U.S. Department of Transportation

National Highway Traffic Safety Administration

NHTSA

DOT HS 812 590

July 2018

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

Introduction

The 1975 Energy Policy Conservation Act (EPCA) requires that the Secretary of the Department of Transportation (DOT) 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 (NHTSA), an agency of the U.S. Department of Transportation (DOT). 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 the impacts of potential standards to inform rulemaking to set 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. 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 such a review in 2005, and seeks another such review at this time.

Overview of Task

The peer review charge is to identify potential opportunities for further improvement 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.

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 determined 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 facilitate estimation of 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 forecast—specified in another input file—of the future vehicle market provides the foundation for analysis. 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, impacts on fuel consumption, and costs. A fourth file contains a wide range of economic and other inputs, such as vehicle survival and mileage accumulation rates (both versus 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.

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	**Simulation of Manufacturers' Application of Fuel-Saving Technologies**
1a	Please comment on the use of technology classes to accommodate different technology-related inputs for different types of vehicles (e.g., small cars, pickup trucks).
1b	Please comment on the technology pathways used to sequence the evaluation of opportunities to apply different types of technologies (e.g., turbocharged engines, automatic transmissions).
1c	Please comment on the model's approach to accounting for the extent to which various technologies are already present in vehicles specified in the baseline fleet.
1d	Please comment on 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.
1e	Please comment on the model's approach to representing manufacturers' product development as a logical year-by-year progression involving the scheduled redesign of vehicles, commonalities within vehicle platforms, and sharing of engines and transmissions.
1f	Please comment on 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 (the model does not currently simulated credit carry-back or credit trading between manufacturers), and the civil penalties levied for noncompliance.

1g	Please comment on the model's approach to varying the relative market shares of passenger cars and light trucks in response to fuel prices.
1h	Please comment on the model's simulation of manufacturers' potential decisions to apply technology, considering the roles of product portfolio and redesign cadence, technology-related inputs, CAFE standards and regulations (e.g., regarding civil penalties), and fuel prices.
2	**Estimation of Impacts**
2a	Please comment on the model's approach to estimating vehicle survival and use (i.e., vehicle miles traveled), including the model's application of the input defining a "rebound" effect.
2b	Please comment on the model's approach to estimating total fuel consumption and carbon dioxide emissions.
2c	Please comment on the model's approach to estimating total emissions of "criteria" pollutants (e.g., nitrogen oxides) and greenhouse gases (e.g., methane) other than carbon dioxide.
2d	Please comment on the model's approach to estimating numbers of highway fatalities.
2e	Please comment on the model's approach to estimating the monetized social benefits of a given regulatory alternative (compared to a defined baseline or "no action" alternative).
2f	Please comment on the model's approach to estimating the monetized social costs of a given regulatory alternative (compared to a defined baseline or "no action" alternative).
3	**General Comments**
3a	Please comment on the organization, readability, accuracy, and clarity of the model documentation.
3b	Please comment on the organization, structure, and clarity of the model input files.
3c	Please comment on the organization, structure, and clarity of the model output files.
3d	Please comment on the model's ease and clarity of operation.
3e	Please provide any other comments you may have on the CAFE model.

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)

Concern 1:
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?

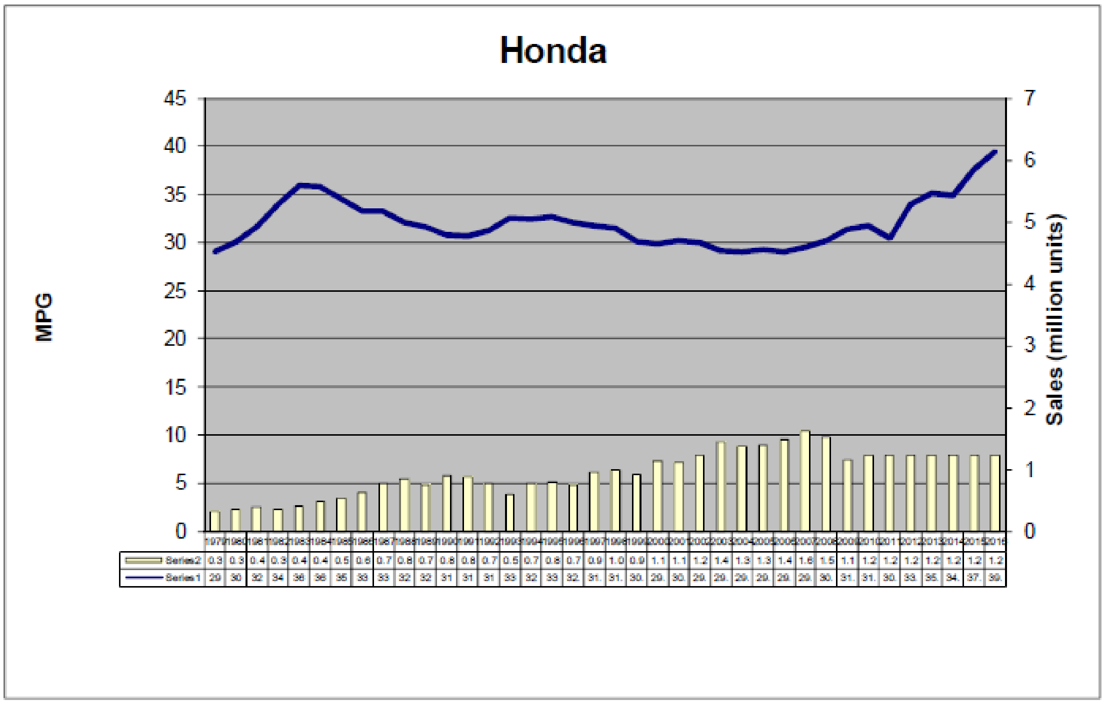
   The simplest solution is to "cap" redesign at some fixed percentage the fleet redesign or **limit the maximum fuel economy improvement in the fleet to the historical average**. This would also necessitate a limit on subsequent year improvements to give a breather.

   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.

