Peer Review of EPA's Response Surface Equation Report

Final Report

United States
Environmental Protection
Agency

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Final Report

Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

Prepared for EPA by
RTI International
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NOTICE

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data that are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments.

EPA United States Environmental Protection Agency

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1 Introduction

The U.S. Environmental Protection Agency's (EPA's) Office of Transportation and Air Quality has developed a statistical approach to access results from the Advanced Light-Duty Powertrain and Hybrid Analysis (ALPHA) model. To demonstrate the credibility of the methodology and gain acceptance in the light-duty automotive community, EPA contracted with RTI International to support an independent peer review.

The ALPHA model is a full vehicle simulation model that is used to assess the effectiveness of different technology packages in vehicles. Effectiveness values from ALPHA act as robust inputs to the Optimization Model for Reducing Emissions of Greenhouse Gases from Automobiles (OMEGA) and to the overall rulemaking process.

Because operating the ALPHA model in real time to conduct full vehicle simulations is cost and time prohibitive, EPA developed a method of deriving the necessary effectiveness values using an industry standard statistical methodology known as a Response Surface Model (RSM). An RSM is used to computationally synthesize a large set of simulation outputs to derive response surface equations (RSEs). The derived RSEs can then be used in place of running the ALPHA model in real time for determining the effectiveness of vehicle technologies.

The peer review was conducted in a manner that is consistent with the guidance in EPA's *Peer Review Handbook* (4th edition).

This report is organized as follows:

- Section 2 details the selection of peer reviewers.
- Section 3 describes the peer-review process.
- Section 4 groups review comments by charge letter topic.
- Appendix A provides peer reviewers' resumes.
- Appendix B provides a copy of the charge letter sent to reviewers.
- Appendices C, D, and E provide exact copies of the reviews submitted by the peer-review panel.

2 Selection of Peer Reviewers

RTI compiled a list of 10 reviewer candidates who had the necessary expertise to make a contribution to this review. RTI contacted each candidate to inquire about their interest, availability, and any potential conflicts of interest with the topic.

Table 2-1 lists the final panel of reviewers. Based on availability and the need to comprehensively cover the topic, RTI selected three peer reviewers. EPA approved all three chosen reviewers. Appendix A contains resumes for each reviewer.

Table 2-1. Selected Peer Reviewers

Reviewer	Affiliation	Expertise?	Conflict of Interest?
Sanya Carley	Indiana University–Bloomington School of Public and Environmental Affairs	Yes	No
Sujit Das	Oak Ridge National Laboratory	Yes	No
Doug Montgomery	Arizona State University	Yes	No

3 Peer-Review Process

Upon completing the peer-reviewer selection process, RTI distributed a charge letter (Appendix B) and review documentation to each reviewer. The charge letter contained instructions for each peer reviewer with respect to the review schedule and the general topics to be addressed in their review. Documentation provided by EPA was sufficient for the reviewers to reproduce the RSEs from the EPA report and test the robustness of the results.

Reviewers were given 3 weeks to write their review report. RTI coordinated a kick-off conference call and a mid-review conference call to ensure that reviewers had every resource they required to conduct a full and comprehensive review of the report. During the review period, reviewers had regular access to both RTI and EPA to ask questions about the RSE report or the peer-review process. All correspondence between a reviewer and EPA was shared with all the review panel members to ensure that everyone had the same information for their review.

At the end of the 3-week period, each reviewer submitted a written report to RTI, and these reports are reproduced in Appendices C, D, and E. RTI adhered to the provisions of EPA's *Peer Review Handbook* guidelines to ensure that the peer-review process followed EPA policy.

4 Review Comments Grouped by Charge Letter Topic

The following section compiles the feedback from peer reviewers by charge letter topic. With the exception of grouping by topic, the comments have not been altered or paraphrased in any way.

<u>TOPIC 1:</u> EPA's overall approach to applying response surface modelling to accessing ALPHA model results and whether the resulting response surface equations provide accurate and robust inputs for the OMEGA model.

