explain how this input is used.

RESPONSE: Model procedures for calculating employment impacts have been updated, as discussed in updated model documentation. Corresponding updated inputs will be discussed in a new Regulatory Impact Analysis.

Engines Worksheet (Table 10):

Recommendation 5:
Explain the purpose and source of the input of minimum and maximum compression ratio of an engine. Are these intended to be 3 or 6 sigma manufacturing tolerances for compression ratio?

RESPONSE: These inputs were added with a view toward providing for explicit representation of engines with variable compression ratio. Model documentation will be updated to clarify accommodation of these ranges.

Recommendation 6:
Add Atkinson 2-cycle and Miller Cycle engines to the Technology Applicability list.

RESPONSE: Model input files will be updated such that worksheets reflect all modeled technologies.

Worksheet (Table 11):

Recommendation 7:
Add 10-speed Automatic and 10-speed DCT Transmissions, using the new TRX11 format, and HEG1 and HEG2 High Efficiency Gearboxes to the Technology Applicability list.

RESPONSE: See response to recommendation 6 above.

Technology Definitions (Table 12):

Recommendation 8:
For Table 12, Technology Definitions, explain the input for ZEV Credits, defined as the "Amount of ZEV credits a vehicle will generate upon application of the technology." Are these the overall ZEV Regulation Credit Requirements shown in Table 4.34 or are these the individual credits generate by different vehicle types (plug-in hybrid electric vehicles (PHEV with 10 mile electric range – 0.4 credits), battery electric vehicle (BEV with 350 mile range – 4.0 credits), and fuel cell electric vehicles (FCEV with 350 mile range – 4.0 credits) as defined on p. 4-43?

RESPONSE: See response to recommendation 2 above.

Technology Assumptions (Table 13):

Recommendation 9:
Explain the input for Consumer Valuation, defined as the consumer welfare loss (or gain) associated with application of the technology. An appropriate reference should also be provided.

RESPONSE: Model documentation will be updated to clarify the interpretation and application of the "Consumer Valuation" inputs. A new Regulatory Impact Analysis will discuss updated input values.

Technology Synergies (Table 15):

Concern 10:
It is not clear how the extensive Argonne National Laboratory's simulation data is applied to the input for Table 15, Technology Synergies.

- The 2016 Draft TAR describes the process of accounting for synergies using the ANL simulations as follows:

A technology group is defined in terms of: engine cam configuration (CONFIG), engine technologies (ENG), transmission technologies (TRANS), electrification (ELEC), mass reduction levels (MR), aerodynamic improvements (AERO), and rolling resistance (ROLL). The combination of technology levels along each of these paths define a unique technology combination that corresponds to a single point in the database for each technology class.

Once a vehicle is assigned a technology state defined as: CONFIG;ENG;TRANS;ELEC;MR;AERO;ROLL), adding a new technology to the vehicle simply represents progress from one technology state to another. The vehicle's fuel consumption is defined as follows:

$$FC_i = FC_0 \cdot (1 - FCI_i) \cdot S_k / S_0$$

(2016 Draft TAR, pp. 13-35 to 13-36)

- The CAFE Model Documentation describes the process of accounting for synergies using Equation 2, as follows:

$$FE_{new} = FE_{orig} \times \frac{1}{(1-FC_0)} \times \frac{1}{(1-FC_1)} \cdots \times \frac{1}{(1-FC_n)} \times \frac{S_{orig}}{S_{new}} \qquad (2)$$

- Instead of showing two different formulations for applying synergy factors in two different documents, only one formulation should be used for clarity.
- According to Equation 2, Soirg and Snew, appear to be uniquely related to application of the 0-th to n-th technologies, which are expected to be different for each level of CAFE compliance and each combination of vehicle classes and technology cost classes listed in Table 15. The draft TAR (p.13-35) states that there are tens of thousands of unique 7-tuples, defined as, CONFIG;ENG;TRANS;ELEC;MR;AERO;ROLL), which were used to develop values for S_k, synergy factor for technology combination k. What is the format for compiling this extensive array of synergy factors in Table 15? Providing an example of the array of synergy factors would be informative.
- Is the "Fuel consumption multiplier" identified in Table 15 equal to the following ratio used in Equation 2? If so, then the "Fuel consumption multiplier" should be defined using this ratio in Table 15.
  Soirg/ Snew
- The "amount by which to offset the technology cost" using "a separate synergy value specified for each technology cost class" is not clearly defined in the 2016 Draft TAR or the CAFE Model Documentation. However, this offset appears to be the "cost adjustment factor" discussed below.
- "Cost adjustment factors" provide accounting corrections for technology costs. Since the Basic Engine path (Figure 2) converges from SOHC, DOHC, and OHV technologies, and since the base input costs are defined for the DOHC path, the system necessitates the use of these adjustments in order to offset the costs of some basic engine technologies used on the SOHC and OHV engines.

(CAFE Model Documentation, p. 21)

The source and/or derivation of cost adjustment factors should be explained.

- The “Cost Class” section of Table 15 appears to be the same as “Engine Technology Classes” shown in Table 13.6. If this is correct, then a common terminology should be used for both tables.

Recommendation 10:

Address the issues identified in Concern 10 regarding the Technology Synergies (Table 15) with appropriate explanations, revisions and additions.

RESPONSE: The model has been updated to calculate fuel economy using model inputs and methods that should be more clearly relatable to results of underlying full vehicle simulations for different combinations of technologies as applied to different types of vehicles. Updated model documentation will discuss these changes, and a new Regulatory Impact Analysis will discuss specific input values. Model documentation will also be revised to clarify the interpretation and application of inputs specifying different cost factors, and a new Regulatory Impact Analysis will discuss specific input values.

Fuel Economy Data (Table 18):

Concern 11:

Table 18 requires “historic and projected (forecast by model year) fuel economy levels for passenger cars, light trucks, and class 2b/3 trucks, for each fuel type (gasoline, diesel, ethanol-85, electricity, and hydrogen).” Concerns with these requirements are:

- What is the source of the historic data fuel economy levels?
- What is the source of the forecast fuel economy levels? Why aren’t the forecast fuel economy levels an output from the CAFE Model?

Recommendation 11:

Address the two items under Concern 11 regarding the source of the historic and forecast fuel economy levels, which are not specified in Table 18, Fuel Economy Data, with appropriate revisions and/or additions. Explain why the forecast fuel economy levels are not the output from the CAFE Model?

RESPONSE: Model documentation will be updated to clarify the interpretation and application of these inputs, and their relationship to endogenously-estimated fuel economy levels. A new Regulatory Impact Analysis will discuss specific input values not discussed in the model documentation.

Economic Values (Table 19):

Concern 12:

- What is the source for the Resale Value as a percentage, which is defined as the average percentage of the vehicle's final MSRP the consumer recoups after selling the vehicle?
- How is resale value used in the CAFE Model?
- Resale value is highly dependent on the years since purchase of the new vehicle, but this does not appear to be required in Table 19.

Recommendation 12:

Address the three items under Concern 12 which are not clear in Table 19 with appropriate revisions and/or additions.

RESPONSE: Model documentation will be revised to clarify the interpretation and application of the model input specifying resale value. A new Regulatory Impact Analysis will discuss specific input values.

Safety Values (Table 22):

Concern 13:

- The vehicle classes that require input of weight thresholds listed in Table 22 (PC, LT/SUV, CUV/Minivan) differ from the vehicle classes shown in Table 8.2 (Lighter Passenger Cars, Heavier Passenger Cars, Lighter LTVs, Heavier LTVs) (2016 Draft TAR).
- The source of the" FMVSS adjustment for new FMVSS below the weight threshold," which is required for Table 22, is not clear. The new FMVSS "may influence the historical relationship between mass and safety." Although Table 8.10 lists additional safety requirements post 2010 (FMVSS, IIHS) (2016 Draft TAR), the table does not identify the weight effects of these requirements, and it is unclear if Table 8.2 includes the weight effects of the new FMVSS.

Recommendation 13:

Make appropriate modifications to ensure that: 1) the vehicle classes that require input of weight thresholds listed in Table 22 are aligned with the vehicle classes shown in Table 8.2 (2016 Draft TAR), and 2) the source of input for the "FMVSS adjustment for new FMVSS below the weight threshold" is clearly defined.

RESPONSE: Model documentation will be revised to clarify that safety calculations are implemented on a vehicle-by-vehicle basis, such that each vehicle can be assigned to the correct "safety class." A new Regulatory Impact Analysis will discuss specific

updated estimates of the coefficients defining the dependence of safety on vehicle mass, and will also discuss estimated impacts of future FMVSS on vehicle mass.

Credit Trading Values (Table 23):

<u>Concern 14:</u>

There are three entries in Table 23 that are labeled "This option is not supported in this version of the model."

<u>Recommendation 14:</u>

In addition to the label, "This option is not supported in this version of the model" for three entries in Table 23, comments on whether the option is expected in future versions of the model would be informative.

RESPONSE: The 2016 Draft TAR analysis did not apply the model's ability to simulate compliance with states' "Zero Emission Vehicle" mandates. These model capabilities and inputs will be documented if applied toward any published analysis.

ZEV Credit Values Worksheet (Table 24)/(DFS Model Values worksheet):

<u>Concern 15:</u>

The DFS model, identified in Table 24, is not mentioned or described in the CAFE Model Documentation or the 2016 Draft TAR.

<u>Recommendation 15:</u>

Provide a reference for the DFS model and a brief explanation of this model.

RESPONSE: The model has been revised to apply new methods for dynamically calculating the relative shares of passenger cars and light trucks in the new vehicle fleet. Model documentation has been revised to reflect these changes, and a new Regulatory Impact Analysis will discuss corresponding specific input values.

Fuel Properties and Emission Costs (Tables 25 and 26):

<u>Concern 16:</u>

- For CAFE compliance purposes, a fuel economy equation, which has been used since 1988, is applied in order to determine what the fuel economy would be if the 1975 baseline fuel was used (NRC, "Cost, Effectiveness, and Deployment of Fuel

Economy Technologies for Light-Duty Vehicles," 2015). The application of this equation is not referenced in Tables 25, or discussed in the 2016 Draft Tar and CAFE Model Documentation.

- The sources for the "Economic costs arising from criteria pollutants and GHG emission damage" are not defined.

Recommendation 16-1:

Provide an explanation of where the fuel economy equation, used to determine what the fuel economy would be if the 1975 baseline fuel was used, is applied in the process of determining CAFE compliance.

RESPONSE: Model documentation will be updated to clarify that model inputs require each vehicle's initial fuel economy rating (for CAFE compliance purposes) to be specified. For any given vehicle that remains physically unchanged, the model assumes that fuel economy rating would continue unchanged.

Recommendation 16-2:

Provide an explanation of the sources for the input of "Economic costs arising from criteria pollutants damage and GHG emission damage."

RESPONSE: A new Regulatory Impact Analysis will discuss sources of specific values quantifying damage costs for criteria pollutants and greenhouse gases.

Tailpipe Emissions (Table 28):

Concern 17:

Table 28 does not define the content of the emission rate tables.

RESPONSE: Model documentation will be expanded to list specific pollutants for which emission rates can be specified.

Recommendation 17:

Provide clarification of what emission rates are actually used in the CAFE modeling. For example:

- Are the emission rates simply the regulatory standards, or
- Are the emissions rates defined as increasing with mileage (Table 28 and Equation 36 refer to "vehicle age"), finally reaching the actual emission standard, within a specified statistical margin, at the specific mileage for the emission standard?

RESPONSE: Model documentation will be revised to more fully discuss the interpretation and application emission rates contained in model inputs. A new Regulatory Impact Analysis will discuss sources of specific input values.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

A complete assessment of the data and assumptions used for the Input to the CAFE Model Documentation can only be determined after Recommendations 1-17 are implemented to resolve the concerns identified above.

RESPONSE: See responses to recommendations 1-17 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1-17 concerning the Input to the Volpe Model Documentation.

RESPONSE: See responses to recommendations 1-17 above.

4. Is there an alternative approach that you would suggest?

No. Implement Recommendations 1-17 is the suggested approach.

RESPONSE: See responses to recommendations 1-17 above.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

Implementation of Recommendations 1-17 will enhance the overall utility and plausibility of the Volpe Model output.

RESPONSE: See responses to recommendations 1-17 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Reviewer Name: _Wallace R. Wade

Review Topic Number: _5.3. The organization, structure, and clarity of the model output files

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

The system produces seven output files listed in Table 31, which shows the available output types and their contents.

Technology Utilization Report (Table 32):

The Technology Utilization Report (Table 32) contains manufacturer-level and industry-wide technology application and penetration rates for each technology.

Comment:
The output in the Technology Utilization Report (Table 32) is clearly defined and specified in adequate detail.

Compliance Report (Table 33):

The Compliance Report contains manufacturer-level and industry-wide summary of compliance model results for each model year and scenario analyzed.

Concern 1:
How are the "Employment hours associated with the production of vehicle models," shown in Table 33, used in the analysis of the CAFE requirements? Are employment hours due to the CAFE standards separated from the overall employment hours?

Recommendation 1:
Provide an explanation of how the "Employment hours associated with the production of vehicle models are used in the analysis of the CAFE requirements. Explain if and how the employment hours due to the CAFE standards are separated from the overall employment hours.

RESPONSE: The model's procedures for calculating employment impacts have been updated, and model documentation will be updated accordingly. A new Regulatory Impact Analysis will discuss corresponding input values and results.

Concern 2:
The "alternative minimum CAFE standard," shown in Table 33, does not appear to be "outlined in the scenarios input section," which is assumed to refer to Table 30, Scenarios

Worksheet. The "alternative minimum CAFE standard" does not appear to be mentioned in the 2016 Draft TAR.

Recommendation 2: Regarding Table 33, provide the proper reference for the "alternative minimum CAFE standard," which currently appears to refer to Table 30, Scenarios Worksheet, but the "alternative minimum CAFE standard" is not mentioned in this table. Provide a reference document for the "alternative minimum CAFE standard."

RESPONSE: Model documentation will be updated to clarify that the alternative minimum CAFE standard refers to the requirement that domestic passenger car fleets meet a minimum CAFE standard, as well as the level required by applying the footprint-based targets only to the manufacturer's own domestic car fleet. These inputs are included in the "scenarios" input file.

Concern 3:
The definition of "The value of the required CAFE standard" is not clear. Is it the fleet "CAFE standard" based on the footprint based fuel economy targets and the sales volume of each vehicle in the fleet?

RESPONSE: Model documentation will be updated to clarify that the required CAFE level refers to the CAFE level the manufacturer is required to meet for the indicated fleet, accounting for the attribute-based targets and the manufacturers' production mix.

Recommendation 3:
Provide the definition of "The value of the required CAFE standard" listed in Table 33.

Concern 4:
The "CAFE (2-cycle) mpg" is defined in Table 33 as the value of the achieved CAFE standard, using a 2-bag test cycle, not including the adjustment for improvements in air conditioning or off-cycle credits. CAFE fuel economy values are calculated on the basis of FTP and HWFET testing, which involve more than 2 bags in the testing process.

Recommendation 4:

Clarify that CAFE compliance fuel economy values shown in Table 33 are based on FTP and HWFET testing (2-cycle test procedure), rather than a 2-bag test cycle.

RESPONSE: Model documentation will be revised to clarify the presumed basis for fuel economy values specified in the model input file containing the analysis fleet.

Concern 5:
- How are the outputs for "CO_2 Required and CO_2 Achieved" used, since EPA uses the OMEGA model for these calculations?
- This raises a more significant concern regarding why EPA could not use the extensive and highly detailed Volpe Model for their analysis of the GHG emission standards.

Recommendation 5:

Provide an explanation of how the outputs for "CO_2 Required and CO_2 Achieved" in Table 33 are used. Consider opportunities for EPA to use the output from the Volpe Model in place of their OMEGA Model output.

RESPONSE: The model has been revised to provide for direct simulation of compliance with greenhouse gas emissions standards. Model documentation has been accordingly updated, and a new Regulatory Impact Analysis discusses corresponding specific input values.

Concern 6:

Regarding the "ZEV Target" and "ZEV Credit" lines in Table 33, does the Volpe Model attempt to comply with the ZEV Targets, within the constrains set in the model? Are any constraints modified or eliminated, such as the requirement for Effective Cost to be < 0 or caps on technology implementation?

Recommendation 6:

Clarify if the Volpe Model attempts to comply with the ZEV Targets shown in Table 33, and explain if any constraints are modified or eliminated in the model for ZEV compliance.

RESPONSE: The 2016 Draft TAR analysis did not apply the model's ability to simulate compliance with states' "Zero Emission Vehicle" mandates. These model capabilities and inputs will be documented if applied toward any published analysis.

Concern 7:

Table 33 lists the total technology costs accrued by all vehicles for a specific model year, manufacturer, and regulatory class. Are the ZEV technologies included in the total technology costs, even though the ZEV requirements are not part of the CAFE program?

RESPONSE: See response to recommendation 6 above.

Recommendation 7:

Provide an explanation of whether the ZEV technologies are included in the total technology costs, and comment on the rationale, considering that the ZEV requirements are not part of the CAFE program.

RESPONSE: See response to recommendation 6 above.

Concern 8:

How are the "Loss in value to the consumer due to decreased range of pure electric vehicles" and the "Total relative loss in value to the consumer due to decreased operating life of pure electric vehicles," shown in Table 33, determined?

Recommendation 8:

Provide an explanation of how the "Loss in value to the consumer due to decreased range of pure electric vehicles" and the "Total relative loss in value to the consumer due to decreased operating life of pure electric vehicles," shown in Table 33, are determined.

RESPONSE: Model documentation will be revise to clarify the interpretation and application of and specified "Consumer Valuation" inputs for specific technology. A new Regulatory Impact Analysis will discuss updated estimates for HEVs, PHEVs, and EVs.

Concern 9:

Footnote 2 on p. 75 in the CAFE Model Documentation identifies significantly different formats for defining credits accumulated by the manufacturer for a specific model year and regulatory class.

- For medium duty vehicles (class-2a shown, but should be identified as class-2b light duty trucks), one credit equates to one gallon per 10k miles. This converts to 0.00001 gal/mi and is apparently handled similar to off-cycle credits which can be added or subtracted from an overall fleet gal/mi.
- For light duty vehicles (passenger cars, class-1 light duty trucks, and class-2a light duty trucks), one credit equates to one mile per 10 gallons. How can this format for credit be converted to a value that can be added or subtracted from an overall fleet gal/mi?

A possible explanation might be as follows:

Baseline vehicle = 35 mpg

Credit = 1 mi/10 gal = 0.1 mi/gal

Improved vehicle = 35mpg + 0.1 mpg = 35.1

Credit = 1/35 – 1/35.1 = 0.02857 – 0.02849 = 0.00008 gal/mi

Note: The 2012 TSD used fuel economy credits expressed in gal/mi units, as shown in Table 5-12 for Efficiency-Improving A/C Technologies and Credits and Table 5-37 for Initial Off-Cycle Credit Estimates. These units can be easily added or subtracted from an overall fleet gal/mi.

(EPA/NHTSA, Joint Technical Support Document: Final Rulemaking for 2017 – 2025 Light-Duty Vehicle Greenhouse Gas and Corporate Average Fuel Economy Standards," August, 2012)

Recommendation 9:

Add clarifications to Footnote 2 on p. 75 in the CAFE Model Documentation to address Concern 9 regarding the different formats used to define credits for light duty vehicles compared to medium duty vehicles, where the credits appear to require that they be in a format which can be added or subtracted from an overall fleet gal/mi.

Also correct "medium duty vehicles "(class-2a)" to read "(class-2b)" in the Footnote on p. 75.

RESPONSE: Model procedures, inputs, and outputs relating to CAFE credits (and, newly, GHG credits) have been updated. Model documentation will be revised accordingly, and a new Regulatory Impact Analysis will discuss specific input values.

Societal Effects Report and Societal Costs Report:

Societal Effects Report (Table 34):

Concern 10:

The Societal Effects Report contains an industry-wide summary of energy and emissions effects.

- "The modeling system generates two versions of each report, where in one, the results are reported by vehicle class (LDV, LDT12a, LDT2b3), while in the other, the results are reported by regulatory class (PC, LT, LT2b3)" (CAFE Model Documentation, p. 76). However, these groups of vehicle classes do not appear to relate to CAFE requirements. The light duty CAFE requirements are for 1) passenger cars, 2) light-duty trucks, and 3) medium-duty passenger vehicles (MDPV) described on p. 1-5 of the 2016 Draft TAR. LT2b3 are included in the Medium- and Heavy-Duty GHG and Fuel Efficiency Standards.
- Table 34, Societal Effects report, notes that the "Rated FE" levels reported is not comparable to the value of achieved CAFE standard shown in the compliance report. The value contained in the Societal Effects Report is computed as total VMT divided by total gallons (with the effect of the on-road gap backed out), and does not incorporate some of the compliance credits.
- An explanation of the derivation of the average on-road fuel economy rating of vehicles is not provided. Since the Volpe Model primarily calculates CAFE compliance fuel economy levels, provide an explanation of the "Rated FE" including why the "on-road gap" is backed out from total gallons.

Recommendation 10-1:

Review the groups of vehicle classes shown on p. 76 of the CAFE Model Documentation described in Concern 10. Explain why they do not correspond to vehicle classes included in the light Duty CAFE Standards or the Medium- and Heavy-Duty Fuel Efficiency Standards. Revise as appropriate.

RESPONSE: As discussed above regarding comments on (CAFE) regulatory class versus technology class, any given vehicle model/configuration may—necessarily—be classified differently for different model calculations. Likewise, vehicle classification for purposes of specifying criteria pollutant emission factors is not always the same as classification for (CAFE) regulatory purposes. Because of these difference, model inputs allow classification to be specified separately for each of these purposes (and, as well, safety). Model documentation has been revised to clarify the differences between classification for CAFE compliance and classification for criteria pollutant emissions calculations.

Recommendation 10-2:

Provide an explanation why the "Rated FE" levels reported are not comparable to the value of achieved CAFE standard shown in the compliance report, as described in Concern 10.

RESPONSE: Model documentation has been revised to further explain differences between average fuel economy levels as determined for CAFE compliance and as estimated to be implied by future aggregate mileage accumulation and fuel consumption.

Recommendation 10-3:

Provide an explanation that the average "on-road gap" is 23 percent and include the reference to p. 10-1 of the 2016 Draft TAR. Explain why the "on-road gap" is backed out from total gallons for the Societal Effects Report.

RESPONSE: Model documentation has been revised to clarify the application of inputs specifying the "on road gap," and how these inputs affect aggregate estimated fuel consumption.

Concern 11:

Are "on-road gaps" applied to the criteria pollutants similar to the "on-road" gap used for calculating "Real-world" CO2 and fuel economy levels?

(2016 Draft TAR, p. 10-1)

Recommendation 11:

Explain whether "on-road gaps" are applied to the criteria pollutants to be compatible with "Rated FE."

RESPONSE: See response to recommendation 10-3 above. Model documentation has been revised to explain that these gaps affect projected fuel consumption, which affect projected upstream criteria pollutant emissions.

Societal Costs Report (Table 35):

The Societal Costs Report contains monetized consumer and social costs including fuel expenditures, travel and refueling value, economic and external costs arising from additional vehicle use, as well as owner and societal costs associated with emissions damage.

Concern 12:

For the "Fuel Tax Cost" output, does this calculation include the individual state fuel taxes, so that vehicle sales and forecasts need to be known by state?

Recommendation 12:

Provide an explanation regarding whether the "Fuel Tax Cost" output calculation includes the individual state fuel taxes according to the vehicle sales and forecasts by state.

RESPONSE: Model documentation will be updated to clarify that the model does not accommodate inputs of state-specific fuel taxation rates, and instead uses national-scale averages of combined federal- and state-level rates.

Annual Societal Effects Report and Annual Societal Costs Report (Tables 36 and 37):

The Annual Societal Effects Report and the Annual Societal Costs Report contain similar results as the Societal Effects Report and the Societal Costs Report, except these outputs further disaggregate the results by calendar year.

Therefore, the Recommendations 10-12 also apply to Tables 36 and 37.

Vehicles Report (Table 38):

The Vehicles Report (Table 38) contains disaggregate vehicle-level summary of compliance model results, providing a detailed view of the final state of each vehicle examined by the model, for each model year and scenario analyzed. The report includes basic vehicle characteristics (such as vehicle code, manufacturer, engine and transmission used, curb weight, footprint, and sales volumes), fuel economy information (before and after the analysis), final technology utilization, and cost metrics associated with application of additional technology.

<u>Comment:</u>

The Vehicles report (Table 38) is comprehensive and well organized. A few concerns were identified and are discussed below.

<u>Concern 13:</u>

Page 84 of the CAFE Model Documentation states “For flex-fuel vehicles (those that operate on gasoline and ethanol-85), only the gasoline fuel economy rating is considered for compliance.” Why is only the gasoline fuel economy rating used, since page 352 (NRC, “Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles,” 2015) shows the formula for the CAFE mpg for an FFV that includes the fuel economy operating when on the alternative fuel (i.e., E85).

<u>Recommendation 13:</u>

Provide an explanation of why, for flex-fuel vehicles, only the gasoline fuel economy rating is considered for compliance when the formula for the CAFE mpg for an FFV includes the fuel economy when operating on the alternative fuel (E85).

RESPONSE: Model documentation will be updated to clarify reporting of fuel economy ratings for FFVs.

<u>Concern 14:</u>

For the Powertrain column in Table 38, does “Conventional” include spark ignition and diesel engines?

<u>Recommendation 14:</u>

Specify that, for the Powertrain row in Table 38, “Conventional” includes spark ignition and diesel engines (if this is the correct assumption).

RESPONSE: Model documentation will be updated to clarify that “conventional” refers to gasoline and diesel engines.

Concern 15:

The Vehicle Power column in Table 38 contains the "Final power rating of a vehicle." Does this include the combined gasoline engine and electric motor power for hybrid vehicles? If this is correct, how is the combined power for hybrid vehicles calculated? For current power split hybrid vehicles, the combined power is not equal to the sum of the gasoline engine and electric motor power, but is less than this sum. The manufacturer generally provides the combined power for current vehicles, but an explanation of the source of this information should be provided in the TAR and /or CAFE Model Documentation.

Recommendation 15:

Provide an explanation that the "Final power rating of a vehicle" for the "Vehicle Power" row in Table 38 contains the combined gasoline engine and electric motor power for hybrid vehicles (if this is a correct assumption). Provide an explanation of the source of this combined power rating for hybrid vehicles in the TAR and /or CAFE Model Documentation to address Concern 15.

RESPONSE: Model documentation will be updated to clarify reporting of vehicle power levels.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

A complete assessment of the data, computational methods, and assumptions used for the Output to the CAFE Model Documentation can only be determined after Recommendations 1-15 are implemented to resolve the concerns noted above.

RESPONSE: See responses to recommendations 1-15 above.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implement Recommendations 1-15 concerning the Output to the Volpe Model Documentation.

RESPONSE: See responses to recommendations 1-15 above.

4. Is there an alternative approach that you would suggest?

No. Implement Recommendations 1-15 is the suggested approach. **RESPONSE: See responses to recommendations 1-15 above.**

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

Implementation of Recommendations 1-15 will enhance the overall utility and plausibility of the Volpe Model output. **RESPONSE: See responses to recommendations 1-15 above.**

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Reviewer Name: _Wallace R. Wade

Review Topic Number: _5.4. The model's ease and clarity of operation

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

Appendix C - CAFE Model Software Manual:

This Appendix in the CAFE Model Documentation provides step by step instructions for using the CAFE Model, including screen shots to illustrate its use.

The model GUI is operated using a simple, easy to use file-menu (Figure 11), with most commonly used shortcuts also available on the model toolbar (Figure 12). For user convenience, most of the menu entries may also be controlled using keyboard shortcuts.

The modeling system automatically generates the seven output files (in CSV format) described in the Output section of the CAFE Model Documentation section.

The model requires the input files (Market-Data, Technology, Parameters, Scenarios) described in the Input section of the CAFE Model Documentation section.

Concern 1:
Figure 19 shows the selection of input files. However, a major section of the CAFE Model Software Manual appears to have been omitted since no explanation of the format for the input files is provided. These input files are critical for ensuring reliable outputs from the Volpe Model.

Recommendation 1:
Add a section to the CAFE Model Software Manual that provides an explanation of the format for the input files.

REPONSE: While model documentation will be updated to more clearly explain the structure of the input files, it would not be practical to reproduce the entire structure of these input files in the model documentation. The model documentation will be expanded to explain the importance of having actual input files available for examination when reviewing corresponding sections of the documentation.

Concern 2:
Figure 25 (and also Figure 26) shows entries for PC, LT and 2b3, but additional explanations are needed.

- Explanations are not provided for the three headings: pSTND, STND, CAFE (where STND appears to be the CAFE standard, CAFE appears to be the calculated achieved compliance against the standard, but pSTND is not defined).
- Page ix states that STD is for the "value of the CAFE standard." The use of STND in Figures 25 and 26 appears to be inconsistent with the "Abbreviations" provided in the CAFE Model Documentation on pp. viii and ix.
- Does CAFE refer to the CAFE standard for all medium/heavy duty trucks in the 2b3 classes? This appears to be the case since, for a typical work factor of about 5000, the 2023 gasoline CAFE target is 5.81 gal/100 mi, or 17.2 mpg, as shown in Figure 25 (Figure VI-6, EPA/NHTSA, "Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles—Phase 2," Federal Register, October 25, 2016).
    - If this is the case, then where are the class 2b3, Medium Duty Passenger Vehicles that are included in the light-duty CAFE standards, accounted for? Are Medium Duty Passenger Vehicles included in the "LT" group?
- The units for credits are not defined. Are these the credits defined in footnote 2 on page 75 (For passenger cars and light duty trucks: one credit equates to one mile per 10 gallons. For medium duty vehicles (class-2b3): one credit equates to one gallon per 10k miles.)?

Recommendation 2-1:

Provide the clarifications identified for the first two issues in Concern 2 regarding Figures 25 and 26 of the CAFE Model Documentation.

RESPONSE: The model's reporting of required and achieved CAFE levels (and, newly, GHG levels) and credits has been revised, and model documentation will be updated accordingly. Regarding MDPVs regulated as light-duty vehicles, average required and achieved CAFE levels reflect this regulatory treatment.

Recommendation 2-2:

Provide an explanation, requested for the third issue in Concern 2, regarding where the class 2b3, medium duty passenger vehicles are included in the light-duty CAFE requirements, as shown in Figures 25 and 26. Clearly show that the Medium Duty Passenger Vehicles are part of the output for the Light Duty vehicle CAFE standard, which should be distinguished from the output for Class 2b3 trucks, which are part of the Medium- and Heavy-Duty Vehicle Fuel Efficiency standard.

RESPONSE: As long as model inputs correctly identify any MDPVs regulated as light-duty vehicles, the model includes these vehicles in manufacturers' light-duty vehicle fleets that are subject to CAFE standards. These vehicles are clearly identifiable as such in the model's vehicle-level output file.

Recommendation 2-3:

Define the units for credits listed in Figures 25 and 26, possibly by reference to Footnotes 1 and 2 on page 75.

RESPONSE: Model documentation will be revised to indicate units in which various credits are denominated.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The CAFE Model Software Manual provides clear step by step instructions for using the CAFE Model, including screen shots to illustrate its use.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Modifications identified in Recommendations 1 and 2 are suggested.

RESPONSE: See responses to recommendations 1-2 above.

4. Is there an alternative approach that you would suggest?

No. Implementing the modifications requested in Recommendations 1 and 2 is the approach suggested.

RESPONSE: See responses to recommendations 1-2 above.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

Implementing the modifications requested in Recommendations 1 and 2 will enhance the overall utility and plausibility of the Volpe Model output.

RESPONSE: See responses to recommendations 1-2 above.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Reviewer Name: Wallace R. Wade

Review Topic Number: 5.5. Any other comments you may have on the CAFE Model

Other Review Topic Numbers (if interactive effects are focus of discussions):____________

Provide an objective assessment of the Volpe Model approach for the review topic: [*Enter response in the text boxes, which will expand as more text is entered.]*

1. What are the most important concerns that should be taken into account related to the review topic?

The CAFE model is a very detailed and well thought out model for estimating the effects, costs, and benefits of the CAFE standards. The most significant recommendations from this review of the model and its documentation are as follows:

Recommendation 1 – Topic 1.3
The Volpe Model should develop a means to recognize and incorporate new vehicle models as well as discontinued models. The workload of new vehicle models needs to be recognized together with the impact on current vehicle redesigns (possibly lengthening the period between redesigns) and the estimates of production volumes for the new as well as current vehicle models.

RESPONSE: The CAFE model is already capable of incorporating new vehicle models and dropping discontinued models, but the composition of the fleet constitutes a set of inputs to the model, and is not inherent in the model itself. Prior to 2010, CAFE rulemaking analyses using the model applied inputs that were informed significantly by manufacturers' forward-looking product plans, including plans to introduce new products and discontinue other products. However, manufacturers' forward-looking product plans being considered confidential business information (CBI), neither these detailed inputs nor the correspondingly detailed inputs could be made publicly available. Starting in 2010, CAFE rulemaking analyses have applied market inputs informed by sources (e.g., CAFE compliance data) that can be made public, but that are not informed by manufacturers' plans to change product offerings. A new Regulatory Impact Analysis will discuss these tradeoffs, and will discuss NHTSA's approach to developing analysis fleet inputs for the model.

Comment – Topic 2.1
The improvements in the current Volpe Model using simulations from ANL's Autonomie model in place of the pairwise synergy factor approach are reasonable and are expected to improve the capability of the Volpe Model to reflect the synergy effects of applying a new technology to vehicles already having a variety of fuel consumption reduction technologies.

Recommendations to Ensure MY 2015 Baseline Fleet Technologies and CAFE Fuel Economy Ratings are Correctly Defined and Compatible

Recommendation 1 - Topic 3.1

The 2016 Draft TAR should be modified to address Concern 1 (Topic 3.1) regarding the need for significantly more information about the specific types and levels of technologies applied to each vehicle type in the MY 2015 (baseline) fleet than illustrated in Tables 4.43and 4.44.

RESPONSE: Compared to the highly-summarized single-chapter discussion of results in the 2016 Draft TAR, a new Regulatory Impact Analysis will present fuller information regarding types and levels of technologies in the analysis fleet and under different modeled regulatory alternatives.

Recommendation 3 - Topic 5.2

The input for the CAFE fuel economy rating of the vehicle (for the MY 2015 baseline fleet) for each fuel type should specify the uncorrected 2-cycle fuel economy from EPA certification test data.

RESPONSE: Model inputs defining the analysis fleet reflect fuel economy levels expected to apply for purposes of CAFE compliance. Model documentation will be updated to clarify this point, and a new Regulatory Impact Analysis will discuss updated inputs defining the analysis fleet.

Comment – Topic 3.1

The mass reduction starting point for the baseline fleet has been an ongoing concern since the publication of the 2012 TSD, as discussed in Finding 6.8 (p. 242) of the 2015 NRC Report (NRC, "Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles, 2015). NHTSA's technique for determining the mass reduction level starting points for the MY 2015 baseline fleet is a good beginning for resolving this concern. However, the several issues with NHTSA's technique will need to be addressed to arrive at a satisfactory resolution for determining the mass reduction starting point for the baseline fleet. A suggested requirement to recognize material usage in the baseline fleet vehicles is consistent with the 2015 NRC Study's Recommendation 6.3 for a "materials based approach…to better define opportunities…for implementing lightweighting techniques."

Recommendation 1 - Topic 3.2

Because of the impact of an economic behavioral model on demand for vehicles of different sizes and market segments, NHTSA should continue to develop, resolve previous issues, and validate an economic behavioral model for eventual incorporation in the Volpe Model. The price that the consumer evaluates in their purchase decision, such as MSRP, monthly payment, and/or monthly lease fee, will need to be determined for a successful economic behavioral model.

RESPONSE: The model has been revised to include procedures to dynamically estimate industry-wide sales of passenger cars and light trucks, and to dynamically estimate the survival of older vehicles in the fleet. Model documentation will be revised to document these model revisions, and a new Regulatory Impact Analysis will document the development of corresponding model inputs. These procedures do not constitute a fully detailed vehicle choice model; further research would be required to determine whether such a model can be practicably and realistically integrated in the CAFE model, and to determine how to address vehicle pricing. DOT has been sponsoring and conducting research and testing in this challenging area since the early 2000s (including demonstrating the potential to integrate such models into the CAFE model) and plans to continue doing so.

<u>Recommendation 2 – Topic 3.3</u>
The Volpe Model does not appear to analyze the Passenger Car Standards as they apply individually to the Import and Domestic Passenger Car fleets. Assess the need to analyze the Passenger Car Standards as they apply individually to the Import and Domestic Passenger Car fleets, and if necessary, implement the capability to include the analysis of Import and Domestic Passenger Car fleets.

RESPONSE: The model has been revised to account for the statutory requirement that compliance be determined separately for fleets of domestic and imported cars. Model documentation has been correspondingly updated, and a new Regulatory Impact Analysis discusses results on this basis.

<u>Recommendations 1- 4 – Topic 3.4</u>
Revise the Engine Level Paths (Figure 2) and Transmission Level Paths (Figure 3) to include the new engine and transmission technologies and the new transmission terminology introduced in the 2016 Draft TAR, including:
- Non-HEVAtkinson 2-cycle engines (ATK2) and Miller cycle engines (MILLER)
- The new transmission terminology, TRX11, TRX12, TRX21, TRX22
- Nine and 10-speed transmissions
- HEG1 and HEG2 High Efficiency Gearboxes

RESPONSE: Model documentation will be updated such that relevant text, tables, and figures reflect the updated set of technologies accommodated by the model. A new Regulatory Impact Analysis will discuss the basis for corresponding inputs to the model.

<u>Recommendation 9 – Topic 3.4</u>
Provide a discussion on whether and how volume-based learning might be better incorporated into cost estimates, especially for low volume technologies. Provide an update on empirical evidence of the cost reductions that occur in the automobile industry with volume, especially for large-volume technologies that will be relied on to meet the CAFE/GHG standards.

RESPONSE: A new Regulatory Impact Analysis will discuss updates to learning assumptions as reflected in updated cost inputs to the model. Further research would be required to determine whether and, if so, how volume-based learning could be simulated endogenously in the model, considering the potential need for these effects to "feed back" with technology application.

Recommendation 1-1 - Topic 4.1
Consider revising the following comment in the 2016 Draft TAR, "in a high fuel price regime, an expensive but very efficient technology may look attractive to manufacturers because the value of the fuel savings is sufficiently high to both counteract the higher cost of the technology and, implicitly, satisfy consumer demand to balance price increases with reductions in operating cost" after consideration of the following comment. Subtracting the value of the fuel savings from the technology cost is indicative of the effective cost. However, in the high fuel price regime, the group of lowest cost technologies will still result in a lower effective cost than with the one expensive technology.

RESPONSE: A new Regulatory Impact Analysis will clarify the influence of fuel price inputs on the model's estimate of "effective cost."

Recommendation 1 – Topic 4.5
The payback periods used in the Volpe Model should be clearly explained, particularly with respect to when the three year period is used and when the 1 year period is used. In addition, the comment that "manufacturers will treat all technologies that pay for themselves within the first three years of ownership (through reduced expenditures on fuel) as if the cost of that technology were negative" needs to be explained.

RESPONSE: A new Regulatory Impact Analysis will clarify the interpretation, specification, and updated inputs specifying payback periods.

Recommendation 3 – Topic 4.5

With an average vehicle price of $34,000, the estimated $2,000 increase for the MY 2025 standards would result in a 5.9 percent increase in vehicle price. If the estimated price elasticity of demand of -1 is correct, then a 5.9 percent decline in sales might result. Address the impact of the 5.9 percent decline in sales on the economy and the automotive industry in the TAR and /or other appropriate documentation.

RESPONSE: The model has been updated to including procedures to estimate impacts on new vehicle sales, and on older vehicle scrappage. Model documentation will be revised to document these new methods, and a new Regulatory Impact Analysis will discuss the development of corresponding model inputs.

Recommendation 8 – Topic 5.1

Provide an explanation of how the light-duty CAFE model interacts with the medium-duty fleet analysis in order to allow "simultaneous analysis of light-duty and medium-duty fleets." Explain that both fleets are required to be analyzed simultaneously to account for the potential interaction, but this simultaneous analysis significantly increases the complexity of analyzing the light-duty CAFE fleet.

RESPONSE: Model documentation will be updated to elaborate on how these interactions are accounted for, on the role of model inputs in determining the nature of any such interactions.

Recommendation 2 – Topic 5.2

Provide an explanation of how the ZEV mandate is handled in the CAFE Model. Include responses to the five questions listed in Concern 2, Topic 5.2. An explanation of how the ZEV mandate is handled should be included in the TAR.

RESPONSE: Documentation will be updated to address the model's handling of the ZEV mandate if this capability is actually exercised for CAFE rulemaking analysis.