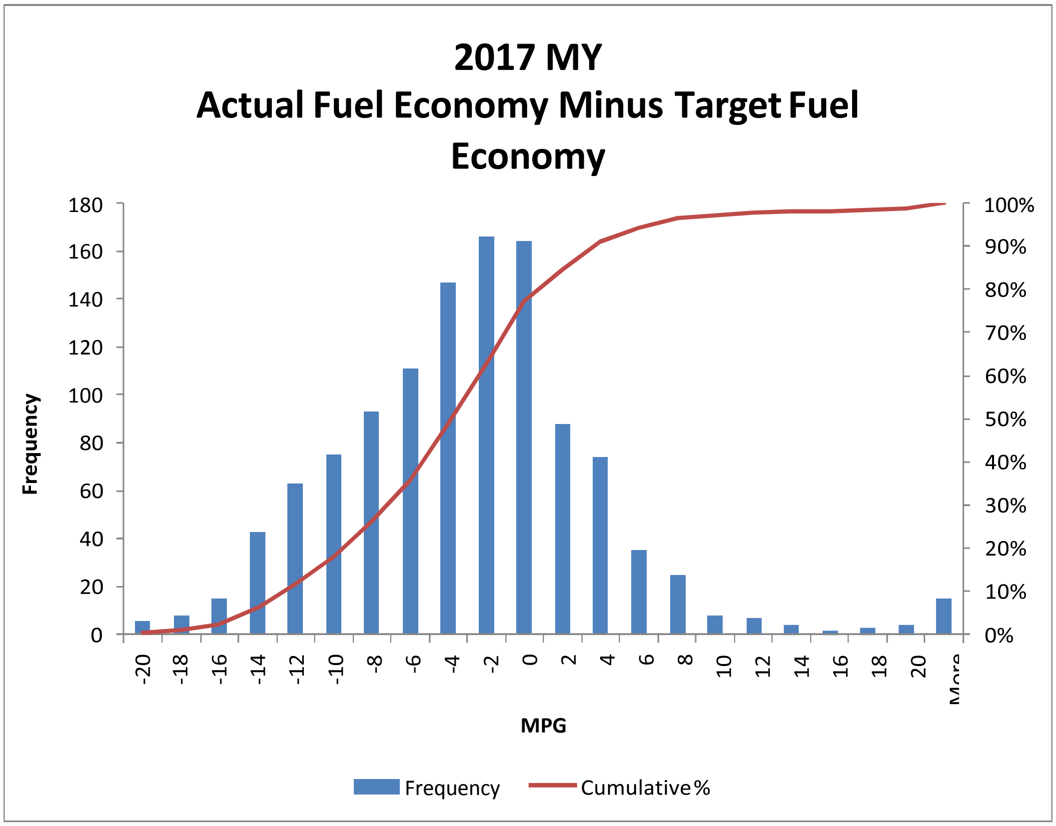
Further this puts an enormous amount of pressure on the fuel pricing assumptions, customers' valuation of fuel economy technology, and other factors outside the control of manufacturers.

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 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. 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.

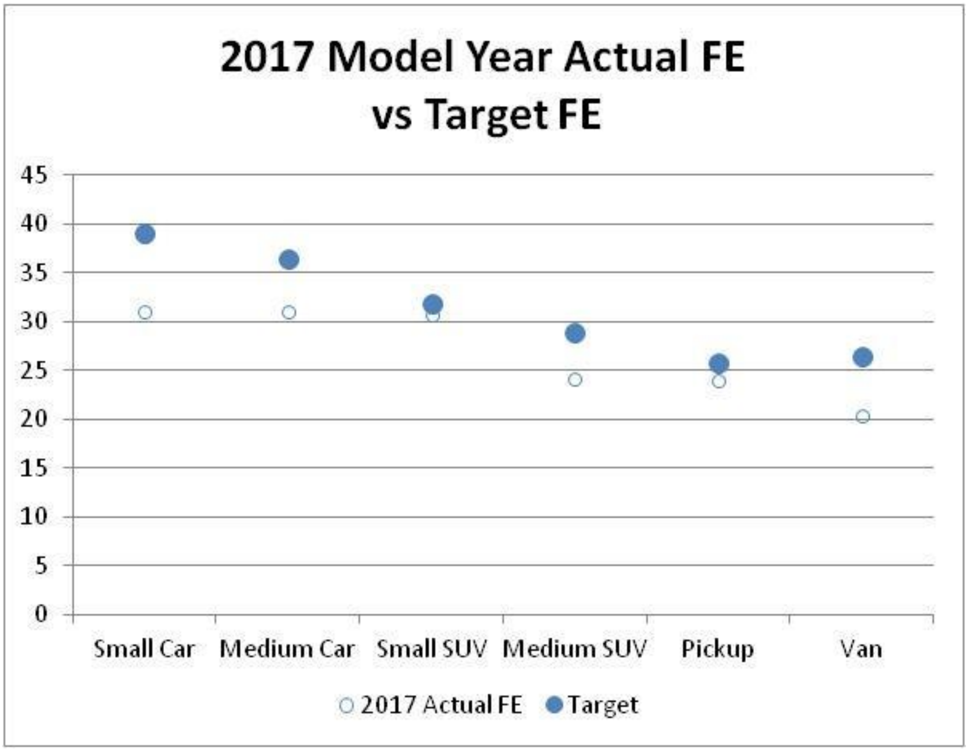
   The reasons for this gap in the small car fleet are many. This category includes many exotic sports cars and some high horsepower products. These products are not marketed for their fuel economy and most of the customers purchasing these products fuel economy is low on their list of priorities.

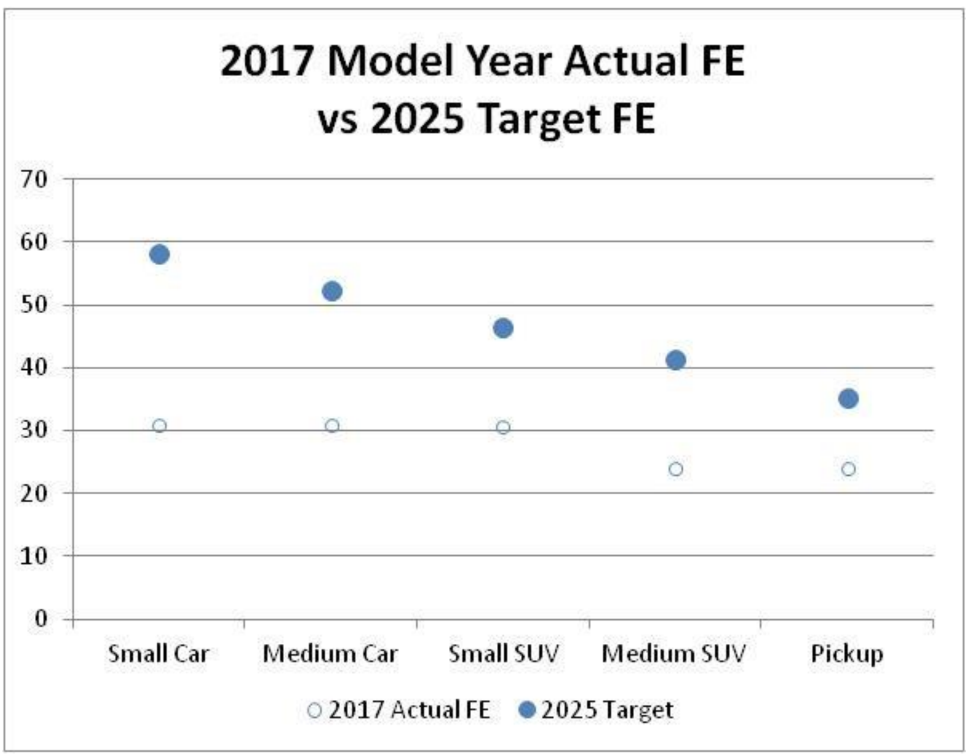
   It should be noted that some of the manufacturers routinely elect to pay CAFE fines and even the gas guzzler penalties in this segment. This behavior is unlikely to change.