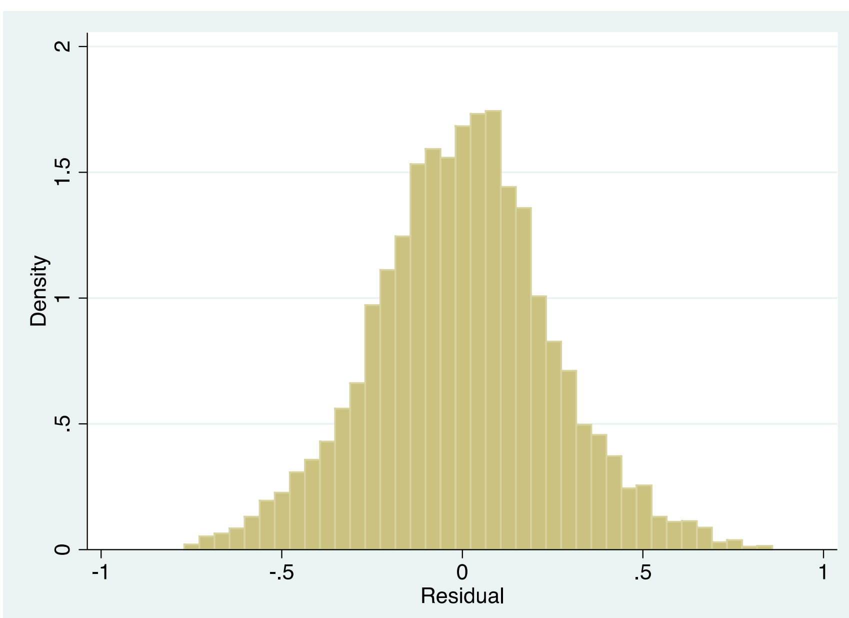
<u>Sanya Carley</u>

1. There are a variety of performance metrics that one could use to assess response surface equation accuracy and adequacy. For this review, I evaluated the size of the residuals, the percent error, and the distribution of the residuals.

2. These statistics confirm that the predicted values have excellent accuracy. The average residual is 0.0013 and the average percent error is -0.0004 percent. All combinations of vehicle type and powertrain perform similarly. The combination that has the highest residual is the High Power/Weight 2014 Atkinson.

3. I also plotted the residuals to see if they fit a normal distribution, as suggested by Bezerra et al. (2008). Figure 4-1 presents a histogram of all residuals across the 8,257 model runs. The distribution appears normal. I also looked at the histograms for all vehicle types, powertrain technologies, and vehicle type-powertrain combinations separately (not shown here). These plots provide no cause for concern.

Figure 4-1. Histogram of Residuals



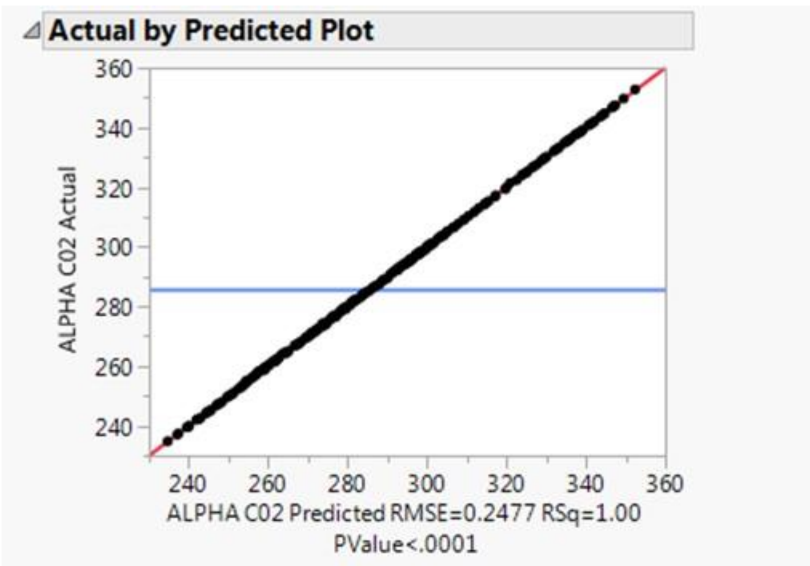
Sujit Das

1. A comparison of CO_2 results between RSE and ALPHA has confirmed the validity of the data transfer between these two models thereby proving the accuracy of the technical application of response surface modeling. A total of 21 results (only 2020_TURB24 was available for LPW_LRL vehicle) out of total 24 vehicle types were examined for the RSM validation. Residuals were found to be between a narrow range of -1.0 and 1.0 gCO_2/mile in all cases. The line slope of the plot of results of ALPHA and RSE was also found to be 45^o and thus has ensured the validity of data transfer between them. In addition, as the physics behind the Mass, Aero, and Roll are quite linear in reality, and so CO_2 emission impacts of any values between the range of these parameters were also found to be reasonable using the RSE results.

Doug Montgomery

I selected a subset of the 24 models for further investigation. I loaded the experimental designs for these models into JMP PRO V 13 and performed my own RSM analysis, fitting the standard second-order model. The results for one of these RSM model from spreadsheet HPW 1026 2017a tab 2014 GDI are discussed below. This is typical of the results I obtained for all models that I investigated.

Figure 4-2. Plot of Actual Versus Predicted Response



The points in this plot lie almost exactly along a straight line, indicating excellent agreement between the simulation model output and the predicted value from the second-order RSM model.