Recommendation - Topic 5.3

Provide an explanation of how the outputs for "CO_2 Required and CO_2 Achieved" in Table 33 are used. Consider opportunities for EPA to use the output from the Volpe Model in place of their OMEGA Model output.

RESPONSE: The model has been updated to provide for explicit simulation of compliance with greenhouse gas emissions standards. Documentation will be updated to reflect these changes, and a new Regulatory Impact Analysis will discuss corresponding model inputs.

Recommendation 2-2 – Topic 5.4

Provide the explanation regarding how the class 2b3, medium duty passenger vehicles that are included in the light-duty CAFE requirements, are handled in Figures 25 and 26 in the CAFE Model Documentation. Clearly show output for Medium Duty Passenger Vehicles as part of the output for the Light Duty vehicle CAFE standard, which should be distinguished from the output for Class 2b3 trucks, which are part of the Medium- and Heavy-Duty Vehicle Fuel Efficiency Standard.

RESPONSE: Model documentation will be updated to explain that as long as model inputs appropriately assign specific MDPVs to manufacturers' light-duty vehicle fleets, these vehicles will be counted toward compliance with CAFE standards rather than toward standards applicable to heavy-duty pickups and vans.

2. Are the data, computational methods, and assumptions (as applicable) reasonable and appropriate given the purpose of the model? Why?

The data, computational methods, and assumptions are likely reasonable and appropriate, but the above summary of key Recommendations should be followed to ensure or enhance the Volpe Model, its documentation and the TAR.

RESPONSE: See responses to above recommendations.

3. What modifications do you suggest to the Volpe Model approach related to the review topic?

Implementing the above Recommendations is the suggested approach.

RESPONSE: See responses to above recommendations.

4. Is there an alternative approach that you would suggest?

No. Implementing the above Recommendations is the suggested approach.

RESPONSE: See responses to above recommendations.

5. [SKIP FOR REVIEW TOPICS 4.4 - 4.6] What is your assessment of the contribution of the review topic to the overall utility and plausibility of the Volpe Model output?

Implementing the above Recommendations will enhance the overall utility and plausibility of the Volpe Model output.

RESPONSE: See responses to above recommendations.

6. [REVIEW TOPICS 4.4 - 4.6 ONLY] What is your assessment of the utility of the output of the model for setting CAFE standards?

7. Provide any additional comments that may not have been addressed above.

Appendix A: Peer Reviewers' Résumés and Curricula Vitae

NIGEL N. CLARK

CURRICULUM VITAE

NIGEL.CLARK@MAIL.WVU.EDU

CAMPUS PROVOST
WEST VIRGINIA UNIVERSITY INSTITUTE OF TECHNOLOGY
MONTGOMERY, WV & BECKLEY WV CAMPUSES

PROFESSOR & GEORGE BERRY CHAIR
MECHANICAL & AEROSPACE ENGINEERING
WEST VIRGINIA UNIVERSITY
MORGANTOWN, WV

AREAS OF INTEREST

Alternative Fuels, Internal Combustion Engines and Emissions, Atmospheric Emissions Inventory, Vehicle Propulsion, Powder and Particle Technology, Multiphase Flows, Thermal Sciences

EDUCATION

1980 - 1985	Ph.D. Engineering University of Natal (now University of KwaZulu-Natal), Durban, South Africa Dissertation title: "A Study of Hydrodynamics and Mass Transfer in Small Bore Deep Shaft Reactors"
1975 - 1979	B.Sc. Chemical Engineering University of Natal (now University of KwaZulu-Natal), Durban, South Africa (Four-year degree accredited by the I.Chem.E. in the UK).

PUBLICATIONS

Dr. Clark is the author or co-author of over 500 publications and presentations, 180 of which appear in reviewed journals. A separate list of publications is available.

RESEARCH FUNDING

Grants and contracts are listed separately. Dr. Clark directs approximately $1 million/year in research, and has been a P.I. on or co-P.I. on approximately $50 million of research during his career. He has received funding from the National Science Foundation, Department of Energy, Department of Transportation, Department of Defense, Environmental Protection Agency, States of California, New York, Texas, Maryland, and West Virginia, major engine manufacturers, oil, fuel and additive manufacturers, the Coordinating Research Council, the Transportation Research Board and industrial and commercial entities.

EMPLOYMENT HISTORY

2015 – Present	Campus Provost West Virginia University Institute of Technology Montgomery, WV and Beckley, WV
1999 – Present	George Berry Chair of Engineering, West Virginia University
1990 – Present	Professor, Department of Mechanical and Aerospace Engineering West Virginia University
2011 – 2015	Associate Vice President, Academic Strategic Planning West Virginia University
2009 – 2011	Member, Board of Governors West Virginia University
2004 – 2009	Director, Center for Alternative Fuels, Engines & Emissions West Virginia University
1986 – 1990	Associate Professor, Department of Mechanical and Aerospace Engineering West Virginia University
1986 – 1995	Adjunct Associate Professor and Adjunct Professor, College of Mineral and Energy Resources
1984 - 1986	Research Assistant Professor, Particle Analysis Center West Virginia University
1982 – 1983	Factory Survey Engineer, Water Research Commission Durban, South Africa. (Surveys into water usage and wastewater disposal.)
1980 – 1982	Contract Researcher, Council for Mineral Technology Durban, South Africa. (Investigation of Deep Shaft Reactors for possible mineral processing application. Involved fundamental analysis of fluid flow.) Supported Ph.D. research.
1981	Part-time Lecturer, Engineering Faculty, University of Durban-Westville, Natal, South Africa. (Lectured in Thermodynamics, Managed Unit Operations Laboratory).

1979 – 1980	Fortran Programmer, CSP Project, University of Natal, Durban. (Modeling for supersonic shock wave gas reactors.)
1978 -1983	Part-time Fortran Programmer, Mobil Refining Co., Durban, South Africa. (Improvement and operation of program to monitor fluidized catalytic cracker performance.)
1977 – 1978	Undergraduate employment at Sugar Milling Research Institute, Durban, South Africa. (Investigation into boiling flows in long tube vertical evaporators, and diffusion coefficients in sugarcane diffusion trains.)

HONORS AND AWARDS

- National Youth Science Week Participant, South Africa, 1974 and 1975
- Top 100, National Mathematics Olympiad, South Africa, 1975
- D.H.S. Memorial Scholarship, 1976 and 1977
- University of Natal Scholarship, 1976
- Member, Students' Representative Council, University of Natal, 1977 and 1978
- Award of Distinction, Powder and Bulk Solids Conference, 1985
- College of Engineering Outstanding Researcher Award, 1986-87
- Ralph R. Teetor Educational Award (Society of Automotive Engineers), 1988
- College of Engineering Outstanding Researcher Award, 1987-88
- Researcher of the Year Award, College of Engineering, 1987-88
- College of Engineering Outstanding Researcher Award, 1988-89
- NSF Presidential Young Investigator, 1989
- Benedum Award for Science and Technology, 1990
- College of Engineering Outstanding Researcher Award, 1989-90
- College of Engineering Outstanding Researcher Award, 1990-91
- College of Engineering Outstanding Teacher Award, 1990-91
- Donald Julius Groen Prize of the Institution of Mechanical Engineers (London), 1992
- College of Engineering Outstanding Researcher Award, 1991-92
- Researcher of the Year Award, College of Engineering, 1991-92
- College of Engineering Outstanding Researcher Award, 1992-93
- Excellence in Oral Presentation Award, SAE Congress 1993
- College of Engineering Outstanding Researcher Award, 1993-94
- College of Engineering Outstanding Researcher Award, 1994-95
- College of Engineering and Mineral Resources Outstanding Researcher Award, 1996-97
- Researcher of the year, College of Engineering and Mineral Resources, 1996-97
- College of Engineering and Mineral Resources Outstanding Researcher Award, 1997-98
- Researcher of the year, College of Engineering and Mineral Resources, 1997-98
- Award of the George Berry Chair of Engineering, WVU, 1999
- Society of Automotive Engineers Recognition Award (for presentation), 1999
- College of Engineering and Mineral Resources Outstanding Researcher Award, 2000-01
- Researcher of the Year, College of Engineering and Mineral Resources, 2000-01
- Donald T. Worrell Award, 2002
- College of Engineering and Mineral Resources Outstanding Researcher Award, 2002-03
- College of Engineering and Mineral Resources Outstanding Researcher Award, 2003-04
- Researcher of the Year, College of Engineering and Mineral Resources, 2003-04
- Fellow, Society of Automotive Engineers, 2005
- College of Engineering and Mineral Resources Outstanding Researcher Award, 2006-07
- College of Engineering and Mineral Resources Outstanding Researcher Award, 2007-08
- Society of Automotive Engineers Excellence in Oral Presentation Award, 2010
- College of Engineering and Mineral Resources Outstanding Researcher Award, 2009-10

INSTRUCTION AT WEST VIRGINIA UNIVERSITY

- Fall 1986, Heat Transfer, MAE 250. Enrollment: 64 (2 sections)
- Summer and Fall 1986, Supervised three graduate MAE Special Topics courses
- Spring 1987, Internal Combustion Engines, MAE 262, Enrollment: 30, Developed significant new course material.
- Spring 1987, Supervised or co-supervised 16 senior students for MAE 136 (Design) or MAE 299 (Special Topics)
- Fall 1987, Thermodynamics and Fluids Laboratory, MAE 145 Enrollment: 35 (3 sections)
- Fall 1987, Co-Advisor to Formula Car Design Team and to one MAE 299 (Special Topics) student, Developed new laboratory
- Spring 1988, Heat Transfer, MAE 158, Enrollment: 70
- Spring 1988, Gas Liquid Systems, CE 491/290 (Team Teaching-Graduate Course), Enrollment: 12
- Spring 1988, Co-Advisor to Formula Car Design Team, Advisor to one MAE 399 and eight MAE 299 (Special Topics) students
- Summer 1988, Advisor to two MAE 299 (Special Topics) students
- Fall 1988, Thermal-Fluids Laboratory, MAE 145, Enrollment: 70
- Fall 1988, Multiphase Flows, MAE 419 (Graduate Course), Enrollment: 10, Developed extensive new course material
- Fall 1988, Co-Advisor to Formula Car Design Team, Advisor to three MAE 299 and one MAE 399 (Special Topics) students
- Spring 1989, Thermal-Fluids Laboratory, MAE 145, Enrollment: 25, Added new laboratory
- Spring 1989, Internal Combustion Engines, MAE 262, Enrollment: 50
- Spring 1989, Co-Advisor to Formula Car Design Team, Advisor to Methanol Car Team, Advisor to Two MAE 399 (Graduate Special Topics) Students
- Fall 1989, Heat Transfer, MAE 158, Enrollment: 30
- Fall 1989, Thermal-Fluids Laboratory, MAE 145, Enrollment: 30, Added new laboratory
- Fall 1989, Advisor to Methanol Car Team (MAE 184 & MAE 299 Students)
- Spring 1990, Thermal-Fluids Laboratory, MAE 14
- Spring 1990, Special Problems: Alternative Fuels, MAE 294
- Fall 1990, Senior Design, MAE 183, Enrollment: 9
- Fall 1990, Topics in Fluids & Solids, MAE 419, Enrollment: 20
- Fall 1990, Thermal Fluids Laboratory, MAE 145, Enrollment: 55
- Spring 1991, Internal Combustion Engines, MAE 262, Enrollment: 30
- Spring 1991, Thermal Fluids Laboratory, MAE 145, Enrollment: 25
- Spring 1991, Senior Design, MAE 184, Enrollment: 9
- Fall 1991, Senior Design, MAE 183, Enrollment: 20
- Spring 1992, Senior Design, MAE 184, Enrollment: 18
- Fall 1992, Internal Combustion Engines, MAE 262, Enrollment: 50
- Fall 1992, Senior Design, MAE 183, Enrollment: 18
- Fall 1992, Topics in Fluids and Solids, MAE 419, Enrollment: 10
- Spring 1993, Senior Design, MAE 184, Enrollment: 10
- Fall 1993, Senior Design, MAE 183, Enrollment: 25
- Fall 1993, Internal Combustion Engines, MAE 262, Enrollment: 60
- Spring 1994, Senior Design, MAE 184, Enrollment: 25

- Fall 1994, Senior Design, MAE 183, Enrollment: 16
- Spring 1995, Senior Design, MAE 184, Enrollment: 15
- Spring 1995, Internal Combustion Engines, MAE 262, Enrollment: 42
- Fall 1995, Senior Design, MAE 183, Enrollment: 16
- Spring 1996, Senior Design, MAE 184, Enrollment: 16
- Fall 1996, Internal Combustion Engines, MAE 262, Enrollment: 48
- Fall 1996, Senior Design, MAE 183, Enrollment: 11
- Spring 1997, Senior Design, MAE 184, Enrollment: 11
- Fall 1997, Senior Design, MAE 183, Enrollment: 12
- Fall 1997, Internal Combustion Engines, MAE 262, Enrollment: 40
- Spring 1998, Senior Design, MAE 184, Enrollment: 10
- Fall 1998, Internal Combustion Engines, MAE 262, Enrollment: 23
- Spring 1999, Strength of Materials, MAE 43, Enrollment: 12
- Fall 1999, Internal Combustion Engines, MAE 262, Enrollment: 32
- Fall 1999, Advanced Vehicle Propulsion (team taught with C. Atkinson), MAE 394C, Enrollment: 8
- Spring 2000, Mobile Source Powerplants, MAE 394E, Enrolment 12
- Fall 2000, Internal Combustion Engines, MAE 262, Enrollment: 25
- Fall 2000, WVU Advanced Vehicle Propulsion, MAE 394C, Enrollment: 10
- Fall 2000, WVU Senior Design – FutureTruck, MAE 183, Enrollment: 8
- Spring 2001, WVU Senior Design – FutureTruck, MAE 184, Enrollment: 8
- Spring 2001, Mobile Source Powerplants, MAE 394E, Enrollment: 15
- Fall 2001, Internal Combustion Engines, MAE 425 (new number system), Enrollment: 36
- Fall 2001, Advanced Vehicle Propulsion, MAE 693 & 593 (new number system), Enrollment: 16
- Fall 2001, Senior Design – FutureTruck, MAE 471, Enrollment: 7
- Spring 2002, Senior Design – FutureTruck, MAE 472, Enrollment: 7
- Spring 2002, Vehicle Propulsion, MAE 693C, Enrollment: 10
- Fall 2002, Senior Design – FutureTruck, MAE 471, Enrollment: 27
- Fall 2002, Internal Combustion Engines, MAE 425, Enrollment: 55
- Spring 2003, Senior Design – FutureTruck, MAE 472, Enrollment: 25
- Fall 2003, Internal Combustion Engines, MAE 425, Enrollment: 68
- Fall 2003, Senior Design – FutureTruck, MAE 471, Enrollment: 25
- Spring 2004, Senior Design – FutureTruck, MAE 472, Enrollment: 23
- Fall 2004, Internal Combustion Engines, MAE 425, Enrollment: 65
- Fall 2004, Senior Design – FutureTruck, MAE 471, Enrollment: 20
- Spring 2005, Senior Design – FutureTruck, MAE 472, Enrollment: 18
- Fall 2005, Internal Combustion Engines, MAE 425, Enrollment: 55
- Fall 2005, Senior Design – FutureTruck, MAE 471, Enrollment: 20
- Spring 2006, Senior Design – FutureTruck, MAE 472, Enrollment: 14
- Fall 2006, Internal Combustion Engines, MAE 425, Enrollment: 64
- Fall 2006, Senior Design – FutureTruck, MAE 471, Enrollment: 30
- Fall 2007, Internal Combustion Engines, MAE 425, Enrollment: 51
- Spring 2008, Heat Transfer, MAE 423, Enrollment: 51
- Fall 2008, Machine Design & Manufacturing, MAE 454, Enrollment: 98
- Spring 2009, Internal Combustion Engines, MAE 425, Enrollment: 62
- Spring 2010, Internal Combustion Engines, MAE 425, Enrollment: 41

GRADUATE SUPERVISION AS A MAJOR ADVISOR (1995 - PRESENT)

DOCTOR OF PHILOSOPHY

Weidong Liu, Data Interpretation Techniques for Inferring Bubble Size and Distribution (December 1995).

Kristine K. Craven, Thermodynamic Model of a Three Chamber Engine (May 1997).

W. Scott Wayne, A Parametric Study of Knock Control Strategies for a Bi-Fuel Engine (May 1997).

Christopher J. Tennant, Application of Automotive Engine Control Technology to General Aviation Aircraft Powerplants (December 1997).

Ali Ihsan Karamavruc, Interpretation of Data From a Horizontal Heat Transfer Tube in a Bubbling Fluidized Bed (May 1995).

Ehab F. Shoukry, Numerical Simulation for Parametric Study of a Two-Stroke Compression Ignition Direct Injection Linear Engine (Aug. 2003).

Csaba Toth-Nagy, Linear Engine Development for Series Hybrid Electric Vehicles (December 2004).

Prakash Gajendran, Development of a Heavy Duty Diesel Vehicle Emissions Inventory Prediction Model (August 2005).

Madhava Madireddy, Methods for Reconstruction of Transient Emissions from Heavy-Duty Vehicles (July 2008).

ABM S. Khan, Route and Grade Sensitive Modeling of Fuel Efficiency and Emissions for Diesel Buses (August 2009).

Clinton Bedick, Optimization of a Retrofit Urea-SCR System (November 2009).

Yuebin Wu, Laboratory and Real-World Measurement of Diesel Particulate Matter (October 2010).

Francisco Posada Sanchez, Enabling HCCI Combustion of n-Heptane through Thermo-Chemical Recuperation (October 2010).

Derek Johnson, Implementation of Wet Scrubbing Technologies to Marine Diesel Engines for the Reduction of NOx Emissions (May 2012)

Lijuan Wang, Heavy-duty vehicles models and factors impacting fuel consumption, (December 2011)

Feng Zhen, Optimization Tool for Transit Bus Fleet Management (December 2012)

Ahmed Al-Samari, Impact of Intelligent Transportation Systems on Parallel Hybrid Electric Heavy Duty Vehicles, (Fall 2014)

Bharadwaj Sathiamoorthy, Spatial and Temporal Investigation of Real World Crosswind Effects on Transient Aerodynamic Drag Losses in Heavy Duty Truck Trailers in the US (Spring 2015)

Matthew Robinson, Analysis and Optimization of a Dual Free Piston, Spring Assisted, Linear Engine Generator (Fall 2015)

Mohammad Alrbai, Modeling and Simulation of a Free-Piston Engine with Electrical Generator Using HCCI Combustion (Summer 2016)

April Covington, Current Student

MASTER OF SCIENCE

Suresh Sunderesan, Measurement of Local Instantaneous Heat Transfer Coefficients and Pressure Fluctuations in a Gas Fluidized Bed (May 1995).

Christopher Tennant, Experimental Investigation of a Bi-Fuel Engine (December 1994).

Steve McConnell, The Design of a Medium Duty Transportable Chassis Dynamometer (December 1995).

J. Todd Messer, Measurement Delays and Modal Analysis for Two Heavy Duty Transportable Emissions Testing Laboratories and a Stationary Engine Emissions Testing Laboratory (December 1995).

Ralph Nine, Volatile and Semi-Volatile Hydrocarbon Speciation of a Current Low Emission Medium Duty Diesel Engine (December 1995).

Franklin Miller, Transient Engine Testing Torque and Speed Compliance (August 1995).

Brian McGrath, Wide-Open Throttle Performance of an Internal Combustion Engine Fueled with M85 (December 1996).

Sumit Bhargava, advised by Dr. Nigel Clark: Exhaust Gas Recirculation in a Lean-Burn Natural Gas Engine (May 1998).

Clarence Gadapati, Fluidized Beds as Automotive Catalytic Converters (May 1998).

Jennifer A. Hoppie, Defining Drivetrain Losses in Developing a Cycle for Engine and Chassis Dynamometer Test Compliance and Uncertainty Analysis of Emissions Test Facilities (December 1997).

James J. Daley, Development of a Heavy Duty Vehicle Chassis Dynamometer Test Route (December 1998).

Subhash Nandkumar, Two-Stroke Linear Engine (December 1998).

Talus Park, Dual Fuel Conversion of a Direct Injection Diesel Engine (May 1999).

Ravishankar Ramamurthy, Heavy Duty Emissions Inventory and Prediction (May 1999).

David Houdyschell, advised by Dr. Nigel Clark: A Diesel-Two-Stroke Linear Engine (May 2000).

Brian E. Mace, Emissions Testing of Two Recreational Marine Engines with Water Contact in the Exhaust Stream (May 2000).

Justin M. Kern, Inventory and Prediction of Heavy-Duty Diesel Vehicle Emissions (May 2000).

Eric Corrigan, Measuring Heavy-Duty Diesel Emissions With a Split Exhaust Configuration (May 2001).

Andrew D. Fuller, A Flow Rate Measurement System for a Mobile Emissions Monitoring System (May 2001).

Ronald P. Jarrett, Evaluation of Opacity, Particulate Matter, and Carbon Monoxide from Heavy-Duty Diesel Transient Chassis Tests (December 2000).

Eric Meyer, Evaluation of Flowrate Measurement Techniques for an On-Road Emissions Monitoring System (May 2001).

Paul Andrei, Real World Heavy-Duty Vehicle Emissions Modeling (August 2001).

Akunor Azu, A Comparison of Real Use Performance of Diesel Fueled Trucks and Hybrid Electric Buses to the Federal Testing Procedure (December 2001).

Bradley R. Bane, A Comparison of Steady State and Transient Emissions from a Heavy-Duty Diesel Engine (May 2002).

Anjali Nennelli, Simulation of Heavy Duty Hybrid Electric Vehicles (December 2001).

Paidamoyo A. Nyika, An Analysis of a Reformulated Emission Control Diesel Effects on Heavy Duty Diesel Exhaust Emissions (December 2001).

Jonathan Smith, Optimum Hybrid Vehicle Configurations for Heavy Duty Applications (August 2001).

Jason Conley, A Rational Understanding of Energy and Power Demands for Hybrid Vehicles (August 2002).

Marcus Gilbert, Investigation into the Use of a Tapered Element Oscillating Microbalance for Real-Time Particulate Measurement (December 2002).

Azadeh Tehranian, Effects of Artificial Neural Networks Characterization on Prediction of Diesel Engine Emissions (May 2003).

Aparna Aravelli, Real-time Measurement of Oxides of Nitrogen from Heavy-Duty Diesel Engines (Dec. 2003).

Thomas Buffamonte, Evaluation of Regulated Emissions from Heavy-Duty Diesel Vehicles in the South Coast Air Basin (Aug. 2003).

J. Axel Radermacher, Repeatability of On-Road Routes and a Comparison of On-Road Routes to the Federal Test Procedure (May 2004).

Nastaran Hashemi, Effects of Artificial Neural Network Speed-Based Inputs on Heavy-Duty Vehicle Emissions Prediction (Aug. 2004).

Ramprabhu Vellaisamy, Assessment of NOx Destruction in Heavy-Duty Diesel Engines by Injecting Nitric Oxide into the Intake (May 2005).

Matthew Swartz, Nitric Oxide Conversion in a Spark Ignited Natural Gas Engine (May 2005).

ABM Siddique Rahman Khan, Evaluating Real-World Idle Emissions from Heavy-Duty Diesel Vehicles (August 2005).

Kuntal Vora (MSAE), Cycles and Weight Effects on Emissions and Development of Predictive Emissions Models for Heavy Duty Trucks (August 2006)

Corey Strimer, Quantifying Effects of Vehicle Weight and Terrain on Emissions, Fuel Economy, and Engine Behavior (November 2006).

Russell King, Design of a Selective Catalytic Reduction System to Reduce NOx Emissions of the 2003 West Virginia University FutureTruck (April 2007).

Derek Johnson, Design and Testing of an Independently Controlled Urea-SCR System for Marine Diesel Applications (July 2008).

Howard Mearns, Design and Testing of the WVU Challenge X Competition Hybrid Diesel Electric Vehicle (May 2009).

Neil Buzzard, Investigation into Pedestrian Exposure to Near-Tailpipe Exhaust Emissions (July 2009).

Idowu Olatunji, Emissions Characterization and Particle Size Distribution from a DPF-Equipped Diesel Truck Fueled with Biodiesel Blends (December 2010).

Sean Lockard, MS, Problem Report

Louise Ayre, MS Design and Evaluation of a Marine Scrubber System (December 2012)

Mehar Ramanjeneya Bade, Current MS Student

ADMINISTRATIVE AND SERVICE ACTIVITIES

MEMBERSHIP OF ENGINEERING INSTITUTIONS

- American Society of Mechanical Engineers (Present Member)
- Society of Automotive Engineers (Present Member, Fellow grade of membership)
- Tau Beta Pi

CONFERENCE ORGANIZATION

- Session Chair, 1986 Powder and Bulk Solids Conference
- Session Chair and member of the Organizing Committee, 1986 Fine Particle Society Annual Meeting
- Session Chair and member of the Organizing Committee, 1987 Fine Particle Society Annual Meeting
- Session Co-chair, 1987 American Society of Civil Engineers Meeting, Buffalo, NY
- Co-Organizer, Society of Automotive Engineers Pittsburgh Chapter Meeting, Morgantown, October 1988
- Session Chair, Society of Automotive Engineers Congress, Detroit, February 1989
- Co-Organizer of Multiphase Flow Symposium, Fine Particle Society Meeting, Boston, 1989
- Chair of 2 sessions, Co-chairman of 1 session, Fine Particle Society Meeting, Boston, 1989
- Co-Organizer of Multiphase Flow Symposium, Fine Particle Society Meeting, San Diego, 1990
- Chair of 1 session, Fine Particle Society Meeting, San Diego, 1990
- Chair of 1 session, Society of Automotive Engineers Congress, Detroit 1992
- Chair of 1 session, Society of Automotive Engineers Congress, Detroit, 1993
- Chair of 1 session, Society of Automotive Engineers Congress, Detroit, 1994
- Chair - 1 session, Co-chair - 1 session, Society of Automotive Engineers Congress, Detroit, 1995
- Chair of 1 session, Society of Automotive Engineers Congress, Detroit, 1996
- Session Organizer, SAE Spring Fuels & Lubricants Meeting, Paris 2000
- Chair of 1 session, Society of Automotive Engineers Fall Fuels & Lubricants Meeting, Baltimore, 2000
- Session Organizer, SAE Fall Fuels & Lubricants Meeting, 2001
- Session Organizer, SAE Spring Fuels & Lubricants Meeting, 2003
- Session Organizer & Chair, 14th Asia-Pacific Automotive Engineering Conference, 2007
- Session Organizer, SAE Fuels & Lubricants Meeting, 2007

SERVICE TO THE DEPARTMENT

- Construction of Undergraduate Thermodynamics and Fluids Laboratory for MAE 145, a new laboratory course. This involved the renovation, or the design and construction, of apparatus for seven different laboratory experiments. (1987-88)
- A.S.M.E. Student Chapter Advisor, 1987, 1988, 1989, 1990. Involved plant tours, section meetings, social events, annual student regional meeting.

JOURNALS, AGENCY AND CONFERENCE REVIEWS (PRIOR TO 1994)

- Powder Technology
- Canadian Journal of Chemical Engineering
- International Journal of Mineral Processing
- A.I.Ch.E. Journal

- Journal of Powder and Bulk Solids Technology
- Particulate Science and Technology
- International Journal of Multiphase Flow
- ASME Journal of Fluids Engineering
- Society of Automotive Engineers Transactions
- Chemical Engineering Communications
- AIME (Mining Engineering)
- Chemical Engineering Science
- International Journal of Vehicle Design
- Industrial and Engineering Chemistry Research
- ASME Fluids Engineering Division Conference Papers
- SAE Congress Conference Papers
- Fine Particle Society Conference Papers
- Proceedings of Institution of Mechanical Engineers (London)
- Reviewer for National Science Foundation Proposals
- Reviewer for Department of Energy Proposals

JOURNAL, PROPOSAL AND CONFERENCE PAPER REVIEWS (1995 - PRESENT)

- Proceedings of Institute of Mechanical Engineers (2/95)
- Canadian Journal of Chemical Engineering (2/95)
- ASME Fluids Eng. Division Conf. Paper (3/95)
- Institution of Chemical Engineers (4/95)
- Powder Technology (USA) (5/95)
- Powder Technology (UK) (5/95)
- A.I.Ch.E. Journal (8/95)
- National Science Foundation (10/95)
- A.I.Ch.E. Journal (10/95)
- A.I.Ch.E. Journal (2nd review of paper) (10/95)
- SAE Congress (3 papers) (10/95)
- SAE Congress (1 paper) (12/95)
- Canadian Journal of Chemical Engineering (11/95)
- SAE Fuels & Lubricants Meeting (1 paper) (1/96)
- Int. Jour. of Multiphase Flow (4/96)
- Powder Technology (4/96)
- A.I.Ch.E. Journal (6/96)
- Industrial and Engineering Chemistry Research (8/96)
- National Science Foundation (10/96)
- Powder Technology (UK) (2/97)
- SAE Conference Papers (2papers) (5/97)
- Int. Jour. of Multiphase Flow (6/97)
- Powder Technology (USA) (6/97)
- SAE Conference Papers (5 papers) (10/97)
- Int. Jour. Multiphase Flow (11/97)
- Proc. Inst. Chem. Engrs. (London) (11/97)
- A.I.Ch.E. Journal (3/98)

- Environmental Science & Technology (3/98)
- Journal of Aerospace Eng. (Proc. Inst. Mech. Engrs.) (4/98)
- Journal of the Air & Waste Management Assoc. (4/98)
- Powder Technology (USA) (5/98)
- Industrial & Engineering Chemistry Research (5/98)
- Chemical Engineering Communications (6/98)
- Society of Automotive Engineers F&L Meeting (4 papers) (6/98)
- Society of Automotive Engineers Congress (10/98)
- Society of Automotive Engineers (Special Manuscript Review) (10/98)
- Powder Technology (London) (10/98)
- ASAE Transactions (10/98)
- ASME ICE paper (11/98)
- Journal of Automobile Eng., Proc. I. Mech. E. (11/98)
- Heat and Fluid Flow (11/98)
- Chemical Engineering Communications (1/99)
- Environmental Science & Technology (7/99)
- ASME ICE Division Conference Paper (7/99)
- Journal of Aerospace Engineering (7/99)
- SAE Fuels & Lubricants Meeting (2 papers) (7/99)
- Environmental Science & Technology (9/99)
- Transportation Research Board Conf. Paper (9/99)
- Powder Technology (London) (10/99)
- Environmental Science & Technology (11/99)
- Journal of Automobile Engineering (11/99)
- Society of Automotive Engineers Conf. Papers (two) (12/99)
- I.Mech. E. Jour. Aerospace Eng. (2nd review) (1/00)
- I.Mech. E. Jour. Automobile Eng. (2nd. review) (1/00)
- A.I.Ch.E. Journal (1/00)
- Powder Technology (London) (1/00)
- Am. Soc. Agric. Engrs. Jour. (3/00)
- Advances in Environmental Research (4/00)
- Am. Soc. Agric. Engrs. Jour. (4/00)
- SAE Fuels & Lubricants Conf. (2 papers) (4/00)
- Environmental Science & Technology (6/00)
- SAE Fuels & Lubricants Conf. (6/00)
- Proc. I. Mech. Eng., Mech. Eng. Sci. (6/00)
- A.I.Ch.E. Jour. (8/00)
- Proc. I. Mech. Eng., Mech. Eng. Sci. (8/00)
- Environmental Science & Technology (8/00)
- SAE Truck & Bus Meeting Paper (8/00)
- A.I.Ch.E. Jour. (11/00)
- Coordinating Research Council – Proposal Review (11/00)
- IEEE Proceedings (UK) (12/00)
- Chemical Engineering Journal (12/00)
- Advances in Environmental Research (2nd. review) (1/01)

- Society of Automotive Engineers Conf. Paper (2/01)
- Powder Technology (7/01)
- Journal of the Air & Waste Management Assoc. (8/01)
- Environmental Science & Technology (8/01)
- Environmental Science & Technology (10/01)
- ASME Journal of Fluids Engineering (10/01)
- AIChE Journal (10/01)
- Chemical Engineering Communications (re-review) (11/01)
- Chemical Engineering Science (1/02)
- Chemical Engineering Communications (1/02)
- Chemical Engineering Research & Design (1/02)
- Energy (2/02)
- Jour. Of the Air & Waste Management Assoc. (7/02)
- A.I.Ch.E. Journal (2nd Review of paper) (7/02)
- Energy & Fuels (7/02)
- SAE Congress papers (two) (11/02)
- Energy & Fuels (1/03)
- International Journal of Thermal Sciences (3/03)
- Energy & Fuels (2nd Review) (6/03)
- Jour. of Automobile Engineering (6/03)
- Jour. of Engine Research (6/03)
- Soc. of Automotive Engineers Powertrain Conf. Paper (7/03)
- Jour. of Automobile Engineering (11/03)
- Soc. of Automotive Engineers Conf. Papers (two) (11/03)
- ASME Transactions: Jour. of Eng. For Gas Turbines & Power (11/03)
- A.I.Ch.E. Journal (12/03)
- Jour. of Environmental Management (12/03)
- Chemical Engineering Communications (12/03)
- Journal of Automobile Engineering (4/04)
- Journal of the Air & Waste Management Assoc. (6/04)
- Environmental Science & Technology (8/04)
- Journal of Automobile Engineering (8/04)
- Journal of Automobile Engineering (Second Review) (8/04)
- Journal of Automobile Engineering (Second Review) (12/04)
- Environmental Science & Technology (3/05)
- Atmospheric Environment (5/05)
- Journal of Environmental Monitoring (5/05)
- ICE2005 Conference, Italy (7/05)
- Review of Scientific Instruments (9/05)
- Journal of the Air & Waste Management Assoc. (9/05)
- Transportation Research Board (Conference Paper) (10/05)
- Mech. Eng. Jour. of Aerospace Eng. (10/05)
- Soc. of Automotive Engineers Congress Paper (11/05)
- Review of Scientific Instruments (second review) (11/05)
- Journal of Automobile Engineering (1/06)

- ASME Internal Combustion Engine Division Conference Paper (1/06)
- Environmental Science & Technology (5/06)
- Environmental Science & Technology (6/06)
- Jour. of Automobile Engineering (7/06)
- Transportation Research Board Paper (9/06)
- ASME Internal Combustion Engines Division Conference Paper (9/06)
- Transportation Research Board Paper (9/06)
- Transportation Research Board Paper (9/06)
- Society of Automotive Engineers Fuels & Lubricants Meeting (10/06)
- Jour. of the Air & Waste Management Assoc. (10/06)
- Society of Automotive Engineers Congress (2 papers) (11/06)
- Journal of Automobile Engineering (second review) (11/06)
- Transportation Research Board Paper (second review) (11/06)
- Society of Automotive Engineers Congress (11/06)
- International Journal of Sustainable Transportation (1/07)
- Powder Technology (3/07)
- Energy & Fuels (3/07)
- Society of Automotive Engineers 8th Int. Conf. on Engines for Automobiles (6/07)
- Asia-Pacific Automotive Engineering Conference (2 papers) (6/07)
- Journal of Automobile Engineering (6/07)
- Environmental Science & Technology (7/07)
- Transportation Research Board Paper (8/07)
- Transportation Research Board Paper (8/07)
- Transportation Research Board Paper (9/07)
- Society of Automotive Engineers Congress (11/07)
- Journal of Automobile Engineering (12/07)
- Environmental Science & Technology (12/07)
- Society of Automotive Engineers Conference Paper (12/07)
- International Journal of Engine Research (1/08)
- Journal of Automobile Engineering (1/08)
- Environmental Health (1/08)
- Energy & Fuels (5/08)
- Transportation Research Board conference paper (9/08)
- Chemical Engineering Science (9/08)
- Applied Energy (12/08)
- Heat Transfer Engineering (2/09)
- ASME Internal Combustion Engines division paper (2/09)
- SAE Conference Paper (6/09)
- Journal of the Air & Waste Management Association (7/10)
- Environmental Science & Technology (10/10)
- International Journal of Engine Research (11/10)
- Combustion Science and Technology (2/11)
- Experimental Thermal & Fluid Science (3/11)
- Environmental Science & Technology (4/11)
- International Journal of Hydrogen Energy (5/11)

- Combustion Science and Technology (5/11) (2nd review)
- International Journal of Sustainable Transportation (2/12)
- Fuel Processing Technology (3/12)
- Energy & Fuels (6/12)
- Society of Automotive Engineers – Conference Paper (7/12)
- International Journal of Hydrogen Energy (7/13)
- Society of Automotive Engineers – Conference Paper (12/13)
- Environmental Science and Pollution Research (1/14)
- Emission Control Science and Technology (10/14)
- Mathematical Problems in Engineering (1/15)
- Atmospheric Environment (2/15)
- Fuel (5/15)

ADMINISTRATIVE AND COMMITTEE SERVICE

- Society of Automotive Engineers Subcommittee Member, 1988-1990
- Undergraduate Advisor for Department, 1987-1996
- Co-Advisor for Society of Automotive Engineers Formula Car Design Team, 1988-89, 1989-1990
- Advisor for the WVU Methanol Car Conversion Team, 1988-1989, 1989-1990
- Member, WVU Water Research Institute Committee, 1987-1992
- Member of Executive Committee of Fine Particle Society, 1987-1991
- Vice Chairman, ASME Mountaineer Group, 1990-1992
- Member ASME Fluids Engineering Multiphase Flow Committee, 1989 - Present
- Advisor for SAE Formula Car Design Team, 1990-Present
- Member, Department Undergraduate Curriculum Committee, 1990-1995
- Member, Department Laboratory Committee, 1990-1991
- Member, Department Promotion and Tenure Committee, 1991-92
- Member of College of Engineering Planning Leadership group, and Chairman of College Strategic Planning Research Committee, 1993
- Chairman, ASME Mountaineer Group, 1992-93
- Vehicle Design Associate of the International Journal of Vehicle Design, 1993-Present
- Member of College Research Committee, 1993-94
- Member of College Initiative Committee on management operations, 1993-94
- Participant, College Retreat on Centers, 1993
- West Virginia University Faculty Senator, 1994-2001
- Diesel Engine Technology Workshop/Presentation for Hercules Aerospace Staff, July, 1994
- Participant, Southern Oxidants Study Work Group, July, 1994
- Advisor to Jennifer Hoppie: "GE Faculty of the Future Undergraduate Research Grant Program", 1994
- Member of Committee to Unify Colleges of Engineering and of Mineral and Energy Resources, 1995
- West Virginia University Faculty Senate Executive Committee Member, 1995-96, 1996-97, 1997-98
- West Virginia University Expert Business Office Task Force on Procurement - Member, 1995
- West Virginia University Senate Committee on Research, Research Grants & Publications - Member, 1995 - 96, Chair Nominee, 1996, Chair, 1997 & 1998
- Senate Representative to University Graduate Council, 1995 - 1996
- West Virginia University Research Advisory Committee, 1995
- West Virginia University Research Task Force: Team Leader for 1/3 of the Task Force, 1996

- West Virginia University Research Task Force Implementation Committee on Funding Strategy, 1996 - 1997
- Review Team for Ph.D. in Chemistry, Member, 1996
- Select Committee on Faculty Rewards (to revise Promotion & Tenure Guidelines), Member, 1996
- College of Engineering and Mineral Resources Promotion and Tenure Committee, 1996-1997
- University Faculty Hearing Panel, 1997-1998
- Advisor to Talus Park, EG&G Byrd Scholar, 1996-1997
- Search Committee for Assoc. Dean of Arts & Sciences, 1997
- WVU Research Corporation Board, 1997 - 2000
- Search Committee for WVU Assoc. Provost for Research, 1998
- Member, Advisory Council to the Assoc. Provost for Research, 1998-2000
- Benedum Award Committee, 1998-1999
- WVU Senate Committee on Committees, Chair-Elect, 1999-2000
- WVU Representative to the Advisory Council of Faculty (State Level, 1999-2000
- WVU Task Force on Salary Policy, 1999-2000
- Committee to select four Eberly Professorships (Arts & Sciences), 1999-2000
- CEMR Dean's Review Committee, 1999-2000
- WVU Faculty Senate Executive Committee (ex-officio member), 1999-2000
- West Virginia University Press Advisory Board, 2000-2002
- Chair, State advisory Council of Faculty, 2000-2001
- CEMR Dean Search Committee, 2000
- Search Committee for Assoc. Director, WVU Research Corporation, 2000
- Faculty Representative for establishment of WVU Compact, 2000-2001
- Search Committee Chair for hiring for two research positions in Petroleum & Natural Gas Engineering, WVU, 2000-2001
- Search Committee for Endowed Professorship in Mathematics, 2001
- Committee to revise statewide Series 36 policy, 2001
- Director, Graduate Automotive Technology Education program (US DOE funded) at WVU, 2000-2001
- Advisor, WVU FutureTruck Student Team, 2000-2001, 2001-2002
- Committee to select Endowed Chairs in College of Law, 2001
- Served on EPA Technical Qualifications Board (Personnel Review), 2002
- Chaired Professors Review Committee, CEMR, 2001/2002
- Committee to select Eberly Professor in Teaching, College of Arts & Sciences, 2002
- Environmental Protection Agency Small Business Innovative Research Review Panel, Washington, DC, June 2002
- Participant, Heavy Duty Vehicle Emissions Modeling Group, California Air Resources Board, 2002
- MAE Dept. Promotion and Tenure Committee, 2002-2003
- MAE Mechanical Engineering Undergraduate Curriculum Committee, 2002
- Reviewed a Faculty Member for Promotion, University of California system, 2002
- Reviewed a Faculty Member for promotion, Wayne State University, 2002
- Chaired a Topic Area for MAE Ph.D. Qualifying Examination Committee (Written & Oral), 2002
- Participated in Argonne National Laboratories, Center for Transportation Research, PM Measurement Forum, Jan. 2003
- Participated in World Bank "Diesel Days" Workshop (Washington, DC), Jan. 2003
- Participated in Energy Frontiers International Workshop (Charleston, SC), Feb. 2003
- WVU Faculty Senator, 2003-2006