   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, Sk, 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

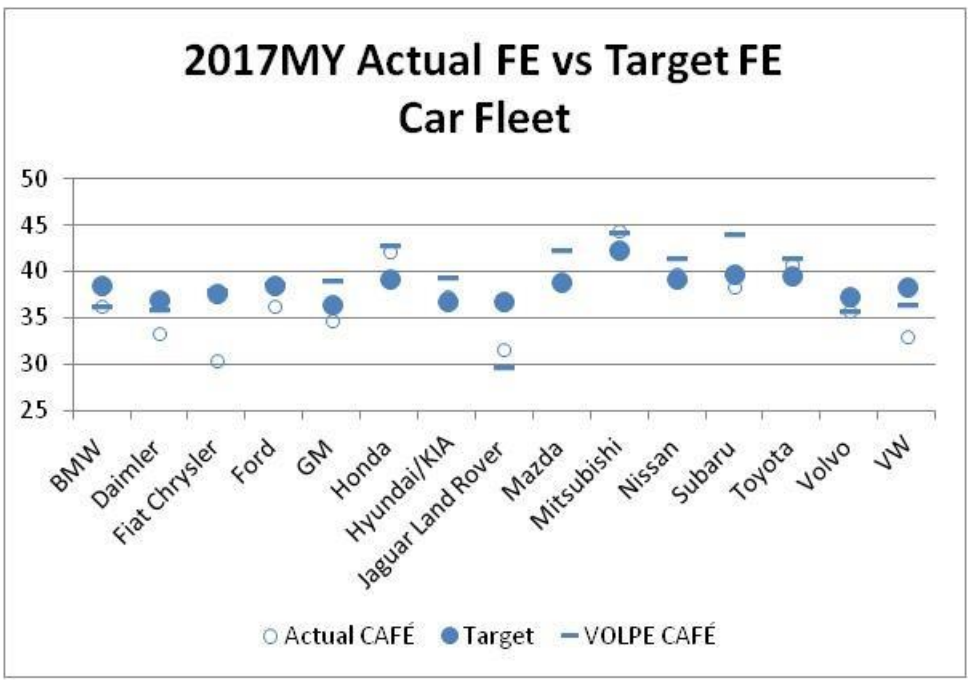
REVIEW TOPIC NUMBER 3.1. DEVELOPMENT AND USE OF MY2015 ANALYSIS (INITIALIZED) FLEET (INCLUDES VEHICLE MODELS AND THEIR EXISTING TECHNOLOGY CONTENT CHARACTERIZED BY ENGINE, TRANSMISSION, VEHICLE ATTRIBUTES, AND OTHER TECHNOLOGIES)

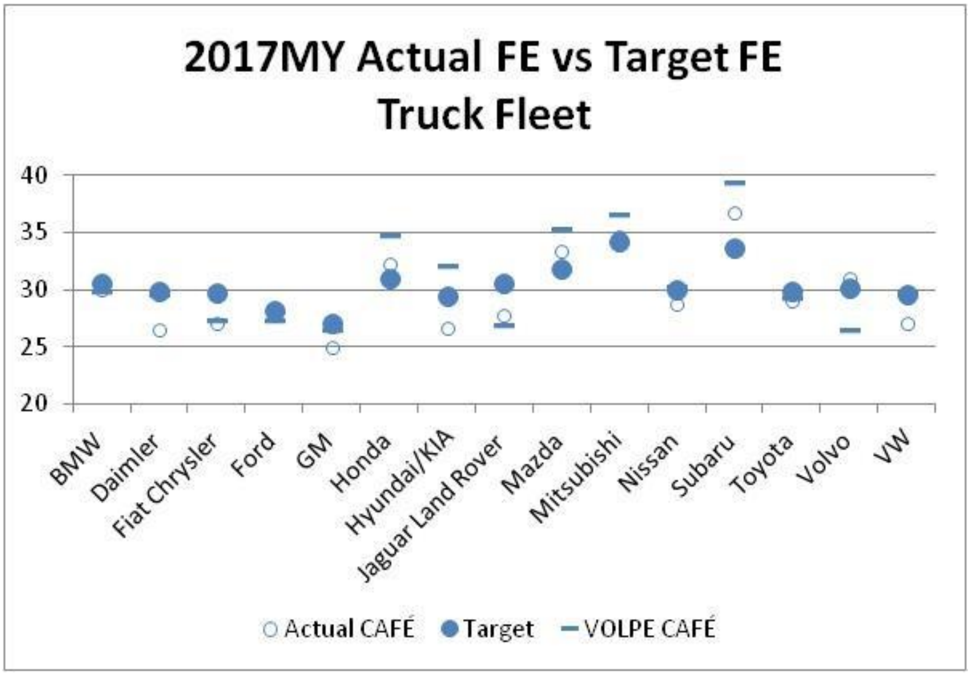
There seems to be some inconsistencies in the application of the MY2015 Analysis Fleet. For example, I counted over 280 line items that met the VOLPE definition of AERO10 yet did not have the technology marked as USED. (Also see 4.4 below)

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

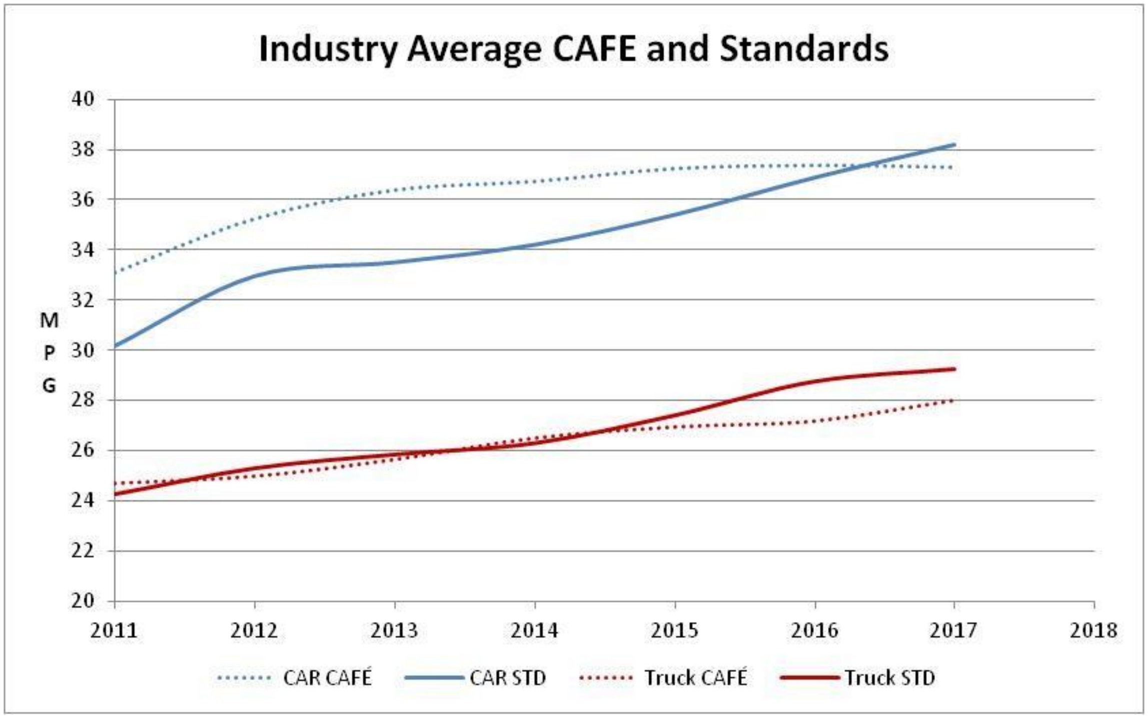
1. What are the most important concerns that should be taken into account related to the review topic?