Figure 4-3. Summary of Fit and Analysis of Variance for the RSM Model

Summary of Fit

RSquare	0.999925
RSquare Adj	0.999921
Root Mean Square Error	0.247653
Mean of Response	285.8269
Observations (or Sum Wgts)	351

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	14	273407.37	19529.1	318414.8
Error	336	20.61	0.061332	Prob > F
C. Total	350	273427.97		<.0001*

The R^2 statistic for the model exceeds 0.99, indicating that most of the variability in the sample data (in excess of 99%) is explained by the RSM model. Also, the R^2-adjusted statistic is also in excess or 0.99. R^2-adjusted is a reflection of potential overfitting; that is including terms not really important in the model just to inflate the ordinary R^2. When these two statistics are in close agreement as they are here there is likely to be no substantial issue with overfitting. The analysis of variance indicates that the model contains at least one statistically significant term.

Figure 4-4. RSM Model Parameters Estimates

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	382.68894	0.075154	5092.1	<.0001*
Mass	-201.7124	0.190516	-1059	<.0001*
Aero	-52.06903	0.190476	-273.4	<.0001*
Roll	-53.30226	0.189323	-281.5	<.0001*
Trans	-18.23885	0.012694	-1437	<.0001*
(Mass-0.10085)*(Mass-0.10085)	8.0152892	3.191378	2.51	0.0125*
(Mass-0.10085)*(Aero-0.09715)	-10.63205	2.735951	-3.89	0.0001*
(Aero-0.09715)*(Aero-0.09715)	-5.158863	3.177543	-1.62	0.1054
(Mass-0.10085)*(Roll-0.09886)	50.490674	2.751456	18.35	<.0001*
(Aero-0.09715)*(Roll-0.09886)	-6.814333	2.723004	-2.50	0.0128*
(Roll-0.09886)*(Roll-0.09886)	-3.497919	3.169082	-1.10	0.2705
(Mass-0.10085)*(Trans-3.68091)	23.883683	0.149944	159.28	<.0001*
(Aero-0.09715)*(Trans-3.68091)	0.4606774	0.150692	3.06	0.0024*
(Roll-0.09886)*(Trans-3.68091)	0.626202	0.149753	4.18	<.0001*
(Trans-3.68091)*(Trans-3.68091)	0.5810956	0.014437	40.25	<.0001*

The second –order model contains 15 parameters; an intercept, four main effects, six 2-factor interactions, and four quadratic terms. The parameter estimates display indicates that all but two of these terms are statistically significant at the 0.05 level. However, in RSM we usually think that it's the order of the model that is most important so we often do not remove non-significant terms from the model unless there are many of them. That is not the case here.

1. **The PRESS Statistic**

In model validation it is important that the model both fit the sample and that it provide good predictions of new data. The PRESS (Prediction Error Sum of Squares) statistic, reported below, is a standard one-sample-at-a-time cross-validation used to assess potential prediction performance.

Figure 4-5. PRESS Statistic

Press

Press	Press RMSE
22.448639323	0.2528957

Notice that the PRESS statistic is very similar to the residual sum of squares from the analysis of variance. An R^2-like prediction error statistic can be computed from PRESS simply by replacing the residual sum of squares in the equation for R^2 by PRESS. This gives:

$$R^2_{\text{Prediction}} = 1 - \frac{PRESS}{TotalSS} = 1 - \frac{22.449}{273428} = 0.9999$$

We would expect the RSM model to explain in excess of 99% of the variability in data produced by the simulation model. This is excellent validation of potential prediction performance.

2. **Summary of Conclusions**
   I conclude that the RSM approach has produced statistical metamodels that are an excellent alternative to the ALPHA simulation model. So long as they are used to interpolate over the ranges of the four factor used in their construction I expect that they will be excellent alternatives to the ALPHA simulation procedure.

<u>TOPIC 2:</u> Reasonableness of any assumptions, implicit or explicit, contained in EPA's execution of the methodology.

<u>Sanya Carley</u>

1. After a thorough review of the report and supporting documentation, my general impression is that response surface statistical methods are an appropriate and efficient approach to generate data needed to populate the OMEGA model. The RSM is an analysis tool that is increasingly accepted in engineering and other disciplines, and subjected to rigorous peer review. An analysis of the model performance in this specific case also leads me to believe that the RSM approach is highly accurate, and capable of generating results that match the significantly more time-intensive ALPHA simulations.

<u>Doug Montgomery</u>

1. I investigated the adequacy of the RSM models by first analyzing the residuals from these models in the spreadsheets that were provided. I constructed normal probability plots of the residuals and plots of the residuals versus the predicted response. These plots investigate the normality of the response variable and the equality of variance assumption, both of which are standard RSM assumptions. The normality assumption is of only moderate importance since the underlying statistical methodology is robust to all but severe departures from normality. A few of the normal probability plots exhibited very small potential departures from normality but nothing severe

enough to call model validity into question.