- Member, Ph.D. Qualifying Examination Committee, Spring 2003
- Participant in Federal Highway Administration Air Toxics Workshop, Chicago May 2003
- Guest Speaker at AAA Auto Skills Competition dinner, May 2003
- Faculty Advisor, Ford Motor Co./DOE FutureTruck Competition, June 2003
- Participant, US Dept. of Energy Invitational Workshop for Advanced Combustion and Fuels, Argonne, IL, June 2003
- Reviewer, as a consultant, for a World Bank handbook, 2003
- Proposal Reviewer, NASEO State Technologies Advancement Collaborative, Nov. 2003
- Participant, HEI-CRC ACES Workshop, Denver, Colorado, Nov. 2003
- Participant, DOE Advanced Reciprocating Engine Systems Workshop, Washington DC, Nov. 2003
- Committee to name two endowed chairs, College of Law, Nov 2003
- Staten Island Ferry Advisory Group (Emissions Reduction), 2003 –2004
- Committee to select the Jackson Family Professor of English Literature, 2003-2004
- Chair-Elect, WVU Curriculum Committee, 2003-2004
- Student Evaluation of Instruction Committee, 2003-2004
- Search Committee for the Associate Provost for Research, 2003-2004
- Committee to select K-Mart Professor of Marketing, 2004
- Committee to select Associate Vice-President for Research, 2004
- Reviewer for WVU Research Corporation PSCoR Proposal, 2004
- Faculty Mentor to Tony Huang, National McNair Scholar, 2004-2005
- Promotion Evaluation for Argonne National Laboratory, 2004
- WVU Benedum Awards Committee, Science & Technology Chair, 2004-2005
- Advisor to Tony Huang for Undergraduate Research Day at the WV Capitol, 2004-2005
- Reviewed proposal for Connecticut Cooperative Highway Research Program, Jan. 2005
- Reviewed two PSCoR proposals for WVU Research Corporation, February 2005
- Research Subcommittee, West Virginia Strategic Planning Initiative, 2005
- Presenter & Participant, US Dept. of Energy Fuels Technology Program Merit Review, March 2005
- Speaker, TRC Workshop on Ultra-Low Sulfur Diesel, Milwaukee, Aug. 2005
- Honors Thesis Advisor to Ryan Starn, 2005
- Member, CRC Fuels for Advanced Combustion Engines Committee, 2005-2006
- Participant, WV Automotive R&D Assessment Team Meeting, 2006
- Faculty Senator, 2006-2009 term
- Faculty Senate Executive Committee Member, 2006-2007
- Member of President's Task Force on Administrative Infrastructure, 2006
- Member, Byrd Professorship Committee, 2006
- Member, Committee on Student Rights & Responsibilities, 2006-2007
- Member of DOE proposal review team, 2006
- Benedum Distinguished Scholars Award Committee, 2006-2007
- Faculty Senate Ad Hoc Committee on Curriculum Committee's Procedures, 2006-2007
- Chair, Search Committee for tenure track faculty hire in MAE, 2005-2006
- Member, Search Committee for research faculty hire in MAE, 2006
- Member, Search Committee for tenure track faculty hire in MAE, 2006-2007
- Supervisor of Drs. Ben Shade, Mohan Krishnamurthy and Andrew Nix (Research Assistant Professors), 2006-2008
- Chair of two sessions, SAE Fuels & Lubricants meeting, January 2007

- Participant & Poster Presenter, FTA Electric Drive Bus Technology Meeting, Nashville, May 2007
- Chair, CEMR Promotion & Tenure Committee, 2006-2007
- Member, Ad Hoc Senate Committee on Curriculum Committees' Procedures, 2007
- Dissertation Opponent, KTH (Royal Institute), Stockholm, Sweden, September 2007
- Member, CEMR Promotion & Tenure Committee, 2007-2008
- Chair, Faculty Search Committee (MAE-TEM), October 2007 – January 2008
- Participant, Electric Drive Strategic Plan Group (Federal Transit Administration) 2007-2008
- Reviewer, US Dept. of Energy OVT-Graduate Automotive Technology Education program, February 2008
- Member, Faculty Senate Executive Committee, 2007-2010
- Chair-elect, WVU Faculty Senate, 2008-2009
- Member, WVU Marketing & Advancement Faculty Advisory Committee for University Communications, 2008
- Member, WVU Parking & Transportation Advisory Committee, 2008-2010
- Reviewer, The Consortium for Plant Biotechnology Research, 2008
- Member, Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles; National Research Council; Transportation Research Board, 2008-2010
- Member, Search Committee for WVU Associate Provost for Academic Programs, 2009
- Member, Search Committee for WVU Provost, 2009
- Member, Search Committee for WVU Chief Information Officer, 2009
- Chair, WVU Faculty Senate, 2009-2010
- Member, Search Committee for WVU Chief Information Officer, 2009
- Chair, Committee to Rescind Asinine Procedures, WVU, 2009
- Presenter: Energy & Transportation issues to Senior 4H Conference, Jackson’s Mill, WV, June 22, 2009
- Member, WVU Board of Governors, 2009-2011
- Member, WVU Board of Governors Strategic Plans, Initiatives and Accreditations Committee, 2009-2011
- Member, WVU Board of Governors Divisional Campus Committee, 2009-2011
- Reviewer, DOE Vehicle Technologies Merit Review, June 2010
- Chair, WVU Strategic Planning Council (10 year institutional plan), 2010
- Speaker, Induction Convocation for National Society Of Collegiate Scholars, WVU, September 2010
- Ex-Officio Faculty Senate Representative, West Virginia University Graduate Council, 2010-2011
- Search Committee, Dual Career Coordinator, West Virginia University, 2010
- Member, West Virginia University Honorary Degree Committee, 2010
- Member, West Virginia University Promotion & Tenure Committee, 2009-2010
- Member, West Virginia University Retention to Graduation Council, 2010-2011
- Member, ASME Soichiro Honda Medal Committee, 2011-2013
- Member, National Academy of Sciences (NAS) Medium- and Heavy-Duty Vehicle Fuel Economy Committee, 2009-2011
- Keynote Address Presenter, 2011 SUN Conference, Ann Arbor, MI, September 2011
- Reviewer for external faculty promotion & tenure case, 2011
- Liaison to WVU Research Roundtable, 2011
- Liaison to WVU Global Engagement Roundtable, 2011
- Member, WVU Parking & Transportation Committee, 2011
- Member, University Planning Committee, 2011
- Invited Speaker, International Commission on Occupational Health, Cancun, Mexico, March 2012

- Reviewer, Health Effects institute document “Ambient Ultrafine Particles: An HEI Perspective,” September 2012
- Member WV Governor’s Task Force on Natural Gas Vehicles, 2012-2013
- Member, National Academies Committee on Medium- and Heavy-Duty Vehicle Fuel Consumption, Part 2, 2013
- Panel Moderator, “Natural Gas as the Bridge to Sustainability and Economic Growth,” Morgantown, WV, April 2013
- Promotion and Tenure Reference for Mississippi State University, 2013
- Attendee, University Economic Development Association Meeting, Pittsburgh, PA, 2013
- Promotion and Tenure Reference for Wayne State University, 2013
- Attendee, American Public & Land Grant Universities Annual Meeting, Washington, DC, 2013
- Reviewer, WVU Senate Research Grant, 2013
- Chair, Search Committee for Chief Academic Officer, WVU Institute of Technology, 2013-2014
- Proposal Evaluator, TransTech Energy Business Development Conference, 2014
- Chair, ASME Sochioro Honda Medal Award Committee, 2014-2015
- Attendee, American Public & Land Grant Universities Annual Meeting, Orlando, FL, 2014
- Judge for two Business Pitch Sessions, TransTech Energy Business Development Conference, 2014
- Presenter at WVU New Faculty Orientation, 2015
- Member, Higher Education Policy Commission Academic Administrators Advisory Committee, 2015
- Member, WVU Global Engagement Committee, 2016

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walt@kreucher.net

Walter M. Kreucher

Area of Expertise

Over thirty years of experience in regulatory and legislative issues related to fuel economy, fuel quality, and alternative fuels

Ran a major inter-industry research project and dealt directly with the Chief Executive Officers of the largest automotive and petroleum companies in the world.

Current

Retired from Ford Motor Company April 2004

Environmental Consultants of Michigan, LLC.

Providing consulting services to groups and organizations outside the automobile industry on fuel economy and fuel related regulatory and legislative matters, management issues, and other business matters.

Experience

1973 – 2004 Ford Motor Company Dearborn, MI

Vehicle Energy Planning Manager

- Managed CAFE compliance, fuel quality and alternative fuel regulatory efforts.
- Negotiated CAFE regulatory and legislative matters.
  - Developed and implemented strategy that resulted in the CAFE reform movement.
  - Developed position papers and background material in support of Congressional debates
  - Developed Hybrid Electric Vehicle Tax Credit
- Provided technical support on fuel economy and fuel quality matters.
  - Key negotiator in the first ever gasoline quality standards (California and Federal)
- Co-Chairman of primary technical committee for the Auto/Oil Air Quality Improvement Research Program; a $40 million joint research program that developed data demonstrating that gasoline quality improvements could reduce vehicle emissions and improve air quality.
  - Worked with the CEO's of fourteen oil companies and the big three automobile companies.
- Developed responses to various vehicle related regulations
- Monitored vehicle certification testing
- Helped develop the first CAFE reporting procedures for Ford.

Education

1969 Detroit Catholic Central High School Detroit, MI

1973 University of Michigan Ann Arbor, MI

- B.S.E., Materials Engineering

1984 University of Detroit Detroit, MI

- M.B.A., with a major in Finance
- Member Beta Gamma Sigma, National Honor Society of top Business School Graduates

José *Mantilla*

Employment History

Current — Director, movendo

2008 . 2011 — Associate Director, AECOM

1999 . 2008 — Senior Environmental Engineer and Transport Planner, United States Department of Transportation John A. Volpe National Transportation Systems Center

1996 . 1999 — Research Assistant, Massachusetts Institute of Technology

Career History

Jose has 20 years of international experience in government and consulting in Australia, the United States, Latin America, Asia and the Middle East. After completing his post-graduate studies at the Massachusetts Institute of Technology, he worked for 10 years at the national research centre of the United States Department of Transportation, where he provided strategic and policy advice to all transport government agencies and the United States Secretary of Transportation on a variety of transport planning, policy, strategy and investment decision-making issues.

During his tenure at the USDOT, he managed a broad range of high profile transport projects, including a number of national public transport initiatives such as the magnetic levitation (Maglev) deployment program. He also managed the regulatory, feasibility and environmental assessments for a number of nationally significant initiatives in the United States such as the implementation of policies to reduce emissions from transport activities across all modes, the development of safety standards for commercial vehicles, the design and implementation of energy efficiency performance metrics, and the national rulemaking program for fuel economy standards for passenger vehicles. In more recent times, he has assisted government and private sector clients on a variety of transport planning and sustainable transport initiatives, including several integrated transport strategies, sustainable transport systems for masterplanning projects, and evaluation of transport emissions and energy efficiency. He has also evaluated economic, policy, technology and infrastructure solutions to enhance the long-term sustainability of the transport sector across multiple dimensions, such as emissions and climate change, safety and health.

José has played a key role in the delivery of numerous studies internationally, including the Tanggu Beitang community in Tianjin (China), Monterrey urban regeneration plan (Mexico) and Nakheel's Tall Tower development in Dubai. He is a co-author of presentations delivered at two workshops in Kuwait sponsored by the United Nations Development Programme and the government of Kuwait as part of the National Traffic and Transport Sector Strategy for Kuwait 2010-2020.

He is an effective oral and written communicator, able to successfully interact with a diverse and multicultural audience of stakeholders and clients, as demonstrated by his ability to secure positive outcomes for several contentious projects.

Qualifications

1999

Massachusetts Institute of Technology
Master of Science in Environmental Engineering

1995

Pontificia Universidad Javeriana, Bogotá, Colombia
Bachelor of Industrial Engineering and Operations Research

Project Experience

Transport Studies for the City of Melbourne

client || City of Melbourne *location* || Melbourne *year* || 2011-2015

During the last five years, Jose has been directly involved in a leading capacity on a number of transport projects for the City of Melbourne, including:

- Low impact freight analysis
- Pedestrianisation of little streets and laneways
- Evaluation of 44 laneways for shared zone designation
- Parking studies
- Motorcycle strategy
- Pedestrian and bicycle strategies
- Transport system review for City North and Arden Macaulay
- Transport efficiency study for the CBD's north edge
- Sustainable transport strategy for Southbank Structure Plan
- Traffic and parking studies for the Southbank Arts Precinct
- Traffic and parking analyses in support of Council's Urban Forest Strategy

Transport planning for the Tanggu Beitang community master plan

client || City of Tianjin *location* || Tianjin, China *year* || 2009

While at AECOM, José developed the sustainable transport strategy and plan for the Tanggu Beitang Community, a 10 square kilometer site in Tianjin. He worked collaboratively as part of an interdisciplinary team of architects, urban designers and planners, transport planners, water engineers, and building efficiency experts. José developed the sustainable transport strategy and functional design of the internal transport system and links to regional road and public transit networks. He also analyzed accessibility and mobility under alternative land use and transport scenarios. As part of this project, he evaluated the benefits of technology and operational initiatives and calculated changes in energy consumption, greenhouse gas emissions, land take, and transport infrastructure requirements and costs.

Update of Singapore economic evaluation parameters

client || Land Transport Authority *location* || Singapore *year* || 2008-2009

While at AECOM, José participated in this project as technical leader – focused on the assessment of transport emissions and environmental benefits. This multi-disciplinary study included the design/delivery of SPS surveys to ultimately derive/update VOT, VOC, and value of statistical life parameters. The study also reviewed and recommended a methodology for assessing wider economics and environmental benefits associated with infrastructure investment in Singapore.

Travelsmart Greenhouse Gas Abatement Program (GGAP) assessment

client || Australian Government Department of the Environment, Water, Heritage and the Arts *location* || Canberra *year* || 2008-2009

While at AECOM, José reviewed the current Greenhouse Gas Abatement Program methodology to calculate emission reductions from the TravelSmart project. He investigated the projects funded across Australia and the respective abatement methodologies and assessments. Based on that review, José developed a greenhouse gas assessment model to derive consistent/standardized emissions abatement results, and evaluated the success of the Program in achieving State/national greenhouse gas reduction goals.

Alternative fuel vehicles in China

client || Ford Motor Company, Massachusetts Institute of Technology and Tsinghua University *location* || Dearborn, Michigan *year* || 1996-1997

While at the Massachusetts Institute of Technology, José analyzed the environmental, economic, and technological implications of the use of coal as a primary transportation fuel for automobiles in China. He researched the economics of the Chinese and Asian coal markets, fuel production technologies and refining processes, and the performance and environmental characteristics of conventional and alternative fuel vehicle technologies. José participated in the development of an engineering and environmental life-cycle model for the analysis of the costs, resource consumption, technology adoption, emissions, and environmental impacts of coal-based alternative-fuel vehicles in China.

Tax credits for advanced technology vehicles

client || Secretary of Transportation, U.S. Department of Transportation

location || Washington, D.C *year* || 1999-2000

While at the U.S. Department of Transportation, José analyzed the potential environmental, economic, and technological impacts associated with a government vehicle tax credit proposal for hybrid-electric and other high-efficiency vehicles. Collaborated with Energy Information Administration (EIA) and Oak Ridge National Laboratories. He adapted the Transportation Module of the EIA National Energy Modeling System (NEMS) to analyze the impacts of the tax credit proposal. As part of this work, José simulated the potential response to the tax credits, in terms of market penetration and change in vehicle fleet mix, and calculated the changes in government tax revenue, fuel consumption, and criteria pollutant and greenhouse gas emissions.

Travel demand management for the Tall Tower

client || Nakheel *location* || Dubai, United Arab Emirates.C

year || 2008-2009

While at AECOM, José contributed to the transport planning for Tall Tower project in Dubai including examination of travel demand management and parking policy aspects necessary to promote urban sustainability by reducing travel demand, enhancing accessibility, providing travel alternatives, and promoting low-emitting transport modes. José work helped to inform overall land use and transport planning for the site and focus development around the public transport system. He also analyzed in detail a number of innovative initiatives for the development site, including personal rapid transit and mobility on demand. On this project, José was also involved in the estimation of reductions in vehicle travel and associated emissions and energy consumption, as well as the changes in public transport ridership, overall trips and distances travelled, and modal split.

Analysis of economic, safety and environmental impacts of Commercial Motor Vehicle (CMV) safety regulations

client || Federal Motor Carrier Safety Administration, U.S. Department of Transportation *location* || Washington, D.C. *year* || 2004-2005

While at the U.S. Department of Transportation, José researched analytical approaches and developed methodologies to evaluate/estimate the potential impacts of CMV accidents. He applied queuing theory to analyze congestion delay, travel time, and travel speed based on the changes in traffic patterns resulting from CMV accidents. He modeled shipping cost changes, fuel consumption, criteria pollutants, greenhouse gas emissions – based on driving behavior and vehicle fleet mix.

Aviation fuel consumption and emissions metrics

client || Federal Aviation Administration *location* || Washington, D.C. *year* || 2008

José worked as part of an interdisciplinary team of scientists, engineers, economists and policy makers from academia, industry and government, including internationally recognized experts in the aviation, engine, fuel and emissions fields. Investigated the advantages and limitations of different fuel consumption and emissions metrics for measuring and tracking aviation efficiency and intensity. Evaluated the environmental effects and costs associated with policy initiatives, operational strategies and technological developments.

Corporate average fuel economy standards

client || National Highway Traffic Safety Administration, U.S. Department of Transportation location || Washington, D.C. year || 2000-2006

While at the U.S. Department of Transportation, José directed the environmental assessment process for the evaluation of revised national fuel economy standards. He collaborated with an interdisciplinary team of engineers, scientists, policy-makers, and economists. As part of this work, he analyzed the economic, environmental, and technological impacts of fuel economy standards for light trucks. He participated in the development of a U.S. passenger vehicle fleet model and estimated the changes in industry costs, criteria pollutant and greenhouse gas emissions, and energy consumption (fuel production / distribution / use) from implementation of the proposed fuel economy standards.

Docklands transport plan and model

client || Places Victoria location || Melbourne year || 2011-2012

In 2011-2012, José contributed to the preparation of the Transport Plan and Transport Model for Docklands. The study involved an extensive survey program with thousands of online and on-the-ground surveys undertaken with workers, residents, visitors and those attending events at Etihad Stadium, to understand travelling habits of people moving to and from Docklands. The work included development of a Transport Model, which takes into account existing and future development and infrastructure proposals in and around Docklands to provide traffic predictions, forecasts of public transport usage and an analysis of pedestrian and cycling patterns at key stages of Docklands development. The Model was used to test and define the preferred land use, transport infrastructure and travel behaviour outcomes for Docklands. The Transport Plan used Model outputs and other sources to examine the key issues and influences on access and mobility at Docklands, and identify the priority transport projects and initiatives required in Docklands over the next ten years and beyond, to ensure Docklands is well placed to cope with the substantial growth still to occur.

Selected Publications and Presentations

June 2010

'Transporte Sostenible: Integración de Planeación Urbana y Transporte' in REvive Monterrey Fórum 2010:
Innovative Transportation Solutions, Monterrey, México

June 2010

'Sustainable Transport: Integration of Land Use and Transport' at the 2010 Australasian Centre for the Governance and Management of Urban Transport (GAMUT) Conference on Sustainable Transport:
Varied Contexts – Common Aims, University of Melbourne, Australia

May 2010

'Sustainable Transport: Integration of Land Use and Transport' in World Metro Rail Summit, Shanghai, China

November 2009

'Transit-Oriented Development: Land Use and Transportation Planning in the Context of Climate Change' in Climate Design: Design and Planning for the Age of Climate Change, P. Droege (editor)

Awards

December 2003

United States Department of Transportation
Excellence Recognition Award
Honor awarded to employees in recognition of their "pursuit for excellence, willingness to take risks, and their unique ability to provide a highly positive example for others."

October 2003

United States Department of Transportation
Award for Partnering for Excellence
Second highest honor in the U.S. Department of Transportation, and highest honor for a team project. Awarded as team member of the Corporate Average Fuel Economy Standards for Light Trucks project.

September 1996-August 1999

United States National Science Foundation
National Science Foundation Graduate Research Fellowship

Wallace R. Wade, P.E.
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Novi, MI 48374
Phone: 248-449-4549
Email: wrwade1@gmail.com

1. Academic Background

MSME	University of Michigan, Ann Arbor	Mechanical Engineering
BME	Rensselaer Polytechnic Institute	Mechanical Engineering

2. Professional Licenses/Certification

Registered Professional Engineer, State of Michigan

3. Relevant Professional Experience

Areas of Expertise:
- Engine research and development
- Emission control systems
- Powertrain electronic control systems
- Powertrain calibration
- Systems engineering

1994 – 2004	Chief Engineer and Technical Fellow
(Retired Oct 2004)	Powertrain Systems Technology and Processes
(32+ years service)	Ford Motor Company, Dearborn, MI

Responsible for development, application and certification of emission and powertrain control system technologies for all Ford Motor Company's North American vehicles.
- Developed technologies for emission control systems, powertrain control systems, OBD II (On-Board Diagnostic) systems and powertrain calibration procedures. Achieved U.S. EPA (Environmental Protection Agency) and CARB (California Air Resources Board) certifications for all 1993-2005 model year North American vehicles.
- Developed and implemented, in production, new technology catalyst systems for increasingly stringent emission standards with significant reductions in precious metal usage.
- Developed technologies for California LEV II (Low Emission Vehicle – 2nd Generation) and EPA SFTP (Supplemental Federal Test Procedure) regulations.
- Developed key low emission technologies for the engine, powertrain control system, exhaust emission and vapor emission control systems in the 2003 California SULEV (Super Ultra Low Emission Vehicle) Ford Focus, which was the first domestic production vehicle complying with the most stringent emission levels required by the California Air Resources Board.

- Developed the first analytical and laboratory based (engine and vehicle) automated powertrain calibration process with objective measures of driveability to replace the traditional on-the-road calibration process resulting in significant reductions in test vehicles and significant improvements in efficiency.
- Initiated production implementation of the first domestic application of a diesel particulate filter (DPF) with active regeneration.

Co-Chairman of the Ford Corporate Technical Specialist Committee which provided corporate overview in promoting deep technical expertise through the selection and appointment of technical specialists.

1992-1994 Assistant Chief Engineer
Powertrain Systems Engineering
Ford Motor Company, Dearborn, MI

Responsible for the development and certification of emission and powertrain control systems for all Ford Motor Company's North American vehicles.
- Developed and implemented, in production, the California LEV (Low Emission Vehicle) requirements featuring palladium-only catalysts and coordinated strategy for starting with reduced emissions (CSSRE).
- Developed and implemented OBD II, which was phased-in on all North American vehicles over the 1994-1996 model years.
- Developed and phased in the advanced EEC V electronic engine control system on all production vehicles over the 1994-1996 model years.
- Led the development and implementation of enhanced evaporative emission and running loss controls that were phased-in over the 1995-1999 model years.
- Led the establishment of systems engineering in the development of powertrain systems. Design specifications were developed for all powertrain sub-systems.

1990-1992 Executive Engineer/Manager
Powertrain Electronics (Containing 4 Departments)
Ford Motor Company, Dearborn, MI

Responsible for the development and production implementation of powertrain electronic control systems (hardware and software) for all of Ford Motor Company's North American vehicles.
- Developed production powertrain electronic control systems for all North American vehicles.
- Developed the technology for OBD II and the advanced EEC V electronic engine control system.
- Led the Powertrain Electronics Control Cooperation (PECC) program resulting in the application of Ford EEC V systems on 30% of Mazda vehicle lines by the 2000 model year.
- Initiated the development of Ford's next generation 32-bit powertrain electronic control system (PTEC) (implemented in the 1999 model year).

1987-1990	Manager Advanced Powertrain Control Systems Department Ford Motor Company, Dearborn, MI

Responsible for the development of powertrain control system technology for future applications.

- Developed the first Ford California ULEV (Ultra Low Emission Vehicle) emission control system. Major improvements in air/fuel ratio control were achieved using a UEGO (universal exhaust gas oxygen) sensor and a proportional control algorithm.
- Developed enhanced evaporative and running loss emission control concepts.
- Developed the first Ford traction control system using engine torque modulation combined with brake modulation.
- Developed the first Ford electronic throttle control (drive-by-wire) system for improved driveability (implemented in production for the 2003 model year).
- Developed engine torque modulation during shifting for imperceptible automatic transmission shifts.
- Initiated the requirements specification for a new 32-bit powertrain electronic control system (PTEC).

1978-1987	Manager Engine Research Department Research Staff Ford Motor Company, Dearborn, MI

Responsible for the creation, identification and feasibility prove-out of advanced engine concepts for next generation vehicle applications.

- Developed the first Ford passenger car, direct-injection diesel that met current emission requirements and provided 10-15% fuel economy improvement vs. indirect injection diesel.
- Developed light-duty diesel electronic control systems that achieved significant reductions in emissions.
- Developed the first Ford adiabatic diesel engine with a ringless ceramic piston operating in a ceramic cylinder.
- Developed the concept and demonstrated the first Ford diesel particulate filter (DPF) with active regeneration that provided over 90 percent reduction in particulate emissions (scheduled for production in a Ford vehicle in 2007).

1974-1978	Supervisor, Development Section Diesel Engine and Stratified Charge Engine Department Ford Motor Company

Responsible for the research and development of low emission, fuel-efficient stratified charge engines (PROCO stratified charge, 3 valve CVCC (Compound Vortex Controlled Combustion), spark ignited-direct injection) and diesel engines.

1972-1974 Supervisor/Senior Research Engineer
Turbine Controls and Combustion Section
Ford Motor Company

Responsible for the research and development of low emission combustion systems for a high temperature, ceramic gas turbine engine.

- Developed the first successful premixed, pre-vaporized, variable geometry gas turbine combustion system that met the most stringent emission standards in the 1970's.

1967-1972 Research Engineer
General Motors Research Laboratory, Warren, MI

Responsible for the research and development of low emission combustion systems for gas turbine, Stirling and steam engines for potential automotive applications.

4. Consulting

2007-2008 Expert Witness for Orrick, Herrington and Sutcliffe, LLP

Expert witness for the plaintiff in a trade secret case involving diesel emission control systems (represented by Orrick, Herrington and Sutcliffe, LLP). Case was successfully settled after expert testimony. (May 2007 – December 2008)

2009 U.S. Environmental Protection Agency/ICF Consulting Group, Inc.

Evaluated the U.S. EPA's methodology for analyzing the manufacturing costs of vehicle powertrain and propulsion system technologies with low greenhouse gas emissions.

2009-Present Technical Advisory Board, Achates Power, Inc.

Technical advisor to Achates Power, Inc. for the development of unique technologies for new, fuel efficient, high power density engines.

2010 Expert Witness for Scott L. Baker, A Professional Law Corp.

Expert witness for the plaintiff in a case involving retrofit emission control systems (represented by Scott L. Baker). Case was successfully settled after expert testimony. (October – November 2010)

2011 Kelso and Company

Provided technology for automotive catalytic converter support mount systems.

2011 U.S. Environmental Protection Agency/ICF Consulting Group, Inc.

Evaluated the U.S EPA's computer simulation of light-duty vehicle technologies for greenhouse gas emission and fuel consumption reduction developed by Ricardo, Inc.

2015 U.S. Environmental Protection Agency/RTI International

Peer Review of EPA's Draft Report, dated November 23, 2015: "Diesel Cost Analysis," Draft Report FEV-P311732-02, dated September 9, 2015.

Peer Review of EPA's Draft Report, dated November 23, 2015: "2013 Chevrolet Malibu ECO with eAssist BAS Technology Study," Draft Report FEV- P311264, dated January 31, 2014.

Peer Review of EPA's Study, dated November 23, 2015: "48V BAS Mild Hybrid System Cost Estimation," Draft Report prepared by SoDuk Lee, PhD. Light-Duty On-Road Center, ASD, EPA, Ann Arbor.

5. Associated Experience

1965-1966 1st and 2nd Lieutenant
U.S. Army

- 1965 Frankford Arsenal – Responsible for developing improvements in the save capability of high-speed aircraft emergency ejection seats using propellant actuated devices.
- 1966 Cam Ranh Bay, Vietnam – Assistant Adjutant, U.S. Army Depot

1967-1991 Lt. Col. and prior ranks
U.S. Army Reserve

Annual Training (Mobilization Designation Training) – Deputy Chief of Staff for Research, Development and Acquisition (DCSRDA), Department of the Army, Washington, DC

- Responsible for technical analysis of critical powerplant programs for the Army's mobility equipment

6. Professional Affiliations

National Academy of Engineering (NAE) – Member (Elected in 2011)
Society of Automotive Engineers (SAE) – Fellow Member
American Society of Mechanical Engineers (ASME) – Fellow Member
Engineering Society of Detroit (ESD) – Member

7. Patents

Issued 29 U.S. patents and numerous foreign patents in the following areas:

- Low emission combustion systems
- Diesel particulate filters
- Adiabatic engine design

- Engine control systems
- OBD II monitor systems
- Traction control

8. Publications

Published 25 technical papers on powertrain research and development in SAE, IMechE, FISITA, ASME, API, NPRA (National Petroleum Refiners Association) and CRC.

9. Significant Awards

- Elected a member of the National Academy of Engineering (NAE), which is among the highest professional distinctions accorded to an engineer – For outstanding contributions in the implementation of low-emission technologies in the automotive industry (2011).
- Recognized as an innovator in the automotive industry by being appointed as one of the first Henry Ford Technical Fellows (1994) (technical ladder position equivalent to Engineering Director in Ford Motor Company).
- ASME Soichiro Honda Medal for technical achievements and leadership in every phase of automotive engineering, including 26 patents related to both gasoline and diesel engines (2007).
- SAE Edward N. Cole Award for Automotive Engineering Innovation – For outstanding creativity and achievement in the field of automotive engineering (2006).
- Honored by being invited to present the 2003 Soichiro Honda Lecture at the ASME Internal Combustion Engine Division Meeting (September 2003). The lecture provided a comprehensive description of the technology incorporated in the first domestic SULEV vehicle.
- Honored by the Inventors Hall of Fame as a Distinguished Corporate Inventor (1997).
- Elected by ASME to Fellow Member Grade in recognition of outstanding accomplishments in engine combustion, efficiency and emissions research and development (2010).
- Elected by SAE to Fellow Member Grade in recognition of major technical contributions in the area of diesel engine research (1985).
- Honored with 5 SAE Arch T. Colwell Merit Awards for SAE technical publications.
- Selected as SAE Teetor Industrial Lecturer (1985-86 and 1986-87) and invited to present lecture at multiple universities.
- Received the prestigious Henry Ford Technology Award for development of regenerative diesel particulate filter systems (1986).
- Honored with the SAE Vincent Bendix Automotive Electronics Engineering Award (1983).

10. Professional Service

- Member of the National Research Council Committee on the Assessment of Technologies for Improving Fuel Economy of Light-Duty Vehicles, Phase 2 (2012-2015)
- Member of the 21st Century Truck Partnership-Phase 2 Study Committee of the National Research Council (2010 – 2011)
- Member of the 21st Century Truck Partnership Study Committee of the National Research Council (2007-2008)
- Member of the Low Heat Rejection Engines Study Committee of the National Research Council (1985-1986)
- Participant in Workshop for the National Research Council's Study on "Automotive Fuel Economy – How Far Should We Go?" (1991)
- Chair, ASME Soichiro Honda Medal Committee (2008-2014)
- Past member of the SAE Forum on Sustainable Development in Transportation to provide a technical response to President Clinton's initiative on future technology and the environment.
- Past member and chairman of the SAE Teetor Educational Awards Committee
- Past member of SAE ABET Relations Committee
- Past member of SAE Transaction Selection Committee for Advanced Powerplants and Emissions
- Past member of SAE Gas Turbine Committee (early 1970's)

Appendix B: Review of New Modules and Phase 2 Reviewer Résumés

NHTSA Phase 2 CAFE Model Review Compilation

Introduction

Three modules were added to the Corporate Average Fuel Economy model as part of the analysis supporting the Preliminary Regulatory Impact Analysis (PRIA) of the proposed CAFE rule announced August 2018, as follows.

- Sales Response Model
- Scrappage Model
- Labor Utilization Calculations

Four independent experts were asked to review the new modules for the appropriateness of their specifications and to suggest any modifications or enhancements that might improve the reliability of the estimated market responses to proposed regulatory actions. The four reviewers are:

- Dr. Alicia Birky, Energetics, Inc.;
- Dr. John Graham, Indiana University;
- Dr. Howard Gruenspecht, Massachusetts Institute of Technology; and
- Dr. James Sallee, University of California, – Berkeley.

This document summarizes their reviews. For each topic a brief introduction indicates the particular themes that emerged as generally consistent among the reviewers' responses. Also, although the reviewers address three or four questions related to each topic, some of the reviewers' comments and suggestions applied to both the sales and scrappage models.

Note that the digests of the individual reviewer's comments are paraphrased. The peer reviewers' full, as-received responses are appended to this summary.

Sales Model

Question Number	Question Topic Description
1	**Sales Model**
1a	Please comment on the appropriateness of including a sales response model in the CAFE model as a means to estimate differential sales impacts across regulatory alternatives.
1b	Please comment on the sales model's specification using an autoregressive distributive lag (ARDL) model time series approach, and comment specifically on the endogeneity of average transaction price.
1c	Please comment on the sales model's integration in the CAFE model, including interactions with the simulation of multiyear product planning, in combination with the dynamic fleet share model used to allocate total new vehicle sales to the passenger car or light truck market segments.
1d	Please comment on the sales model's specification as independent of vehicle scrappage, and on the resultant calculation of vehicle miles traveled (VMT).

Summary

The reviewers agree that including sales response and scrappage models is appropriate; however, their analysis raises fundamental issues regarding the model's specification and implementation. Reviewers suggest that a discrete choice model might be more appropriate in describing the sales response and might have a more solid grounding in economic theory than the aggregate sales/scrappage responses validated on historical data that frames the sales and scrappage models embedded in the CAFE model.

The CAFE model reviewers also note that the automobile ownership profile of consumers appears to be changing and those changes may be quite significant by the end of the period addressed by the model. These changes call into question the assumption that predictions built on past data can predict future consumer response.

A related issue raised by the reviewers is the calculation of VMT based on the vehicle's vintage. The reviewers suggest that VMT attributable to an additional vehicle in a household may be dependent on the number of vehicles already in the household and may not be only dependent on the vehicle's vintage as implied by the inputs to the CAFE model. The reviewers indicate that these issues could be better addressed by a household transportation modal choice model.

Reviewers also note that regardless of the model's formulation, the new and used car markets should be integrated. In other words, the reviewers suggest that more reliable estimates could be generated by integrating the sales and scrappage models and by including the used car market in the specification. If the alternative integrated model is a modal choice model, as suggested above, then a caveat is that vehicle purchase and scrappage decisions are rarely made by the same households. Other specification issues warranting further examination or explication include: the extent to which manufacturers pass-through technology development and manufacturing costs to the consumer; the omission of consequential variables, such as disposable income, that are causally related to the dependent variable; and the method used to determine the distribution of sales across vehicle types.

Reviewers point to the implausibility of the fleet size results where the relaxation of the fuel economy standards of the "preferred alternative" leads to a smaller fleet of cheaper vehicles than the size of the "baseline alternative's" fleet of more expensive vehicles. Along with the independent specifications of sales and scrappage, the reviewers observe that the high degree of simultaneity and endogeneity in the models might lead to the questionable result and call into question the reliability of the models' estimates.

One unanimous reviewer recommendation is to apply sensitivity analyses to test more fully the robustness of the estimates, especially regarding the estimated price elasticity of demand which may be outside the range found in the literature. A further suggestion is to run alternative model specifications and compare resulting estimates. Sensitivity analyses and alternative model specifications may also be used to test for the effects of potential exogenous shocks to the system, such as policy changes not present in the historical data.

Birky

1a.

- Fundamental issue: The PRIA indicates that the model goals are to address consumer and manufacturer behavior, but the sales model is not specified as a choice model.
- The complexity of specifying a model with a high degree of endogeneity requires additional validation and sensitivity analyses.

1b.

- Because the rationale for using ARDL is not explicit, the reviewer assumption is that partial adjustment is the rationale.
- The expectation is that labor force participation (LFP) is positively associated with sales; however, the coefficient of lagged LFP is large and negative, which is counterintuitive and casts doubt on the entire model specification. One missing variable may be disposable income.
- Endogeneity does create difficulties which can only be solved with complex modeling approaches.

1c.

- The specific approach to estimating fleet share of the two vehicle types by determining car share independently of truck share is inappropriate since decisions to purchase are made using a joint determination of the properties of cars and trucks. A possible approach is a single equation for car (or truck) share that includes attributes of both cars and trucks.
- **Recommendation**: Use a logit model that includes at least three (cars, pickups, and vans/cross-overs/ SUVs) or possibly four vehicle types.

1d.

- With the caveat that the decisions to purchase a new vehicle and to scrap an existing vehicle are rarely made by the same household, the model objectives would be better served by a household choice model that includes the used car market. Acknowledges that no existing demand model captures this joint decision.
- Vintaged VMT schedules taken from R. L. Polk & Company are influenced by many trends that may not be valid in the future, including for example ownership rates (which are not reported as part of model results).

- **Recommendation:** predict national VMT demand based on economic indicators, demographic changes, and characteristics of vehicles, and scale the VMT schedules to determine VMT by age. Scaling has the potential to obscure a shift in VMT between older and newer vehicles that accompanies changes in vehicle stock or fuel prices.

Graham

1a

- The sales response model is appropriate. The high cost/impact of regulations requires analysis even more so than in previous instances of emissions, safety, and fuel economy standards.
- An engineering approach to the problem is not sufficient; a model must also consider consumer responses to policy changes.

1b

- The pass-through assumption is reasonable, but the explication should offer more justification as to why that is the case:
  - **Recommendation**: Add references to the extensive literature on pass-through in the automobile industry.
  - Pass-through pricing is more germane in the long run than in the short run, which is critical given the time span of the model.
  - The footprint adjustments to the regulations, which affect the entire industry rather than only a subset of manufacturers, will lead to a higher degree of pass-through.
  - Pass-through pricing is a feature of competitive markets; today's automobile market exhibits a higher degree of competitiveness than in the late 20th century.
- One aspect of the model specification is the omission of indicators of consumer access to credit (e.g., average interest rates). Also missing is used car pricing. **Recommendation**: Add these two omitted variables.
- A related result is that variables measuring fuel economy do not increase the explanatory power of the model. **Recommendation**: Use a net-price approach, similar to that used in past RIAs, to estimating the future impacts of fuel-economy regulation with the assumption that the net price includes just 2.5 years of consumer valuation of future fuel savings. This is consistent with the model's treatment of how manufacturers choose which fuel savings technologies to develop. Sensitivity analyses using 1 and 4 years should be performed.
- **Recommendation**: Rewrite Section 8.3, "Consumer Valuation of Improved Fuel Economy," to highlight the literature documenting consumer undervaluation of fuel economy when purchasing vehicles.
- Endogeneity can be addressed in the write-up by a qualitative discussion of bias that considers the direction of the bias. This discussion will relate to the reasonableness of the value of the coefficient indicating the price elasticity of demand. The model may be used to control for reverse causation. (Although high prices may decrease sales volume, high sales volume may increase average prices.)
- **Recommendation**: Use a literature-based coefficient of the long-term impact of vehicle price on demand and then use the model to apportion the total effect across the years in the time frame.