   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.

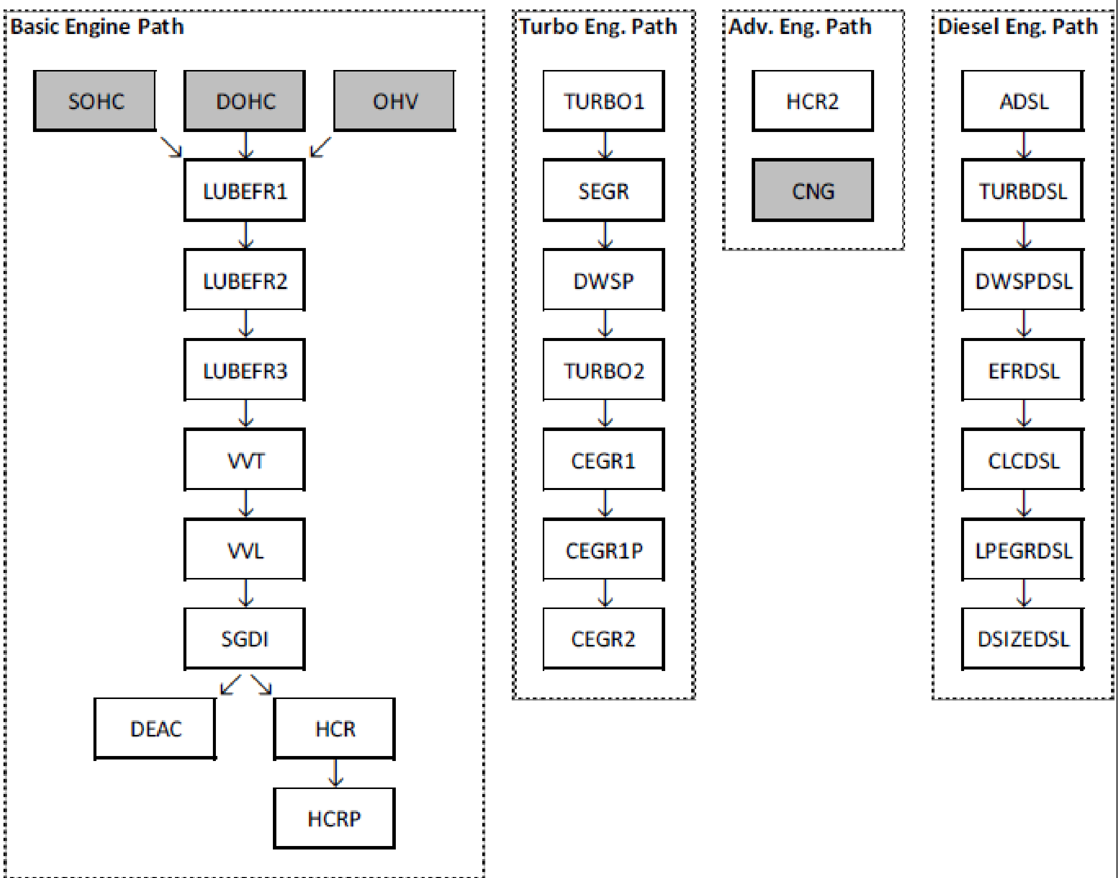


Figure 2. Engine-Level Paths

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.

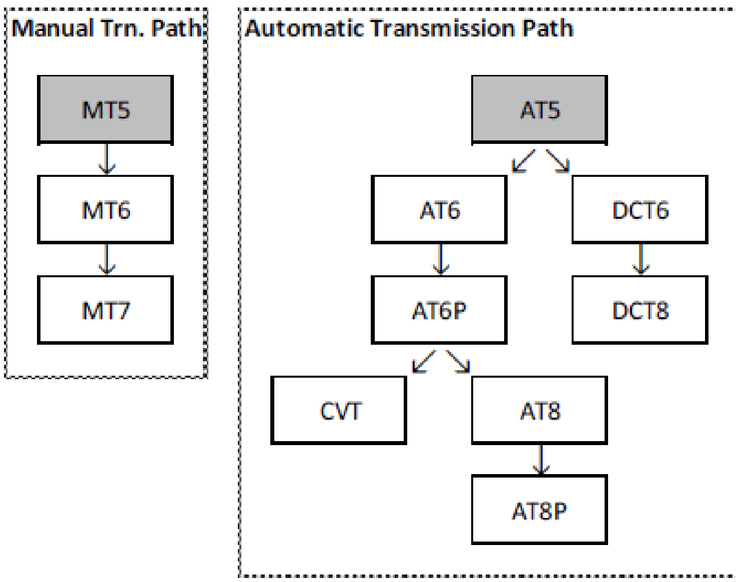


Figure 3. Transmission-Level Paths

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

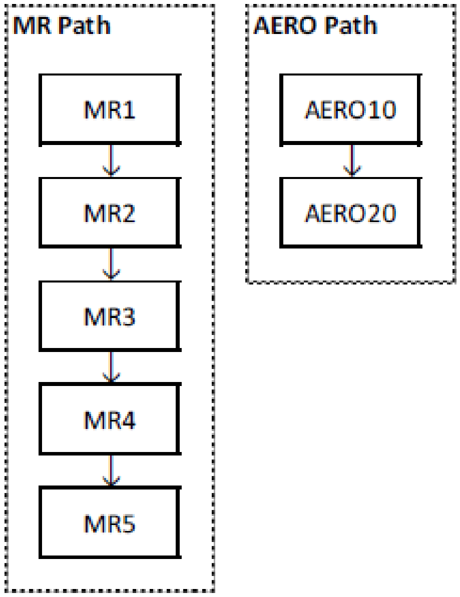


Figure 4. Platform-Level Paths

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.