2. The equal variance assumption is more important, and moderate to large departures from this assumption may require remedial measure such as the use of variance-stabilizing transformation. Similarly [to the normal probability plots], some of the plots of residuals versus the predicted response exhibited a non-random pattern, but none of the patterns were serious enough to question the equal variance assumptions.

3. It is also worth noting that the model residuals are extremely small as all models provide extremely good fits to the data obtained from the simulation model.

TOPIC 3: Clarity, completeness and accuracy of the technical application of response surface modelling.

Sujit Das

1. Response surface methodology (RSM) explores the relationships between several explanatory variables and one or more response variables. A sequence of designed experiments (DOE) was used, i.e., the main idea of RSM to obtain an optimal response. A DOE used in this case was based on an automated process that is configured to produce a complete set of ALPHA results for all combinations of engines, transmissions, roadloads, and vehicle types to be used in the OMEGA analysis. It is a relatively easy statistical model to estimate and apply, even when little is known about the process. It maximizes the production of a special substance by optimization of operational factors. A factorial experiment or a fractional factorial design generally used to estimate RSE process has generated as series of equations from a complete set of ALPHA data for each vehicle type and powertrain model. A second-degree RSE polynomial model was developed for each 24 vehicle cases based on a combination of 6 vehicle types and 4 powertrain types in the present analysis.

2. Overall, the quality of RSE methodology appears to be reasonable for the four independent variables considered. The validity of this methodology need to reexamined if it is expanded to a higher number of independent variables in the future.

TOPIC 4: Any recommendations for specific improvements to the functioning or the quality of the methodology.

Sanya Carley

1. **Design of Experiments:** A future extension of model validation could be an assessment of the RSM output with actual testing data. One should assume that the results would be similar to the estimates of comparison between ALPHA and RSM, however, since the EPA's previous work found that ALPHA estimates were within the margin of 3% error as compared to actual vehicle performance testing.

2. **Transparency:** As stated in the report, one of the benefits of the RSM is "increased transparency regarding synthesis of ALPHA simulation into OMEGA modeling". It is not entirely clear to me how the use of RSM will increase transparency. But I strongly encourage and support full transparency of modeling inputs, outputs, processes, and supporting information.

   EPA response: *EPA's mention of transparency refers to comments received from stakeholders discussing the challenge to understand portions of the Lumped Parameter Model that was previously used to determine the effectiveness of vehicle technologies. In response, a full matrix of ALPHA model runs along with the industry standard RSE methodology completely replaces the Lumped Parameter Model providing a straightforward method for stakeholders to evaluate.*

<u>Sujit Das</u>

1. Section 6. Baseline Vehicle Adaptation needs further details in terms of the necessary process steps for adjusting the effectiveness of a baseline vehicle to match the ALPHA model. The adjustment approach for the baseline vehicle adaptation is an interesting one as it allows ~ 50 alternative options to consider in a baseline vehicle.

   EPA response: *Since the writing of the report, the ALPHA model parameters were expanded eliminating the need for the Baseline Vehicle Adaptation described in section 6. This section of the report has also been deleted as this process is no longer applicable.*

2. Since the RSE final output is CO2 emissions provided to the OMEGA model with the technology alternatives necessary to produce the most cost-effective path for compliance, a short discussion of it will be useful for unfamiliar users.

   EPA response: *One of the preprocessing steps for the OMEGA model is to produce approximately 50 technology improvement options for each vehicle in the current baseline fleet. The OMEGA model iterates through the technology options for all vehicles in a manufacturers fleet until compliance is achieved.*

3. A description of three different transmission types considered and denoted by numerals (i.e., 2, 4, & 5) would be useful. An appropriate justification needs to be included why other two types, i.e., 1 and 3 were not considered for the RSM DOE analysis.

   EPA response: *Transmissions 2, 4, and 5 represent three actual transmissions that EPA benchmarked for efficiency. For successful use in the RSM, the increase in efficiency needs to be as linear as possible. Randomly assigning the numbers 1, 2, and 3 for example would have resulted in a very nonlinear response and not suitable for the RSM. The efficiencies for the three transmissions plotted against the numbers 2, 4, and 5 were quite linear in this case and was chosen for simplicity. A future case with a different mix of transmissions may require more resolution either by using decimal points or larger numbers to find the proper number to represent a particular transmission for a linear* *response.*

4. It is unclear why the assumed vehicle mass reduction value is not actually reflected in the ALPHA spreadsheets provided, e.g., for 2020 TURB24 vehicle, 3109.15 lbs and 2961.3 lbs Test Weight have been assumed for a mass reduction of 5% and 10%, respectively, for a baseline vehicle Test Weight of 3257 lbs? Similar level of difference was found in all 21 different vehicle type/powertrain considered for RSM.