1c

- The model does not account for the economic and environmental effects of the preferred alternative's elimination of the State-level zero-emission vehicle (ZEV) standards.
- **Recommendation**: Include the elimination of the ZEV standards in the sales-response model.
- **Recommendation**: Include the cost savings from elimination of the State-level ZEV requirements

1d - No response

Gruenspecht

The reviewer performed a close analysis of model output of both the CAFE and CAFE_ss runs. The latter set of runs incorporate statutory constraints on possible compliance responses.

1a.

- The overall light-duty vehicle (LDV) sales response reported in the model is plausible.
- However, sales outcomes of the Baseline (B) and Preferred (P) Alternatives do not diverge until MY2022 despite the difference in prices between the two cases. Why is there a lag?
- In addition, the CAFE and CAFE_ss runs, which use different price paths, produce the same sales differences between the B and P cases for MY2022 through MY 2032. This implies that other factors are driving sales outcomes other than pricing. What are these additional factors?
- The price elasticity of sales in the model run is markedly below the -0.2 - -0.3 range documented in the accompanying analyses, which itself is below the range of estimated price elasticities most often cited in the literature.
    - **Recommendation**: Perform a sensitivity analysis to test the sales response at higher price elasticities.
- The passenger car/light truck (PC/LT) sales distribution model results is consistent with other results showing that sales by vehicle type responds to different fuel economy standards by vehicle type and fuel prices. However, if standards are fully phased in by MY2025 in the Baseline, why does the difference in LT share of sales continue to grow between the B and P cases?
- The addition of sales response makes the CAFE model more "thorough and up-to-date." However, given the issues indicated above, especially those with regard to price elasticity, the wrong sales response model could lead to less accurate estimates than a model totally excluding sales response.

1b. - No response

1c.

- The reviewer could not assess the multi-year planning feature of the model and its interaction with the market effects questioned in 1a.
- Model validation based on historical data may reduce the ability of the model to distinguish the results of different policy options (which by definition are not reflected in the historical record). The effects of the policy options could be overwhelmed by underlying factors that are present in the history.
- Modeling of product planning at the manufacturer's level could present a risk of mischaracterizing the aggregate picture.

1d.

- Sales response and scrappage response are not independent processes.
- The CAFE_ss model results in a fleet that is markedly larger in the Baseline condition by 2037 than in the Preferred alternative. This is an unexpected result that may be a result of sales and scrappage being analyzed independently rather than in a comprehensive transportation mode choice model.
- The current sales model framework does not consider the demand side of the used car market, which will directly affect scrappage decisions.
  - **Recommendation**: Hold the total number of vehicles constant in both the B and P cases.
- The model posits that VMT per year drops as vehicles age with a rapid decline between ages 6 and 11. No justification is given for the assumption that a consumer's VMT will change given the age of a newly acquired vehicle. The model also accounts for the rebound effect where more efficient vehicles induce additional trips. Examining the CAFE_ss_NOREBOUND runs, the reviewer finds that the percent differences in VMT over the simulated years is much smaller than runs that include the rebound effect.
  - **Recommendation**: Increase the VMTs assigned to older vehicles in the B case versus the P case such that total non-rebound VMT would remain constant between the two cases.
- There are significant advantages to integrating scrappage and sales models, including a reconsideration of how VMTs are accumulated in the modeling.

Sallee

1a.

- The sales response parameter is highly uncertain and difficult to estimate; therefore, it should be subject to sensitivity analyses.
- Possible approaches to improving the estimate include using varying scenarios of the sales response rather estimating than a suspect (due to endogeneity) single-regression coefficient.
- The CAFE model analysis does not isolate exogenous cost increases which contributes to the difficulty of estimating the parameter; an additional difficulty is that the cost increase affects the entire market.
- **Recommendation:** Present an ensemble of results using different values for the magnitude of new car sales response rather than the current approach.
- Discrete choice models are bounded by the choice of an "outside good" (e.g., not buying a car); what are the estimates of these bounds and how might they affect overall fleet size? However, a caveat is that the literature reports the results from static models of short-term effects.
- The pass-through reported in the CAFE model likely overstates the effects of technology deployment costs on new car sales. Economic theory indicates that only true marginal costs of technology would be reflected in the price. Fixed costs are properly included in the cost-benefit analysis, but they distort the sales response model.
- A microeconomic choice model of the vehicle purchasing decision takes into account price net the benefits to the consumer. Using gross prices is misleading. However, producing better (and presumably more expensive) cars could provide a net benefit to consumers and nevertheless expand sales. However, the effect of CAFE standards on overall market size is ambiguous.

- The reviewer distinguishes “steeply sloped” footprint rules from relatively flat regulatory regime schedules. In the flatter case the market size analysis may be misleading.
- The reviewer notes that the ownership model is changing due to new transportation options such as ride share and vehicle subscriptions.

1b

- There is no clear “identification strategy” behind the model specification, so it is difficult to interpret the coefficients.
- Use the econometric model presented to inform alternative scenarios rather than treat it as a conclusive estimate.
- Price endogeneity leads to a biased estimate of the parameter. Prices and quantities are positively correlated in the raw data. Price also is related in the data to changes in the composition of the fleet. The dearth of macro variables in the specification, e.g., interest rates or exchange rates, that affect the automobile market likely leads to bias.
- The model’s goodness of fit with historical data is not enough to indicate an unbiased causal relationship. In addition, the length of the time series lessens the likelihood that the price coefficient is stable over time.
- The model documentation indicates that price changes affect the level of sales, which the reviewer finds to be “peculiar.”
- **Recommendation**: Apply the Newey-West correction to HAC in the standard errors.
- **Recommendation**: Use a vector autoregression rather than ARDL.
- Quarterly data may not be an improvement on annual data given the possibility that seasonal effects are biasing the results.

1c

- New and used car markets interact, but the model does not integrate them.
- The model produces counterintuitive results for the net impacts on fleet size.
- The reviewer has no issues (in contrast to Birky) of estimating total fleet size in one step and the light truck share in a second step.

1d

- New and used car markets should be integrated.
- VMT likely scales less proportionately with fleet size.
- Adding more vehicles to the fleet should cause age-specific VMT to decline.
- **Recommendation**: Start with a fundamental classic economic choice model where the input to utility is VMT to determine the effect of adding an additional vehicle to a household on VMT.

Scrappage Model

2	Scrappage Model
2a	Please comment on the appropriateness of including a scrappage model in the CAFE model as a means to estimate the potential impact of CAFE standards on used vehicle retention.
2b	Please comment on the scrappage model's specification using a form common in the relevant literature. Are there better approaches that allow for both projection (as is necessary in this context) and a focus on new vehicle prices (exclusively)?
2c	Please comment on the scrappage model's integration in the CAFE model, addressing the vehicles affected by the scrappage model, and the extent to which changes in expected vehicle lifetimes are consistent with other assumptions.

Summary

The reviewers pose a related and analogous set of questions and issues for the scrappage model as the sales response model, including issues related to counterintuitive results, endogeneity, missing variables, and the use of a reduced form predictive model rather than a structural causal model. While inclusion of a scrappage model is deemed appropriate, the reviewers note that specifying the two models independently and without direct inclusion of used car prices results in coefficients and aggregate fleet size effects that may not represent causal relationships.

Reviewers point out that the scrappage model does not account for consumer preference for performance, the relationship of performance to fuel consumption, nor the resulting total price of fuel to the consumer. In addition, the model omits repair and maintenance in scrappage decisions. One reviewer notes that the use of scrap metal prices is not completely representative of the markets for scrapped vehicles since used cars also have value in the export market, as well as scrap metal.

Birky

2a

- Scrappage has been neglected in the literature and "a realistic representation of scrappage is an excellent contribution." Adds the caveat that an ideal model would be responsive to demographic variables, as well as existing and new vehicle attributes.

2b

- Fuel consumption is associated with performance variables that consumers value. Inconsistent estimates of the fuel price coefficients in the model may be due to omitting vehicle performance-related variables from the specification.
- **Recommendation**: Use additional statistics to select variables that might add more predictive power to the model, i.e., determining whether to use average price per vehicle or the aggregate price of a manufacturer's vehicles.
- **Recommendation**: Consider export value, which is captured by National Automobile Dealers Association (NADA) residual values and auction prices rather than the value of scrap metal.
- **Recommendation**: Consider other income variables as alternative to gross domestic product (GDP) to increase the explanatory power of the model since income gains have has been less than GDP growth.
- Incremental fleet size is unintuitive; worries about total VMT.

- **Recommendation:** Consider some measure of accumulated VMT within the scrappage model.

2c

- **Recommendation**: Perform sensitivity analyses of the impact of the scrappage model on expected lifetime vehicle mileage.
- **Recommendation**: Explore the counter-intuitive finding of fleet-size decrease with the reduction of CAFE stringency. The decrease may result from the independence of the scrappage and sales models in the CAFE model specification.

Graham

2a

- Scrappage model is appropriate and supports existence of "Gruenspecht Effect." Suggests several papers as basis for how this should be modelled.

2b, 2c

- Appreciated the effort to describe relative magnitudes of sales and scrappage responses, and does not expect them to be equal. Not surprised by differing fleet sizes across alternatives.
- Would have expected the scrappage effect to be largest for oldest vehicles.
    - **Recommendation**: Perform sensitivity analysis on the vintage in which the scrappage rates are most affected by the regulations.
- The fuel economy regulations should not affect household demand for travel so the VMT effect could be zero.
    - **Recommendation**: Hold VMT constant, but vary share of VMT allocated to differently aged vehicles.
- Thinks that is important to consider impact of potential vehicle upsizing due to footprint based standards.
    - **Recommendation**: Add a qualitative discussion of consumer upsizing to SUVs and provide a quantitative assessment of whether the upsizing results from the current regulations.

Gruenspecht

2a

- Scrappage behavior is important to consider for safety, emissions and fuel consumption outcomes.
- Historical data show scrappage rates are related to fuel prices and fuel economy; there would be a reduction of scrappage rates in augural standards compared to preferred alternative, as shown in the NPRM and PRIA.
- The scrappage model does not account for maintenance and repair costs, which are a part of the scrappage decision.
- Although the model uses new vehicle prices, they do not directly affect scrappage.

- The Baseline fleet size increase over the preferred alternative is due to a larger scrappage response than sales response; this is implausible as all vehicles are more expensive and fleet size should shrink.
- Further, scrappage rates respond to new vehicle price differences in the augural and preferred alternative 2 years earlier than new light-duty vehicle sales response.
- The assumption that repair events related to VMT accumulation do not affect the scrappage decision seems “extreme,” and may partially account for the large scrappage response as new car prices increase.

2b, c – No response

Sallee

2a

- The scrappage model warranted; however, the scrappage model as implemented may not increase the accuracy of the model.
- Misidentification of the causal chain omits the intermediate effect of new car prices on used car prices which then affects scrappage rates.
- Model specification is exposed to simultaneity and omitted variable biases; however, this is a difficult problem to address.
    - **Recommendation**: Use existing evidence to estimate the new vehicle sales response which is then linked to scrappage by an equilibrium choice model.
- The choice in model specification should be based on economic theory, not goodness of fit, to produce a causal model rather than a predictive one.
- Price should be net of changes in quality.
- Use of ad hoc adjustment on future survival rates is problematic.
- Sallee would prefer the use of a data-informed equilibrium model based on theory.
- The presentation of model results does not provide enough information about the estimates for the reader to judge their robustness.
  The sales response model does include a discussion of stationarity (e.g., are the estimators stable over the time period of the model?), but there is not enough discussion of the time series properties of the measures included in the scrappage model. Further, there is insufficient discussion of the use of 3-year lags and why this was thought to be optimal.
- Fleet size results are problematic; are cars Giffen goods as implied by the model?
- Thinks that durability is important to consider, but that the scrappage model may not have captured how new vehicle prices *cause* changes in scrappage rates.
    - **Recommendation**: Separate the analysis of future trends in the longevity of vehicles from the determination of the price coefficients.

2b

- Used vehicles are an intermediate causal step, which the model needs to incorporate directly into its specification.
    - **Recommendation**: Specify a consumer choice model following economic principles that recognizes the flow of once new cars into the used car market over time. The model needs to include the "outside good" – i.e., not owning a car.
- Starting with new cars prices cascade through the vintages, which does not comport with the PRIA's suggestion that there will be a larger scrappage effect on middle-aged used vehicles than on those older or younger.

2c

- VMT schedule is related to fleet size. More vehicles in the fleet leads to lower VMT per vehicle. Current methodology likely overestimates VMT per vehicle.
- The heterogeneity of the Gruenspecht effect across fuel economy levels within a model year probably matters for VMT and fuel leakage, and should be better considered.
- **Recommendation**: in specifying the model, consider that better technology leads to more turnover of the fleet.

Labor Utilization Calculations

3	Labor Utilization Calculations
3a	Please comment on the inclusion of each source of employment related to automobile production and sales.
3b	Please comment on assumptions regarding labor hours, production location (domestic/foreign), and supplier impacts.
3c	Please comment on methods used to calculate changes across alternatives.

Summary

The reviewers provided a smaller volume of responses regarding labor utilization. The comments note that the model takes a piecemeal approach to specifying the labor utilization model and omits downstream effects on labor of changes in the fleet due to fuel economy regulations. The downstream effects would include, for example, labor related to repair and maintenance. Another suggestion for the model is the incorporation of the effects of State-level ZEV requirements on employment. A further proposal is to change the entire modeling approach and use a macroeconomic input-output model to better track changes in employment through all labor market sectors.

Birky

3a

- Downstream employment for maintenance and repair is not included.

3b

- The impact of CAFE on labor hours and costs may not be constant over time as is assumed by the model.

3c - No response

Graham

3a, b, c

- **Recommendation**: Consider the macroanalysis by Carley, Duncan, Graham, Siddiki, and Zirogiannis (2017).
- The PRIA omits the positive and negative impacts of State-level ZEV requirements.

Gruenspecht

3a, b, c - No response

Sallee

3a

- Model takes a piecemeal approach and only considers some of the pieces of automobile-related economic activity
- Alternatives to CAFE model approach include and reviewer discusses each approach in more detail and salience for the current modeling effort
    - Omit labor from the model altogether

  - Use a standard input-output model of economic impact to capture multiplier effects throughout the economy
  - Capture a different set of “pieces” using the current approach
  - Calculate the net real income effect of the policy and apply a generic macro multiplier
- Recommends contrasting the current approach with a more general economic impact multiplier approach

3b

- **Recommendation**: Perform sensitivity analyses, so as not to imply a point estimate.
- Sallee likes the location-specific approach used in the model.
- The following are observations and suggestions:
  - Include more discussion of the use of average rather marginal labor hours to calculate the impact on jobs of changes in sales; however, the use of average labor hours seems appropriate.
  - Use natural experiments to estimate job inputs because of the lumpiness and localization of labor adjustments in the automobile industry.
  - Study long-term trends in labor hours per unit produced.
  - Note that revenue per worker for technology costs is problematic; it is likely that revenues will rise less than costs, thus lowering revenue per worker.
  - Check whether analysis double counts some workers in the production value chain when calculating revenue per worker.
  - Provide additional discussion about the location of the production of advanced technologies; the assumption that the location of the work is fixed (i.e., not affected by the CAFE regulations) is warranted.
  - Consider that it is misleading to separate analysis from the employment rate context.

3c

- The model’s general approach for estimating differentials seems reasonable.

Peer Review Charge

"CAFE Model"

Introduction

The 1975 Energy Policy Conservation Act (EPCA) requires that the Secretary of the Department of Transportation set Corporate Average Fuel Economy (CAFE) standards for passenger cars, light trucks and medium-duty passenger vehicles at the maximum feasible levels and enforce compliance with these standards. The Secretary has delegated these responsibilities to the National Highway Traffic Safety Administration, an agency of the U.S. Department of Transportation. Another DOT organization, the Volpe National Transportation Systems Center, provides related analytical support.

In 2002 the Volpe Center and NHTSA staff collaborated to develop a modeling system—referred to here as the "CAFE model"—to analyze how manufacturers could comply with potential standards, and estimate the impacts of regulatory alternatives to inform rulemaking actions that establish CAFE standards. Since that time, DOT staff have collaborated to significantly expand, refine, and update the CAFE model, using the model to inform major rules in 2003, 2006, 2009, 2010, 2012, and 2016. To inform the proposed rule announced August 2018, DOT staff introduced significant new elements to the model, including methods to estimate changes in vehicles sales volumes, vehicle scrappage, and automotive sector labor usage.

Each of these regulatory actions involved consideration of and response to significant public comment on model results, as well as comments on the model itself. In addition to DOT staff's own observations, these comments led DOT staff to make a range of improvements to the model. Insofar as a formal peer review could identify additional potential opportunities to improve the model, DOT sponsored a review of the entire model in 2017. At this time, DOT seeks review of some of the significant new elements added to the model after that review.

Overview of Task

The peer review charge is to identify potential opportunities to improve specific capabilities recently added to the CAFE model. Past comments have sometimes conflated the model with inputs to the model. The peer review charge is limited to the model itself; in particular, rather than addressing specific model inputs which are provided by DOT staff to facilitate review of the model, peer reviewers should address only the model's application of and response to those inputs. However, an evaluation of new relationships within the model is expected to require evaluation of the model's characterization of those relationships – through statistical model coefficients, for example. While those enter the model as "inputs" that can be modified by the user, they are a critical component of the relationships within the model. Thus, it is appropriate to evaluate those coefficients – as they relate to the sales response, scrappage response, and employment response on which this review is focused – as part of this review.

Additional Background

CAFE standards determine the minimum average fuel economy levels required of each manufacturer's fleets of vehicles produced for sale in the United States in each model year. The 2007 Energy Independence and Security Act (EISA) amended EPCA such that these standards must be expressed as mathematical functions of one or more vehicle attributes related to fuel economy. DOT must set CAFE standards separately for passenger cars and light trucks, and must set each standard at the maximum feasible level separately for each model year. Compliance is determined separately for fleets of domestic and imported passenger cars, and domestic passenger car fleets are also subject to a minimum standard based on the projected characteristics of the overall passenger car fleet. A fleet that exceeds the applicable standard in a model year earns CAFE "credits," and subject to a range of conditions, manufacturers can use these credits to offset other model years' and fleets' (including other manufacturers' fleets) CAFE "shortfalls." If a fleet does not meet a requirement, and the manufacturer does not obtain and apply enough credit to cover the shortfall, the manufacturer is required to pay civil penalties.

The purpose of the CAFE model is to estimate the potential impact of new CAFE standards specified in an input file that can contain a range of potential regulatory alternatives to be evaluated. The process involves estimating ways each manufacture <u>could</u> (not "should" or "is projected to") respond to standards, and then estimating the range of impacts that could result from those responses. A detailed representation of the current new vehicle market, specified in another input file, describes that current state of fuel economy technology among all new vehicles offered for sale in the model year (the most recent model year characterized in this way is MY2016). A third file houses a range of inputs defining key characteristics of the range of fuel-saving technologies to be considered—characteristics such as the applicability to specific types of vehicles and costs. The fuel economy improvement associated with a given combination of fuel economy technologies (when applied to a particular class of vehicle) is now contained within the CAFE model itself. While it can be viewed, and even modified, by the user, it is not required as an input to the model. A fourth file contains a wide range of economic and other inputs, such as vehicle survival and mileage accumulation rates (by vehicle age), projected future fuel prices, fuel properties (e.g., carbon content), air pollutant emission factors, coefficients defining potential impact of mass reduction on highway safety, and the social value of various externalities (e.g., petroleum market factors, criteria pollutant and greenhouse gas emissions, fatalities). Considering each manufacturers' projected production, the CAFE standards under consideration, the projected characteristics of the included fuel-saving technologies, and several other input assumptions (e.g., fuel prices and buyers' effective willingness to pay for fuel economy), the model iteratively applies increasing amounts of fuel-saving technology in response to these inputs, and then calculates impacts such as costs to vehicle purchasers, fuel savings, avoided emissions, and monetized costs and benefits to society.

Several elements that appear in the input files reflect earlier versions of the CAFE model, which relied more heavily on static inputs rather than the endogenous relationships present in the current version. In particular, the input files contain remnants from the now-outdated implementation of both sales and scrappage.

While the market data file still contains a static sales "forecast," it is merely a continuation of MY2016 volumes and is used only computationally (and mostly for testing). Rather, the current model defines sales in a given model year based on a function in the code (and described in the suggested documentation). This model relies on a set of exogenous economic factors (GDP growth rate and labor force participation – in both the current and previous periods) to estimate the total unit sales of new light duty vehicles in a given model year. That total is then apportioned to body-style groups based on a “dynamic fleet share” model – essentially a series of difference equations that is also present in EIA’s National Energy Modeling System (NEMS), though which we apply slightly differently. Once the share of each vehicle style, either car-style or truck-style, is determined, new sales are apportioned to each group and then distributed to each vehicle model based on their relative share of each style in the 2016 new vehicle market. It is worth noting that this does not necessarily preserve the market share of each of NHTSA’s regulatory classes because many vehicle models (over 20% of the current market) have both “car” and “light truck” versions for regulatory purposes. We choose to preserve the market definitions rather than the regulatory definitions in assigning sales.

Similarly, the “parameters” input file contains a set of vehicle survival rates that are also vestigial. Vehicle survival is now determined endogenously within the model run in a way that is responsive to changes in new vehicle prices, cost per mile of travel, and a set of exogenous economic factors. As the model calculates the lifetime mileage accumulation, fuel consumption, fuel expenditures, and various emissions values, it does so using these dynamically defined scrappage rates.

Finally, the employment calculations produced in the CAFE model are not only new in the current version, they are unlike the other two components in this review in that they do not contribute to the benefit cost calculations performed by the model (or subsequently by NHTSA based on changes in employment). The employment calculations are a function of new vehicle sales, as one would expect, but also on technology expenditures by manufacturers that influence upstream employment in the supplier network.

Charge Questions

In your written comments, please provide a detailed response to all of the following questions that are within your area of expertise. Reviewers will be expected to identify additional topics or depart from these examples as necessary to best apply their particular areas of expertise. Comments shall be sufficiently clear and detailed to allow readers to thoroughly understand their relevance to the CAFE model.

1	**Sales Model**
1a	Please comment on the appropriateness of including a sales response model in the CAFE model as a means to estimate differential sales impacts across regulatory alternatives.
e1b	Please comment on the sales model’s specification using an ADRL model time series approach, and comment specifically on the endogeneity of average transaction price.
1c	Please comment on the sales model’s integration in the CAFE model, including interactions with the simulation of multiyear product planning, in combination with the dynamic fleet share model used to allocate total new vehicle sales to the passenger car or light truck market segments.
1d	Please comment on the sales model’s specification as independent of vehicle scrappage, and on the resultant calculation of VMT.
2	**Scrappage Model**
2a	Please comment on the appropriateness of including a scrappage model in the CAFE model as a means to estimate the potential impact of CAFE standards on used vehicle retention.
2b	Please comment on the scrappage model’s specification using a form common in the relevant literature. Are there better approaches that allow for both projection (as is necessary in this context) and a focus on new vehicle prices (exclusively).

2c	Please comment on the scrappage model's integration in the CAFE model, addressing the vehicles affected by the scrappage model, and the extent to which changes in expected vehicle lifetimes are consistent with other assumptions.
3	**Labor Utilization Calculations**
3a	Please comment on the inclusion of each source of employment related to automobile production and sales.
3b	Please comment on assumptions regarding labor hours, production location (domestic/foreign), and supplier impacts.
3c	Please comment on methods used to calculate changes across alternatives.

Reviewer Name: Alicia K Birky

Review Question Number: 1a

Review Question Topic Description: Sales Model

1a Please comment on the appropriateness of including a sales response model in the CAFE model as a means to estimate differential sales impacts across regulatory alternatives.

Ideally, regulatory impact would be considered in a systems framework in order to capture important feedbacks. Therefore, including response of vehicles sales to *both* increased vehicle price and decreased fuel economy is highly appropriate. However, it seems that the analysts are tackling issues that are outside the original intent of the model and that current needs may be better met with alternative modeling methodologies and structures. In particular, the PRIA clearly states that the goals of the model changes are to address manufacturer and consumer behavior, yet the model components and system are not choice models. For further details, see answer to question 1d.

At the same time, when increasing the realism and complexity of models, analysts must always weigh the increased power of the model against increased uncertainty and error. These issues can and should be explored with validation and sensitivity analyses.

Reviewer Name: Alicia K Birky

Review Question Number: 1b

Review Question Topic Description: Sales Model

1b Please comment on the sales model's specification using an autoregressive distributive lag (ARDL) model time series approach, and comment specifically on the endogeneity of average transaction price.

The rationale for the ARDL approach is not described in the model documentation or the PRIA. Here I assume the rationale is an assumption of partial adjustment.

Since the equation estimates total sales (rather than change in sales) in response to a *change* in vehicle price and a *change* in GDP growth rate (per the PRIA), the impacts of these changes are temporary if the sum of the coefficients on lagged sales is less than one (as it is in table 8-1). However, the labor force participation enters the equation as a value, rather than a change in value. Therefore, a change in one year (followed by a constant value) leads to a permanently different level of sales. This seems theoretically supportable.

However, based on the resulting coefficients shown in table 8-1, it appears there may be an issue with the specification of the model. I would expect the net impact of labor force participation to be positive – an increase in participation should increase sales. While the coefficient on LFP is positive as expected, the coefficient on lagged LFP is negative and an order of magnitude larger, indicating a net inverse relationship for a sustained change in LFP. This calls into question the results of the other coefficients and indicates possible misspecification. One possible missing variable is disposable income which may not track with changes in GDP or LFP.

Regarding the simultaneity of average vehicle transaction price and sales: Sales prices of individual models or vehicle body styles and sales volumes are definitely jointly determined, with manufacturers and dealers adjusting price incentives as volumes fluctuate. This does create difficulties that can only be accounted for with complex modeling approaches. In competitive markets and in the long run, I would expect market average prices to track changes in manufacturing costs fairly closely.

Reviewer Name: Alicia K Birky

Review Question Number: 1c

Review Question Topic Description: Sales Model

1c Please comment on the sales model's integration in the CAFE model, including interactions with the simulation of multiyear product planning, in combination with the dynamic fleet share model used to allocate total new vehicle sales to the passenger car or light truck market segments.

Using a dynamic fleet share model is highly appropriate since the light truck share in both the short and long run has historically been responsive to fuel price and theoretically should be responsive to cost of driving and vehicle price. However, the specific fleet share approach -- determining the car share independently of truck share, then renormalizing -- seems inappropriate. Clearly these are joint determinations and the properties of both cars and trucks influence the decision to purchase one versus the other. A single model should be used to determine both. An alternative that would be similar to the approach currently in use would be to use a single equation for car (or truck) share but alter it to include both car and truck attributes to capture the cross elasticities of demand.

A more ideal approach would be a logit formulation that includes all modeled body styles. Unfortunately, a large amount of choice among body styles does not relate to economics but rather is more hedonic and subject to transients in consumer tastes. Given the fluid definition of some body styles as either cars or light trucks (i.e., cross-overs and car-based SUVs) as well as shifts in consumer tastes, a logit that uses three – cars, pickups, and vans/cross-overs/SUVs – or perhaps four body styles may prove more tractable.

Reviewer Name: Alicia K Birky

Review Question Number: 1d

Review Question Topic Description: Sales Model

1d Please comment on the sales model's specification as independent of vehicle scrappage, and on the resultant calculation of VMT.

The PRIA states that regulatory impact assessments should "reflect how alternative regulations are anticipated to change the behavior of producers and consumers." Yet at the same time, it also states that neither the dynamic scrappage model nor revised sales response model "are consumer choice models." VMT demand, the decision to purchase a new vehicle, which vehicle to purchase, and whether to use the purchase to replace an existing vehicle, are joint consumer decisions made at the household level. Therefore, the feedbacks of interest likely are better addressed in a household choice model that includes a market for used vehicles. That said, the decision to *scrap* a vehicle (remove it from the national in-use fleet) and the decision to purchase a new vehicle often are not made by the same household. No national-level transportation demand models (that this reviewer is aware of) tackle the issue with this level of complexity.

However, the vehicle-focused method used to calculate total VMT -- using historically derived, vintage specific, per-vehicle VMT – neglects important determinants of demand that are central to the issues this update is attempting to address. The IHS/Polk data used to derive the vintaged VMT schedules include an array of economic and demographic trends that may or may not be representative of future VMT demand, including ownership rates. The independent sales and scrappage functions determine ownership rates, but this result is not reported nor compared to historical trends, so it is not possible to assess how consistent the model is with these trends or with trends in VMT per household or per capita. For example, in response to a decrease in vehicle price, a household could decide to purchase a new vehicle that they otherwise would not, yet keep all currently owned vehicles. The additional vehicle could spur additional household VMT as some multiple occupant trips are now taken independently or as some foregone trips are now possible. However, it is unlikely that the total household VMT would increase by the total annual VMT of a new vehicle.

In the absence of a household-choice model, an alternative approach would be to calculate national VMT demand as a function of economic and demographic variables, including ownership rates, as well as vehicle fleet attributes. The vintaged VMT schedules could be scaled accordingly to achieve the calculated total VMT. Unfortunately, this approach does not address the potential shift of VMT between older and newer vehicles that could occur with changes in the vehicle stock composition and with changes in fuel prices. This latter effect is important in short run responses to fuel price changes, where multi-vehicle households are able to choose which vehicle is used or to adjust overall vehicle usage based on per-mile costs.

Reviewer Name: Alicia K Birky

Review Question Number: 2a

Review Question Topic Description: Scrappage Model

2a Please comment on the appropriateness of including a scrappage model in the CAFE model as a means to estimate the potential impact of CAFE standards on used vehicle retention.

Ideally, regulatory impact would be considered in a systems framework in order to capture important feedbacks. The VMT "rebound" effect has been fairly well covered in the literature, but other feedbacks, both positive and negative, have received less attention. Response of scrappage rates and vehicle turnover are important and often neglected components of the impact of fuel economy standards on in-use fleet fuel consumption. Therefore, a realistic representation of scrappage is an excellent contribution. Ideally, scrappage should be responsive to existing and new vehicle attributes as well as demographic variables.

Reviewer Name: Alicia K Birky

Review Question Number: 2b

Review Question Topic Description: Scrappage Model

2b Please comment on the scrappage model's specification using a form common in the relevant literature. Are there better approaches that allow for both projection (as is necessary in this context) and a focus on new vehicle prices (exclusively)?

While the focus is on the impact of new vehicle price on scrappage at each vintage, other factors are appropriately included. However, I believe there are some issues with the specification (model used to derive coefficients as described in PRIA section 8.10).

While the intent is to measure the impact of a vehicle price increase that arises from an increase in CAFE, it is important to control for other vehicle attributes that also relate to vehicle price and fuel cost per mile. While the model controls for new vehicle fuel cost per mile, there are other attributes valued by customers that are correlated with fuel consumption (e.g. horsepower, weight, acceleration time, torque, etc.). By not controlling for these other vehicle attributes, the price and cost per mile metrics are capturing these other feature differences that are positively valued and that could influence the scrappage rate of used vehicles in different directions. Where increases in performance are correlated with higher fuel consumption, an increase in new vehicle fuel cost/mile could increase rather than decrease scrappage (and vice versa), particularly of any vintages that may be deemed "under-performing." I believe the inconsistent and sometimes counter-intuitive behavior of the fuel price coefficients among the vehicle classes is likely due to this oversight.

The interpretations of the coefficients on fuel cost and lagged fuel cost seem somewhat confused in the PRIA discussion. The mechanism of impact on scrappage generally relates to the comparison of fuel cost between the vintage vehicle and the new vehicle. However, the model includes these 2 measures separately and the interpretation is complex. In the case of the vintage vehicle (same) fuel cost per mile coefficients, the sum of the two coefficients is the scrappage response in the situation where fuel price does not change. All else being equal, I would expect higher scrappage to be related to higher cost per mile, i.e., positive coefficients. However, the sum of the coefficients is negative for all body styles, though only weakly so for cars. I believe the counter-intuitive behavior likely relates to the issue discussed above.

The model documentation indicates that other vehicle attributes are included in the scrappage model values worksheet but it was not clear (given the scope of this review) how they figure into the model.

A few additional comments:

- The model uses average new vehicle prices as a measure of general price trends, partly due to data availability. However, the PRIA states that aggregate prices may be most appropriate because "it is likely manufacturers will cross-subsidize costs." I agree that the cross-subsidization problem is an issue and aggregate price could therefore be more appropriate than model- or even body-specific data. However, I wonder if additional statistics might provide additional predictive power, such as indicators of variation/spread.

- I agree that future models should definitely consider incorporating separate price series by body style (cars, SUVs, and vans, and pickups; PRIA, p. 1009) since these trends are not necessarily the same and manufacturers may “subsidize” across body styles.
- Transaction prices do not include trade-in values which clearly are very important. In addition, only the value of scrap metal is discussed in conjunction with scrappage decisions. However, many older used vehicles are scrapped from the U.S. vehicle stock but are exported to other countries. For many vintages, the export value would be a better indicator of this decision point. Possible measures to consider that capture trends in resale and scrappage values include NADA residual values and auction prices.
- GDP growth and unemployment rates were explored as indicators of economic activity, with only GDP used in the final models. Given that salaries have not kept pace with economic growth, other income variables might improve explanatory power.
- Scrappage decisions also depend on accumulated VMT while annual VMT will respond to scrappage (lower scrappage due to higher cost could lead higher annual VMT in older vehicles). It doesn’t appear that the impact of changes in VMT are considered in the scrappage. This effect is likely to be significant for system changes that could arise if ride-hailing services and automated vehicles become commonplace. On the other hand, this effect may be small in aggregate for the purposes and use of this model.

Reviewer Name: Alicia K Birky

Review Question Number: 2c

Review Question Topic Description: Scrappage Model

2c Please comment on the scrappage model's integration in the CAFE model, addressing the vehicles affected by the scrappage model, and the extent to which changes in expected vehicle lifetimes are consistent with other assumptions.

The dynamic scrappage model affects scrappage at all vehicle ages but is formulated to allow differential response to new vehicle price depending on age, with increasing impact on older vehicles. Over the scenarios analyzed, the impact of the dynamic scrappage model on expected vehicle lifetime mileage is small. Given the relatively small changes in vehicle price and fuel economy, small changes are within expectations. To fully comment on the model implementation, it would be necessary to see the results of sensitivity analyses over a larger variation in inputs. Examining the modeling differences (PRIA, section 8.10.10), the impact on expected lifetime mileage is within the realm of expectations as well.

The decrease in the size of the in-use vehicle fleet as a result of reducing the CAFE stringency is not an intuitive finding and is worth additional exploration. This may solely be the result of scrappage and sales models that were derived and operate independently. This counter-intuitive finding is even more important since total VMT is determined using age-specific VMT curves rather than a demand function. The impact of the change in vehicle stock (both total number and average age) on total VMT should be vetted against expected trends in VMT demand.

Reviewer Name: Alicia K Birky

Review Question Number: 3a

Review Question Topic Description: Labor Utilization Calculations

3a Please comment on the inclusion of each source of employment related to automobile production and sales.

Labor economics is outside my area of expertise so my comments here are very limited.

The PRIA indicates that only direct employment changes were included while vehicle maintenance and repair was not, though it recognizes that used vehicle sales, parts, and maintenance and repair are the major revenue source for dealerships. It seems like changes to the parts, maintenance, and repair labor, revenue, and profitability could be significant.

Reviewer Name: Alicia K Birky

Review Question Number: 3b

Review Question Topic Description: Labor Utilization Calculations

3b Please comment on assumptions regarding labor hours, production location (domestic/foreign), and supplier impacts.

Labor economics is outside my area of expertise so my comments here are very limited.

A number of assumptions are made regarding values that are held constant at 2016 values but the validity of some of these assumptions is not substantiated. In particular, assembly labor hours per unit for vehicles, engines, and transmissions; and the factor between direct assembly labor and parts production jobs are held constant. These assumptions may not hold for two reasons:

1) As CAFE standards become ever more stringent, the technologies used to meet them will increase powertrain complexity (at an increasing rate). This will likely have different impacts on product design, fabrication, and assembly.
2) The cost of new technologies is expected to decrease over time as a function of learning, typically in fabrication and assembly. Reduction of these costs likely includes reduction in labor hours and learning may reduce some labor components more than others.

Reviewer Name: Alicia K Birky

Review Question Number: 3c

Review Question Topic Description: Labor Utilization Calculations

3c   Please comment on methods used to calculate changes across alternatives.

This topic is outside of my expertise.

Peer Review Comments on CAFE Model by John D. Graham, Ph.D. (October 10, 2018)

1. Sales Model.
   a. Appropriateness of a sales-response model in the CAFE model.

It is entirely appropriate – indeed necessary – for DOT/EPA to include a sales-response model in the CAFE model. Without a sales-response model, it is not feasible to perform a valid benefit-cost analysis of this regulation, or to make valid projections of this regulation's potential impacts on gasoline consumption, oil consumption, greenhouse gas emissions, and emissions of other pollutants related to smog and soot. Since the energy and environmental outcomes relate directly to the statutory goals of the regulatory programs in question, it is apparent that the potential impacts of regulations on vehicle sales must be addressed analytically by DOT/EPA.

If the 2021-2025 CAFE/GHG standards were projected to have only a slight impact on vehicle production costs and vehicle prices, then it might be defensible for DOT/EPA to perform only a qualitative analysis of the impacts on vehicle sales, and proceed with an engineering-oriented estimate of the energy and environmental outcomes of interest. In this rulemaking, however, DOT/EPA are projecting a cumulative cost/price impact of almost $2,000 per vehicle in 2025 compared to vehicle costs/prices associated with a freeze of the 2020 Federal standards.

By way of comparison, there is no previous rulemaking in the history of DOT or EPA that has been predicted to have a cost/price impact in the range of $2,000 per vehicle. In fact, I recently prepared a report for the University of Pennsylvania where I catalogued the estimated vehicle cost/price impacts of every significant DOT and EPA standard covering vehicle emissions, safety, and fuel economy since the 1960s (N = 39). (I can share this report, which will soon appear in a book to be published by the Brookings Institution). The average cost/price impacts were never in excess of $1,000 per vehicle except for the 2011-2016 CAFE/GHG standards, where the cost/price impact exceeded $1,000 when adjustments were made to express the monetary impact in 2016 dollars. (In that rulemaking, DOT/EPA did include a quantitative analysis of sales response, though it was more simplified than the analysis included in this PRIA). There were only 4 rulemakings of the 39 where the cost/price impact was greater than $500 per vehicle, and the median cost/price impact per vehicle for the 39 rulemakings was about $100 per vehicle. Thus, a sales-response model is much more crucial in this rulemaking than it has been in previous EPA and DOT rulemakings on vehicle emissions, safety, and fuel economy standards.

A $2,000 vehicle price increase is more than a 5 percent rise in the average transactions price for a new passenger vehicle in the U.S. market (currently the average transactions price is about $35,000 per new vehicle). A 5 percent rise in new vehicle price will not influence the sales decisions of all, most, or a majority of consumers but it could certainly impact the purchasing decisions of a significant number of consumers in the market. The issue here is not whether the price increment would cause a household to go from owning a car to not owning a car. The issue is whether the price increase on new vehicles might cause some households to delay their purchase of a new car, hold on to their existing car longer, consider a used car instead of a new car, or own one fewer car than they would otherwise own. (Another possibility that DOT/EPA do not address quantitatively – but does mention on p. 950 -- is that the consumer might downgrade the quality of new car that they purchase, due to the affordability issue).

An engineering approach to this regulation is simply insufficient. Behavioral changes by consumers can have important impacts on how fast the DOT/EPA regulations achieve their statutory objectives (since new vehicles are generally cleaner and more fuel efficient than old vehicles), and the behavioral choices by consumers can have potentially perverse consequences for safety and other important public and private outcomes.

Moreover, there is a stream of academic literature, beginning with Gruenspecht (1982) and extending to Jacobsen and van Bentham (2015), demonstrating the importance of considering sales response in economic models of CAFE and GHG standards. The PRIA on p. 922 (footnote 480) appropriately cites those two classic papers as academic foundation for the modeling that has been performed.

Thus, without question, a sales-response model should be incorporated into the CAFE model, especially for this relatively high-cost rulemaking.

b. Time-series model.

In order to establish the impact of changes in vehicle price on volume of vehicle sales, DOT and EPA presume that regulation-induced increases in the costs of vehicle production will be reflected in average new vehicle prices, and that those changes in new vehicles prices will have impacts on new vehicle sales that are equivalent to what time-series modeling suggests has occurred in the 1979-2015 period. There are some important assumptions here that need to be teased out, discussed, and justified by DOT/EPA.

Are Changes in Vehicle Production Costs Fully Reflected in New Vehicle Prices?