<u>Recommendation 7:</u>
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.

<u>Concern 8:</u>
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 <u>required</u> baseline fuel economy used the Volpe Model for adding technologies to provide improvements over the baseline fuel economy to achieve CAFE compliance.

<u>Recommendation 8:</u>
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 <u>required</u> 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.

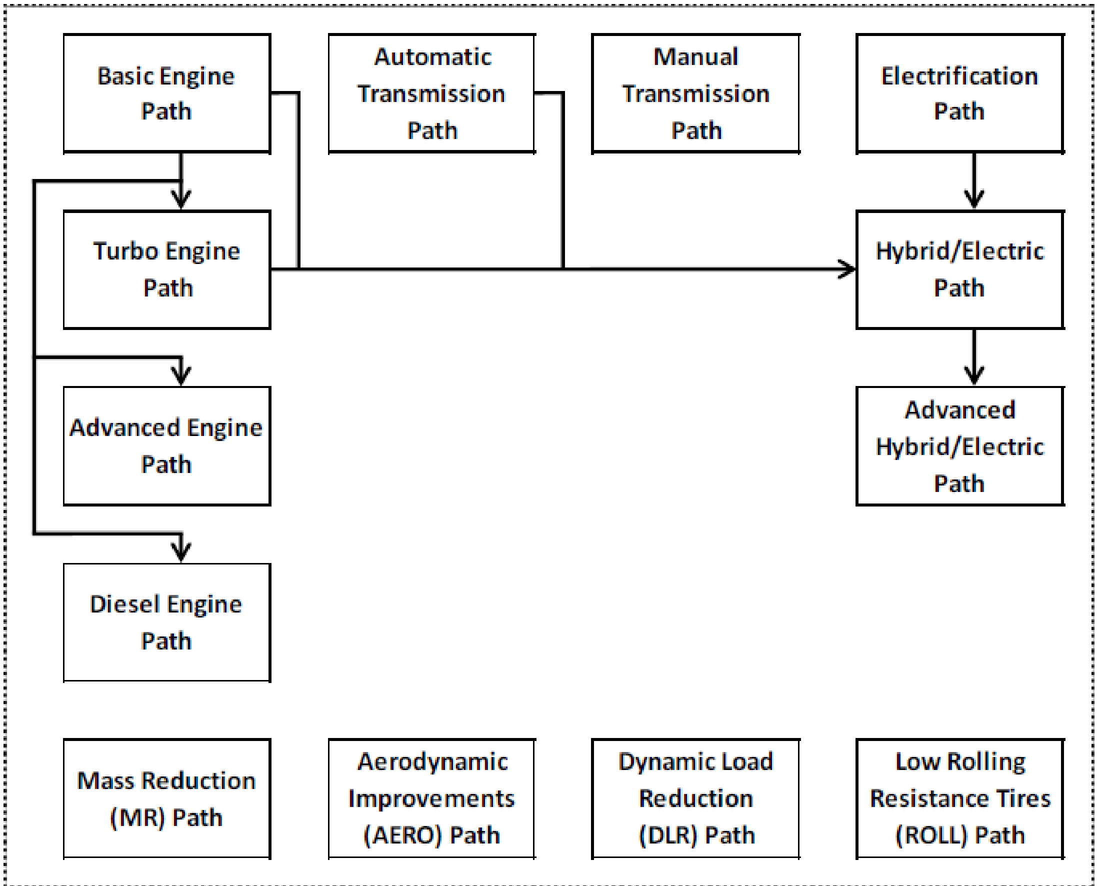


Figure 6. Technology Pathways Diagram

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)

Concern 2:
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

$$MI_{i,MY,CY} = VMT_{C,a} \times (1+r)^{CY-BaseCY} \times \left[1 + \varepsilon \times \left(\frac{CPM_{i,MY,CY}}{CPM_{H,a,BaseCY}} - 1\right)\right] \quad (15)$$

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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4.6. 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)

<u>Concern 1:</u>
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.

<u>Recommendation 1:</u>
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:

$$E_{MY,CY}^{veh} = \frac{\sum_i \sum_{FT} MI'_{i,MY,CY} \times FS_{i,MY,FT} \times E_{i,MY,a,FT}}{1e6} \quad (36)$$

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:

$$E_{MY,CY}^{ref} = \frac{\sum_{FT}(QUADS_{MY,CY,FT} \times E_{FT} \times 1e9)}{1e6} \quad \textbf{(38)}$$

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)

<u>Concern1:</u>
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.

<u>Recommendation 1:</u>

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.

<u>Concern 2:</u>

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.

<u>Recommendation 2:</u>

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.

<u>Concern 4-2:</u>

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?

<u>Recommendation 4-2:</u>

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.

<u>Concern 4-3:</u>

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.

<u>Recommendation 4-3:</u>

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.

<u>Concern 4-4:</u>

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?

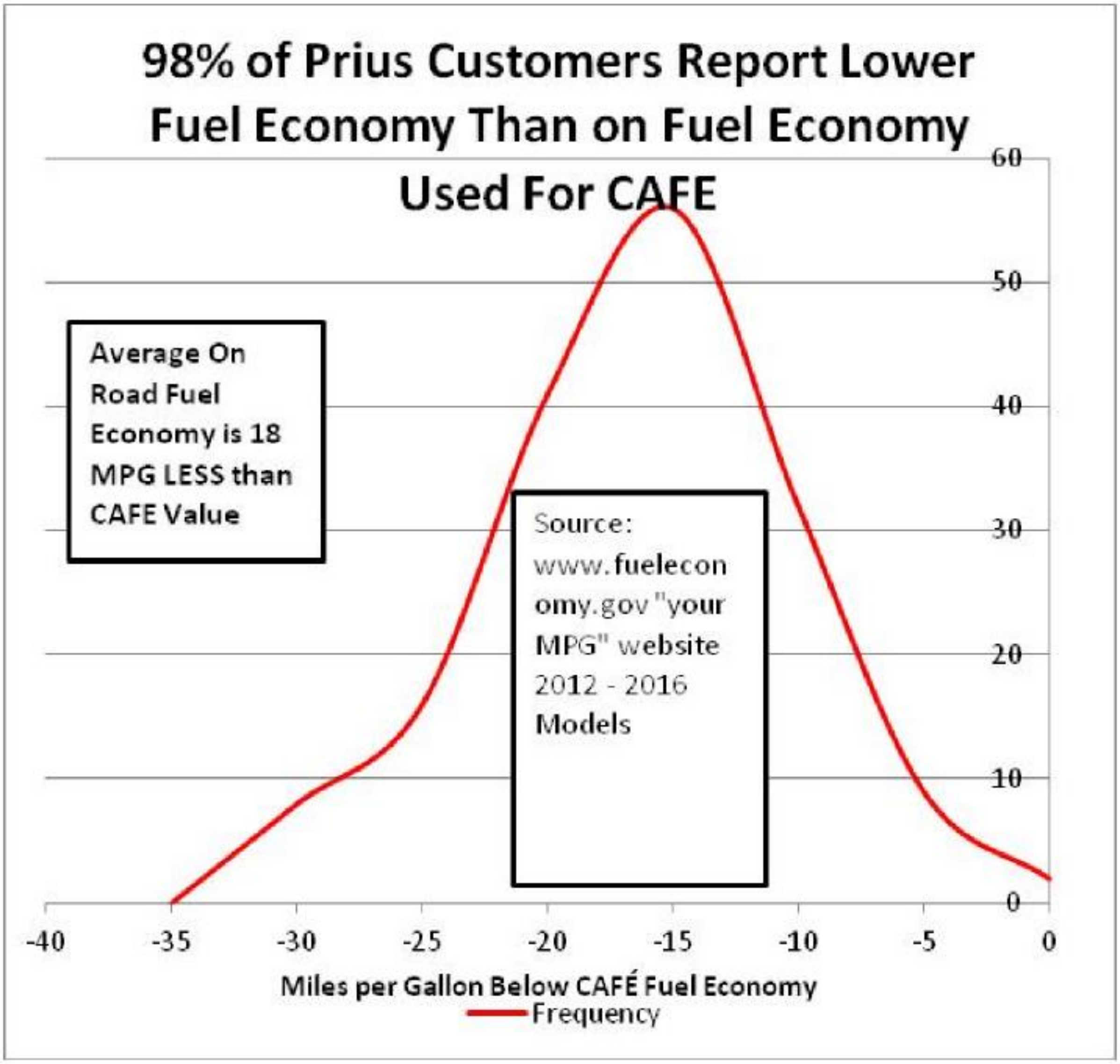
   The existence of the "Energy Paradox"[7] is well documented. It may not be as confounding as the proponents of CAFE believe.