   EPA response: *The mass reduction is calculated from the curb weight of the vehicle, not the test weight. The test weight adds 300 lbs. to the curb weight. For this example, 3257 lbs. test weight – 300 lbs. = 2957 lbs. curb weight. 10% of 2957 lbs. = 295.7 lbs. Subtracting 10% of the curb weight from the test weight (3257 lbs. - 295.7 lbs.) results in a final test weight of 2961.3 lbs.*

5. The draft report mentions about six vehicle types in OMEGA analysis and four powertrain categories in the ALPHA. It is unclear about the consistency in the number of vehicle types and powertrain categories between these two tools and thereby to what extent does the current RSM cover the overall analysis scope of the OMEGA technology options?

   EPA response: *At the time of this report, there were 6 vehicle types and 4 powertrain types resulting in 24 RSEs. The 6 spreadsheets provided represented the complete set of ALPHA runs for each vehicle type. The 4 individual tabs in each spreadsheet filtered the specific set of runs for each of the 4 powertrain types resulting in 24 combinations and a 1 to 1 correlation between the ALPHA DOE and the RSM.*

6. In spite of the fact that there are four independent variables, i.e., mass reduction, aerodynamic drag reduction, rolling resistance reduction, and transmission type have been used for the development of RSE equations, but +50 ALPHA data variables have been included in the several vehicle spreadsheets provided. It'd be good to provide the description of each of the ALPHA variables for an understanding of impacts of the four major dependent variables considered.

   EPA response: *The ALPHA variables define each powertrain type and are held constant for each DOE generated. The descriptions of the individual ALPHA data variables are beyond the scope of this review.*

7. As the RSE "Effectiveness" implementation is expanded beyond the currently limited six vehicles, four powertrains, and three transmission type options provided, the user-friendliness in terms of

inputs should be kept in mind. Using the current framework provided as an example, it is difficult for a novice user to perform a quick analysis. Specifically, a discussion on the "Baseline Vehicle Adaptation" procedure needs to be included in the documentation, when all original LPM technology options are also available for RSM for the baseline vehicle adaptation. Some Comments/Warning should be included if the results are invalid for transmission cases 1 & 3 as is the case now. The inputs for Vehicle Type, Model, and Transmission in Column A should be interlinked with the corresponding numeric value in Column B on this worksheet.

EPA response: *As stated above, the Baseline Vehicle Adaptation is no longer used in the RSM process. The RSM tool in the form presented is designed as part of an automated process and not for manual input at this release.*

8. It'd be useful for the EPA draft report completeness to provide some background information on the models and tools used in EPA's light-duty Greenhouse Gas (GHG) rulemakings for unfamiliar audience.

   EPA response: *The report mentions the tools for historical context without extensive detail as this is beyond the scope of this review. Details for the previous tools used can be found here:*

   https://www.epa.gov/regulations-emissions-vehicles-and-engines/midterm-evaluation-light-duty-vehicle-greenhouse-gas

9. Not sure whether any model validation was done in terms of using the model to predict the response for one or more combinations of design factors that were not used to build the RSM models? What agreements between the two results were found for such a validation?

   EPA response: *As stated earlier, the road load factors included in the RSM are linear and predictable. Many additional ALPHA runs were performed to verify that the ALPHA model and the RSM remain stable for these intermediate values.*

Appendix A. Peer Reviewers' Resumes

SANYA CARLEY

School of Public and Environmental Affairs
Indiana University, Room 353, 1315 East Tenth Street, Bloomington, IN 47405
(812) 856-0920; scarley@indiana.edu

PROFESSIONAL APPOINTMENTS

Associate Professor, School of Public and Environmental Affairs, Indiana University	2014 - present
Chair, Policy Analysis and Public Finance Faculty Group	2016 - present
Assistant Professor, School of Public and Environmental Affairs, Indiana University	2010 - 2014

PROFESSIONAL AFFILIATIONS

Research Fellow, Center for Organization Research and Design	2016 - present
Research Member, The Richard G. Lugar Center for Renewable Energy	2013 - present
Member, Scholars Strategy Network	2017 - present
Brain Trust Member, IronOak	2016 - present

EDUCATION

University of North Carolina at Chapel Hill. Ph.D. Public Policy, 2010.
Dissertation Committee: Richard Andrews (Chair), Doug Crawford-Brown, Gary Henry, Richard Newell, Tim Johnson

University of Wisconsin-Madison. M.S. Urban and Regional Planning, Masters Certificate, Energy Analysis and Policy, 2006.

Swarthmore College. B.A. Economics, B.A. Sustainable Development, 2003.