First, there is the question as to whether regulation-induced costs will be reflected in average new vehicle prices. The time-series analysis assumes this relationship rather than establishing this relationship. As far as I can tell, the PRIA addresses this matter only once and only very briefly. On p. 929, the PRIA states that “manufacturers will attempt to recover these additional costs by raising selling prices for those or other models that they offer.” The PRIA does not present any evidence that auto manufacturers will be successful in raising prices in response to regulatory cost impositions. The alternative possibilities are the manufacturers finance these costs by reducing labor compensation and/or reducing returns to owners/investors or squeezing dealers or suppliers.

There is a strong theoretical foundation, explained in OMB Circular A-4, for the assumption that regulatory costs will be passed through to consumers in the form of higher prices when markets are competitive (meaning lots of producers and lots of consumers, and good market information and so forth). However, the academic literature on the U.S. automotive industry has not historically treated this industry as classically competitive. Indeed, most of early modeling of the U.S. auto sector used oligopolistic assumptions rather than perfectly competitive assumptions (see Bresnahan, 1981; Berry et al., 1995; Goldberg, 1995 and 1998; and Kleit, 2004). The dominant theories of oligopoly pricing do not lead to a strong prediction on price impacts due to regulation, and it has been established that this issue needs to be addressed empirically on a case-by-case basis rather than be resolved by reference to theory alone (Davis & Knittel, 2016).
A substantial economics literature addresses how manufacturing companies handle changes in their costs of inputs. Dornbusch (1987) theorized that firms operating in a competitive setting increase the amount of “pass-through” as the proportion of the market that is exposed to the cost increase grows. If only one of many firms experiences the cost increase, pass-through pricing may not occur. Ashenfelter, Ashmore, Baker, and McKernan. (1998) confirmed the theoretical prediction in their study of the office supply retail sector. A large stream of literature has confirmed the “pass-through” hypothesis as it relates to the auto industry (Knetter, 1989 and 1993; Feenstra, 1989; Gagnon & Knetter, 1994; Goldberg, 1995; Feenstra, Gagnon, & Knetter, 1996; Goldberg, 1997and 1998; Gron

& Swenson, 2000; Kleit, 1990). I recommend that the final PRIA include appropriate references to this literature.

In a classic study Gron and Swenson (2000) examined list prices of automobiles at the model level in the United States from 1984 to 1994, coupled with data on production, vehicle characteristics, foreign versus domestic firm ownership, wages of employees, exchange rates, imported parts content, tariffs, and other variables. Although their work rejects the hypothesis of 100 percent pass-through of cost to consumer price, they find higher rates of pass-through than previous studies, and much of the incomplete pass-through occurs when cost increases impact only a few models or firms. Confirming earlier studies, they show that U.S. auto manufacturers engage in more aggressive pass-through pricing than Asian and European manufacturers (greater than 100% in some specifications), possibly due to the eagerness of importers to enlarge market share in lieu of recovering regulatory costs, at least in the short run (see Dinopolous & Kreinin, 1988; Froot, 1989). This study helps explain why pass-through pricing is a more viable hypothesis in the long run than in the short run.

The original design of the CAFE program is a contrasting case where pass-through pricing was difficult for some automakers. All auto makers, regardless of their product mix, were subject to the same fleet-wide average CAFE standard, such as 27.5 miles per gallon for cars in 1990. In practice, those standards impacted only three high-volume companies (General Motors, Ford, and Chrysler) because the Big Three produced a higher proportion of large and performance-oriented vehicles than did Japanese companies. As a result, Toyota and Honda consistently surpassed the Federal fleet-wide standard for cars without any regulatory cost (i.e., partly due to their smaller product mix). In the 1975-2007 period, the Big Three were not able to pass on all of their compliance costs to consumers and thus experienced some declines in profitability due to CAFE (Kleit, 1990 and 2004; Jacobsen, 2013a).

When the CAFE program was reformed for light trucks in 2008 (and for cars in 2011) on the basis of vehicle size (the so-called "footprint" adjustments to CAFE stringency), the technology costs of CAFE standards were spread more evenly among automakers, although the overall societal efficiency of the regulation diminished (due to the removal of downsizing as a compliance option) (see Ito & Sallee, 2018). Given that the size-based CAFE/GHG programs are not concentrating the costs of compliance on one or two automakers, it is reasonable to predict a fairly high degree of pass-through pricing for the 2021-2025 CAFE /GHG standards. In a related literature on manufacturer pricing responses to a national carbon tax, Bento and Jacobsen (2007) and Bento (2013) report high rates of pass-through pricing (on the order of 85%). Carbon taxes are more efficient than footprint-based CAFE standards but both instruments are likely to impact a wide range of companies in the auto sector and result in a high degree of pass-through pricing by impacted companies.

It should also be noted that the U.S. automotive industry is much more competitive today than it was in the 1970-2000 period. The market share of General Motors, once the dominant, majority producer in the U.S. market, has declined dramatically, and a variety of Japanese and Korean companies have captured market share. Moreover, the rise of startups (e.g., Tesla and other electric vehicle start-ups) and ride-sharing services (e.g., Uber) are adding a new, competitive dimension in the U.S. industry. As a result some of the most recent auto regulatory studies have given more emphasis to analytic results based on competitive models than oligopolistic models (e.g., Davis & Knittel, 2016). Thus, the assumptions being made in the PRIA about pass-through pricing are defensible but they do need to be defended. Hopefully this discussion, and the related references, have helped in this regard.

Are Consumers Likely to React the Same to CAFE-Induced Price Increases as They Do to the General Price Increases Observed in a National Time Series Model From 1979 to 2016?

The big issue here is how to address price increases caused by the addition of fuel-saving technologies induced by regulation, as it is reasonable to believe that consumers will value the enhanced fuel economy to some degree. In contrast, a consumer does not necessarily value the additional costs of wages paid to executives or workers, or the additional prices for raw materials that impact the cost of vehicle production. The typical consumer might value an extra 5 miles per gallon of fuel economy, since that will translate into lower operating costs for the vehicle when the vehicle is used by the consumer.

In previous RIAs where DOT/EPA analysts have quantified sales impacts of CAFE /GHG standards, a price elasticity of demand of -1.0 has been applied to the net vehicle price increase, where net vehicle price is equal to the gross average technology cost per vehicle minus the present value of fuel savings for the consumer who purchases the vehicle. (Actually, the present value of fuel savings is computed for the original ownership period and then a standard resale value is added for the rest of the vehicle life). As far as I know, the -1.0 elasticity figure does not have a solid grounding in economic evidence and was used simply for illustrative purposes. Moreover, previous RIAs did not present evidence to support the assumption that resale value for fuel-economy technology is similar to resale value for the vehicle as a whole. Thus, DOT/EPA are well justified in taking new evidenced-based approaches to the price elasticity, consumer valuation, and resale questions.

The PRIA contains a new autoregressive distributed-lag (ARDL) model that relates lagged national values of vehicle sales to changes in average vehicle price, changes in GDP growth, and measures of consumer confidence. Aggregate quarterly data is used for the 1979-2015 period. The model fits the data reasonably well, the explanatory variables behave as expected based on theory and prior evidence, and statistical analysis revealed little evidence of autocorrelation or other statistical problems. Based on the model, a $1,000 increase in average new vehicle price is associated with a loss of 170,000 units of sales in year 1, followed by an additional 600,000 losses in vehicle sales over the next 10 years – in effect, the adverse effect of the $1,000 price increase tapers with time. The PRIA characterizes this response as a price elasticity of demand in the range of -0.2 to -0.3.

A weakness in the model is that it does not include important variables concerning consumer access to credit such as average interest rates on car loans. A focus on subprime buyers might be appropriate since they are likely to be the marginal consumer (as they are the most credit constrained). It also does not address movements in used car prices, a surprising omission given that used cars are a prominent potential substitute for new cars.

Both of these variables (interest rates on car loans and used car prices) have been shown to be significant in recent national time-series modeling – interest rates on car loans are negatively associated with new vehicle demand and used car prices are positively associated with new vehicle demand (McAlinden, Chen, Schultz, & Andrea, 2016). Since both of these variables are well known to affect new vehicle sales, the sales-response model would be more credible if these two variables were included and if their estimated coefficients exhibited the theoretically expected behavior.

The omission of used vehicle prices is particularly concerning since the linkage between consumer demand for new versus used vehicles is a key theme of the PRIA and the preamble's case for less stringent standards. DOT/EPA should explore adding these variables and report what they learn.

While these variables may also be endogenous (like new vehicle prices may be endogenous), that is not an argument for ignoring them. They should be analyzed and discussed.
A paradox of the national time-series modeling is that inclusion of fuel-economy variables did not improve the explanatory power of the model. This analytic outcome is troubling because DOT/EPA analysts also review (pp. 938-939) several recent large-sample vehicle transactions-price studies that find that that consumers value highly the fuel-economy of vehicles, as fuel economy is capitalized (reflected) in the prices of used and new vehicles (Busse, Knittel, & Zettelmeyer, 2013; Allcott, Mullainathan, & Taubinsky, 2014; and Sallee, West, & Fan, 2016). While it is encouraging that DOT/EPA analysts explored several variants of fuel-economy variables, it is concerning that none of these variables improved the time-series model statistically. Thus, the time-series findings that are reported and discussed in the PRIA on p. 949 (Table 8-1) – and subsequent outcomes from the CAFE model -- do not account for the potential effects of changes in average fuel economy on new vehicle demand. This omission leaves the sales-response model vulnerable to the allegation that it overstates the adverse effect of fuel-economy regulation on new vehicle demand, since it incorporates only gross technology costs and ignores consumer interest in fuel economy.

I recommend that the paradox be resolved in the following way in the final RIA. The national time series model should be used by DOT/EPA as one approach to estimating the price-elasticity of demand but the future impacts of fuel-economy regulation on new vehicle sales should be based on a net-price concept rather than the gross costs of technology. This approach is similar to the net-price concept that DOT/EPA have used in the past in previous RIAs except, in this and future rulemakings, the net vehicle price should assume substantial consumer undervaluation of fuel economy. Specifically, the net price should assume 2.5 years of consumer valuation (not full valuation) of future fuel savings (since the date of original purchase), the same limited valuation period that the CAFE model is already using to establish which fuel-saving technologies will be adopted voluntarily in the market, without any regulatory pressure. This net-price recommendation will account for limited consumer demand for fuel economy while also bringing analytic consistency to what DOT/EPA are assuming in another module of the CAFE model.

The PRIA exposes itself to this paradox by giving inappropriate emphasis to the recent econometric studies showing high consumer valuation of fuel economy. It is already well known throughout the industry that consumers do not fully value fuel-saving technologies offered on new or old vehicles (see National Research Council, 2015, and Carley et al., 2017). The 2015 National Academies study undertook a survey of industry experience with fuel saving technologies. The authors concluded with the observation that the industry experts believe that consumers behave as if they value only 1 to 4 years of fuel economy (i.e., serious undervaluation of fuel economy) when purchasing new vehicles. Since 2.5 years is the middle of this range, I recommend that 2.5 years be used in computing the net per-vehicle price of regulation and in projecting impacts on vehicle sales. Sensitivity analyses should be performed using 1 and 4 years.

The full-valuation results reported by Busse, Knittel, and Zettelmeyer (2013) and Sallee et al. (2016) are based on changes in fuel prices, not changes in fuel-economy technology. (The results reported by Allcott, Mullainathan, & Taubinsky, 2014, again based on changes in fuel prices, do not support full valuation). The CAFE /GHG standards operate by changing vehicle characteristics, not by changing fuel prices. The two mechanisms of change can have equivalent effects in a rational-choice model but may not be viewed the same way in a behavioral assessment of consumer choice. Consumers may be more cautious about changes in technology than changes in fuel price, even when the two mechanisms have the same present-value financial impact on the consumer.

A recent study by Leard, Linn, and Zhou (2017), using data and methods similar to Busse, Knittel, and Zettelmeyer (2013) and Sallee et al. (2016), does not find full consumer valuation of fuel economy. Importantly, this study focuses on changes in technology as well as changes in fuel price. Moreover, our group at IU recently completed a study of HEVs – using a paired-comparison method with gasoline vehicles -- where we found that several HEV models have had very little consumer uptake even though they are financially attractive from a total cost of ownership perspective. The poor uptake of affordable HEVs cannot be fully explained by shortfalls in other vehicle attributes such as performance and fuel economy. Thus some of the real-world experience with HEVs also suggests consumer undervaluation of fuel economy.

I recommend that section 8.3, "Consumer Valuation of Improved Fuel Economy" (pp. 934-940), be reconsidered and rewritten to reflect the decades of industry marketing experience with fuel economy technology, as reviewed by the National Research Council (2015), the stated preference studies that address directly the limited extent of consumer interest in fuel-economy technology (see the citations in Carley et al., 2017), the fact that Busse, Knittel, and Zettelmeyer. (2013) and Sallee et al. (2016) address consumer response to fuel price changes rather than technology changes, the fact that Allcott, Mullainathan, and Taubinsky (2014) did not find full consumer valuation (even when studying fuel price changes), the fact that Leard et al. (2017) find consumer undervaluation with technology changes, and the fact that HEVs have very limited consumer uptake, even when they are financially attractive from a total cost-of-ownership perspective (Duncan et al., 2019).
The inability of the national time-serious model to find a significant impact of fuel economy on vehicle sales is not difficult to understand if the average consumer is assumed to undervalue fuel economy to a substantial degree. The "signal" provided by the quarterly differences in vehicle fuel economy, when dampened by consumer undervaluation, may simply be too small to find a fuel-economy effect, given the quarter-to-quarter "noise" (random movement) in national vehicle sales. On the other hand, the lack of a significant fuel-economy effect in the national time series model does not mean that the effect is zero. We already have plenty of evidence from better research designs that the effect is nonzero, though consumer demand is substantially less than full valuation as defined by rational-choice theory.

With respect to the endogeneity issue, I think the national time series model is vulnerable to the criticism that average vehicle transactions prices and average volumes of new vehicle sales are determined simultaneously in the market. When sales are low (e.g., in recessionary periods), transactions prices likely fall (e.g., due to dealer and manufacturer discounts); when sales volumes are high, discounts off list prices may diminish, keeping transactions prices relatively high (see PRIA, p. 947, paragraph 2, sentence #2). Transactions prices surely do have a negative causative effect on vehicles sales, but this causative relationship could be mis-estimated in the national time series model due to a failure to control for the reverse causation -- the positive causative effect of sales volume on average transactions price. This omission may help explain why the estimated coefficient on vehicle price in Table 8-1 is so modestly sized and close to zero.

It is doubtful that the endogeneity concern can be addressed convincingly within the national time-series modeling framework. I recommend instead that DOT/EPA analyze the likely direction of the bias, and discuss this limitation qualitatively in the final RIA. In addition, DOT/EPA should not rely entirely on the national time series model to estimate the price-elasticity of demand for use in the CAFE model. Instead, DOT/NHTSA should also explore the price-elasticity studies published in the literature and reviewed by McAlinden et al. (2016), Appendix II, 63-64. I believe that this literature, with a proper focus on long-term price elasticity of demand, provides support for a price elasticity of demand that is well below -1.0 (in absolute value) but probably a bit higher than -0.2. This literature-based estimate can provide an alternative estimate for use in the sales response module of the CAFE model. I recognize, as explained on p. 952 of the PRIA, that the CAFE model requires dynamic projections of vehicle sales and a point estimate of long-term price elasticity of demand from the literature does not provide the desired dynamic property. However, it might be feasible to use a literature-based estimate to define the total long-term impact of vehicle price on new vehicle demand, and then use the national time-series model to allocate the total effect to different years within the ten-year time horizon. In this way, the national time-series model is being used in a more limited way than it is currently used.

c. Integration of sales-response model in the CAFE model.

The sales-response model is generally integrated into the CAFE model in a logical fashion. An exception may be that the regulatory alternatives discussed in the preamble are not reflected accurately in either the sales-response model or the CAFE model. As I understand the preamble and the regulatory alternatives under consideration, DOT/EPA's preferred option is to freeze the Federal standards at 2020 levels and preempt separate State-level GHG and ZEV standards.

If instead the status quo policy is maintained, it should be assumed that the 2021-2025 Federal standards would be supplemented by the California ZEV standards in States representing approximately 30 percent of the new vehicle population in the United States. The California GHG standards would have no incremental economic or environmental effects since compliance with the Federal standards is recognized as per se evidence of compliance with the California GHG standards.

The preferred regulatory proposal would then alter the status quo by freezing the Federal standards at 2020 levels and eliminating the State-level ZEV standards. As currently designed, the sales-response and CAFE models are well designed to address the Federal freeze but they ignore the economic and environmental impacts of removing the State-level ZEV requirements. Removing the State-level ZEV requirements can certainly be expected to have national ramifications since the State-level ZEV requirements cover approximately 30 percent of the national market for new vehicles and since the ZEV requirements are a de facto electric-vehicle requirement of 5 percent to 20 percent of an automaker's State-specific new vehicle fleet in 2025. Technically, the ZEV requirements are not a market-share requirement; they are a compliance credit requirement but both CARB and the stakeholder community view the credit requirements as a tool to boost the commercialization of electric vehicles.

The final RIA needs to incorporate the proposed elimination of the ZEV program into both the sales-response model and the CAFE model. The analytic complications for the RIA are less complex on the benefit side of the ledger than on the cost side of the ledger.

On the benefit side of the ledger, it is unlikely that the ZEV program contributes any significant GHG and energy security benefits, since national GHG emissions and oil-consumption levels are not influenced by a State-level policy nested within a binding Federal performance standard. Insofar as the electric vehicles produced and sold in response to the State-level ZEV requirements are counted by vehicle manufacturers in Federal compliance statistics, the practical effect of the ZEV requirements is to ease the compliance burdens of the Federal standards, allowing vehicle manufacturers to sell gasoline-powered vehicles nationally with a somewhat higher level of GHG emissions and gasoline consumption than would occur if the State-level ZEV requirements did not exist.

It is possible but doubtful that ZEV States will accomplish some incremental control of smog and soot pollution from the ZEV requirements. For sure, the ZEV program was launched in 1990 by CARB with an eye toward helping California cities (especially Los Angeles) come into compliance with EPA's national ambient air quality standards for criteria air pollutants. However, the EPA LEV II and LEV III standards (and the sister standards adopted by CARB) for gasoline vehicles adopted since 1990 reduce dramatically the amount of pollution from new passenger vehicles that contributes to smog and soot. Those standards, which operate in conjunction with low-sulfur gasoline requirements on refiners/blenders, increase the longevity of catalysts and ensure that vehicles did not contribute significantly to smog or soot for 150,000 miles of vehicle lifetime. Since 2008-9, CARB has recognized that GHG control may be a more compelling rationale for the ZEV program than is control of residual pollution related to smog and soot. For sure, Los Angeles and some other communities in ZEV States will not comply with EPA's health-based air quality standards for the forseeable future. However, this noncompliance is related not to conventional emissions (e.g., NOx) from new passenger vehicles (which are quite small) but from the large volume of older, dirtier passenger vehicles in the fleet as well as the large volume of heavy trucks, construction/agricultural vehicles, and stationary sources that are not covered by the ZEV program.

Some analysts in California and other ZEV States may see the ZEV program not as a short-term effort to control GHG emissions but as a long-term technology-forcing policy to stimulate technological innovation and commercialization in the auto sector. However, ZEV requirements are not necessary to stimulate technological innovation and commercialization of electric vehicles. California can make greater progress in this regard by taking the same steps that Norway has already taken: Subsidize consumer demand for electric vehicles to the point where 30 percent of new passenger vehicles in Norway are electric in their propulsion system. Norway has launched this policy without adopting a ZEV requirement and without shifting the costs of the policy to consumers in other countries in Europe.

On the cost side of the ledger, the State-level ZEV requirements can be predicted to cause a distortion in the pricing of new passenger vehicles in the United States. In order to sell an adequate number of ZEVs in California and other States that require ZEVs, auto makers cannot price an electric vehicle at its incremental cost of production (roughly $10,000 per vehicle in 2025 according to EPA/DOT, assuming driving range of 200+ miles). Instead, CARB and EPA generally assume that automakers will treat the costs of the ZEV program as an R&D expense, and spread those costs across all of the new vehicles that automakers sell in the U.S. market. The pass-through effect of the ZEV requirements on new vehicle prices in the United States has not been estimated in the PRIA, even though the preamble to the proposed rule asserts Federal preemption of the ZEV requirements.

With regard to the average cost of producing a new vehicle, the presence of the State-level ZEV requirements have offsetting effects on automakers. The incremental cost of the Federal programs will be smaller in the presence of State-level ZEV requirements than without the State-level ZEV requirements, since the electric vehicles produced to comply with the State-level ZEV requirements count toward an automaker's Federal compliance statistics. However, the combined cost of the Federal and State-level requirements will be greater than the Federal requirements alone, since most automakers would not produce costly electric vehicles in the absence of State-level ZEV requirements. In a recent study of the interaction of the Federal CAFE /GHG and State-level ZEV requirements, we found that the net effect of the addition of the State-level ZEV requirements to the Federal regulations was to increase the average cost of vehicle production (nationwide) by $400 to $700 per vehicle. Those extra costs are large enough to have a significant impact on the results of the sales-response model, the fleet-turnover model and the CAFE model as a whole. Thus, I recommend that DOT/EPA include the cost savings from the elimination of the State-level ZEV requirements in the final RIA for this rulemaking.

1d. Sales-model's specification as independent of vehicle scrappage and impacts on VMT.

No comment.

2. Scrappage Model
   a. Appropriateness of including a scrappage model in the CAFE model.

As explained above, the transportation sector's impact on national GHG emissions and national petroleum consumption is triggered by the use of both used and new vehicles. Vehicle use is operationalized in the PRIA through the metric of vehicle miles of travel (VMT). Thus, DOT/EPA need to know how long a vehicle will be driven (before it is scrapped), and the expected number of VMT for each anticipated year of the vehicle's lifetime. Those mileage schedules may change subtly yet significantly under different CAFE /GHG standards.

In order to appreciate why a scrappage model is needed for the CAFE model, consider how CAFE /GHG standards are likely to impact the average prices of new and used vehicles. If the national volume of new vehicle sales rises due to costly CAFE /GHG regulations, then it should be expected that the demand for new passenger vehicles will decline while the demand for used vehicles will rise (other factors held constant). Unless there is a supply response in the market for used vehicles, the greater demand for used vehicles will bid up prices for used vehicles (Gruenspect, 1982). The opposing effects occur because a used (old) vehicle is a potential substitute for a new vehicle. Ultimately, more VMT will occur in used vehicles relative to new vehicles compared to what would have occurred without stricter CAFE /GHG regulation. Likewise, a freeze on Federal CAFE /GHG standards will tend to allocate more VMT to new vehicles than to old vehicles.

The market dynamics do not end here because there is also a supply response in the used vehicle market due to a rise in average prices of used vehicles. The supply response operates through the scrappage rates on older vehicles.

Consider the recurring decision problem faced by the owner of an old vehicle (Jacobsen & van Bentham, 2015). Each time a vehicle breaks down, the owner must decide whether to repair and keep the vehicle, repair and sell the vehicle, or scrap the vehicle. Rational choice theory predicts that he/she will choose to scrap it if and only if the prevailing price in the used-car market falls below the repair cost plus any residual value. As the prices of used vehicles rise, scrapping an old vehicle becomes less attractive. Thus, a supply response to higher used car prices operates through a tapering in the rate at which owners of old vehicles scrap their vehicles.

Scrap rates, which are usually expressed on an annual basis, follow familiar patterns. They increase with vehicle age from about 1-2 percent for 2 year-old vehicles to almost 15 percent for 20-year old vehicles. The adjustments to scrappage rates due to CAFE /GHG standards will tend to be marginal changes to the age-specific scrappage rates mentioned here. Without knowing the change in scrappage rates, it is not feasible for DOT/EPA analysts to figure out how many total vehicles will be used or the age distribution of those vehicles.

> Fortunately, there is a useful recent literature in economics that provides intellectual guidance on how DOT/EPA should analyze scrappage rate changes and the associated changes in the age-distribution of the vehicle fleet (e.g., see Jacobsen, 2013b; Jacobsen & van Bentham, 2015; Davis & Knittel, 2016). It is appropriate and important for the final RIA to include a scrappage model, since it helps quantify accurately the impacts of the CAFE /GHG standards on GHG emissions, oil consumption, and safety outcomes.

b and c. Specification of the scrappage model and integration into the CAFE model.

The key issue in the specification of the scrappage model is how to allocate changes in scrappage rates due to regulatory policy to vehicles of different ages. The draft PRIA makes a plausible argument that the changes in scrappage rates are likely to be larger for vehicles in the middle of the average lifespan (6 to 14 years old) than for vehicles early in the lifespan (1 to 5 years old) and very old vehicles (15 or more years old). Before reading the PRIA, I would have thought the effect might be greatest for the oldest vehicles. It might be useful, in the final RIA, to report some sensitivity analysis on this assumption.

In assessing the plausibility and implications of the scrappage effect, I appreciated the PRIA's effort on pp. 1056-1059 to compare the relative size of the sales-response and scrappage effects. For each additional new model that is sold due to tighter CAFE /GHG standards, somewhere between 2 and 4 used vehicles are removed from the fleet. I did not expect the ratio to be 1 to 1 (in part for the reasons explained on p. 1057 of the PRIA) and thus was not expecting a constantly-sized vehicle population under different regulatory alternatives. It is also useful to remember, as explained on p. 1058, that average VMT per year is much larger for new vehicles than for old vehicles, and retained used vehicles will have few years remaining compared to a new vehicle. It is reassuring that the overall impact on national VMT, ignoring the rebound effect, of the various regulatory alternatives is quite small (0.4% larger in the baseline 2025 standards than in the preferred "freeze" proposal) but I might have predicted that any overall change to VMT would be effectively zero, since the regulatory alternatives don't have much obvious impact on the average household's demand for travel. It might make sense to consider a scenario analysis where total VMT is fixed with and without the regulatory alternatives but the share of VMT allocated to vehicles of different ages is allowed to vary. Leakage in GHG control (or gasoline consumption) that is attributable to shifting the shares of VMT by vehicle ages strikes me as more plausible than leakage in GHG control (or gasoline consumption) that is generated by changes in overall VMT in the country. Nonetheless, my impressions here are more intuitive than they are based on hard analysis.

I conclude with a technical comment that does not fit neatly into the structure of the questions but seems highly relevant to the CAFE model. There is a small but growing body of literature suggesting that the current structure of CAFE standards, coupled with rapidly growing stringency within footprint categories, is causing a phenomenon that is sometimes called "vehicle upsizing." A simple form of upsizing is a shift from passenger cars to light trucks; a more complicated form is a shift upward in average footprint within the categories of cars and trucks. The upsizing phenomenon is seen as negative from a societal perspective because it creates leakage in energy and GHG savings, and because it may have adverse safety consequences due to aggressivity.

If upsizing is actually occurring to a significant extent due to the current schedule of CAFE /GHG standards, it would seem that a CAFE freeze (or any attenuation of the planned hikes in regulatory stringency) would have the qualitative effect of moderating the extent of upsizing in the U.S. market.

As I read the PRIA, it does not consider this unintended but potentially beneficial side effects of reducing the rate at which CAFE /GHG standards become more stringent. I recommend that the final RIA include at least a qualitative discussion of this matter, and possibly a scenario analysis that gives some quantitative weight to the upsizing story.
One could argue that the perverse effects of upsizing, if they are large and important, might be best addressed – not by reductions in regulatory stringency but – by another redesign of the CAFE /GHG standards to discourage upsizing. That strikes me as an entirely different rulemaking. But there may be merit in pointing out that perverse effects of upsizing are attenuated with less stringent standards, such as those considered in this rulemaking.

3. Labor Utilization Calculations

The best way for me to comment on this section of the PRIA is to simply urge DOT/EPA to consider the macroeconomic analysis produced by Carley et al. (2017). This analysis is much broader and richer than the analysis presented in the PRIA, and it shows that the employment impacts of causal mechanisms not considered in the PRIA (e.g., gasoline savings) are potentially much larger than the employment impacts considered in the PRIA. It is encouraging that the PRIA considers the employment stimulus in the supply chain; it is concerning that that the PRIA does not consider the positive and negative employment impacts of the State-level ZEV requirements, especially since much of the supply chain for electric vehicles is likely to be located outside the United States for the foreseeable future.

a. Sources of employment related to auto production and sales.
b. Assumptions about labor hours, location, supplier impacts.
c. Calculating changes across alternatives.

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Reviewer Name: Howard Gruenspecht

Review Question Number: 1a

Review Question Topic Description: Please comment on the appropriateness of including a sales response model in the CAFE model as a means to estimate differential sales impacts across regulatory alternatives.

Response:

Inclusion of a well-specified sales response model to consider differential sales impact across regulatory alternatives is useful. Extensive research referenced in the documents that are the subject of this review (the NPRM, the PRIA, and the draft model documentation) cite significant evidence that, holding other factors constant, the overall level of motor vehicle sales is inversely related to the level of new vehicle prices. Consumers are free to adjust both the quantity and composition of their new vehicle purchases in response to fuel economy policies that affect the price and other characteristics of new vehicle offerings.[1] A well-specified sales response model will improve the ability of the CAFE model to reflect the implications of regulatory alternatives on vehicle purchase decisions and the resulting implications for fuel consumption, emissions of CO2 and other pollutants, and safety.

Following a discussion of relevant literature, the documents provided for review estimate a regression model for new light-duty vehicle (LDV) sales. According to the documents, the price elasticity of new vehicle sales implied by the estimated regression is in the range of -0.2 to -0.3. The discussion of the literature also indicates that some research suggests a higher sensitivity of sales to prices, which is consistent with my understanding. One issue here is that higher prices arising from manufacturers' application of fuel economy technologies to comply with CAFE standards also provide savings in consumer fuel costs, which as discussed elsewhere in the documents has private value to consumers. The documents discuss a range of views in the literature regarding the extent to which vehicle buyers consider potential fuel savings that may soften the effect of higher prices on sales. Because of this, price changes associated with increased use of fuel saving technologies may have a different effect on sales than price changes of equal magnitude that are driven by labor and materials costs or by other policies, such as regulations to limit conventional pollutants that address externalities but do not provide private savings directly to vehicle owners.

In reviewing the model results, I compared the baseline (B) case incorporating the augural standards and the preferred alternative (P) case that freezes CAFE standards at the model year 2020 level. As discussed in the documents, consumer price increases between these cases are equal to the sum of average incremental technology costs and civil penalties per vehicle (compare, for example, tables 12-75 and 9-56 in the PRIA). However, those numbers do not match the results in the Excel run reports for the central analysis "CAFE" runs. I raised this with the technical lead for the review, who explained that the results used in the rulemaking documents were from the "CAFE_ss" runs, which

[1] There is also ample empirical evidence that changes in fuel prices also affect the perceived value of fuel efficiency in relation to other vehicle characteristics.

take account of statutory constraints that preclude consideration of some possible real-world compliance strategies. Thereafter, I refocused my review on the “CAFE_ss” cases.

(a) Overall light duty vehicle (LDV) sales response

The overall sales responses in the model runs are qualitatively plausible. First, the difference in sales between the B and P cases over time is consistent with the growing difference in vehicle prices as the difference across the cases in fuel economy standards grows over the 2022-25 period. Specifically, as fuel economy standards and their effect on vehicle prices grow over 2022-25, there are a larger number of LDV sales in the P case where vehicle prices are lower. Over 2022-32, overall LDV sales in the P case exceed those in the B case by about 1.18 million vehicles (0.6%).

While the new vehicle sales response patterns are broadly plausible, there are some issues that merit further attention or explanation.

- Table 12-75 and the output files show a significant difference in LDV prices between the B and P cases, with LDVs being more expensive in the in the B case where fuel economy standards continue to increase after model year (MY) 2020. The price difference start at low levels in MY 2017 and grow over time, reaching $1,350 in MY 2021, the first year when the applicable fuel economy standards differ between the B and P cases. Despite the discrepancy in prices, and statements in the documents that each $1,000 increase in the average new vehicle price causes approximately 170,000 lost units in the first year, followed by a reduction of another 600,000 units over the next ten years as the initial sales decrease propagates over time through the lagged variables and their coefficients. The output files show identical sales outcomes in the B and P cases for LDVs through MY 2021.

- Differences in sales between the P and B cases do not begin until MY2022 even though the reported price differences start in MY 2017. Unless I have misread the output files, it would be useful to explain why differences in price levels do not affect sales prior to MY2022 or, if the model code is faulty, to update it to address this problem.

- Another concern arises from comparisons between the CAFE and CAFE_ss versions of the model runs. Although there are differences between the price paths between these two runs, representing different interpretations of limitations on manufacturers’ CAFE compliance strategies, the reported sales differences between the B and P cases for MY2022 through MY2032 are identical in the CAFE and CAFE_ss output reports for total LDVs, passenger cars (PCs), and light trucks (LTs) in each year. This outcome suggests that something other than the difference in new LDV prices is driving sales differences across cases representing the B and P policy alternatives. Unless I have misread the model results, it would be useful to understand why the difference in prices between these two cases does not lead to corresponding differences in LDV sales results.

- A third observation is that the price elasticity of sales in the model run results appears to fall well below the -0.2 to -0.3 range discussed in the documents. The average price impact reported over MY2022 through MY2028 for all LDVs averages over $1,800 per vehicle, more than 5 percent of the average new vehicle price which is roughly $35,000. Annual vehicle sales in the runs over this period are about 17.9 million. Based on the percentage change in vehicle prices, the elasticity range of -0.2

to -0.3 translates into a range of annual sales impacts from 184,000 on the low end to 276,000 on the high end. In looking at the run results, however, sales impacts over MY2023-2028 average only 118,000 and even in their peak year, MY2027, are only 173,000, below the range implied by the low end of the cited elasticity range. The bottom line is that the run results seem to imply price elasticities in the range of -0.1 to -0.2, well below the -0.2 to -0.3 range mentioned in the documentation. As noted in the documents, even the cited range is below many other published estimates. It might be useful to look into this and provide a sensitivity analysis to consider the implications of a sales response at the high end, or even above, -0.2 to -0.3 range.

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(b) New LDV sales mix response

Another relevant aspect of the new vehicle sales response is the effect of CAFE standards on the sales mix. The run results show that freezing standards at their MY2020 level in the P case raises overall sales above those in the B case, increasing PC sales by more than it reduces LT sales. Over 2022-2032, lower LT sales (-2.11 million vehicles, -2.3%) in the P case compared to the B case are more than offset by higher PC sales (+3.28 million vehicles, +3.1%). Such an outcome is consistent with the notion that higher fuel economy standards in the B case serve to push the new vehicle market mix towards a higher sales share for LTs as a part of the consumer behavioral response.

The PC/LT sales mix response in the model runs is consistent with other evidence that the sales mix responds to differential fuel economy standards across vehicle classes as well as fuel prices. The share of light trucks in sales data as reported by the Commerce Department's Bureau of Economic Analysis was generally below 25 percent through the mid-1980s. When oil prices fell sharply in the mid-1980s, new vehicle buyers shied away from passenger cars whose size and performance was constrained by CAFE standards. The sales share of light trucks grew dramatically as consumers adopted minivans and then sport utility vehicles, which were subject to less stringent fuel economy requirements. By the early 2000s, light trucks regularly accounted for more than half of all light duty vehicle sales. From the mid-2000s through 2014, the light truck share of sales moved in a relatively narrow band influenced by both economic and oil price developments. From mid-2014 on however, the light truck sales share has again risen during a time of falling oil prices and increasingly stringent CAFE standards. It is worth noting that BEA and NHTSA use a different approach to categorizing cars and light trucks – for example, BEA counts all crossover utility vehicles (CUVs) as light trucks, while NHTSA counts some as cars and others as light trucks (Stone & Hamilton, 2017). However, whether the NHTSA or BEA categorization scheme is considered, the relationship identified above generally holds.

The model run results show a relatively modest reduction in the LT share of sales in the P case relative to the B case, with the LT share of sales in MY 2026 about 1 percentage point lower in the P case, where fuel economy standards are frozen at the MY 2020 level, than in the B case, where they continue to increase (45.4% in P versus 46.5% in B). This seems qualitatively reasonable. However, given that the standards are fully phased in by MY2025 in the B case, it would be helpful to explain why the difference in the LT share of sales between the B and P cases continues to grow, reaching nearly 2.5 percentage points by MY 2032.

(c) Additional comments relevant to review question 1a

The prior version of the CAFE model assumed that both the overall level of sales and the sales mix was invariant across the regulatory alternatives being evaluated. The treatment of the literature related to sales response in the model documentation and the PRIA seems to be more thorough and more up to date than that in that presented in documents supporting earlier analyses of this matter.

Given the weight of evidence in the literature on the price elasticity of new car demand and consumer valuation of fuel economy, it is definitely worthwhile to take account of sales response in modeling and analysis supporting CAFE rulemaking. However, one cannot arrive at a categorical conclusion that ANY sales response model is better than none. For example, a model that significantly overstated the responsiveness of the level and mix of new LDV sales to changes in the cost and pricing of new vehicles could conceivably lead to estimates that are less accurate than a model that entirely ignores the sales response.

My reading of the literature, including both recent work and earlier studies of the price elasticity of new care demand is that the -0.2 to -0.3 range cited in the model and rulemaking documents is likely to be a more reasonable view of sales response than the zero response assumption used in the prior version of the CAFE model. As noted above, the results of the CAFE_ss model runs appear to be consistent with a price elasticity below that range, suggesting the need to consider sensitivity runs using alternative parameter values that raise the modeled sales elasticity into, or even slightly above, the identified range.

Reviewer Name: Howard Gruenspecht

Review Question Number: 1c

Review Question Topic Description: Please comment on the sales model's integration in the CAFE model, including interactions with the simulation of multiyear product planning, in combination with the dynamic fleet share model used to allocate total new vehicle sales to the passenger car or light truck market segments.

Response:

The integration of the sales model into the CAFE model is important. The reduction in the LT share of total LDV sales in the P case compared to the B case has an effect on fuel consumption outcomes that would not be considered if the effect of alternative regulatory choices on the sales mix is ignored. Similarly, the shift towards accumulation of more VMT by older vehicles that on average are less fuel efficient and also less safe than newer models, would also be missed absent consideration of the sales response.

I could not assess the multiyear product planning aspect of the model. It is possible that the planning mechanism is at least partially responsible for some of the apparent lags and attenuation of market responses identified in some of my other responses to this review request.

Two additional observations may also be relevant. First, modelers understandably have an interest in developing code that can replicate historical data, as the ability of a model to replicate history, especially out-of-sample historical data, can help to validate models and increase confidence in model projections. Inevitably, however, both the past and future evolution of the market will be heavily influenced by factors other than the policy paths under evaluation. Given that the primary purpose of the present model is to compare the implications of alternative policy paths, the accuracy of estimated projection levels over the historical data period, particularly when the full historical data set is used to estimate the model, could weaken the model's ability to reflect differences across prospective policy cases.

Second, there can also be a tradeoff between the amount of detail that a model seeks to provide and the risk of mischaracterizing the big picture. In the present context, some of the modeling of product planning at the individual manufacturer level may present this risk, although it may be necessary to the extent that certain details must be considered given the statute that governs the rulemaking process.

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Reviewer Name: Howard Gruenspecht

Review Question Number: 1d

Review Question Topic Description: Please comment on the sales model's specification as independent of vehicle scrappage, and on the resultant calculation of vehicle miles traveled (VMT).

Response:

It is important to take account of both sales and scrappage changes, since existing vehicles and new vehicles are substitutes. Personally-owned vehicles (POVs), whether new or used, also compete with other less-similar transportation modes, including public transportation and ride-sharing options, although for many purposes and locations alternatives to POVs may be very limited. The literature on transportation mode choice, stemming from seminal work by Daniel McFadden and others, suggests a nested structure. Decisions about where to live, where to work, mode choice for non-discretionary travel, and the amount and mode of discretionary travel are at the top level. Conditional on choices made regarding location of residence and work locations, which in many cases are unlikely to be significantly affected by CAFE policies, transportation mode choices then consider options such as POVs, ride sharing, public transit (where available), biking, and walking. Within the set of POVs, the next level of the decision problem involves choices among vehicles of different makes, model, and age. Generally, one would expect different POVs (for example a new car and a used car within that is a few years older) to be closer substitutes for each other than a POV and another mode of transit.

Within this standard framework, the consideration of sales responses and scrappage responses as independent processes is problematic, because it fails to use important information regarding the total demand to operate POVs, which has implications for projections of the fleet size.

The sales response model takes the reasonable view that the technology costs of CAFE compliance serve to raise new car prices. Notwithstanding savings in fuel costs from higher vehicle efficiency, which several recent articles suggest are mostly or fully factored into vehicle purchase decisions, consumers respond by reducing their new LDV purchases. This is supported by the literature and also by the observation that even in the absence of higher fuel efficiency standards manufacturers retain the option to incorporate fuel efficient technology at higher cost (and price) and increase their sales volume if customers actually preferred to purchase more expensive high-efficiency vehicles to lower-price, lower-efficiency options. Past experience shows that consumers have moved in this direction during past periods of high gasoline prices, but available data suggest that today's fuel economy standards, let alone the further increases through MY 2025 under the augural standards, are already binding under current market conditions.