   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?

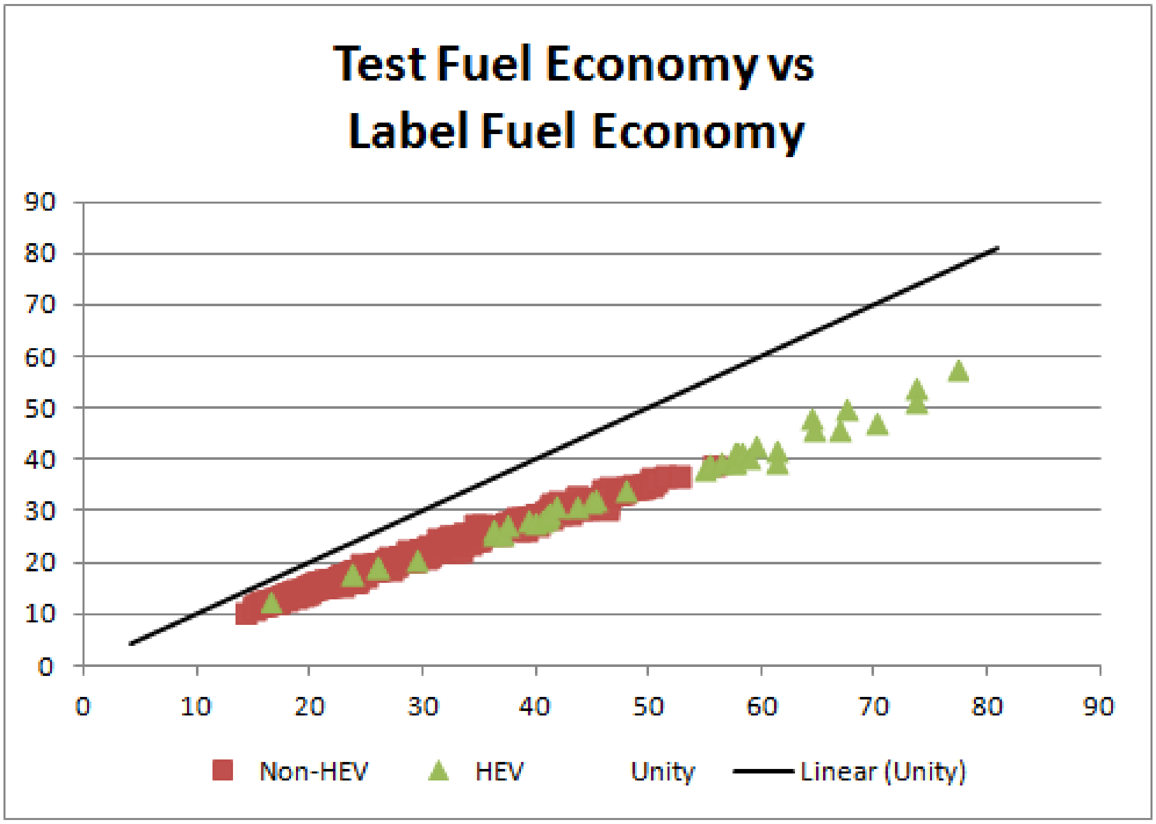
Update the input files to reflect realistic assumptions for the true cost of ownership.

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.

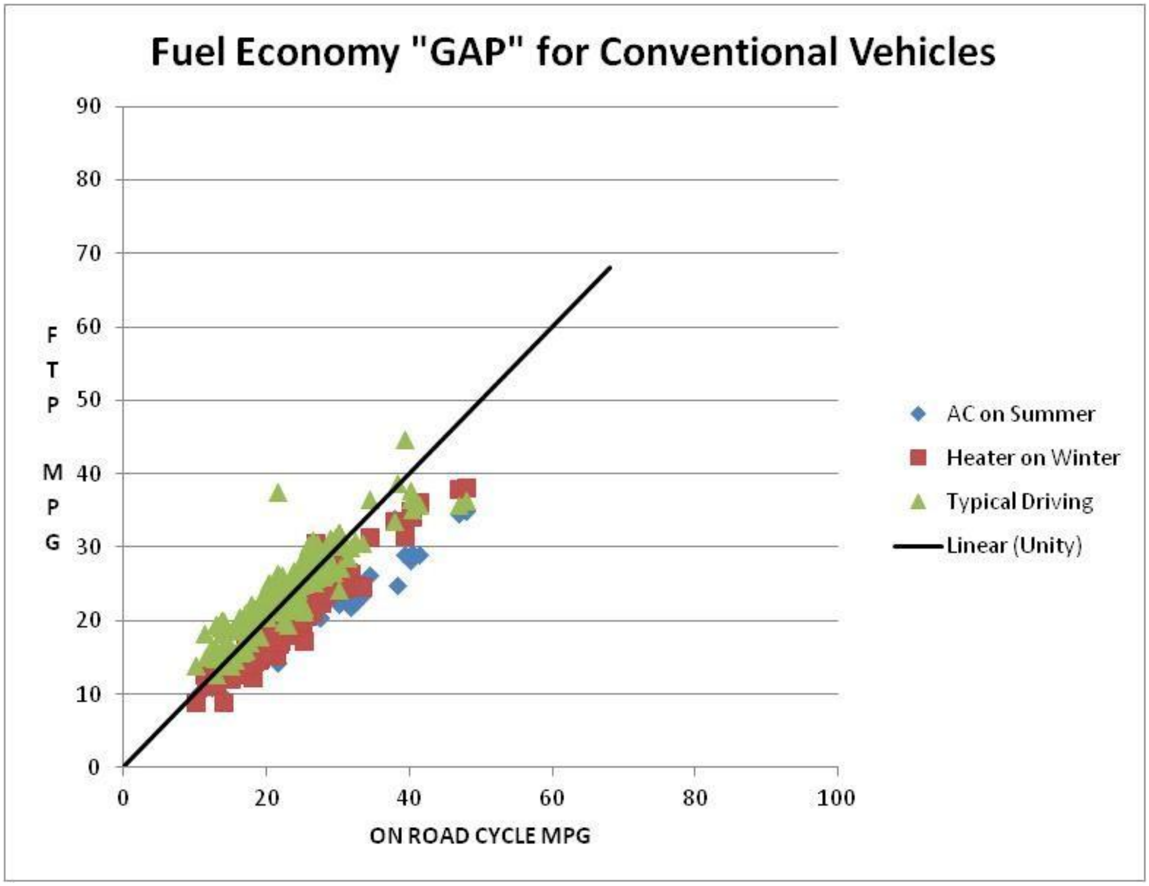
EPA conducted an additional study in 2006[13] confirming that HEVs operate substantially differently on the road than they do during official testing. Based on a 2006 review of several independent studies EPA concluded:

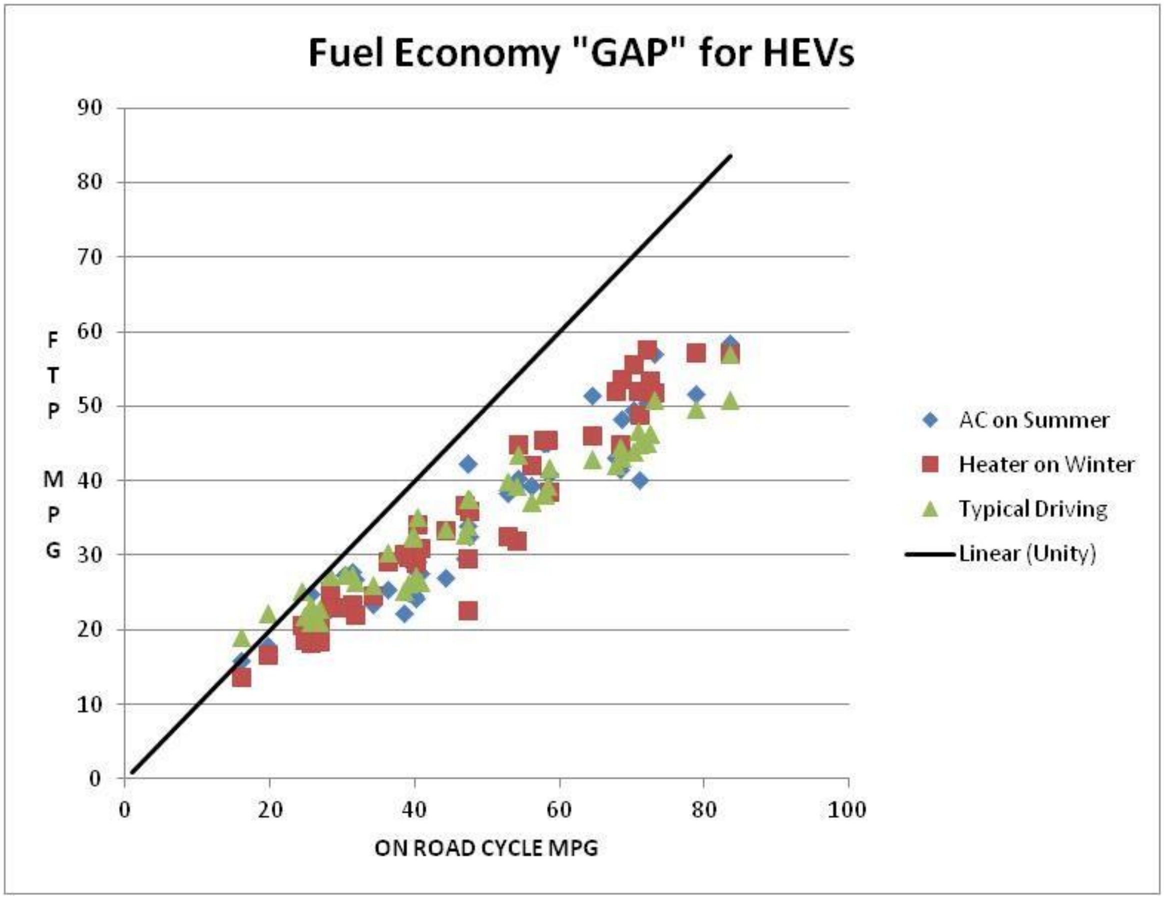
1. Hybrid vehicles showed a slightly greater impact of **aggressive driving** on fuel economy than conventional gasoline vehicles (**33% lower fuel economy versus 29% lower fuel economy for a conventional vehicle**).
2. Hybrid vehicles tended to show greater sensitivity to air conditioning operation 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.

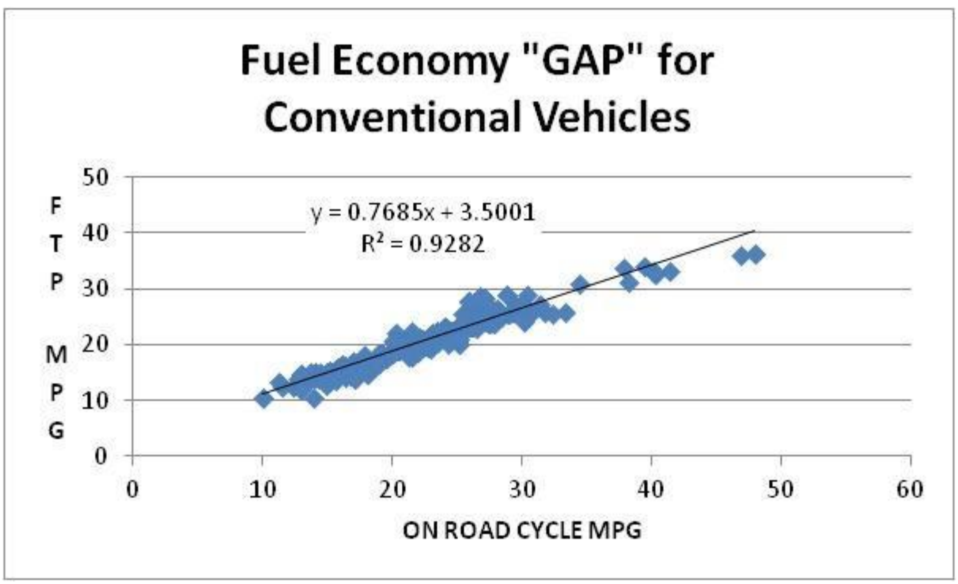
The Agency promulgated new rules effective in 2008 for fuel economy labels. These new fuel economy label requirements ***recommended*** that manufacturers conduct testing using a five-cycle test sequence (few of the producers of HEVs chose this option).