AREAS OF RESEARCH

Energy Policy, Electricity Markets, Transportation Industry, Energy-based Economic Development, Policy Instruments, Electric Vehicles, Distributed Generation

CONSULTING AND WORK EXPERIENCE

Consultant, Institute for International Business, Indiana University, Bloomington, IN. (2013)
Consultant, Environmental Protection Agency, Conflict Prevention and Resolution Center, Washington D.C. (2010)
Consultant, Research Triangle Institute International, Center for Technology Applications, Research Triangle Park, NC. (2009 - 2010)
Consultant, ARCeconomics, SC. (2007 - 2010)
Consultant, The Nicholas Institute for Environmental Policy Solutions, Durham, NC. (2008)
Graduate Fellow, Center for Sustainable Energy, Environment, and Economic Development, Chapel Hill, NC. (2006 - 2010)
Energy Program Specialist, Wisconsin Public Utility Institute, Madison, WI. (2005 - 2006)
Consultant, World Bank Group, Development Economic Research of the Public Sector, Washington D.C. (2003 - 2006)

BOOKS

Carley, S., Lawrence, S. 2014. Energy-based Economic Development: How clean energy can drive development and stimulate economic growth. Springer: New York.

Reviews of the Book:

1. Sharma, K. R., Wilson, E. 2016. Book Review of "Energy-based Economic Development: How clean energy can drive development and stimulate economic growth." *Journal of Policy Analysis and Management* 35(3): 728-731.
2. Ghadimi, H. 2017. Book review: Energy-based Economic Development: How clean energy can drive development and stimulate economic growth. *Economic Development Quarterly* 31(1): 92-96.

PEER OR EDITOR REVIEWED PUBLICATIONS

* Denotes student co-author at time of writing

Carley, S., Evans, T. P., Konisky, D. M. 2018. Adaptation, culture, and the energy transition in American coal country. *Energy Research & Social Science*.

Nicholson-Crotty, S., Carley, S. 2017. Policy Learning in the Context of State Energy Policy. Forthcoming, *State Politics and Policy Quarterly.*

Carley, S., Baldwin, E.*, MacLean, L. M., Brass, J. N. 2017. Global Expansion of Renewable Energy Generation: An Analysis of Policy Instruments. *Environmental and Resource Economics* 68(2): 397-440.

- Winner of the 2014 Best Paper Award for Research in Comparative Policy Analysis, honored by the Association of Public Policy Analysis and Management and the International Comparative Policy Analysis Forum.

Carley, S., Nicholson-Crotty, S., Miller, C.* 2017. Adoption, Reinvention, and Amendment of Renewable Portfolio Standards in the American States. *Journal of Public Policy* 37(4): 1-28.

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Davies, L. L., Carley, S. 2017. Emerging shadows in national solar policy? Nevada's Net Metering Transition in Context. *The Electricity Journal*.

Krause, R., Lane, B., Carley, S., Sperl J.*, Graham, J. 2016. Assessing the Demand for Electric Vehicles under Future Cost and Technological Scenarios. *International Journal of Sustainable Transportation* 10(8): 742-751.

Clark-Sutton, K.*, Siddiki, S., Carley, S., Wanner, C.*, Rupp, J., Graham, J.D. 2016. Plug-in electric vehicle readiness: Rating cities in the United States. *The Electricity Journal* 29(1): 30-40.

Carley, S. 2016. Energy programs of the American Recovery and Reinvestment Act of 2009. *Review of Policy Research* 33(2): 201-223.

Carley, S. 2016. The American Recovery and Reinvestment Act of 2009: What have we learned? *Review of Policy Research* 33(2): 119-123.

Zirogiannis, N., Alcorn, J.*, Rupp, J., Carley, S., Graham, J. 2016. State regulation of unconventional gas development in the U.S.: An empirical evaluation. *Energy Research and Social Science* 11:142-154.

Nicholson-Crotty, S., Carley, S. 2016. Effectiveness, Implementation Capacity, and Policy Diffusion: Or, "Can We Make that Work for Us?" *State Politics and Policy Quarterly* 16(1), 78-97.

Paydar, N.*, Schenk, O., Alcorn, J.*, Bowers, A., Carley, S., Rupp, J., Graham, J.D. 2015. The Effect of Community Reinvestment Funds on Local Acceptance of Unconventional Gas Development. *Economics of Energy & Environmental Policy* 15(1): 1-26.

Esposito, D.*, Rupp, J., Carley, S. 2015. Interaction of risks associated with natural gas and renewable based electricity. *The Electricity Journal* 28(8): 69-84.

Siddiki, S., Dumortier, J., Curley, C., Carley, S., Krause, R. 2015. Regulating for Innovation and Technology Adoption: The Case of Plug-In Vehicles. *Review of Policy Research* 32(6): 649-674.