While some reduction in new LDV sales under increasingly stringent standards could be reflected in decisions to entirely forego the use of POVs, it difficult to envision that higher new vehicle prices associated with more stringent standards would induce consumers to hold a larger total fleet of POVs. Despite this, the CAFE_ss model run results report a "many for one" replacement. By 2030, the fleet is nearly 5.9 million vehicles (1.9%) larger in the baseline (B) case with the augural standards than in the preferred alternative (P) case where new care fuel economy standards and new car prices are lower, a difference that grows to 7.1 million vehicles (2.2%) by 2037. This outcome occurs notwithstanding important costs, including registration fees and required insurance for each vehicle held as discussed in the documents, as well as time-consuming and costly safety and emissions inspection requirements in many jurisdictions that make it extremely awkward and costly to substitute several existing vehicles for a new purchase that is foregone. This unexpected and unlikely result seems directly tied to the use of empirical sales and scrappage models that are independently derived rather than jointly developed within the context of a transportation mode choice model.

What appears to be missing in the current model is a framework to determine how many existing vehicles consumers wish to hold. While new car prices can be used as an explanatory variable in a scrappage model, it is used car prices that directly enter into economic scrappage decisions that are made following the incidence of an event that requires repairs to be made to restore a vehicle to operable condition   The price of used cars is definitely influenced by new car prices, but ultimately depends on the balance between supply and demand for used vehicles. The independent scrappage model used in the CAFE model, however, does not consider the demand side of the market for used cars. In particular, it is difficult to understand why an increase in the price of new cars in the B case – accompanied by some increase in the price of used cars as consumers substitute towards them and used car prices rise to reduce the scrappage rate – would lead to a situation in which consumers want to hold more cars than they do in the P case. A useful case to consider would hold the total number of vehicles is held constant across the P and B cases. Such as case could still slightly overstate the reduction in scrappage, since there could be some shifting to other modes, or away from transportation services entirely, as new car prices rise between in moving from the P case to the B case.

The topic question also refers to the calculation of VMT. It appears that the present CAFE model, like prior versions, holds the distribution of VMT accumulation by age and vintage fixed over time other than its consideration of the rebound effect. As shown by figure 8-6 of the PRIA, there is a substantial reduction in average VMT accumulation with age, with an increasingly steep drop off beginning at age 6. For example, new passenger cars average nearly 16,000 VMT per year, decreasing to about 12,000 VMT per year by age 6, followed by a more rapid decline to an average near 5,000 VMT per year by age 11, with continued declines thereafter. This model feature causes a significant disconnect in the relationship between the overall fleet size change and aggregate VMT traveled across the B and P cases. By 2030, the fleet size is nearly 5.9 million vehicles (1.9%) higher in the B case than in the P case, a difference that grows to 7.1 million vehicles (2.2%) by 2037. In the CAFE_ss results, total VMT in the B case is also significantly higher than in the P case – with a difference of 2.6 percent in 2030 and 3.4 percent by 2037. However, this difference in VMT is mainly driven by the rebound effect, as the shift to more efficient vehicles in the B case encourages additional marginal trips by lowering incremental fuel cost per mile traveled. The rebound effect is extensively discussed in the document, but is beyond the scope of this review question.

One can separate the effect of the rebound from that associated with substituting existing vehicles for new ones by looking at the CAFE _ss_NOREBOUND cases that assume the absence of any rebound effect. Percentage differences in aggregate VMT between the “no rebound” versions of B and P cases are much smaller – only 0.5 percent in 2030 and 0.7 percent difference in 2037.

While it does seem plausible that higher new car prices will lead consumers to substitute existing vehicles for some new car purchases, it does not seem plausible that decisions to reduce new car purchases, accompanied by delays in the trade-in of existing vehicles with further impacts among users who might have purchased a relatively young used vehicle that was traded in to replace an older existing vehicle, there is little apparent justification for the model’s implicit assumption that when a consumer substitutes an older vehicle for a newer one, he or she is making a simultaneous decision to reduce annual VMT based on the average VMT schedule for each age of vehicle. A useful case for VMT, which could be combined with the case holding the total number of vehicles in use constant across the P and B cases recommended above, would be to adjust the distribution of VMT accumulation by age to increase the VMT accumulation of older vehicles in the B case relative to that in the P case in a manner that would hold total non-rebound VMT constant across the two cases. Much of the mechanics to implement this case could be carried out using an approach similar to that that is already used to incorporate the rebound effect – see discussion in section 8.9.2 of the PRIA. The constant non-rebound aggregate travel case could slightly overstate non-rebound VMT, but is likely to be closer to reality than the present modeling approach, which assumes that consumers' annual travel changes dramatically when an older car is substituted for a newer one even without the consideration of any rebound from more fuel-efficient new vehicles.

Note that the lack of an adjustment to account for increase in average VMT/year for existing vehicles to reflect their increased use in applications that would be served by additional new vehicle sales in the P case, where lower new LDV prices would result in higher sales of new LDVs, largely, but not completely, offsets the effects of "the many for one" substitution of existing vehicles for new ones.

In sum, there could be significant advantages in more closely integrating the analysis of scrappage and new vehicle sales in the CAFE model. Moreover, this integration could be further extended to specifically consider VMT.

Reviewer Name: Howard Gruenspecht

Review Question Number: 2a

Review Question Topic Description: Please comment on the appropriateness of including a scrappage model in the CAFE model as a means to estimate the potential impact of CAFE standards on used vehicle retention.

Response:

If CAFE standards affect the level of new vehicle sales, adjustment to scrappage of existing vehicles can be an important part of the overall behavioral response to CAFE standards. Given differences in fuel economy, emissions, and safety performance across vehicle vintages, consideration of scrappage can have important implications for safety, emissions, and fuel consumption outcomes.

As discussed in the documents, there have been significant changes in scrappage patterns over time. There are two distinct challenges: characterizing absolute scrappage behavior and properly representing differences in scrapping decisions across alternative policies. Both are important, but the latter is most important in the present context. For example, some of the literature cited in the documents shows that both historical and prospective scrappage patterns for existing vehicles are sensitive to fuel prices, as the market value of existing vehicles with lower/higher fuel economy are differentially impacted by realized fuel price outcomes. Absent an ability to accurately project the trends and volatility in fuel prices, it is extremely difficult to accurately project scrappage levels, although one could still be confident that for any fuel price scenario, there would be a reduction in overall scrappage in the case with the augural standards relative to the preferred alternative that freezes fuel economy standards at their MY2020 level as discussed in the NPRM and the PRIA.

Scrappage decisions are driven by the economics of vehicle repair decisions. A vehicle is typically scrapped when the cost of repairing it, which can range from trivial (replacement of a bulb, wiper, or gas cap) to expensive (engine or transmission replacement) exceeds the difference between the post-repair and scrappage value of the vehicle. While the incidence and severity of breakdowns for existing vehicles is not influenced by the cost of regulatory compliance for new vehicles, the ability to substitute existing vehicles for new ones suggests that higher new vehicle prices will be reflected in higher used vehicle prices, resulting in reduced scrappage.

The scrappage equation estimated in the CAFE model uses new vehicle prices as an explanatory variable. Although new vehicle prices do affect used vehicle prices, they do not enter directly into scrappage decisions. Presumably, when new vehicle prices are lower, used vehicle prices are also lower. Therefore, given incidence of repair for existing vehicles in a given vintage/age bucket, lower new vehicle prices should lead to an INCREASE in scrappage in the P case relative to the B case, with less retention of existing vehicles. However, it appears from the reported results that this effect appears to be much larger than the effect on new car sales, with the result that there is significant shrinkage in the overall fleet associated with lower new car prices. This seems implausible, in that LDVs are now less expensive from the consumer perspective.

In reviewing the analysis, I compared results for cases representing the augural standards (baseline) and the proposed alternative, referred to as B and P cases respectively. As discussed in my response for review question number 1a (RQN 1a), I focused on the CAFE_ss runs, which match the results reported in the documents. According to the technical monitor for the review, this set of runs reflect statutory constraints that preclude certain compliance strategies.

As noted in my response to RQN1a, there is a very significant difference in the vehicle fleet size in the baseline and proposed cases, with the baseline fleet being noticeably larger than the proposed fleet, with the gap growing to 5.9 million vehicles by 2030 (B:306.0 million, P:300.1 million). At the same time, cumulative new vehicle sales from 2018 to 2030 are 984,000 less in the B case than in the P case (B:230.24 million, P:231.23 million). Starting from the 2017 fleet that is reported as 234 million vehicles for both cases, the difference in implied cumulative scrappage over 2018-30 is 7.45 million vehicles (B:158.20 million, P: 165.65 million), nearly 4.5 percent. On its face, this result is puzzling.

Endogenous scrapping reflects the notion that consumers respond to the higher price of new vehicles in the B scenario by reducing new vehicle purchases and increasing the retention of existing vehicles to provide personal mobility. If higher new vehicle prices in the B case do not result in lower sales of new LDVs than would occur in the P case, there is no reason for the B case to have higher retention of existing vehicles than the P case, and markets for used vehicles should balance at the same used vehicle price level in both cases, leading to identical scrappage behavior. However, contrary to this observation, the reported results for scrappage generated by the model are not actually synchronized. While differences in new LDV prices between the B and P cases do not cause the affect new LDV sales until 2022, scrappage starts to be affected by new vehicle price differences starting in 2018. As a result, with no change in new vehicle sales, the in-use fleet reported is already 1.18 million vehicles larger in the B case than in the P case.

While substitution between new and existing vehicles in providing services is well established in the literature, the notion that one new LDV would be replaced with multiple existing ones, as suggested by comparison of the B and P case fleet sizes, seems implausible, as discussed above and in my response to RQN1d.

The basic economic model of scrappage outlined above generally applies without regard to the cause of a repair event, which may arise due to an accident, wear/failure related to age, wear/failure related to VMT accumulation, or wear/failure related to the extent and quality of prior maintenance activity. To the extent that wear/failure linked to VMT accumulation plays a significant role, the comment in my response to RQN1d regarding the likely increase in average annual VMT accumulation for existing vehicles as they are increasingly used in place of new vehicles would, holding other factors constant, would tend to partially offset the decrease in scrappage resulting from higher used vehicle prices.

As previously noted, the model includes code to adjust VMT resulting from the rebound effect. However, there appears to be no difference in comparing scrappage outcomes between the B case that incorporates rebound (CAFE_ss) and the alternative version with no rebound effect (CAFE_ss_NOREBOUND). Thus, even when the code that adjusts VMT for rebound is used to reflect rebound itself or, as recommended in a previous response, to reflect the repurposing of existing vehicles for more intensive use, scrappage schedules by age appear to be unaffected. The implicit assumption that wear/failure related to VMT accumulation does not play a role in shifting the distribution of required repairs for vehicles within a given vintage/age bucket seems extreme, and could provide a partial explanation for why the scrappage equation may be showing too large a scrappage response to higher new car prices.

Reference

Stone, D., & Hamilton, M. (2017, May 24). Crossover utility vehicles blur distinction between passenger cars and light trucks (Web page in "Today in Energy" series). Washington, DC: Energy Information Administration. Available at www.eia.gov/todayinenergy/detail.php?id=31352

Reviewer Name: James Sallee

Review Question Number: 1a

Review Question Topic Description: Please comment on the appropriateness of including a sales response model in the CAFE model as a means to estimate differential sales impacts across regulatory alternatives.

In brief, it is conceptually correct to include a sales response. It is important for the analysis to demonstrate how changes in new vehicle sales can impact the analysis, in particular allowing this to affect fleet VMT and alter the used vehicle market.

In practice, however, the merits of including this margin are unclear. The econometric estimates used are not credible by modern academic standards. Thus presenting results based only on the sales response coefficients estimated is potentially misleading. A number of factors (specified below) suggest that the sales response coefficient is likely overstated, though bias in the coefficient could go either way.

The central parameter (how new vehicle sales will change when new vehicle prices are increased) is difficult to estimate reliably. As a result, it is critical to conduct (and exhibit) sensitivity analysis. My opinion is that it would be better to present an ensemble of results using different scenarios about the magnitude of the new car sales response, rather than the current approach, which relies on a problematic coefficient from a single regression.

Challenges for estimating the necessary parameter: Conceptually, the parameter of interest is the slope of aggregate demand for new automobile: that is, by how much will sales change under a long-run exogenous cost increase that impacts the entire automobile market.

The econometric analysis does not have a strategy for isolating exogenous cost increases, but instead measures the correlation between endogenous price changes and new vehicle quantities. This endogenous variation in price embodies changes in fleet composition and other attributes, and it represents equilibrium outcomes influenced by both supply and demand factors. I say more about this fundamental limitation in my response to review question 1b. Here I mention the inherent difficulty in estimating this parameter, as well as concerns about how CAFE is assumed to influence cost, and finally how cost changes translate into price.

The effect of a cost shock on new vehicle sales is unknown: Unfortunately, I am not aware of any credible estimates of the causal effect of an aggregate (i.e., market wide) cost (or price) shock in the new vehicle market on new vehicle sales. In principle, one could look to tax policies, exchange rate fluctuations, wage rates or commodity price shocks. For example, U.S. States often have specific sales tax rates that apply to vehicle purchases—changes in those rates (if they exist) could be used in a difference-in-differences analysis to test for sales impacts.

But even in these situations, much of what is more credibly estimable is likely to represent shorter-run responses, and many sources of variation will have other issues of interpretation. For example, one might argue that sales tax rates are not salient and so an analysis of State tax rates will yield a too conservative estimate.

In discrete choice models of the automobile market, the choice of the “outside good” represents the same conceptual margin (the decision not to buy a car). Thus another approach to grounding the fleet size effects is to study the outside good margin estimates from that literature. This margin, however, tends to be sensitive to modeler choices, and much of the literature relies on static models that capture only one year.

Thus, the point of this comment is not to be critical of the model chosen in the current PRIA per se, but instead to reaffirm the idea that this parameter is highly uncertain and should be added into a model only in way that allows for sensitivity analysis.

Pass-through is uncertain: The technology component of the CAFE model outputs *cost* changes. These need to be translated into *price* changes in order to be multiplied through the coefficients from the sales regression.

The modeled approach assumes that all cost increases are passed through into consumer prices—i.e., the CAFE model takes projected cost changes and multiplies them by the price coefficient from the regression in Table 8-1. For welfare analysis with a fixed fleet size (i.e., no sales response), this is palatable because in terms of economic welfare, whether consumers or producers bear the burden is not material for the overall cost-benefit ratio (though it of course matters for any distributional analysis).

The pass-through assumption matters, however, for estimating the sales quantity response. It is likely that some of the burden of additional technology deployment will be borne by producers in the form of lost profits (especially any fixed costs, as discussed below), suggesting that the sales response model likely overstates the size of any effects on the new car market.

There is a literature on cost pass-through, which is focused largely on exchange rates and trade, in the automobile industry. That literature tends to find incomplete pass-through. See Gron and Swenson, (2000) for relevant estimates and a discussion of the prior literature.

Are fixed (indirect) costs contaminating the analysis? The technology cost estimates described in Chapter 9 of the PRIA imply that the CAFE model passes indirect costs (e.g., research and development) into prices. Economic theory would predict that only true marginal costs (i.e., costs that scale directly with each new unit sold) would impact strategic pricing. The automobile market is typically understood as a market with imperfect competition, in which firms exercise pricing power. As a result, true fixed costs (costs that do not scale with the number of units sold) will be irrelevant to a firm’s strategic pricing considerations, except as it ultimately impacts entry and exit. Instead, fixed costs will simply reduce manufacturer profits without passing through into prices, and therefore will not impact sales quantities in equilibrium. Again, indirect costs that are induced by the regulation belong in the cost-benefit analysis—they are a cost to society—but assuming they are passed fully into prices likely leads to an exaggeration of the magnitude of impacts on new vehicle sales.

The relevant price effect for the analysis is the technology cost net of the perceived benefits of any improved attributes (including fuel economy): Any conventional microeconomic choice model of the new vehicle purchasing decision would take into account not only the retail price of an automobile, but also its attributes and its expected operating costs. If CAFE makes cars more expensive, but also better, then the net impact on demand will be the difference between the two. Driving sales estimates from the *gross* price changes, as the PRIA does, is misleading.

Theory predicts that a tighter regulation has a net negative impact on vehicles because, assuming that the standard is binding, it forces the market away from the bundle of price-fuel economy-performance attributes that the consumer most wanted. As such, a view of how regulation should affect sales can be well grounded in theory. For a discussion of how a binding standard can be understood as raising the net price of vehicles, taking into account changes in attributes, see Fullerton and Ta (2019).

(There are two caveats to this related to constant technology and imperfect competition. The Fullerton and Ta analysis is a perfect competition model. See Fischer (2010) for a discussion of how automakers may not provide the optimal bundle in order to exercise price discrimination. Second, this reasoning assumes a constant technology space available. If regulation accelerates technological progress, then it is possible cars are made better faster as a result of the policy, which could expand sales.)

Performance standards have uncertain impacts on market size: The academic literature has considered how fleet average performance standards such as CAFE affect the overall size of a market. Such standards act as implicit subsidies to products that exceed the standard and implicit taxes on products that are below it. This has a net ambiguous sign on the size of the market, such that tighter standards can actually increase market size, rather than shrink it (see Holland, Hughes, & Knittel, 2009).

The CAFE model deployed in the current PRIA takes a different view, which is to minimize the "mix shifting" implications and model the automaker compliance response to a tighter CAFE standard as being entirely of the form of technology deployment. This view assumes that *all* models are being made more expensive, in which case it is clear the total car market would shrink as the standard tightened. This might be a reasonable approach if the CAFE standard is very tight, and if the standard is attribute-based (e.g., footprint based).

If the standard is not especially tight, however, or if the standard is flat (not attribute based), then there will be a substantial number of products that are above the standard in the baseline scenario, so that those products are implicitly *subsidized* by CAFE. This makes the overall market size impacts ambiguous. This points to two concerns.

First, NHTSA's CAFE model seems to minimize mix shifting channels as a compliance strategy, which implies that it is likely to overstate the market size quantity affects by overstating the technology costs that are deployed and passed through into prices in equilibrium. Second, while the most important cases for the regulatory analysis are of steeply sloped footprint rules, the CAFE model is designed to run on alternative flat schedules as well. When used to consider flatter schedules, the market size analysis can be quite misleading if it assumes all vehicles have price increases.

Changing ownership model for vehicles: Finally, as something of a tangent, I would note that this industry is poised for significant change in the near future as the ownership model of vehicles undergoes experimentation. Automakers are introducing vehicle subscriptions, and ride-sharing is growing exponentially (though from a small base as a share of all travel). It is not clear how this would be modeled because it is not clear how this would impact the *difference* between two regulatory scenarios, but it may become a relevant consideration moving forward.

Reviewer Name: James Sallee

Review Question Number: 1b

Review Question Topic Description: Please comment on the sales model's specification using an autoregressive distributive lag (ARDL) model time series approach, and comment specifically on the endogeneity of average transaction price.

The regression approach is described throughout section 8.6, and the estimates are included in a single Table 8-1. Some information is not included that limits my ability to assess the details of the estimation (more on this below), but a high level assessment is possible.

Most importantly, the regression estimated in the PRIA lacks an "identification strategy"; that is, there is no attempt to isolate plausibly exogenous variation in prices that can nail down the desired interpretation of a movement along a long-run demand curve. This muddles the interpretation of the coefficient, and implies that it should be used with extreme caution (if at all).

At the same time, as mentioned in my response to review item 1a, I do not know of a truly reliable way to estimate the new vehicle sales quantity impacts of exogenous aggregate price changes. I think that the model estimated is useful in establishing plausible magnitudes of the new vehicle sales effects, but should be presented as a guiding heuristic and used to inform several alternative scenarios, rather than treated as a precise, conclusive estimate.

Price is endogenous, leading to likely bias in the estimated parameter: The regression results reported in Table 8-1 regress quantity on price. This is literally the textbook example of simultaneity bias presented in most econometrics texts. To identify the slope of the demand curve accurately, one needs an instrumental variable or a natural experiment that shifts supply.

As the PRIA notes (p. 947), in the raw data, prices and quantities correlate positively. This is exactly what happens when price and quantity data are due more to shifts in demand than supply—movements of the demand curve along a (relatively) constant supply curve yield a positive correlation between prices and quantities in the observed data. The fact that the specification reported in Table 8-1 happens to find a negative effect of prices on sales in no way alleviates the broader concern about causal identification.

(The article by Busse, Knittel, & Zettelmeyer [2013], which cited elsewhere in the PRIA for its results on fuel economy valuation, is perhaps instructive. That paper shows that gasoline price shocks that shift demand lead to larger changes in price than quantities in new vehicle transactions. Prices and quantities move together, but it is predominantly a change in prices that restores equilibrium.)

Price also changes in the data due to compositional changes. For example, the PRIA notes (p. 947) that prices were highest from 1996-2006. This is the time period in the auto market when SUV sales peaked. The higher prices in that era are likely due in no small measure to this composition effect. The regression takes no steps to control for composition, which muddles the interpretation of the coefficient further.

Finally, garden variety omitted variable bias is likely present in some degree. The specification includes a very sparse number of macroeconomic controls, not taking into account, for example, interest rates or exchange rates, both of which have important effects on the automobile market.

For all of these reasons, the basic approach of using a time series regression over a long history is subject to biases. (Note that all of the same problems exist for the econometric analysis that relates new vehicle prices to scrap rates, and many of my comments here echo my comments on the scrap response estimation.)

The goal here is causal inference, not prediction: In assessing the model, the PRIA refers only to its time series properties and goodness of fit (see p. 949 for the latter). The goal of this regression, however, is to identify the causal effect of prices on sales, not to achieve forecast accuracy. The critical concern should be whether the coefficient is consistently estimated. Perfect prediction in sample is not evidence of unbiased (consistent) causal identification.

Time trends in the effect size: Economic theory says that it is likely (though not certain) that as people get wealthier, they would be less price sensitive. This suggests that there might logically be a time trend in the price coefficient. This could again dampen the sales price effects of CAFE projected in future vintages. (This is similar to the way that the rebound effect is modeled in the Small and Van Dender (2006), as well as others, and is related to the fact that most discrete choice models of car purchasing use price divided by income as a regressor.) More generally, the time series covers a very long history, and there is little reason to believe that the price coefficient is stable over that time. This can be tested within the data.

Challenges in evaluating the ARDL regression approach: Some essential information is not displayed, which means that it is impossible to fully assess the model. In particular, the dependent variable is not defined. Is this regression estimated in first differences? The right hand side regressors are also not labeled clearly. Are the sales lags differenced as well, or are they in levels? Basically none of the regressors are labeled clearly enough to be sure of how the regression was run based on the PRIA.

The CAFE model documentation offers an additional representation of the same model on p. 77 which seems to indicate that all of the variables are in levels, except for price, which is run in first differences. This then suggests a model where price *changes* are supposed to have an effect on the level of sales. This seems to be a peculiar specification. If one starts with an equation in which level sales are influenced by level prices (as is standard), then it is logical to take first differences and regress changes of quantities on changes of prices. Lagging the dependent variable but differencing the independent variable is unusual.

Building on this last point, only a single specification is reported. It matters a great deal for assessment of the model whether the price coefficient is fairly robust to alternative modeling choices and specifications, such as changes in lag length and inclusion of alternative controls.

The table also does not include the number of observations, or explain how standard errors were adjusted. The standard errors reported imply implausibly precise coefficient estimates. Likely this is due to not adjusting the standard errors for autocorrelation. The PRIA does not mention any correction to the standard errors. Newey-West corrections should be used.

A vector autogression might be better than the ARDL for attempting to deal with the supply and demand simultaneity. But note that such an approach does not fully overcome the threats to causal inference noted above.

The PRIA states that a variety of alternative approaches were considered, but none “offered a significant improvement” (p. 948). But, it is not stated how an improvement is defined. Perhaps it was based on prediction accuracy, but as noted above, the overriding concern here is causal identification, not prediction.

Quarterly data: It is not at all obvious that quarterly data represent an improvement over annual data, especially if the autocorrelation in the data is not being accounted for in the standard errors. The first-difference regression in quarterly time risks conflating short-term intertemporal fluctuations in quantity with the desired long-run demand response, i.e., seasonal effects (which are large for automobiles) could be biasing the regression.

Reviewer Name: James Sallee

Review Question Number: 1c

Review Question Topic Description: Please comment on the sales model's integration in the CAFE model, including interactions with the simulation of multiyear product planning, in combination with the dynamic fleet share model used to allocate total new vehicle sales to the passenger car or light truck market segments.

In reality, new and used vehicle markets interact. Economic theory predicts that the price of used cars influences the demand for new cars, and vice versa. The CAFE model does not integrate these two markets, however, but instead estimates reduced form regressions that determine the relationship between new vehicle prices and new sales, and separately new vehicle prices impact on scrappage.

This is potentially problematic because any errors in the two analyses could compound, rather than counteract each other, yielding net impacts on the size of the fleet that are at odds with economic theory. This appears to have happened in the PRIA, where less expensive new vehicles are projected to shrink the car market, implying that consumers, faced with cheaper cars, choose to substitute away from cars towards other forms of transportation.

I discuss this further in my review items 2a and 2b regarding the scrap model, as well as in item 1d. Here I mention briefly the specific points of integration raised in the question.

Regarding multiyear product planning: I was unable to find discussion in the PRIA or CAFE model documentation about how the sales results impacted the multiyear product planning schedules, or vice versa. I speculate that the concern was whether or not sales volume fluctuations should be assumed to influence the planning schedule, whereas in the current model they are not connected. I suspect that this is not a critical concern: the sales volume changes, while important, are probably not so large as to cause major changes to the product refresh/redesign cycle for most vehicles.

Regarding the fleet share: I have no objection to the separate estimation of the total fleet size in one step and the share of the fleet projected to be a light truck in a second step.

Reviewer Name: James Sallee

Review Question Number: 1d

Review Question Topic Description: Please comment on the sales model's specification as independent of vehicle scrappage, and on the resultant calculation of VMT.

As stated in my response to review questions 1c, 2a and 2b, it is important that the new and used markets interact within the CAFE model. If the CAFE model wishes to fully incorporate fleet size effects into the cost-benefit analysis, it needs to do so in a way that is internally consistent with economic theory. This will require some theoretical equilibrium bridge between the markets, rather than two parallel reduced form econometric exercises.

Even so, one could argue that the new vehicle cost shocks are the initial shock to the market, and that the effect of this shock can be taken in isolation. It does make sense to think that some consumers may be driven primarily by economic fundamentals—like income growth, fuel prices and interest rates—when deciding whether or not to buy a new vehicle. But, the equilibrium price of used vehicles will matter to others. Think for instance of how consumers coming off lease will make a decision of whether to purchase the leased vehicle or return it and lease (or buy) a new model. The residual value is central to this decision.

New vehicle sales will influence the VMT schedule: Much of the final cost-benefit analysis depends on the total VMT in the fleet. This depends on the fleet size (and its age distribution, because the VMT schedule is age dependent) and the VMT per vehicle schedule.

The current model assumes that the fleet VMT schedule is independent of fleet size. This is unlikely. All else equal, adding more and more vehicles to the fleet will surely cause the age-specific VMT per vehicle schedule to decline. That is, the marginal driver induced to own a car (or to divest) likely drives far less than the average. Put differently, total VMT likely scales less than proportionately with the fleet size.

(Note that this is a claim about the marginal person who in equilibrium owns a vehicle under one CAFE scenario but would not under another, who in the end is likely someone owning an inexpensive used car. The marginal person who buys a new car likely moves from a young new car to a new car, with ownership impacts cascading through the markets.)

It seems entirely possible to start with a more fundamental economic choice model where the key input to utility is VMT. The cost of VMT depends on the number of vehicles available, as well as the cost per mile of those vehicles and other attributes that determine vehicle quality. Data could be used to calibrate such a model. At the household level, it is certainly possible to imagine identifying the causal impact of adding an additional vehicle to the household's total travel. Panel data from emissions control systems that include odometer readings could likely be used to detect some of these relationships. This has significant conceptual appeal as a "top down" model that recognizes the interactions between fleet size and the variable that ultimately matters, which is aggregate VMT.

I make related observations in my response to review question 2c.

Reviewer Name: James Sallee

Review Question Number: 2a

Review Question Topic Description: Please comment on the appropriateness of including a scrappage model in the CAFE model as a means to estimate the potential impact of CAFE standards on used vehicle retention.

The PRIA is certainly right in stating that the interaction of the new and used vehicle fleets is an important margin and can have a significant impact on the cost-benefit analysis of fuel economy regulations. As such, including a scrap model is a great idea and could improve the regulatory analysis substantially.

As with any modeling consideration, however, it is important that the addition of a feature to a model makes the model's output more accurate towards its purpose. This may not be the case for the scrap model, given the limitations on how it is derived and integrated.

My concern is based on three issues: (1) the reduced form method employed; (2) the risk of unreliable coefficient estimates central to the exercise; and (3) the fact that the model produces outcomes that seem to be at odds with economic theory. Additional comments are organized by these three issues.

1. The reduced form model exposes the model to a risk of illogical outcomes: The CAFE model uses shocks to new vehicle prices in two separate analyses, one of which determines scrappage, and the other of which determines the new vehicle sales response. As the PRIA itself notes, in reality, these two processes are inherently linked—the causal chain is that new vehicle cost shocks impact new vehicle sales, which changes used vehicle prices, which changes used vehicle scrap rates. In other words, the new vehicle sales outcome is an *intermediate* step in the chain affecting scrappage.

The model skips over this causal chain, letting new vehicle cost shocks act on scrap directly. This means that misspecification, or even just uncertainty around the coefficients, can lead to logically inconsistent results on total fleet size. For example, suppose that the estimated effect of new vehicle prices on new vehicle sales is lower than the truth, and the estimated effect of new vehicle prices on scrap rates is greater than the truth. This can create a compounding error, where the net fleet size effects are grossly wrong.

I offer more detailed comments on this issue in my response to question 2b. Briefly, a model that explicitly that imposes equilibrium conditions and directly links the new sales and scrap decisions would protect against some of the most significant possible errors. There is some precedent in the literature for this which points to a better approach.

2. The estimation of the causal effect of new vehicle prices on scrap rates is subject to biases: The PRIA shows time series (panel) regressions that relate scrappage rates to new vehicle prices. Put simply, this regression lacks an "identification strategy"—that is, the PRIA does not make a positive case as to why this regression ought to be expected to deliver a consistent coefficient estimate. Given that prices are clearly an endogenous variable, the regression is exposed to garden variety simultaneity and omitted variable biases. This regression would not pass muster in an academic research article.

To be clear, this comment is not meant to be overly critical of the panel analysis in the PRIA. The regressions run are sensible and the results are interesting. The point is that this is a difficult problem to solve reliably.

As a result, it is all too easy for both of these analyses to contain substantial errors that compound each other. Thus, instead of relying on these coefficients per se, I would prefer an approach that uses whatever evidence is available to estimate new vehicle sales responses and then links them to scrap rates via an equilibrium choice model, rather than attempting two decoupled reduced form estimations.

The model requires a causal effect of prices on scrappage: The counterfactual policies are modeled as producing a shock to prices, ceteris paribus. Thus, conceptually, the CAFE model requires an estimate of the causal effect of permanent increases (changes) in the average new vehicle price on the longevity of the used fleet.

Many of the features of the regression are discussed as if the goal is *prediction* rather than *causal inference*. The key here is not prediction. Specifications should be chosen based on economic theory and a concern over eliminating biases, rather than on goodness of fit. The former issue is essentially not discussed in the PRIA, and nearly all specification decisions are described as driven entirely by goodness of fit statistics.

Price is endogenous: At the most basic level, new vehicle prices are an equilibrium outcome. A regression of quantity on price is literally the textbook example for simultaneity bias in nearly every econometrics textbook. There is just no reason to believe that this regression delivers unbiased (consistent) estimates of the causal relationship.

New vehicle price variation in the time series reflects lots of things—shifts in demand, changes in vehicle attributes, changing composition of vehicles across classes, etc.

Price should be net of quality changes: The PRIA uses estimates of price that do not account for changes in vehicle quality, including fuel economy. This seems to me deeply problematic, as the right conceptual idea is to ask how a change in the desirability of vehicles, taking price and attributes into consideration, changes ownership. The PRIA argues that the ideal specification ignores quality changes, but I do not understand or agree with the arguments made. For example, on p. 1010, the PRIA argues that the purpose of the analysis is to test whether consumers fully value attributes (namely fuel economy) so it is improper to assume valuation and adjust for it. But I see no way in which the regressions run test this question, nor do I see how that is being *tested* anywhere else in the CAFE model.

Price data is lacking: The scrappage data assembled for this estimation seem quite appropriate, and I know of no better data. The new vehicle price data, however, are coarse. At least in recent years, much more granular price series exist (the best are from J. D. Power or NADA) that could account for price trends in different vehicle classes and that can account for attribute differences.

Out of sample projections of trends are central to the analysis: By necessity, the model must make predictions far into the future, but this is nearly always puts an economic model uncomfortably out on a limb. In this case, a really impactful parameter is the projection of a trend in vehicle durability.

The model produces such implausible survival rates in future cohorts that the modelers chose to add an ad hoc adjustment (the exponential function patch for survival after age 20) to force all vehicles into a (subjectively defined) reasonable scrap pattern. If such an adjustment is required to the regression coefficient outputs, it begs the question of whether the coefficients should be put used in lieu of a reasonable approximation in the first place.

Some signs of concern: A few variables of interest perform strangely in at least some of the vehicle classes—namely the maintenance cost variable and interest rates. These anomalies could just be due to poor data, but they do point to the possibility that the regressions are simply not reliable causal estimators.

There are some alternatives: In contrast, note that the heavily referenced study by Jacobsen and van Benthem (2015), as well as some other studies of scrappage, are based on using gasoline price shocks or other identification strategies. Thus, there are ways of disciplining a model with data, i.e., using econometric analysis to inform the parameters of an equilibrium model based on theory.

There are some challenges in evaluating the econometric estimation: There were some modeling choices that I simply could not evaluate with the given information.

As a minor (but important) point, the main estimating equation does not specify the unit of observation, nor does any table list the number of observations or unit of observation. Tables also do not present standard errors, which makes it difficult to assess many coefficient estimates. Standard errors need to be adjusted for serial correlation, and perhaps two-way clustered to allow correlation in the errors by age.

More significantly, nearly all of the relationships of interest are polynomials. There are no summary statistics reported, so it is nearly impossible for the reader to judge the economic magnitude of the effects given what is reported (i.e., to assess marginal effects at the mean of the sample.)

There are very few alternative specifications shown, with the major difference being the polynomial shape of the age variable. It is simply impossible from the given set of results to judge how robust these estimates are.

In contrast to the new vehicle sales regression reported in the PRIA's section 8.6, the discussion of the scrappage regressions does not include any discussion of the time series properties of the estimators. It is important to test for non-stationarity, for example.

In many cases, the most important impact of new vehicle prices are in three year lags, and contemporaneous prices are often economically and statistically insignificant. The PRIA argues that the largest effects at three years is logical given the prominence of three year leases. This is plausible, but there are also lots of five year leases, and customers who buy their vehicles tend to put them back on the market later than three years on average. Thus, it begs the question of why all the specifications include only 3 lags. No information is given about what happens at higher lags. In one or two places, it is asserted that 3 lags is "optimal" but what this means is not explained.

Is this model dynamically consistent? The reduced form approach does not necessarily build in the dynamic relationships between shocks today and how that impacts the fleet tomorrow. In reality, if a shock today causes a lot of scrappage of a particular cohort today, then another shock tomorrow can be expected to have an attenuated effect, because there is already a smaller remaining population.

The CAFE model produces permanent (growing) shocks to the new vehicle prices. This makes it essential that the model correctly understand these "harvesting" effects. I do not believe that the current reduced form approach solves this problem correctly. This is an important issue. An equilibrium model, in which supply and demand for each type of vehicle is equated, will naturally account for these types of considerations, but a reduced form regression does not.

A very minor point on scrap metal: Many "scrapped" vehicles are in fact exported to Mexico or some other country. This will (correctly) be measured as "scrapped" in the data. For this reason, the value of scrap metal is probably not a particularly critical variable.

3. The results on net fleet size are problematic: The PRIA documents final model results that imply that more expensive new vehicles lead to a larger total vehicle fleet. This is problematic.

A generic economic model of this situation is that there are two goods, A and B, which are close substitutes for each other, and a third good X, which represents all other goods in the economy (i.e., some composite). A decrease in the price of A is said to reduce demand for B. This leads to a decrease in the price of good B. Now, the price of both A and B have fallen. But, the model posits that the reduction in prices of A and B causes net substitution toward X. Basic economics suggests that this is unlikely to make sense.

To say it another way, a CAFE rollback makes vehicle ownership less expensive (for both used and new vehicles), which means that we should expect more vehicles. Yet the analysis predicts that consumers will substitute away from vehicle ownership as vehicles become cheaper. This in essence states that cars are Giffen goods.[2]

The PRIA argues at points that the counterintuitive net effect on fleet size is logical. In those discussions, the document emphasizes that a reduction in new vehicle prices (e.g., from a rollback) will reduce demand for used vehicles, thereby lowering prices. This is true, but the discussion fails to recognize that it also reduces the supply of used vehicles (in the next period). This supply shift will lead to increases in used car quantities, more so as supply is relatively inelastic.

A note on the distinction between longevity trends and causal impacts of CAFE: A major point of discussion (and interesting finding) is the very strong trend over time in vehicle durability. Cars last longer now than they used to. The model predicts that this trend will continue.

Many of the main results of the PRIA are driven by this projected future trend in vehicle longevity. While there are certainly concerns with using a time trend that essentially must be based on twenty year old vintages (as the more recent vehicles have not reached old ages to ensure that they will truly last longer), the evidence that longevity is changing is compelling and this should be integrated into the analysis.

But note that the analysis can model the longevity of future cohorts of vehicles using these estimates without also using the new vehicle price causal impact coefficients. That is, the impact of new vehicle prices on scrappage and the time trends in cohort durability are simply separate issues. The analysis could eschew reliance on the more dubious causal price coefficients while preserving a future-projected longevity.

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[2] [Editor's note: A "Giffen good" in economics and consumer theory is a product whose consumption increases as the price rises -- and vice versa—violating the basic law of demand in microeconomics. Named for 19th century Scottish economist Sir Robert Giffen.]

Reviewer Name: James Sallee

Review Question Number: 2b

Review Question Topic Description: Please comment on the scrappage model's specification using a form common in the relevant literature. Are there better approaches that allow for both projection (as is necessary in this context) and a focus on new vehicle prices (exclusively)?

Used vehicle quantities should be an equilibrium outcome: The ideal model will involve an equilibrium in which vehicle supplies and demands are equated at each moment in time, and supplies are updated dynamically as the fleet ages. This disciplines the model to produce certain intuitive relationships.

In contrast, the current CAFE model is restricted (for practical reasons) to derive only a reduced form (econometric) relationship using historical data between new vehicle prices and scrap rates. The review question specifically asks whether a model can be better if it exclusively focuses on new vehicle prices. My view is that a reduced form econometric exercise that relies solely on new vehicle prices to determine scrappage is inherently problematic. But, the results of this econometric analysis can be used to inform a model that is designed to constrain outcomes to follow economic principles, such as the closer substitutability of similar aged vehicles. What seems most critical is that the new vehicle sales and scrap results be forced into a relationship in a theoretical model, with parameters potentially informed by the type of econometric analysis produced in the PRIA.

It is possible and desirable to build a model that accounts for used vehicle prices. In such a model, the shock of a new vehicle cost change will reverberate through the market and influence scrap rates *through its impact on used vehicle prices.* Such a model is preferable to the current approach that directly posits a reduced form effect of new vehicle prices on scrap rates using econometrics for the reasons discussed in my response to question 2a—namely that any errors in this analysis can be compounded with errors in the new sales forecast when the two streams of analysis are not explicitly linked.

Note also that there is plenty of quality data on used vehicle prices. In recent years, there is very detailed data available from J. D. Power, from wholesale auctions (Manheim or AuctionNet), or Edmunds. Stretching even further back are Blue Book and Black Book estimates.

To improve the current analysis, it is not necessary to have reliable econometric estimates of all of the various channels (though this would of course be ideal). What is important is that the model be derived from a consumer choice model that follows economic principles. Such a model would recognize the mechanical relationship between new vehicle sales today and the supply of used vehicles tomorrow, as well as modeling new vehicles as substitutes for used vehicles. Critical also is an explicit representation of the "outside good"—that is, the choice to not own a car. It is this margin that links to the overall fleet size, which is the key outcome of the scrap model.