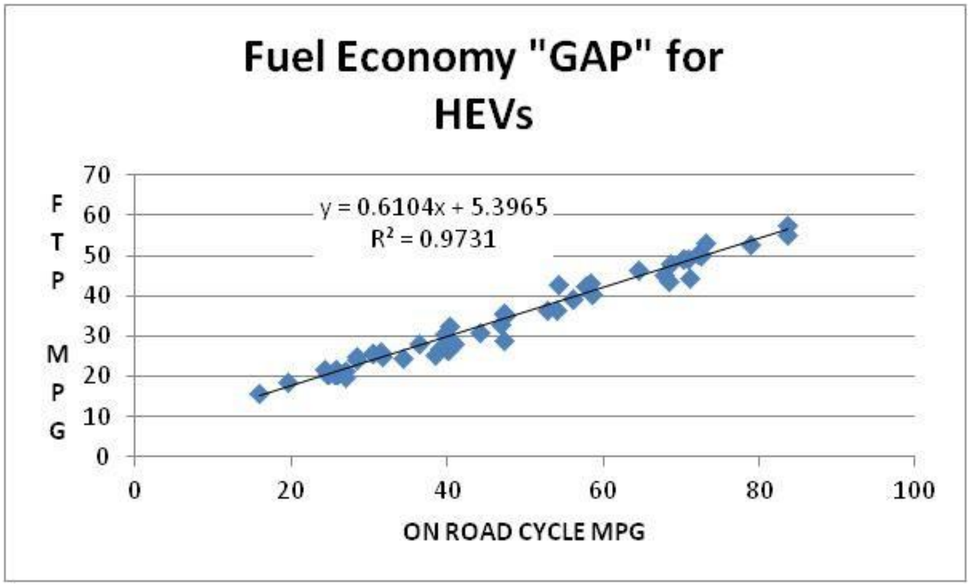
Manufacturers were given the option to conduct the full test and use the vehicle specific data to adjust their fuel economy data or were permitted to use generic fuel economy adjustment values. The Agency permitted hybrid vehicles to use the gasoline vehicle adjustment equation even though all indications 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
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)


Fuel Economy "GAP" for Conventional Vehicles
y = 0.7685x + 3.5001
R² = 0.9282
FTP MPG
ON ROAD CYCLE MPG



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.

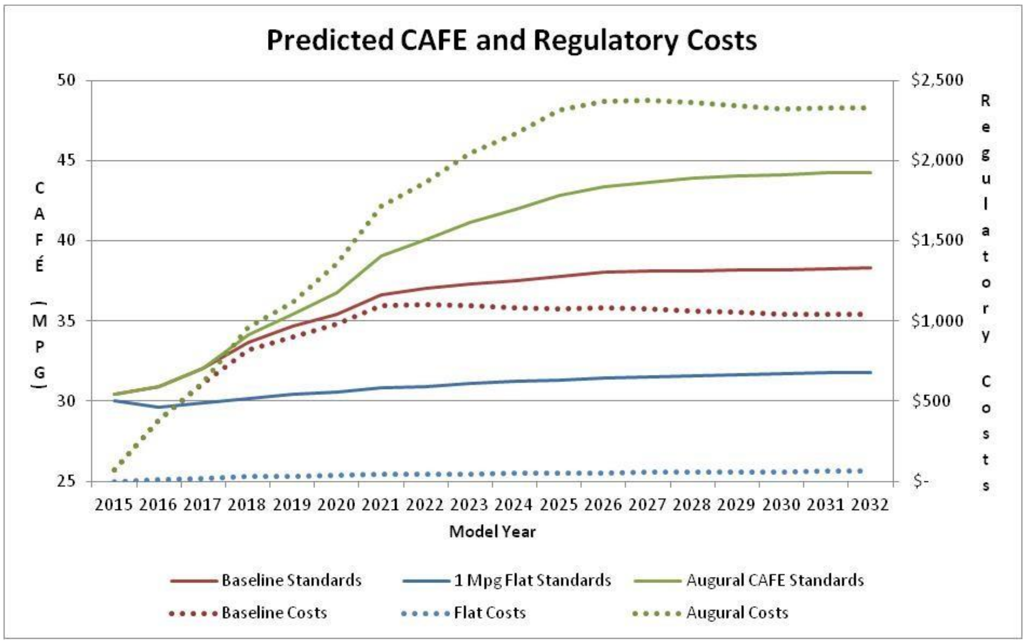
   There is no clear way to wade through the output files in any expeditious manner that would facilitate an easy review by anyone who didn't build the model.

   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 "accumulated by the manufacturer" rather they are "the total consumer costs accumulated are reported on a 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.

<u>Concern 3:</u>
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)?

<u>Recommendation 3:</u>
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.

<u>Concern 4:</u>
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.

<u>Recommendation 4:</u>
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:

<u>Concern 5:</u>
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.

<u>Recommendation 5:</u>
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)

<u>Concern 10:</u>
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)

<u>Recommendation 10:</u>
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.

<u>Concerns 11, 12, and 13:</u>
The "cost adjustment factors," "Maintenance Cost Table and Repair Cost Table, and "Stranded Capital Table" should have additional explanations together with references.

<u>Recommendation 11:</u> 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.

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

(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.

Recommendation 17:
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.

Concern 18:
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.

Recommendation 18:
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:

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

- 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):

Concern 14:

There are three entries in Table 23 that are labeled "This option is not supported in this version of the model."

Recommendation 14:

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):

Concern 15:

The DFS model, identified in Table 24, is not mentioned or described in the CAFE Model Documentation or the 2016 Draft TAR.

Recommendation 15:

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):

Concern 16:

- 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" CO_2 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.

Comment:

The Vehicles report (Table 38) is comprehensive and well organized. A few concerns were identified and are discussed below.

Concern 13:

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).

Recommendation 13:

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.

Concern 14:

For the Powertrain column in Table 38, does "Conventional" include spark ignition and diesel engines?

Recommendation 14:

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.

<u>Concern 15:</u>

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.

<u>Recommendation 15:</u>

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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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
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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. <u>Consulting</u>

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)

DOT HS 812 590
July 2018

U.S. Department
of Transportation

National Highway
Traffic Safety
Administration

NHTSA

13745-071918-v3a