Warren, D.*, Wendling, Z.*, Bower-Bir, J.*, Fields, H.*, Richards, K., Carley, S., Rubin, B. 2015. Estimating State and Sub-State Economic Effects of a Carbon Dioxide Tax Policy: An Application of a New Multi-Region Energy-Economy Econometric Model. *Regional Science, Policy and Practice* 7(3): 119-139.

MacLean, L., Brass, J., Carley, S., El-Arini, A.*, Breen, S.* 2015. Democracy and the distribution of NGOs promoting renewable energy in Africa. *Journal of Development Studies* 51(6): 725-742.

Dumortier, J., Siddiki, S., Carley, S., Cisney, J.*, Krause, R., Lane, B., Rupp, J., Graham, J. 2015. Effects of providing total cost of ownership information on consumers' intent to purchase a hybrid or plug-in electric vehicle. *Transportation Research Part A: Policy and Practice* 72: 71-86.

Carley, S., Nicholson-Crotty, S., Fisher, E.* 2015. Capacity, Guidance, and the Implementation of the American Recovery and Reinvestment Act. *Public Administration Review* 75(1): 113-125.

Carley, S., Hyman, M.* 2014. The American Recovery and Reinvestment Act: Lessons from Energy Program Implementation Efforts. *State and Local Government Review* 46(2): 140-147.

Baldwin, E.*, Brass, J., Carley, S., MacLean, L. 2014. Issues of scale in distributed generation electrification for rural development. *WIRES: Energy and Environment.*

Warren, D.*, Carley, S., Krause, R., Rupp, J., Graham, J. 2014. Predictors of attitudes toward carbon capture and storage using data on world views and CCS-specific attitudes. *Science and Public Policy.*

Krause, R., Carley, S., Warren, D.*, Rupp, J., Graham, J. 2014. Not Under My Backyard: Geographic proximity and public acceptance of CCS facilities. *Risk Analysis* 34(3): 529-540.

Wendling, Z. A.*, Attari, S. Z., Carley, S., Krause, R. M., Warren, D.*, Rupp, J., Graham, J. D. 2013. On the importance of strengthening moderate beliefs in climate science to foster support for immediate action. *Sustainability* 5(12): 5153-5170.

Krause, R., Carley, S., Lane, B., Graham, J. 2013. Perception and Reality: Public Knowledge of Plug-in Electric Vehicles. *Energy Policy* 63: 443-440.

Lane, B., Messer, N.*, Hartman, D.*, Carley, S., Krause, R., Graham, J. 2013. Government promotion of the electric car: Risk management or industrial policy? *European Journal of Risk Regulation* 2: 227-245.

Carley, S., Krause, R., Lane, B. Graham, J. 2013. Intent to purchase a plug-in electric vehicle: A survey of early impressions in large US cites. *Transportation Research Part D: Transport and Environment* 18: 39-45.

Brass, J., Carley, S., MacLean, L., Baldwin, E.* 2012. Power for development: An analysis of on-the-ground experiences of distributed generation in the developing world. *Annual Review of Environment and Resources* 37: 107-136.

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Carley, S., Miller, C.* 2012. Regulatory stringency and policy adoption: Reassessment of renewable portfolio standards. *Policy Studies Journal* 40(4): 730-756.

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Gaul, C.*, Carley, S. 2012. Solar set asides and renewable energy certificates: Early lessons from North Carolina's experience with its Renewable Portfolio Standard. *Energy Policy* 48: 460-469.

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Carley, S. 2012. Energy demand-side management: New perspectives for a new era. *Journal of Policy Analysis and Management* 31(1): 6-32.

Carley, S., Brown, A., Lawrence, S. 2012. Economic development and energy: From fad to a sustainable discipline? *Economic Development Quarterly* 26(2): 111-123.

Carley, S. 2012. National clean energy standards: Experience from the states. *Review of Policy Research* 29(2): 301-307. Originally printed in *SPEA Insights*, July 2011.

Carley, S. 2011. Decarbonization of the U.S. electricity sector: Are state energy policy portfolios the solution? *Energy Economics* 33(5): 1004-1023.

Carley, S. 2011. Normative dimensions of sustainable energy policy. *Ethics, Policy & Environment* 14(2): 211-229.

Carley, S. 2011. The era of state energy policy innovation: A review of policy instruments. *Review of Policy Research* 28(3): 265-294.

Carley, S., Lawrence, S., Brown, A., Nourafshan, A.*, Benami, E.* 2011. Energy-Based Economic Development. *Renewable and Sustainable Energy Reviews* 15(1): 282-295.

Carley, S. 2010. Historical analysis of U.S. electricity markets: Reassessing carbon lock-in. Energy Policy 39(2): 720-732.

Carley, S. 2009. Distributed generation: An empirical analysis of primary motivators. *Energy Policy* 37(5): 1648-1659.