The preferred "equilibrium first" approach is used in some of the existing literature, including the Jacobsen and van Benthem (2015) study cited in the PRIA, as well as some papers not cited in the PRIA, such as Adda and Cooper's *Balladurette and Juppette: A Discrete Analysis of Scrapping Subsidies,* (2000). Thus, while it may not be easy to build upon, there are existing studies that lay a foundation for analysis that links used and new vehicle markets through a more fundamental structure.

A minor point of the discussion of scrappage and age: The discussion on pages 995-7 suggests that there will be a larger effect on middle-aged vehicles than on older vehicles or younger used vehicles based on the degree to which new vehicles are substitutes (as well as the number that are close to the margin of scrap). This discussion seems to miss the fundamental point that prices will "cascade"—that new vehicle prices will impact the prices of young used vehicles, but those prices in turn impact the prices of middle used vehicles, which in turn impacts the prices of older used vehicles.

Reviewer Name: James Sallee

Review Question Number: 2c

Review Question Topic Description: Please comment on the scrappage model's integration in the CAFE model, addressing the vehicles affected by the scrappage model, and the extent to which changes in expected vehicle lifetimes are consistent with other assumptions.

As stated in my responses to review questions 2a and 2b, the critical issue of integration is that the new vehicle sales projections and the scrap results should be constrained to relate to each other in a way that matches economic reasoning. Details of this view are included in the answers to those questions. Here I make three other points.

The VMT schedule will be influenced by the fleet size: When we add more vehicles to the fleet, it makes sense to expect that this will lead to a decrease in the VMT-per-vehicle schedule. This is acknowledged very briefly on p. 1059, but left as future work.

Imagine a household with multiple drivers but one car. Suppose they add a second car. It is intuitive to expect that total driving in the household (including both cars) will rise. But, it seems very unlikely that VMT would double. Similarly, as the fleet continues to rise faster than the population (as noted in the PRIA), one would not expect the total VMT to rise at the same proportional rate as the number of registered vehicles, but instead to rise more slowly. This of course is a testable hypothesis historically in the aggregate. One could also use the National Household Travel Survey to look for within household patterns for how total VMT scales with fleet size in order to assess how important this issue is.

Another way to state the same concern is that the marginal driver—i.e., the person who decides to own a vehicle or not as a result of changes in CAFE—is very likely to have a lower VMT demand than the average. This means that we should expect the fleet size changes to be overestimates of real changes in aggregate VMT under the current methodology.

This exaggeration could very well be substantial. Thus my concern about this issue rivals the central concern about how the new vehicle sales and scrap responses are implemented separately. It is quite possible that modeling a change in total fleet size, where the VMT-age schedule per vehicle is held fixed, could lead model output to be less accurate than a model with static fleet sizes, even if the dynamic fleet size model correctly predicts the number of registered vehicles.

Heterogeneity (probably) matters: The Gruensprecht effect for fuel economy regulations implies not only that used vehicles will last longer when new vehicles become less desirable (net of price), but also that there will be a shift towards greater longevity that is especially pronounced for less efficient used cars. The reason is that regulations will impose a bigger burden on the least efficient new vehicles.

The Jacobsen and van Benthem (2015) study finds not only that the overall effect on used vehicles is important, but also that the relative effect of tighter fuel economy standards on the longevity of inefficient vehicles is important.

Note that footprint-based standards may mute this difference substantially. The CAFE model is designed to be run with a flat standard as well, however, and this modeling issue would clearly be important in that case.

If CAFE accelerates technology, the improvement in future cohorts will accelerate turnover through a quality dimension: Analysts have described the move to footprint based standards as something that ensures that more of the compliance efforts of automakers comes through technology deployment, rather than mix shifting. Let us suppose that a tighter CAFE rule will not just force existing technologies to be deployed, but will also lead to more research and development and/or technology cost reductions from learning by doing.

If true, this will mean that successive vehicle cohorts will be “better” (i.e., on a higher technology frontier). As new vehicles are “more better” than existing vehicles, the used fleet will represent a less close substitute, leading to more demand for new vehicles and faster turnover, all else equal. Thus, if tighter fuel economy rules do in fact accelerate technological progress (some suggestive evidence of endogenous technological progress rates is found in Knittel’s *Automobiles on Steroids,* (2011) and in Reynaert’s *Abatement Strategies and the Cost of Environmental Regulation: Emission Standards on the European Car Market* (2014), then there could be an important “quality” channel that influences turnover rates. Given that the CAFE model includes a very detailed assessment of technology, consideration of this channel seems feasible.

Reviewer Name: James Sallee

Review Question Number: 3a

Review Question Topic Description: Please comment on the inclusion of each source of employment related to automobile production and sales.

This review question essentially asks whether the labor market impacts calculations are correctly scoped—that is, whether the appropriate markets and channels are included. What the labor market analysis does is capture a specific set of effects in the *automobile supply chain*. It uses a piecemeal approach: it decides to include specific sectors and omits others. There are alternatives.

One alternative is to not quantify job impacts. This is a defensible choice because of the uncertainties involved and because the jobs impact is not a necessary component of the cost-benefit analysis.

A second alternative is to conduct a more general economic impact assessment using a standard model (like REMI or IMPLAN). These tools, while imperfect, are widely used and can be useful in characterizing the likely impact of the regulation throughout the wider economy, not just the most directly related automobile markets.

A third alternative is to attempt to capture more or fewer pieces of the automobile industry in the existing piecemeal approach, i.e., one could attempt to model how the change in total VMT would impact expenditures on induced travel, maintenance, gasoline station workers, etc.

A fourth alternative is to attempt to calculate only a net overall real income impact of the policy, and then apply a generic macroeconomic multiplier.

All of these alternatives have merit. At the end of the day, my own judgment is that the scope of the analysis described in the current PRIA is useful, but potentially misleading. It should be described carefully as an "incomplete sectoral effect" and should perhaps be shown in parallel with a more general economic impact multiplier approach. That is, it should be characterized as the impact of the regulation on the automobile sector, not as the overall jobs impact of the regulation. In addition, it would be ideal to conduct analysis that confirms that the auto sector impacts are in fact the most significant channels. More details follow.

The case against showing job impacts (alternative 1): Past analyses have eschewed quantification of jobs impacts because it is extremely difficult to predict the full set of ways that a shock to the economy will propagate through various markets. In my response to review question 1a-c, I assert that the sales quantity impact of CAFE is not well estimated. That sales effect is the input to this exercise. That uncertainty is compounded by the fact that it is inherently difficult to model an equilibrium jobs impact for any case, and that, as discussed in review item 3.b, in this market there are lots of reasons to worry about the jobs impacts described here.

As a result, it is not clear that quantifying a jobs number is better than not quantifying one at all. At a minimum, the uncertainty here implies that it is essential to offer a set of scenarios about jobs impacts that correspond to alternative assumptions about the size of sales impacts.

The case for using an input-output tool (alternative 2): It is perhaps natural to simply include the most directly impacted sectors (i.e., dealers and auto assembly). It is, however, potentially misleading to do so because it risks compounding a bias among policy analysts to think only of the direct effects of a regulation on the regulated sector itself.

General equilibrium economic impact tools (like REMI) exist and are used on a regular basis. These tools are highly imperfect (because modeling counterfactual economies is extremely difficult), but I see no reason that they are not as valid as the jobs impact that is included in the current analysis. It may thus be useful to include them alongside the values focused solely on the automobile supply chain.

What are the largest labor market impacts of the regulation? (alternative 3): If one wishes to stick with a piecemeal approach, the current approach seems sensible, but my concern is (again) that it plays into an overly narrow understanding of how regulation affects the economy.

In principle, there are many other jobs impacts possible. For example, higher fuel economy reduces the cost of travel, which could lower job search costs and otherwise spur economic growth through induced travel (the magnitude of which is also an output of the CAFE model). In a standard economic impact model like IMPLAN, one could posit shocks to the economy from the regulation due to both auto sales and fuel sales or transportation services. I would not be surprised if the latter dominated the calculation.

It is appealing to begin with the most direct impacts on the production sector itself, but if these jobs numbers are meant to play a serious role in the policy analysis, then it might be valuable to conduct a scoping analysis that would consider how large the economic impacts might be of all of the channels. That is, even if they cannot be reliably pinned down, it would be valuable to assess whether a focus on the auto value chain is actually where the largest effects should reside.

The case for a generic income effect to calculate jobs (alternative 4): On theoretical grounds, the general equilibrium impact of shifting resources from one sector to another can be quite minimal, depending on labor market conditions and how easily factor allocations can adjust. What is better grounded in theory regarding CAFE regulations is that, if regulations are binding—that is, they force consumers to move from a more desired set of vehicles towards vehicles that, net of fuel savings, are not what they wanted—then consumers experience a real income loss as a result of the policy. (This logic is described in Fullerton & Ta,[2019])

Thus, a final alternative would be to skip any focus on the auto industry but instead calculate the real income loss of the policy using the consumer choice and technology cost components of the CAFE model, then using macro estimates of the multiplier effects of real income shocks from the literature to characterize an overall effect on jobs.

Reviewer Name: James Sallee

Review Question Number: 3b

Review Question Topic Description: Please comment on assumptions regarding labor hours, production location (domestic/foreign), and supplier impacts.

This review question essentially asks whether the key parameters and assumptions used in the jobs impact are appropriate. In sum, there are many reasons to doubt the parameters used, especially the technology cost jobs effect. However, I am not aware of more reliable estimates, and the approaches taken seem to use common and sensible methods for calculating jobs impacts. As a result, I would again emphasize the value in *conducting and reporting sensitivity analysis* around the jobs impact numbers, rather than reporting a single number as it if were a reliable point estimate.

One nice feature of the approach is that it uses the model-specific vector of quantity changes, linking each model to its production location. This is useful because there is an important average difference between the production location of light trucks and passenger cars (given trade barriers for the former), and because the CAFE model is attentive to these different regulatory classes in its quantity analysis.

Average versus marginal: The assembly, dealer and supplier impacts rely on calculations of average labor hours per vehicle produced. It then implicitly assumes that average labor hours are the same as marginal labor hours in calculating the jobs impact of a change in vehicle sales. Little to nothing is said about the reliability of that assumption, which ought at least to be recognized.

I see little reason to believe that average and marginal labor hours are necessarily the same, though perhaps they are not too far apart.

One possible concern is that prior research has demonstrated that adjustment in the automobile assembly sector tends to be “lumpy”—that is, rather than making small gradual adjustments, many changes are large scale (i.e., adding a shift, canceling overtime, repurposing a plant) (e.g., Bresnahan & Ramey [1994]), This means that small shocks may lead to no labor market impacts, but larger shocks may lead to much bigger changes. That paper uses demand shocks for particular models to study labor at a given plant, which is a viable strategy for directly estimating the marginal labor effects—though the estimated parameter may have a shorter-run interpretation than is ideal for the CAFE analysis. In other words, in this particular market, there is hope for directly estimating the jobs impact induced by changing quantities using natural experiment methodologies.

In terms of the upstream supply “multiplier” that is used, there is a similar question of marginal versus average inputs. The same question arises yet again for employment at dealerships. Do dealerships readily scale up the salesperson hours as modeled, or do small fluctuations in demand simply change the arrival rate of interested customers that changes their efficiency (e.g., labor hours per unit sold)? Direct estimation of how auto market fluctuations translate into dealership labor hours should be feasible using employment data.

All of this is more to make the point that there is substantial uncertainty about the relevant parameter, rather than to levy criticism on the approach used. The use of the average labor hours is a standard and sensible approach in economic impact analysis. It seems broadly appropriate in this context. There may be some scope for using natural experiments to directly identify marginal effects, but the approach taken for estimating dealership, assembly and upstream supply hours per unit seems reasonable.

Add a historical reality check: This industry has undergone several waves of change in terms of the role of workers, with a long-term decline in the number of workers required to produce a unit. It would be worth describing these trends. If there has been a change in labor hours per unit in the last 10 to 15 years, then it would likely be worth scaling down the expected impacts in the near future years under the assumption that this trend would likely continue. (This is not an assertion that the CAFE policy itself is likely to impact the trend, but rather an assertion that today's value of labor hours per unit might be misleading for even the near future.)

Revenue per worker for technology costs more problematic: In addition to the automobile production value chain, the model estimates the change in jobs due to the need to develop and bring to market new technologies. The approach taken is to calculate annual revenue at OEMs and major auto supply companies and then divide by their labor hours in order to calculate a revenue per worker measure. A change in revenue caused by CAFE is then assumed to change the number of workers so as to maintain the original revenue per worker metric. CAFE impacts revenue in two ways—firstly through changing quantities, and secondly through changes in vehicle production costs (which are assumed equal to changes in prices, thereby impacting revenue per unit sold).

Here the proposition that average and marginal effects are equal is even more dubious than in the case above. This analysis seems intended to capture things like design engineering, contracting with suppliers, or tweaks to the assembly line. Many of these things are fixed costs—e.g., if Ford has to deploy a new part on the 2019 Fusion, it will have to employ an engineer to design, test and calibrate the part regardless of how many Fusions it sells that year. It seems likely that the marginal jobs impacts due to an increase in technology deployment costs would exceed the impact implied by the average revenue per worker parameter. Likely revenues would rise by less than costs, squeezing profits and lowering revenue per worker. (In contrast, this is less obvious for revenue changes due to quantity changes, which perhaps suggests that the two should be decomposed.)

Also, the calculation of revenue labor hours is explained only in a footnote (footnote 510, p. 962 of the PRIA) that simply says public documents for a non-random sample of firms was analyzed to come up with revenue per worker. There is not enough detail in this information to fully assess the credibility of the chosen parameter.

Chance of double counting in the technology cost values: The revenue per worker calculations for the OEMs and the parts makers would seem to include the assembly/production workers that are also analyzed in the production value chain analysis. This therefore appears to involve double counting of some workers.

Location uncertainty: An important question is whether alternative CAFE rules might alter the location of production (e.g., inside or outside of the United States). But, there does not seem to be a direct and credible way to make claims about how the location of production would change, so that assuming locations are fixed (as is done in the analysis) seems like the best approach.

The analysis could include some statistics on the location of production of the most advanced technologies, if that is available. It seems possible that more advanced technologies are more likely to be produced in the United States.

The other consideration is to analyze trends in foreign shares and production locations. If there is an important trend, this could be used to adjust the numbers used for future years. The point is not to establish different jobs multipliers for different policy counterfactuals, but instead to project forward a common multiplier to be used for all policy alternatives.

Full employment: In the midst of a discussion of how the net jobs impact depends on labor market tightness, the PRIA asserts that “no assumption” about full employment was made. But, this is not true. Implicitly it is being assumed that there is sufficient labor supply slack so that additional employment in the sector is not directly offsetting labor in another sector. It seems misleading to assert that the analysis is able to abstract from the employment rate context.

Reviewer Name: James Sallee

Review Question Number: 3c

Review Question Topic Description: Please comment on methods used to calculate changes across alternatives.

As I understand the calculation of labor market impacts, each policy alternative produces a vector of technology adoption choices and a vector of model quantities. These outcomes, along with measures of production location and percent foreign content, are then plugged directly into the labor impact equations. A variety of assumptions about the production process, location of production, etc. are held fixed in a common way across all scenario alternatives.

For the purposes of this exercise, and given the lack of detailed information available to speculate on how labor input or production location decisions would be sensitive to policy details, this approach seems to be the best available.

In other words, my concerns—which I detail in review questions 3.a and 3.b—are with the overall approach to calculating jobs impacts in all cases, not how the approach generates *different* results across scenario alternatives. Using the same equations and holding fixed most of the key parameters across scenarios and driving changes strictly from vehicle technology and quantity vectors seems appropriate.

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Reynaert, M. (2014, October). *Abatement strategies and the cost of environmental regulation: emission standards on the European car market* (Discussion Paper Series DPS14.31). Leuven, Belgium: KU Leuven Center for Economic Studies. Available at https://ssrn.com/abstract=2523841 or http://dx.doi.org/10.2139/ssrn.2523841

Small, K. A., & Van Dender, K. (2006, April 10). *Fuel efficiency and motor vehicle travel: the declining rebound effect* (UC Irvine Economics Working Paper #05-06-03). Irvine: University of California. [Corrected July 17, 2006, and August 18, 2007; shorter version published in *Energy Journal*, 28(1), pp. 25-51.] Available at www.economics.uci.edu/files/docs/workingpapers/2005-06/Small-03.pdf

Phase 2 Reviewer Résumés

Alicia Birky

Analysis Team Lead

EDUCATION

Accredited Institutions

Ph.D., Policy Studies, University of MD College Park, 2008.
B.S., Aerospace Engineering, University of MD College Park, 1988, Summa Cum Laude.

Security Clearance

NA

Employment

Energetics Incorporated
TA Engineering, Inc.
PNNL Joint Global Change Research Institute
NASA Headquarters
University of MD, College Park
National Renewable Energy Laboratory
Swales Aerospace

SUMMARY

Dr. Birky is an engineer and policy analyst with more than 16 years of academic and professional experience at the intersection of science, technology, policy, and markets relating to global climate change, energy conservation, and criteria emission reduction. She has developed a working knowledge of policy-making and analysis, as well as strategic planning and program development, management, implementation, and evaluation. Her broad range of experience results in excellent cross-disciplinary technical and communication skills. She has experience working with clients and stakeholders from private industry, federal and state government, independent laboratories, and non-profit organizations. Clients have included Oak Ridge National Laboratory, DOE, Argonne National Laboratory, the National Petroleum Council, EPA, the Baltimore Port Authority, the Maryland Environmental Service, and Constellation Energy. She has collaborated with the National Renewable Energy Laboratory, Sandia National Laboratory, the Maryland Department of the Environment, the Baltimore Port Alliance, the Maryland Environmental Finance Center, and the Maryland Motor Truck Association.

Dr. Birky's main area of expertise is transportation, including light and heavy highway vehicles, non-road equipment, harbor craft, and ocean vessels. Her skills include quantitative and qualitative analysis of technologies, programs, and policies, including assessment of technical, economic, operational, political, social, and market opportunities and constraints. She is skilled in the development and application of econometric, systems dynamics, cost-benefit, emissions, consumer choice, market adoption, and stock accounting models. She has applied these skills to energy demand modeling and to program evaluation, verification, and measurement. She also is adept at communication of technical information in written and oral formats for technical and non-technical audiences.

EXPERIENCE

Energetics Incorporated, Columbia, Maryland
09/2014 – Present

Dr. Birky is the Analysis Team Lead within Energetics' Sustainable Transportation Solutions Division where she supports the Department of Energy's (DOE) Energy Information Administration (EIA) and Office of Energy Efficiency and Renewable Energy (EERE). She collaborates with staff from DOE and the National Laboratories, including Argonne, Oak Ridge, Sandia, and the National Renewable Energy Laboratories. She provides analytical, technical, and management support for research and development programs with a main focus within the EERE Vehicle Technologies Office (VTO). She is responsible for conducting technical and policy analysis on the costs and benefits of technologies being developed by EERE and applies existing analytical models and develops custom tools where necessary. Her duties include assisting EERE staff in responding to requests for information from Congress, EERE management, and other program stakeholders; preparing data in support of program budget development; and supporting the DOE peer and merit review processes. She is responsible for the management of tasks, projects, and team members.

Dr. Birky recently completed a modeling effort with EIA to integrate highly automated vehicles (HAVs) and Mobility as a Service (MaaS) into the National Energy Modeling System (NEMS) Transportation Module (TRAN). Technical work included estimating the impact of vehicle automation on vehicle cost, weight, fuel economy, and other attributes; determining the technology applicability in various vehicle type and end-use markets, including MaaS and transit; and estimating vehicle and transportation system impacts including vehicle use and life, travel demand by various modes, vehicle efficiency, system efficiency, and energy use. She conceptualized new NEMS model components to estimate HAV vehicle cost and adoption by ride-hailing fleets; developed the model approach, structure, and algorithms to integrate HAVs; tested/validated the model equations and inputs in Microsoft Excel; then developed FORTRAN code to include the new HAV components in the TRAN module. She also assisted EIA with conceptualizing modeling approaches (to be pursued in future work) for private consumer adoption, estimation of impact on passenger miles of travel, and mode choice.

Dr. Birky also currently supports the VTO Analysis Team with a primary focus on heavy highway vehicles. She is leading a study of the potential impact of connected and automated vehicle technology on the future energy demand of freight trucks. She leads the heavy vehicle portion of the VTO program benefits analysis, which includes developing advanced technology deployment scenarios; assessing technology fuel consumption benefits over defined duty schedules; estimating technology costs; performing a market adoption analysis; and projecting future fleet fuel savings. For this project, she is currently leading efforts to update the heavy vehicle market adoption and stock accounting models to incorporate regulatory classes and new technology options, such as plug-in hybrid, battery electric, and hydrogen fuel cell trucks. Dr. Birky developed the ASCENTT tool (Assessment of Cycle Energy for Truck Technologies), an engineering-based “road loads” model that estimates the fuel consumption of heavy trucks and assesses the fuel savings of advanced technologies deployed in various duty cycles defined by speed, distance, and grade. She recently completed development of a heavy vehicle choice modeling framework that incorporates payback analysis in a logit model structure. To capture the heterogeneity of the commercial vehicle market, this model includes characterization of vehicles by weight class, body style, and usage, as well as characterization of a range of fleet vehicle purchasers.

Dr. Birky led an analysis of the potential for electrification of the transportation system “beyond light duty.” The scope of this study included all highway vehicles in weight classes 2b-8 as well as non-road mobile equipment used for goods and people movement. Dr. Birky employed both qualitative and quantitative analysis techniques to perform a market and industry assessment, determine the state of electrification, identify high potential applications, identify barriers to widespread adoption, and develop possible strategies to overcome these barriers. Dr. Birky and her team assisted in the development and facilitation of, as well as presentation in, a stakeholder workshop to solicit manufacturer and user perspectives. Based on the results of the workshop, Dr. Birky is led a follow-on study of electrification of class 2b-3 pickup trucks and vans.

Dr. Birky developed the LVCFlex light vehicle consumer choice model for VTO and has been responsible for model maintenance, application, and development. This spreadsheet tool utilizes the nested multi-nomial logit methodology found in NEMS to project market share of advanced and alternative technology vehicles. This simplified version of the NEMS Consumer Vehicle Choice Component allows the user to flexibly define vehicle technologies within five vehicle size classes and five technology groups in the nesting structure. It allows investigation of the NEMS model assumptions and methodologies and evaluation of various scenarios for technology development and deployment. She developed an Excel VBA application to translate vehicle attribute data from a standard data file into the input format required by the LVCFlex model. This application automates development of market scenarios based on vehicle simulation results. She is collaborated with an inter-laboratory team, led by ANL, to compare the results of consumer light vehicle choice models under a consistent set of input assumptions. She assists VTO in exploring alternative approaches for modeling and studying consumer behavior, technology diffusion, and market transformation as it applies to highway vehicles.

TA Engineering, Inc., Baltimore, MD
07/2008 – 09/2014

As a Senior Technical Analyst, Dr. Birky was responsible for leading the analysis of technologies, policies, and programs to reduce energy consumption and emission of greenhouse gases and criteria pollutants from mobile sources. She supported compliance of US DOE VTO with the requirements of the Government Performance, Reporting and Accountability Act (GPRA) and held primary responsibility for evaluation of VTO's heavy vehicle program elements. She served as Lead Analyst for the evaluation of the energy saving benefits associated with the US DOE's SuperTruck research and development program. She interfaced with the SuperTruck industry partners to gather information on research elements and expected benefits; developed truck platforms representative of these elements and achievement of program goals; developed technology cost projections; modified analytical tools to incorporate these research findings; performed a market analysis of the representative platforms; and projected future petroleum and emission savings.

Dr. Birky provided technical assistance to the National Petroleum Council (NPC) for their study titled Advancing Technology for America's Transportation, published in 2012. She developed a light vehicle consumer choice model in Excel that applies the methodology found in the Energy Information Administration's (EIA's) NEMS Consumer Vehicle Choice Component. She was asked to give a presentation on the model to DOE's Undersecretary for Science, Dr. Steve Koonin. She also made modifications to the TRUCK heavy vehicle market penetration model to accommodate the NPC's analytical requirements and provided technical assistance in employing the model.

In support of VTOs program benefits analysis, Dr. Birky developed an engineering-based model to assess the fuel consumption benefits due to heavy truck technologies deployed in various duty cycles. The Heavy Truck Energy Balance (HTEBdyn) model estimates vehicle power requirements and fuel consumption of conventional and advanced technologies, including advanced combustion technologies; turbo-compounding; organic Rankine cycle waste heat recover; and regenerative braking in hybrid drivetrains. Dr. Birky has made numerous improvements to VTO's TRUCK heavy vehicle market penetration model and developed a national heavy truck stock accounting model to project future fuel and carbon emission savings from deployment of advanced technology vehicles. Dr. Birky also utilized the data extracted from the US EPA's NONROAD model to develop a tool for the projection of energy use and carbon emissions from the national stock of non-highway equipment.

Dr. Birky served as Lead Analyst for the Port of Baltimore Clean Diesel Program which awarded grants to private equipment owners to upgrade drayage trucks, cargo handling equipment, locomotives, and harbor craft. The program was funded by the American Recovery and Reinvestment Act through the EPA National Clean Diesel Campaign. She provided technical support during program development and implementation and held lead responsibility for technical evaluation of applications and estimation of program benefits and outcomes. She developed a model to evaluate the emission of criteria pollutants from specific non-road equipment and utilized this model to assess the emission savings potential of applicants' proposed measures. She also developed tools for assessing reductions in fuel consumption and criteria emissions from installation of exhaust treatment devices and from repowering or replacing drayage trucks, locomotives, and harbor craft. Finally, she developed tools to apply the program's technical evaluation criteria to all applications.

Dr. Birky served as Project Manager for the Port of Baltimore Diesel Emissions Reduction Opportunities study performed on behalf of the Port and funded by the US EPA. She collaborated with Port officials and equipment owners and operators to assess technical and operational issues and strategies for transoceanic vessels, heavy trucks, locomotives, and cargo handling equipment serving the Port. She supervised junior staff and served as lead author on all project documentation.

Dr. Birky also supported analysis of building energy efficiency upgrades and was responsible for the development of a Measurement and Verification Plan for a major retailer and developed an eQuest energy consumption simulation model of an educational facility.

PNNL Joint Global Change Research Center, College Park, MD
03/2004 – 10/2004

Dr. Birky served as a graduate research intern and performed research on the sources and process of technological change in energy production systems and its representation in integrated assessment models. She also researched learning / progress curves and the underlying mechanisms of organizational learning with an emphasis on energy technologies and industries. While employed at JGCRI, Dr. Birky developed a research agenda on sources of innovation in automotive energy saving technologies.

NASA Headquarters, Washington, DC
09/2001 – 11/2002

As a Program Planning Specialist, Dr. Birky participated in strategic planning and program evaluation activities. She provided direct support to the Associate Administrator for Earth Science and other senior executive staff and assisted with budget preparation, strategic planning, and development of research program roadmaps and implementation plans. She was responsible for the communication of Office of Earth Science mission, goals, strategies, implementation plans, and projected benefits to internal and external stakeholders, including the NASA Administrator; OMB; Congress; national and international professional and scientific organizations; and the public. She developed content for senior executive staff presentations, program factsheets, web pages, Congressional testimony, budget submissions, performance and accountability reports, policy summaries, and various internal reports. She drafted the OES section of the FY 2001 President's Report on Aeronautics and Space. She received a NASA Fast Award for developing a one-page template to communicate to OMB examiners complex OES science program goals and projected benefits. This template allowed OES to overcome a communication barrier that had caused a great deal of tension between OES and OMB.

National Renewable Energy Laboratory, Washington, DC
08/1998 – 08/2001

Dr. Birky served as a Senior Analyst and provided direct support to the U.S. DOE Office of Transportation Technologies. She was responsible for the evaluation of program benefits and performed research on policies and technologies to improve vehicle fuel economy, promote alternative fuel use, reduce dependence on imported oil, and reduce emission of greenhouse gases. Her duties included assessment of environmental and economic impacts; research on consumer preferences; development of strategic plans; and preparation of technical reports, conference papers, and presentations. She developed models and tools for market-based policy and program analysis, including consumer choice, econometric, cost-benefit, input-output, demand forecasting, and stock accounting models.

University of Maryland, College Park, MD
08/1997 – 05/1999

While pursuing her PhD in Policy Studies, Dr. Birky supported the Maryland School of Public Affairs in various teaching and research positions. She served as an Adjunct Lecturer for Quantitative Analysis of Policy Issues, an econometric modeling course for graduate policy students. In collaboration with a co-lecturer, she developed the syllabus and course materials; led lectures and held office hours; and administered all grades. As a Teaching Assistant for Quantitative Aspects of Global Environmental Problems, she led discussion sessions, assisted students on request, and graded homework assignments and exams. She held the position of Instructor for the School's summer Math Immersion class for three years. She was responsible for selecting the course text; developing the syllabus and lecture materials;

and holding lectures and office hours. She also served as a Research Assistant for the Chesapeake Biological Laboratory's Patuxent Landscape Modeling Project where she supported dynamic model calibration through use of remotely sensed data, specifically Normalized Difference Vegetation Index (NDVI) data obtained from various satellite archives.

Swales Aerospace, Beltsville, MD
08/1988 – 09/1997

As a Spacecraft and Instrument Systems Senior Engineer, Dr. Birky provided mechanical and spacecraft systems engineering support to NASA Goddard Spaceflight Center (GSFC) Earth science missions. She served as the interface among project scientists and engineers and performed technical feasibility studies and failure modes and effects analyses (FMEA). As an Engineer in the Structural Dynamics and Loads group, she provided comprehensive structural dynamics support to GSFC missions from preliminary design through launch and on-orbit support. She developed Finite Element Models (FEMs); performed flight loads, jitter, and structural-thermal-optical (STOP) analyses; specified dynamic and static test levels; correlated models to test data; and supported structural and environmental tests. She was responsible for presenting analysis methodology and results at preliminary and critical design reviews.

AWARDS, HONORS, AND SPECIAL RECOGNITON

NASA Fast Award, 2002
Tau Beta Pi
Sigma Gamma Tau

PROFESSIONAL AFFILIATIONS

SAE Member
Transportation Research Board (TRB) Member

PUBLICATIONS

1. Gao, Z., A. Lin, S.C. Davis, A.K. Birky, and R. Nealer (2018) Quantitative Evaluation of MD/HD Vehicle Electrification using Statistical Data, presented at the Transportation Research Board 2018 Annual Meeting, January.
2. Birky, A.K., M. Laughlin, K. Tartaglia, R. Price, B. Lim, and Z. Lin (2017) Electrification Beyond Light Duty: Class 2b-3 Commercial Vehicles. ORNL/TM-2017/744, December.
3. Stephens, T.S., A. Birky and D. Gohlke (2017) Vehicle Technologies and Fuel Cell Technologies Office Research and Development Programs: Prospective Benefits Assessment Report for FY 2018. ANL/ESD-17/22, November.
4. Stephens, T.S., R.S. Levinson, A. Brooker, C. Liu, Z. Lin, A. Birky, and E. Kontou (2017) Comparison of Vehicle Choice Models. ANL/ESD-17/19, October.
5. Birky, A.K., M. Laughlin, K. Tartaglia, R. Price, and Z. Lin (2017) Transportation Electrification Beyond Light Duty: Technology and Market Assessment. ORNL/TM-2017/77-R1, September.
6. Gao, Z., Z. Lin, T.J. La Clair, C. Liu, Jan-Mou Li, A. Birky, and J. Ward (2017) Battery capacity and recharging needs for electric buses in city transit service. Energy, 122: 588-600.
7. Stephens, T.S., A.K. Birky, J. and Ward (2014) Vehicle Technologies Program Government Performance and Results Act (GPRA) Report for Fiscal Year 2015, Argonne National Laboratory report ANL/ESD-14/3.
8. TA Engineering, Inc. (2012) DOE SuperTruck Program Benefits Analysis, Final Report, prepared for U.S. DOE and Argonne National Laboratory, lead author, December 20.
9. Birky, A.K., M. Miller and J.S. Moore (2010) Emission Reductions from Port of Baltimore Maritime

Vessels and Cargo Handling Equipment, DRAFT Final Report. Prepared by TA Engineering, Inc., for the Maryland Port Administration, Maryland Department of the Environment, and the Maryland Environmental Service. September 27.

10. Birky, A.K., M. Miller, and J.S. Moore (2010) Emission Reductions from Port of Baltimore Drayage Trucks, DRAFT Final Report. Prepared by TA Engineering, Inc., for the Maryland Port Administration, Maryland Department of the Environment, and the Maryland Environmental Service. March 10. Birky, A.K., M. Laughlin, K. Tartaglia, R. Price, B. Lim, and Z. Lin (forthcoming) Electrification Beyond Light Duty: Class 2b-3 Commercial Vehicles, ORNL/TM-xxxx/xx.
11. Clarke, L., J. Weyant, and A. Birky (2006) On the sources of technological change: Assessing the evidence, *Energy Economics* 28, 579-595.
12. Johnson, L., D. Greene and A. Birky (2003) Is the barrel half full or half empty? Implications of transitioning to a new transportation energy future, in Transportation, Energy, and Environmental Policy: Managing Transitions, report of the VIII Biennial Asilomar Conference, September, 2001, 104-129. Washington, DC: National Academies Transportation Research Board.
13. Birky, A.K. (2001) NDVI and a simple model of deciduous forest dynamics, *Ecological Modeling* 143, 43-58.
14. Birky, A.K., J.D. Maples, J.S. Moore Jr, and P.D. Patterson (2000) Future world oil prices and the potential for new transportation fuels, Transportation Research Record 1738, 94-99.

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Education

Post-Doctoral Fellow (1984), Environmental Science and Public Policy, Harvard School of Public Health. Advisors: Professors Donald Hornig, Marc Roberts, and Howard Raiffa.

Ph.D. in Urban and Public Affairs (1983), The Heinz School, Carnegie-Mellon University.
Dissertation: "Automobile Safety: An Investigation of Occupant-Protection Policies."
Committee: Professors M. Granger Morgan, Steven Garber and Alfred Blumstein.

M.A. in Public Affairs (1980), Duke University.
Thesis: "The Value of a Life: What Difference Does It Make?"
Advisor: Professor James W. Vaupel.

B.A. with Honors in Economics and Politics (1978), Wake Forest University.
Honors Paper: "A Cost-Benefit Analysis of the 55 MPH Speed Limit."
Honors Paper: "A Theory of Criminal Punishment."
Advisor: Professor Jack Fleer.

Recent Positions

Dean, School of Public and Environmental Affairs, Indiana University, Bloomington and Indianapolis, Indiana, 2008 to present

Leads innovative, two-campus $64-million professional school with programs in arts administration, criminal justice, environmental science and policy, health care management, public budgeting and finance, non-profit management, and public affairs. Orchestrated strategic planning processes with faculty, staff, students, alumni and donors, leading to publication of "SPEA 2015" and "SPEA 2020." Accomplishments to date: (1) hired fifty one new tenure-line faculty on the two campuses (Bloomington and Indianapolis); (2) raised $17 million in philanthropic support from individuals, corporations, and foundations; (3) Master's in Public Affairs Program (Bloomington) rose to #1 out of 272 programs in the 2019 *U.S. News and World Report* national survey; (4) launched the "Indiana Futures Project" through the School's Public Policy Institute, a community-based deliberation prior to Indiana's state-level elections in November 2012 and November 2016; and (5) tripled the rate of student enrollment in overseas study programs, including newly added SPEA programs in Beijing, Berlin, Croatia, Hanoi, Kenya, London, Moscow, Pamplona, Siberia, Speyer, Australia, Caribbean-Bonaire and Mexico to the already robust course offerings in 12 other locations; (6) launched SPEA Connect, the first fully on-line MPA program offered by a top graduate program in public affairs; (7) expanded by 75% (to more than 2,500) the number of undergraduate majors on the Bloomington campus; (8)

secured new laboratory space for SPEA's environmental science faculty while renovating existing space to meet the needs of public affairs faculty and staff on both campuses. A $12 million addition to the main SPEA building, named after former U.S. Treasury Secretary Paul O'Neill, opened in early 2017 to serve the needs of graduate students.

Dean, The Pardee RAND Graduate School, RAND Corporation, Santa Monica, California, 2006 to 2008

Led innovative policy-analysis Ph.D. program based on apprenticeship relationships with RAND researchers. Responsible for curricula, faculty oversight, student recruitment and placement, fundraising, commencement exercises and disciplinary issues. Streamlined the core curriculum, established new analytic concentrations, expanded recruitment of female and minority students, added a weeklong workshop on American culture for international fellows, and revamped the dissertation process to enable students to start the dissertation process earlier. Raised $3.4 million in philanthropic gifts from individuals and corporations to support scholarships, dissertations and other educational expenses.

Administrator, Office of Information and Regulatory Affairs, US Office of Management and Budget, Executive Office of the President, Washington, D.C., 2001 to 2006

Oversaw for President George W. Bush federal regulatory policy, statistical policy and information policy. As Senate-confirmed political appointee, directed a staff of 50 career policy analysts with backgrounds in science, engineering, economics, statistics and law. Strengthened the role of benefit – cost considerations in federal regulation while establishing new information-quality procedures in the federal government. Simplified hundreds of regulations and helped design valuable new rules on clean air, auto fuel economy and food safety.

Founding Director, Center for Risk Analysis, Harvard School of Public Health, Boston, MA, 1989 to 2001

Created mission-oriented Center with programs in automotive safety, environmental health, and medical technology. Raised over $10 million in governmental and private support. Financed eight new faculty positions, new course development, and numerous doctoral students.

Deputy Chairman, Department of Health Policy and Management, Harvard School of Public Health, Boston, MA, 1987 to 1992

Supported Department Chairman in curriculum reform, faculty recruitment and evaluation, budgeting and student recruitment and placement.

Staff Associate, Committee on Risk and Decision Making, National Research Council/National Academy of Sciences, Washington D.C., 1979 to 1981

Supported Study Director and Committee Chairman in preparation of an NAS report on the future of risk analysis in national policy.

Academic Appointments

Professor of Public Affairs (with tenure), School of Public and Environmental Affairs, Indiana University, Bloomington and Indianapolis, IN (2008 to present).

Professor of Policy Analysis, Pardee RAND Graduate School, Santa Monica, CA (2006 to 2008).

Professor of Policy and Decision Sciences (with tenure), Department of Health Policy and Management, Harvard School of Public Health, Boston, MA (1991 to 2003).

Associate Professor of Policy and Decision Sciences, Department of Health Policy and Management, Harvard School of Public Health, Boston, MA (1988 to 1991).

Assistant Professor of Policy and Decision Sciences, Department of Health Policy and Management, Harvard School of Public Health, Boston, MA (1985 to 1988).

Assistant Professor, School of Urban and Public Affairs, Carnegie-Mellon University, Pittsburgh, PA (1984 to 1985).

Doctoral Students and Fellows

Adam Abelkop (Ph.D.)	Jill Morris (Ph.D.)
Jessica Alcorn (Ph.D.)	Doreen Neville (Sc.D.)
Sandra Baird (Fellow)	Naveed Paydar (Ph.D.)
Agi Botos (Ph.D.)	Susan Putnam (Sc.D.)
Phaedra Corso (Ph.D.)	Alon Rosenthal (Sc.D.)
Joshua T. Cohen (Ph.D.)	Dana Gelb Safran (Sc.D.)
Alison Taylor Cullen (Sc.D.)	Mary Jean Sawey (Fellow)
Diana Epstein (Ph.D.)	Maria Seguí-Gómez (Sc.D.)
George Gray (Fellow)	Joanna Siegel (Sc.D.)
Sara Hajiamiri (Ph.D.)	Andrew Smith (Sc.D.)
Evridiki Hatziandreu (Sc.D.)	Tammy Tengs (Sc.D.)
Neil Hawkins (Sc.D.)	Kimberly Thompson (Sc.D.)
David Holtgrave (Fellow)	Edmond Toy (Ph.D.)
Nancy Isaac (Fellow)	Eve Wittenberg (Ph.D.)
Bruce Kennedy (Fellow)	Zach Wendling (Ph.D.)
Michelle Lee (Ph.D.)	Scott Wolff (Sc.D.)
Younghee Lee (Ph.D.)	Fumie Yokota (Ph.D.)
Ying Liu (Ph.D.)	Yu Zhang (Ph.D.)
Arthur Ku Lin (Ph.D.)	

Extramural Grant Support from the Federal Government

Principal Investigator. Evaluation of Countermeasures to Reduce Drinking and Driving. U.S. Centers for Disease Control. $75,000. 1990-91.

Co-Investigator. Harvard Injury Control Research Center. U.S. Centers for Disease Control. $2.0 million per year. 1990-94.

Principal Investigator. The Determinants of Lifesaving Investments. U.S. National Science Foundation. $150,000. 1993-95.

Principal Investigator. Harvard Injury Control Research Center. U.S. Centers for Disease Control. $1.2 million per year. 1995-97.

Principal Investigator. Community-Based Intervention to Encourage Rear Seating of Young Child Passengers. U.S. Centers for Disease Control. $200,000. 1998-00.

Awards

Elected Fellow, National Academy of Public Administration (2009).

Distinguished Lifetime Achievement Award, Society for Risk Analysis (2008).

Co-Recipient (with Ryan Keefe and Jay Griffin) of the annual Best Paper Award in Risk Analysis (2008), vol. 28.

Alumni Merit Award, Carnegie Mellon University (2002).

Annual Public Service Award for Achievements in Risk Communication to the American People, Annapolis Center, Annapolis, Maryland (1998).

Award for Outstanding Service in Helping to Develop and Support the National Agenda for Injury Control, U.S. Centers for Disease Control (April 25, 1991).

Outstanding Oral Presentation, "The Case for Motor Vehicle Injury Control", Society for Automotive Engineers, Industry-Government Meetings (May 16, 1991).

Co-Recipient (with Steven Garber) of the annual Herbert Salzman Award for the "Outstanding Paper" in Volume 3 of the Journal of Policy Analysis and Management (1984).

Service

Member, U.S. Environmental Protection Agency Chartered Science Advisory Board, Washington, D.C. (2017-2020.

Member, National Association for Urban Debate Leagues Governing Board, Chicago, IL (2017 to present).

Member, Committee on Preparing the Next Generation of Policy Makers for Science-Based Decisions. National Research Council/National Academy of Sciences (March 2014 to June 30, 2016).

Director, National Science Foundation International, Ann Arbor, MI (2013 to present).

Expert Witness, Boies, Schiller, Flexner, Table Saw Safety (2009 to 2013).

Faculty Advisor to IU Ballroom Dance Club (2011 to present).

Faculty Advisor to IU Debate Team (2009 to present).

Member, International Advisory Board of Germany's Helmholtz-Programme "Technology, Innovation and Society" (2010 to 2015).

Member, Administrative Conference of the United States (2011 to 2012).

Chairperson, Regulatory Occupations Evaluation Committee (ROEC), State of Indiana (2010 to 2014).

Member, The B. John Garrick Foundation for the Advancement of the Risk Sciences, Advisory Board (2010 to 2015).

Member, Dow AgroSciences Advisory Committee (2010 to 2013).

Member, American Chemistry Society (2008 to present).

Member, Board of Scholars, American Council for Capital Formation (1995 to 2000 & 2007 to present).

Member, Scientific and Technology Council, International Risk Governance Council, Lausanne, Switzerland (2008 to 2015).

Member, Board of Directors, International Risk Governance Council, Geneva, Switzerland (2006 to 2008).

Member, Committee on the Status and Future of Federal e-Rulemaking (2008).

Member of the Scientific Advisory Panel, Green Chemistry Initiative, State of California (2007 to 2008).

Member, Public Health Policy Advisory Board (1997 to 2001).
Member, National Council on Radiation Protection and Measurement (1997 to 2001).

Member, Editorial Board, Risk: Health, Safety and Environment (1990 to 2001).

Member, Editorial Board, Journal of Risk Research (1990 to 2001).

Member, Editorial Board, Risk Analysis: An International Journal (1989 to 2001, 2008 to present).

Member, Editorial Board, Injury Control and Safety Promotion (1999).

Member, Editorial Board, Accident Analysis and Prevention: An International Journal (1990 to 1999).

Member, Editorial Board, Journal of Benefit-Cost Analysis (2001 to present).

Elected President, Society for Risk Analysis (1995 to 1996).

Member, Ad Hoc Committee on Risk Analysis, Advisory Body to the President of the National Academy of Sciences (1994).

Member, Board of Visitors, Wake Forest University (1991 to 1994).

Member, Committee to Review the Structure and Performance of the Health Effects Institute, Board on Environmental Studies and Toxicology, National Research Council (1992 to 1993).

Member, Motor Vehicle Safety Research Advisory Committee, U.S. Department of Transportation, Washington, D.C. (1990 to 1993).

Member, Highway Safety Study, Strategic Transportation Research Committee, Transportation Research Board, (1989 to 1991).

Member, Committee to Identify Measures that May Improve the Safety of School Bus Transportation, Transportation Research Board, (1987 to 1988).

Books

John D. Graham, Laura Green, and Marc J. Roberts, In Search of Safety: Chemicals and Cancer Risk, Harvard University Press, Cambridge, MA, 1988.

John D. Graham (ed.), Preventing Automobile Injury: Recent Findings of Evaluation Research, Auburn House Publishing Company, Dover, MA, 1988.

John D. Graham, Auto Safety: Assessing America's Performance, Auburn House Publishing Company, Dover, MA, 1989.
John D. Graham (ed.), Harnessing Science for Environmental Regulation, Praeger, Westport, CT, 1991.

John D. Graham and Jonathan B. Wiener (eds.), Risk versus Risk: Tradeoffs in Protecting Health and the Environment, Harvard University Press, Cambridge, MA, 1995.

John D. Graham & Jonathan B. Wiener, eds., Risk vs. Risk: Tradeoffs in Protecting Health and the Environment (Chinese edition, translated by XU Jianhua & XUE Lan, Tsinghua University Press, 2018)

John D. Graham (ed.), The Role of Epidemiology in Regulatory Risk Assessment, Elsevier Science, Amsterdam, NL, 1995.

John D. Graham and Jennifer K. Hartwell (eds.), The Greening of Industry: A Risk Management Approach, Harvard University Press, Cambridge, MA, 1997.

John D. Graham, Bush on the Home Front: Domestic Policy Triumphs and Setbacks, Indiana University Press, Bloomington, IN, 2010.

Kristin S. Seefeldt and John D. Graham, America's Poor and the Great Recession, Indiana University Press, Bloomington, IN, 2013.

Eberhard Bohne, John D. Graham, Jos C.N. Raadschelders in collaboration with Jesse Paul Lehrke, Public Administration and the Modern State: Assessing Trends and Impact, Palgrave Macmillan, Houndsmills, Basingstoke, Hampshire, 2014.

Adam Abelkop, John D. Graham, and Todd Royer, Persistent, Bioaccumulative, and Toxic (PBT) Chemicals, CRC Press, Boca Raton, FL, 2015.

John D. Graham, Obama on the Home Front: Domestic Policy Triumphs and Setbacks, Indiana University Press, Bloomington, IN, 2016.

Published Papers and Reports (* indicates peer reviewed)

1. Vaupel, James W. and Graham, John D., "Egg in Your Bier?" Public Interest, Winter 1980, 3-17.

2.* Graham, John D. and Vaupel, James W., "The Value of a Life: What Difference Does It Make?" Risk Analysis, Volume 1, 1981, 89-95; reprinted with revision, What Role for Government? eds., Richard Zeckhauser and Derek Leebauert, Durham, NC: Duke University Press, 1983, 176-186; reprinted, Risk Benefit Analysis in Water Resource Planning and Management, ed., Yacov Y. Haimes, New York: Plenum Press, 1981, 233-244.

3.* Graham, John D., "Some Explanations of Disparities in Life Saving Investments", Policy Studies Review, Volume 1, 1982, 692-704.

4.* Graham, John D., "On Wilde's Theory of Risk Homeostasis", Risk Analysis, Volume 2, 1982, 235-237.

5. Graham, John D. and Gorham, Patricia, "NHTSA and Passive Restraints: A Case of Arbitrary and Capricious Deregulation", Administrative Law Review, Volume 35, 1983, 193-252.

6. Graham, John D., "Automobile Crash Protection: Institutional Responses to Self-Hazardous Behavior", Risk Analysis, Institutions, and Public Policy, ed., Susan G. Hadden, Associated Faculty Press, 1984, 39-59.

7.* Graham, John D. and Garber, Steven, "Evaluating the Effects of Automobile Safety Regulation", Journal of Policy Analysis and Management, Volume 3, No. 2, 1984, 206-224.

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9. Crandall, Robert W., and Graham, John D., "Automobile Safety Regulation and Offsetting Behavior: Some New Empirical Estimates", American Economic Review, Volume 74, No. 2, May 1984, 328-331.

10.* Graham, John D., "Technology, Behavior, and Safety: An Empirical Study of Automobile Occupant-Protection Regulation", Policy Sciences, Volume 17, 1984, 141-151.

11. Graham, John D., "The Failure of Agency-Forcing: The Regulation of Airborne Carcinogens Under Section 112 of the Clean Air Act", Duke Law Journal, February 1985, 100-150; selected for republication in Land and Environment Law Review, ed., Stuart L. Deutsch, 1986.

12. Graham, John D., "Secretary Dole and the Future of Automobile Airbags", Brookings Review, Summer 1985, 10-15.

13. Graham, John D., Raiffa, Howard and Vaupel, James W., "Science and Analysis: Roles in Risk and Decision Making", Risk Evaluation and Management, eds., Vincent Covello, Joshua Menkes, and Jeryl L. Mumpower, New York: Plenum Press, 1986, 503-518.

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53. Gray, George M., Cohen, Joshua T., and Graham, John D., "The Challenge of Risk Characterization: Current Practice and Future Directions", Environmental Health Perspectives Supplements, Volume 101 (Suppl. 6), 1993, 203-208.

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55. Graham, John D., "The Economics of Controlling Outdoor and Indoor Air Pollution" in Indoor and Outdoor Air Pollution and Human Cancer, ed., U. Veronesi, European School of Oncology, Springer-Verlag, Berlin, 1993, 149-162.

56. Putman, Susan W. and Graham, John D., "Chemicals vs. Microbials in Drinking Water: A Decision Sciences Perspective", Journal of the American Water Works Association, Volume 85, 1993, 57-61.

57. Graham, John D., "Incorporating Scientific Judgment into Quantitative Risk Assessment", The Toxicology Forum, Winter 1993, 51-62.

58. Gray, George M. and Graham, John D., "Intuitive Toxicology: Comments on Public Perceptions and the Role of Institutional Affiliation in Expert Opinions", Comments on Toxicology: A Journal of Critical Discussion on the Current Literature, Volume 4, 1993, 501-504.

59.* Putman, Susan W. and Graham, John D., "Formaldehyde Science: From the Laboratory to the Regulatory Arena" in Keeping Pace with Science and Engineering, ed., Myron F. Uman, National Academy Press, Washington, D.C., 1993, 189-220.

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61. Graham, John D., "The Fate of the Maximally Exposed Individual Under the 1990 Amendments to the Clean Air Act", a paper presented to the Committee on Risk Assessment Methodology, National Research Council, National Academy of Sciences, Washington, D.C., August 1993.

62. Graham, John D., "Making Sense of Risk", AG in Perspective, Volume 1, No. 1, September 1993.

63.* Evans, John, Graham, John, Gray, George and Sielken, Jr., Robert, "A Distributional Approach to Characterizing Low-Dose Cancer Risk", Risk Analysis, Volume 14, No. 1, 1994, 25-34.

64.* Safran, Dana Gelb, Graham, John D., and Osberg, J. Scott, "Social Supports as a Determinant of Community-Based Care Utilization Among Rehabilitation Patients", Health Services Research, Volume 28, No. 6, 1994, 729-750.

65. Putman, Susan W. and Graham, John D., "Environmental Regulation", Essay in The Encyclopedia of the Environment, Boston: Houghton Mifflin Company, 1994, p. 224.

66. Graham, John D., "Synopsis of the BELLE Conference on Chemicals and Radiation" in Biological Effects of Low Level Exposures: Dose-Response Relationships, ed., E.J. Calabrese, Lewis Publishers, Ann Arbor, MI, 1994, 271-274.

67. Graham, John D. and Sadowitz, March, "Superfund Reform: Reducing Risk through Community Choice", Issues in Science and Technology, Summer, 1994, 35-40.

68. Graham, John D., "Hammers Don't Cut Wood: We Need Pollution Prevention and Comparative Risk Assessment" in Worst Things First? The Debate over Risk-Based National Environmental Priorities, eds., Adam M. Finkel and D. Golding, Johns Hopkins University Press, 1994, 229-236.

69.* Evans, John S., Gray, George M., Robert L. Sielken, Jr., Smith, Andrew E., Flores, Ciriaco Valdez, and Graham, John D., "Use of Probabilistic Expert Judgment in Uncertainty Analysis of Carcinogenic Potency", Regulatory Toxicology and Pharmacology, Volume 20, 1994, 15-36.

70. Graham, John D., "The Risk Not Reduced", New York University Environmental Law Journal, Volume 3, No. 2, 1994, 382-404.

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University School of Law Conference, Superfund Reauthorization: Theoretical and Empirical Issues, December 3, 1993.

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Executive Courses

Course Director, Risk Analysis, Office of Continuing Education, Harvard School of Public Health (1991 to 2001).

Course Director, Risk Communication, Office of Continuing Education, Harvard School of Public Health (1995 to 2001).

Teaching Experience

Quantitative Policy Analysis, Graduate Level, Harvard School of Public Health, 1985 to 1990.

Methods of Cost-Benefit Analysis and Cost-Effectiveness Analysis for Health and Medicine, Graduate Level, 1991 to 2000.

Principles of Risk Analysis, Executive Education, Harvard School of Public Health, 1992 to 2000.

Principles of Risk Communication, Executive Education Harvard School of Public Health (Boston and Brussels), 1998 to 2000.

Introduction to Policy Analysis, Graduate Level, Pardee RAND Graduate School, 2006 to 2008.
Hazard Management in the U.S. and Europe, IU Overseas Study Course, Undergraduate Level (King's College – London), Indiana University, 2009 to 2017.

Case Studies in Policy Analysis, Undergraduate Level, Indiana University, 2012.

Introduction to National and International Policy, Undergraduate Level, Indiana University, 2013 to 2014.

Energy Policy from a Nation-State Perspective, Graduate Level, Indiana University, 2014, 2016.
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John D. Graham and Laura Cavagnaro, Commentary: "Save Big 3 by Making Buyers See Green for Fuel-Sipping Cars", Detroit Free Press, March 11, 2009.

John D. Graham, "Obama's Auto Pitfalls", The Journal of the American Enterprise Institute, August 16, 2009.

John D. Graham, "President Obama Can Shore Up His Popularity by Pushing Immigration Reform", appeared in 33 different newspapers including Taiwan News//Taipei, May 1, 2010; Fresno Sunday Bee, May 2, 2010; Contra Costa Sunday Times, May 9, 2010.

John D. Graham, "Small Cars and Personal Responsibility", The New York Times, May 27, 2010.

John D. Graham, "Can Obama Learn from Bush's Domestic Playbook?" The Washington Post, Political Bookworm by Steven Levingston, May 14, 2010.
http://voices.washingtonpost.com/political-bookworm/2010/05/can_obama_learn_from_bushs_dom.html

Denvil R. Duncan and John D. Graham, "Replacing the Gasoline Tax with a Road User Fee", The Ripon Forum, Vol. 47, No. 3, Summer 2013, p. 22.

Congressional and Administrative Testimony

John D. Graham, Testimony on "Clean Air Act Amendments of 1990", S.816: The Toxics Release Prevention Act of 1989, Subcommittee on Environmental Protection, Committee on Environment and Public Works, U. S. Senate, Washington, D.C., 101st Congress, Second Session, 1989.

John D. Graham, "Recommendations for Improving Cancer Risk Assessment", comments submitted to the National Academy of Sciences, California's Environmental Protection Agency and the U. S. Environmental Protection Agency, July 1, 1992.

John D. Graham, Testimony on S. 3373, "The Bullet, Death, and Family Dissolution Act", Subcommittee on Social Security and Family Policy, Finance Committee, U. S. Senate, Washington, D.C. 102nd Congress, Second Session, October 23, 1992.

John D. Graham, Comments submitted to Ms. Dorothy Strunk, OSHA, regarding Risk-Risk Analysis, October 23, 1992.

John D. Graham, Comments submitted to Mr. Orron Kee and Mr. Barry Felrice, NHTSA, regarding CAFÉ and Safety, January 4, 1993.

Susan Putnam, John D. Graham, George Gray, Sandy Baird, Katy Walker, and Kim Thompson, Comments on EPA's Integrated Risk Information System, submitted to the U. S. Environmental Protection Agency, April 15, 1993.

John D. Graham, Testimony on "Reform of the Delaney Clause", Subcommittee on Department Operations and Nutrition, Committee on Agriculture, U. S. House of Representatives, Washington, D.C., 103rd Congress, First Session, July 14, 1993.

John D. Graham, Testimony on "Reform of the Delaney Clause", Joint Hearing, House Subcommittee on Health and Environment and Senate Committee on Labor and Human Resources, Washington, D.C., 103rd Congress, First Session, September 21, 1993.

John D. Graham, Testimony on "The Role of Risk Analysis in Environmental Policy Making", Committee on Energy and Natural Resources, U. S. Senate, Washington, D.C., 103rd Congress, Second Session, November 9, 1993.

John D. Graham, Testimony on "The Role of Risk Assessment in Environmental Protection", Subcommittee on Transportation and Hazardous Materials, Committee on Energy and Commerce, U. S. House of Representatives, Washington, D.C., 103rd Congress, Second Session, November 17, 1993.

John D. Graham, "The Role of Risk Analysis in Environmental Protection", Subcommittee on Environment, Energy, and Natural Resources, Subcommittee on Legislation and National Security, Committee on Government Operations, U. S. House of Representatives, Washington, D.C., 103rd Congress, Second Session, February 1, 1994.

John D. Graham, Testimony on Title III, H.R. 9, "Risk Assessment and Cost-Benefit Analysis of New Regulations", Committee on Science, U. S. House of Representatives, Washington, D.C., 104th Congress, First Session, January 31, 1995.

John D. Graham, Testimony on Title III, H.R. 9, "Risk Assessment and Cost-Benefit Analysis of New Regulations", Committee on Commerce, U. S. House of Representatives, Washington, D.C., 104th Congress, First Session, February 2, 1995.

John D. Graham, Testimony on S. 291, "Regulatory Reform Act of 1995", Governmental Affairs Committee, U. S. Senate, Washington, D.C., 104th Congress, First Session, February 15, 1995.

John D. Graham, Testimony on S. 123, S. 229, S. 333, and S. 343, "Impacts of Regulatory Reform on Environmental Law", Committee on Environment and Public Works, U. S. Senate, Washington, D.C., 104th Congress, First Session, March 22, 1995.

John D. Graham, Statement to the National Transportation Safety Board, Supplemental Restraint Panel, Washington, D.C., March 17, 1997.

John D. Graham, Statement to the National Transportation Safety Board, Effectiveness Panel, Washington, D.C., March 19, 1997.

John D. Graham, Testimony on S. 981, "Regulatory Improvement Act of 1997, " Committee on Governmental Affairs, U. S. Senate, Washington, D.C., 105th Congress, First Session, September 12, 1997.

John D. Graham, Testimony on "The Role of Risk Science in Decision Making", Committee on Science, U. S. House of Representatives, Washington, D.C., 105th Congress, June 10, 1998.
John D. Graham, Testimony on the "Regulatory Improvement Act of 1999" (S. 746), Committee on Governmental Affairs, U. S. Senate, Washington, D.C., April 21, 1999.

John D. Graham, Testimony on "Reauthorization of the Clean Air Act", Committee on Governmental Affairs, U. S. Senate, Washington D.C., October 14, 1999.

John D. Graham, Testimony on "Biotechnology in the Year 2000 and Beyond", U. S. Food and Drug Administration, Washington, D.C., November 30, 1999.

John D. Graham, Testimony on "Comparative Risk Assessment and Environmental Decision Making", Committee on Environment and Public Works, U. S. Senate, July 27, 2000.

John D. Graham, Testimony on "Cost-Justifying Regulations: Protecting Jobs and the Economy by Presidential and Judicial Review of Costs and Benefits", Subcommittee on Courts, Commercial and Administrative Law, House Judiciary Committee, U.S. Congress, May 4, 2011.

John D. Graham, Testimony on "How A Broken Process Leads to Flawed Regulations", OMB-OIRA Oversight Hearing, Committee on Oversight and Government Reform, House of Representatives, United States Congress, September 14, 2011.

John D. Graham, Testimony on the "Office of Information and Regulatory Affairs: Federal Regulations and Regulatory Reform under the Obama Administration", Committee on the Judiciary, House of Representatives, United States Congress, March 21, 2012.

John D. Graham, Testimony on "Regulatory Aspects of Trans-Atlantic Trade and Investment Partnership (TTIP)", U.S.-EU Free Trade Agreement, Committee on Trade, European

Parliament, Brussels, Belgium, October 14, 2013.

John D. Graham, Testimony on "Secret Science Reform Act of 2014", Committee on Science, Space and Technology, Secret Science Reform Act of 2014, U.S. House of Representatives, Washington, D.C., February 11, 2014.

John D. Graham, Testimony on "The First Step to Cutting Red Tape: Better Analysis", Joint Economic Committee, U.S. Congress, Washington, D.C., April 30, 2014.

John D. Graham, Testimony on "A Regulatory Budget and the U.S. Economy", Committee on the Budget, United States Senate, Washington, D.C., December 9, 2015.

John D. Graham, Testimony on "Examining Federal Rulemaking Challenges and Areas of Improvement Within the Existing Regulatory Process", Subcommittee on Regulatory Affairs and Federal Management, Committee on Homeland Security and Governmental Affairs, United States Senate, Washington, D.C., March 19, 2015.

John D. Graham, Testimony on "Surface Transportation Reauthorization: Performance, not Prescription", Subcommittee on Surface Transportation, Committee on Commerce, United States Senate, Washington, DC., March 24, 2015.

John D. Graham, Testimony on "The Federal Government on Autopilot: Delegation of Regulatory Authority to an Unaccountable Bureaucracy", Committee on the Judiciary, U.S. House of Representatives, Washington, D.C., May 24, 2016.

John D. Graham, Testimony on "Proposed Crew-Staffing Rule", Federal Railroad Association, Docket No: FRA-2014-0033, U.S. Department of Transportation, Washington, D.C., July 15, 2016.

John D. Graham, Testimony on "Midterm Review and an Update on the Corporate Average Fuel Economy Program and Greenhouse Gas Emissions Standards for Motor Vehicles", Subcommittee on Commerce, Manufacturing, and Trade and the Subcommittee on Energy and Power, U.S. House of Representatives, Washington, D.C., September 22, 2016.

Personal Facts

Born October 3, 1956 (Pittsburgh, PA); married to Susan W. Graham; daughters, Jennifer Ann Staver and Kathryn Graham; granddaughters Louisa and Isabella; hobbies include golf, ballroom dancing and bridge. Home address: 2417 Boston Road, Bloomington, IN 47401

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HOWARD GRUENSPECHT
Massachusetts Institute of Technology
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Education:

1979-1981 and 1976-1977 YALE UNIVERSITY, New Haven, CT
Ph.D. in Economics, 1982
· Dissertation: "Differentiated Regulation: The Case of Auto Emissions Standards"
· Brookings Research Fellow 1979-1980

1972-1975 McGILL UNIVERSITY, Montreal, P.Q., CANADA
B.A. in Economics 1975
· Allan Oliver Gold Medal

Professional Experience:

2017- MASSACHUSETTS INSTITUTE OF TECHNOLOGY ENERGY INTIATIVE
Senior Energy Economist
Conducts research on energy storage and energy use in electricity generation and transportation

2003-2017 U.S. ENERGY INFORMATION ADMINISTRATION
Deputy Administrator
· Chief operating officer of $122 million energy analysis and data program
· Responsibilities include oversight of energy data and analysis programs, budget formulation and execution, frequent testimony before Congressional committees, interagency deliberations and public speaking engagements.
· Presidential Distinguished Executive Rank Award, 2007
Adelman-Frankel Award, U.S. Association for Energy Economics, 2015

2000- 2003 RESOURCES FOR THE FUTURE, Washington, DC
Resident Scholar
· Conducted policy-relevant research on energy and environmental issues.

1991- 2000 U.S. DEPARTMENT OF ENERGY, Washington, DC
Director, Office of Economic, Electricity and Natural Gas Analysis
Deputy Assistant Secretary for Economic and Environmental Policy
· Developed positions on energy, regulatory, and environmental policy issues, including electricity restructuring and climate change.
· Represented the Department in testimony before Congressional committees, legislative negotiations for 1992 National Energy Policy Act, international scientific and negotiations on the Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change, interagency deliberations and public speaking engagements.
· Presidential Distinguished Executive Rank Award, 1999

1989-1991 EXECUTIVE OFFICE OF THE PRESIDENT, Washington, DC

Senior Staff Economist, Council of Economic Advisers

- Developed CEA positions on energy, environmental, regulatory, and trade policy issues, including the Clean Air Act and global change.
- Drafted environment sections of 1990 Economic Report of the President and Interagency White Paper on the Economics of Long-term Climate Change.
- Represented CEA in interagency deliberations, congressional negotiations and public speaking engagements.

1988-1989 U.S. INTERNATIONAL TRADE COMMISSION, Washington, DC

Economic Adviser to the Chairman

- Executed economic analyses of antidumping, countervailing duty, and escape clause cases as a primary input to the Chairman's injury determinations.
- Directed staff regarding the structure and content of reports prepared in response to requests from the Office of the Trade Representative and Congress.
- Advised the Chairman on personnel matters involving senior economics positions inside the Commission.

1982-1988 TEPPER SCHOOL OF BUSINESS

CARNEGIE MELLON UNIVERSITY, Pittsburgh PA

Assistant Professor of Economics

- Responsibilities included research, publication, and teaching in economic and social regulation and international trade and competitiveness.
- Courses taught included Energy and Environmental Economics, Microeconomics, International Trade and Competitiveness, and Political Economy.

1984-1985 THE BROOKINGS INSTITUTION, Washington DC

Associated Staff

- Co-authored Regulating the Automobile, a study of safety, emissions, and fuel economy regulation and its impact on the automobile industry.

1978-1979 THE WHITE HOUSE, Washington, DC

Assistant Director, Economics and Business, Domestic Policy Staff

- Advised the Assistant to the President for Domestic Affairs and Policy on regulatory, economic, and trade policy issues.
- Negotiated policy positions on regulatory, economic and trade issues within the Administration and with senior congressional staff.
- Drafted decision memos presenting agency positions to the President.

Other Professional Activities:

Guest lecturer on energy issues for classes at Yale, Carnegie Mellon, and George Washington universities – usually 1 class or seminar per year at each institution over the last several years

Author or co-author of academic and policy papers – list of selected papers is attached

Referee for several professional journals.

HOWARD K. GRUENSPECHT: Selected Publications and Working Papers

(Note: excludes book reviews, testimonies, presentations, published comments, etc.)

Portney, Paul, Ian Parry, Howard Gruenspecht, and Winston Harrington. "The Economics of Fuel Economy Standards." *The Journal of Economic Perspectives*, vol. 17, no. 4, pp 203-217 (2003)

Gruenspecht, Howard. Regulatory Tailoring, Reliability, and Price Volatility with Stochastic Breakdowns. RFF Discussion Paper 02-37. September 2002

Gruenspecht, Howard and Robert Stavins. "New Source Review Under the Clean Air Act: Ripe for Reform" *Resources*, Winter 2002.

Gruenspecht, Howard. "Zero Emissions Vehicles: A Dirty Little Secret" *Resources* Winter 2001.

Gruenspecht, Howard and Tracy Terry. Horizontal Market Power in Restructured Electricity Markets, Office of Policy, Department of Energy, PO-0060, March 2000.

Gruenspecht, Howard and John Conti. Supporting Analysis for the Comprehensive Electricity Competition Act, Office of Policy, Department of Energy, PO-0058, May 1999.

Richels, Richard., Jae Edmonds, Howard Gruenspecht, and Tom Wigley. The Berlin Mandate: The Design of Cost-effective Mitigation Strategies. (In) *Report on the Regional Distribution of the Costs and Benefits of Climate Change Policy Proposals*, Energy Modeling Forum-14, Stanford University, Stanford, California, 1996

Gruenspecht, Howard. "Trade and Environment: A Tale of Two Paradigms," in Agriculture, Trade, and the Environment: Discovering and Measuring the Critical Linkages, M. Bredahl, ed., Westview Press (1996).

Rosenthal, Donald, Howard Gruenspecht, and Emily Moran. "Effects of Global Warming on Energy Use for Space Heating and Space Cooling in the United States," *The Energy Journal*, vol. 16, no. 2, pp.77-96 (1995).

Lave, Lester and Gruenspecht, H.K. Benefit-cost analysis and effluent fees: A Critical Review. *Journal of the Air and Waste Management Association*, vol 41, no. 5 pp. 679-701 (1991).

Gruenspecht, Howard. "Forging New Links With Economic Policy," *EPA Journal*, vol. 16, no. 5, pp.36-38 (1990).

Gruenspecht, Howard, John Antle, Richard Schmalensee. "The Economy and the Environment," in Economic Report of the President, Council of Economic Advisers, Washington, DC 1990.

Gruenspecht, Howard, and Lester Lave. "The Economics of Health, Safety and Environmental Regulation," in Handbook of Industrial Organization, vol II, R. Schmalensee, R.D. Willig, eds., Elsevier, New York, 1989.

Gruenspecht, Howard. "Export Subsidies for Differentiated Products," *Journal of International Economics*, vol.24 pp.331-344 (1988).

Gruenspecht, Howard. "Dumping and Dynamic Competition," *Journal of International Economics*, vol 25. pp.225-248 (1988).

Crandall, Robert, Howard Gruenspecht, Ted Keeler, Lester Lave, Regulating the Automobile Brookings Institution, Washington, DC 1986.

Gruenspecht, Howard. "Differentiated Regulation: The Case of Automobile Emissions Standards," *American Economic Review*, vol 72, no.2, pp.328-331 (1982)

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CURRENT EMPLOYMENT AND AFFILIATIONS

Assistant Professor, Department of Agricultural and Resource Economics (July 2015—present)
University of California, Berkeley
Faculty Research Fellow, National Bureau of Economic Research (April 2010—present)
Public Economics and Energy and Environmental Economics Programs
Research Associate, Energy Institute at Haas (March 2016—present)
Faculty Affiliate, E2e Program (January 2014—present)
Faculty Affiliate, Institute for Research on Labor and Employment (July 2016—present)

PAST EMPLOYMENT

Assistant Professor, Harris School of Public Policy Studies (July 2008 – June 2015)
University of Chicago
Visiting Researcher, University of California Energy Institute (August 2010 – December 2010)

EDUCATION

University of Michigan, Ph.D. in Economics (2008)
Dissertation: *Three Essays in Public Economics*
Committee: Joel Slemrod (Chair), Rebecca Blank, James Hines, Jeffrey Smith
University of Michigan, M.A. in Economics (2005)
Macalester College, B.A. in Economics and Political Science, *Summa Cum Laude*, ΦBK (2001)

PUBLISHED ARTICLES (peer reviewed unless otherwise noted)

"The Use of Regression Statistics to Analyze Imperfect Pricing Policies" (with Mark R. Jacobsen, Christopher R. Knittel and Arthur van Benthem) *Journal of Political Economy* conditionally accepted.

"The Economics of Attribute-Based Regulation: Theory and Evidence from Fuel-Economy Standards" (with Koichiro Ito) *Review of Economics and Statistics* 100, May 2018, pp. 319-336.

"Tax Incidence with Endogenous Quality and Costly Bargaining: Theory and Evidence from Hybrid Vehicle Sales" (with Sumeet Gulati and Carol McAusland) *Journal of Public Economics* 155, November 2017, pp. 93-107.

"Disparities in Complex Price Negotiations: The Role of Consumer Age and Gender" (with Ambarish Chandra and Sumeet Gulati). *Journal of Industrial Economics* 64(2), June 2017, pp. 235-74.

"Do Consumers Recognize the Value of Fuel Economy? Evidence from Used Car Prices and Gasoline Price Fluctuations" (with Sarah West and Wei Fan) *Journal of Public Economics* 134, March 2016, pp. 61-73.

"Designing Policies to Make Cars Greener: A Review of the Literature" (with Soren T. Anderson) *Annual Review of Resource Economics* 8, 2016, 157-80.

"The Intergenerational Transmission of Automobile Brand Preferences: Empirical Evidence and Implications for Firm Strategy" (with Soren T. Anderson, Ryan Kellogg and Ashley Langer) *Journal of Industrial Economics*, 63(4), December 2015, pp. 763-793.

"New Evidence on Taxes and the Timing of Birth" (with Sara LaLumia and Nicholas Turner) *American Economic Journal: Economic Policy*, 7(2), May 2015, pp. 258-293.

"Rational Inattention and Energy Efficiency" *Journal of Law and Economics*, 57(3), August 2014, pp. 781-820.

"What Do Consumers Believe About Future Gasoline Prices? (with Soren T. Anderson and Ryan Kellogg) *Journal of Environmental Economics and Management*, 66(3), November 2013, pp. 383-403.

"The Value of Honesty: Empirical Estimates from the Case of the Missing Children" (with Sara LaLumia) *International Tax and Public Finance*, 20(2), April 2013, pp. 192-224.

"Car Notches: Strategic Automaker Responses to Fuel Economy Policy" (with Joel Slemrod) *Journal of Public Economics*, 96(11-12), December 2012, pp. 981-999.
*Awarded the 2015 Atkinson Award (Best Paper in the *Journal of Public Economics* 2012-4)

"Financial Reporting, Tax, and Real Decisions: Toward a Unifying Framework" (with Douglas A. Shackelford and Joel Slemrod), *International Tax and Public Finance*, 18(4), August 2011, pp. 461-494.

"Using Loopholes to Reveal the Marginal Cost of Regulation: The Case of Fuel-Economy Standards" (with Soren T. Anderson) *American Economic Review* 101(4), June 2011, pp. 1375-1409.

"The Surprising Incidence of Tax Credits for the Toyota Prius" *American Economic Journal: Economic Policy*, 3(2), May 2011, pp. 189-219.

"Forecasting Gasoline Prices Using Consumer Surveys" (with Soren T. Anderson, Ryan Kellogg and Richard M. Curtin) *American Economic Review Papers & Proceedings* 101(3), May 2011, pp. 110-114. (Not Peer Reviewed)

"Fuel Economy Standards: Impacts, Efficiency, and Alternatives" (with Soren Anderson, Carolyn Fischer and Ian Parry), *Review of Environmental Economics and Policy*, 5(1), Winter 2011, pp. 89-108.

"The Taxation of Fuel Economy" *Tax Policy and the Economy* v. 25, Editor Jeffrey R. Brown, NBER: University of Chicago Press, 2011, pp. 1-38. (Not Peer Reviewed)

"A Cautionary Tale About the Use of Administrative Data: Evidence from Age of Marriage Laws" (with Rebecca M. Blank and Kerwin Kofi Charles), *American Economic Journal: Applied Microeconomics,*1(2), April 2009, pp. 128 - 149.

"On the Optimal Allocation of Students and Resources in a System of Higher Education" (with Alexandra M. Resch and Paul N. Courant) *The B.E. Journal of Economic Analysis & Policy* (Advances Tier), 8(1), Article 11.

WORKING PAPERS

"Who Benefits When Firms Game Corrective Policies?" (with Mathias Reynaert) *Submitted*.

SELECTED WORK IN PROGRESS

"Pigou Creates Losers: On the Implausibility of Pareto Improvements from Pigouvian Taxation"

"Are Local Air Pollution Regulations for New Vehicles Effective and Efficient?" (with Mark Jacobsen, Joseph Shapiro and Arthur van Benthem)

"Durable Goods Demand and the Rationality of Consumers' Price Expectations: Evidence from Gasoline and Diesel" (with Ryan Kellogg)

AWARDS AND HONORS

Sloan Foundation Grant (*Heterogeneity, Equity and Energy Policy* 2017-8)
Club Six (2017, recognition for teaching scores above 6 out of possible 7, Haas MBA)
Hellman Family Faculty Fund Award (2017)
UC Regents' Junior Faculty Fellowship (2016)
France-Berkeley Fund Award (2016)
Atkinson Award (2015, for best Paper in the *Journal of Public Economics* between 2012-2014)
Best Teacher in a Core Course, The Harris School (2012, 2013)
W.E. Upjohn Institute Early Career Research Grant (with Reed Walker) (2012)
Certificate of Excellence in Reviewing, *Journal of Public Economics* (2012)
John V. Krutilla Research Award from Resources for the Future (2009 - 2010)
National Tax Association Dissertation Award (2008)
National Science Foundation Graduate Research Fellowship (awarded 2003)
Population Studies Center Trainee Fellowship, University of Michigan (2003-2008)

TEACHING

University of California, Berkeley
Environmental and Resource Economics, ARE 261 (PhD)
Environmental Economics, EEP 101/ECON 125 (Undergraduate)
Economic Analysis for Business Decisions (Core micro for MBAs), MBA201A
taught at Haas School of Business

University of Chicago (all for MPP students)
Policy Approaches to Mitigating Climate Change
Topics in U.S. Tax Policy
Empirical Methods in Policy Analysis II
Science, Technology and Policy

REFEREE

Editorial Council Member (2014-) *Journal of the Association of Environment and Resource Economists*

American Economic Review, Journal of Political Economy, Quarterly Journal of Economics, Econometrica, American Economic Review: Insights, Journal of Public Economics, American Economic Journal: Economic Policy, American Economic Journal: Applied Economics, Review of Economics and Statistics, RAND Journal of Economics, Journal of Environmental Economics and Management, National Tax Journal, Journal of the Association of Environment and Resource Economists, Journal of Labor Economics, International Economic Review, European Economic Review, International Tax and Public Finance, Journal of Law & Economics, Economic Journal, Energy Journal, Canadian Journal of Economics, Nature, B.E. Journal of Economic Analysis & Policy, Economic Inquiry, Journal of Human Resources, Economic Letters, Energy Economics, Environmental and Resource Economics, Journal of Urban Economics, Journal of Policy Analysis and Management, Transportation Research Part A, Journal of Population Economics, Environmental Policy and Governance, Scottish Journal of Political Economy ***Grants:*** *National Science Foundation, European Science Foundation, Sloan Foundation, Smith Richardson Foundation, Time-Sharing Experiments for the Social Sciences*

SELECTED PRESENTATIONS

Invited **2017:** UC Santa Cruz (Economics) **2016:** Berkeley (Economics), UC Davis (ARE), Texas A&M (Economics), FGV Rio de Janeiro (Economics), Resources for the Future, Arizona State **2015:** LSE (Economics), Berkeley (Goldman), UCLA (Luskin), Colorado School of Mines (Economics), Universidad de Chile (Business School), Pontificia Universidad Catolica de Chile (Economics) **2014:** Michigan (Ross), Berkeley (ARE), University of Pennsylvania (Wharton), Berkeley (POWER Conference), Yale (FES), Illinois (Economics), National Tax Association Spring Symposium, Federal Trade Commission, EPA, University of Leuven (Economics), Universidad de Chile (Business School), Pontificia Universidad Catolica de Chile (Economics) **2013:** Georgetown (Economics), Illinois (Economics), Wisconsin (Economics) **2012:** Maryland (Economics), Northwestern (Law), Universidad de Chile (Business School), Oxford (Business School); **2011:** Columbia (Economics), Maryland (AREC), Syracuse (Maxwell), Illinois (Finance), Ohio State (Economics), Illinois (Sustainability Center), NYU (Law conference), University of Illinois at Chicago (Sustainability workshop), Treasury, EPA, Resources for the Future (Conference); **2010:** MIT (Economics), Yale (FES), Berkeley (ARE), Berkeley (UCEI), NBER Tax Policy and the Economy, University of Chile; **2009:** Cornell (Economics), Minnesota (Applied Economics), North Carolina State University (Economics), Berkeley (POWER Conference), University of Illinois at Chicago (Economics), Macalester College (Economics); **2008:** Resources for the Future, University of Chicago (Harris), University of Pennsylvania (Wharton), University of British Columbia (Economics), University of Kentucky (Martin/Economics), University of Indiana (SPEA), University of California, Irvine (Economics), Treasury, Ford Motor Company

Conference **2018:** ASSA (AEA) **2017:** National Tax Association, ASSA (AEA) **2016:** NBER EEE Summer Institute, Stanford Institute for Theoretical Economics, National Tax Association, Heartland Environmental and Resource Economics **2015:** NBER EEE **2014:** ASSA (AEA and AERE), NBER EEE, NBER Public Economics, Oxford Tax Systems Conference, Michigan Tax Invitational **2012:** NBER Public Economics, National Tax Association, Michigan Tax Invitational **2011:** National Tax Association, ASSA, Association of Environmental and Resource Economics, International Institute of Public Finance, University of California Energy Institute; **2010:** NBER Public Economics, Iowa State Bioenergy Camp; **2009:** ASSA, National Tax Association, Heartland Environmental and Resource Economics; **2008:** APPAM, National Tax Association; **2007:** NBER Summer Institute (EEE), National Tax Association, APPAM

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National Highway
Traffic Safety
Administration

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