Carley, S. 2009. State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy Policy* 37(8): 3071-3081.

Law Journal Publications

Carley, S., Messer, N.* Graham, J. 2012. Innovation in the Auto Industry: The Role of the U.S. Environmental Protection Agency. *Duke Environmental Law and Policy Forum* 21: 367-399.

Carleyolsen, S. 2006. Tangled in the Wires: An Assessment of the Existing U.S. Renewable Energy Legal Framework. *Natural Resources Journal* 46 (3): 759-792.

Book Reviews

Carley, S., Graff, M.* 2017. Review of "Climate and Clean Energy Policy: State Institutions and Economic Implications." American Review of Public Administration. Forthcoming.

Peer-Reviewed Policy and Business Reports

Carley, S., Duncan, D., Graham, J. D., Siddiki, S., Zirogiannis, N., 2017. "A Macroeconomic Study of Federal and State Auto Regulations with Recommendations for Analysts, Regulators, and Legislators."

Carley, S., Davies, L. 2016. "Nevada's Net Energy Metering Experience: The Making of a Policy Eclipse?" Brookings Institution Report.

Carley, S., Duncan, D., Esposito, D.*, Graham, J. D., Siddiki, S., Zirogiannis, N., 2016. "Rethinking Auto Fuel Economy: Technical and Policy Suggestions for the 2016-17 Midterm Reviews."

Carley, S., Jasinowski, J., Glassley, G.*, Strahan, P.,* Attari, S., Shackelford, S. October 2014. "Success Paths to Sustainable Manufacturing."

School of Public and Environmental Affairs, 2011. "Plug-in Electric Vehicles: A Practical Plan for Progress." The report of an expert panel [Contributing author].

Policy Reports and White Papers

Indiana University Public Policy Institute, February 2012. "An environmentally sound energy policy: One key to Indiana's economic future." Policy brief prepared for Indiana policymakers by the Indiana Policy Choices Energy and Environment Commission [Commission member and contributing author].

Carley, S., Hyman, M.* The "Grand Experiment:" An early review of energy-related American Recovery and Reinvestment Act Efforts. *PERI Working Paper Series Report 338*.

Carley, S., Desai, S., Bazilian, M., Kammen, D. 2012. Energy-based economic development: Prioritizing opportunities for developing countries. *FEEM Working Paper 25.2012.*

Baldwin, L.*, Carley, S., Gardner, W.*, June 2011. "Demand-side Management and Energy Efficiency in Indiana: A Comparison of Policy Instruments." Policy brief prepared for the Indiana Utility Regulatory Commission.

The Nicholas Institute, 2009. "An Evaluation of Utah's Greenhouse Gas Reduction Options." Technical policy report prepared for the state of Utah. [Contributing researcher].

Carleyolsen, S., Voss, S., 2006. "Recommendations for the Governor's Taskforce on a Wisconsin Bioindustry Strategy." White Paper prepared for the Wisconsin's Bioindustry Consortium Taskforce.

Carleyolsen, S., Rude, J., Jenkins, A., 2006. "IGCC: A Cost-Benefit Analysis." White Paper prepared for the Wisconsin Public Service Commission and the Wisconsin IGCC Governor's Taskforce.

Carleyolsen, S., Meyer, T., Scott, I., Rude, J., 2005. "Estimating Economic Value of Jefferson County Parks, Trails, and Open Space." White Paper given to the Jefferson County Board of Supervisors. Jefferson County, WI.

MEDIA PUBLICATIONS

Carley, S. October 2017. Op-Ed: Mandates help motorists, economy in the long run. Printed in McClatchy papers.

Carley, S., Konisky, D. March 2017. Op-Ed: Changes to Indiana's Solar Policy Misguided. *The Herald-Times* (as well as numerous other outlets).

Jasinowski, J., Carley, S. 2014. Op-Ed: Sustainable Manufacturing Makes Cents. *Manufacturing Leadership Journal*.

Carley, S., Hyman, M. January 12, 2012. Op-Ed: "'Green energy' is the best route to profitable public investment." Printed in McClatchy papers, including the Miami Herald, Kansas City Star, and the Sacramento Bee (Also printed in 37 other U.S. news outlets).

OTHER PUBLICATIONS

Carley, S. January 2017. How states are grappling with solar panels, net energy metering, and the evolving electric utility industry. Scholars Strategy Network Brief.

Graham, J. D., Cisney, J.*, Carley, S., Rupp, J. 2014. No time for pessimism about electric cars. *Issues in Science & Technology*.

Carley, 2014. Response to Pollin, R. 2014. A Clean Energy Program for the United States. *Boston Review*. July/August Issue.

Carley, S. 2012. Electric vehicles: Public acceptance, infrastructure and policy. *USAEE Dialogue* 20(3).

Graham, J., Carley, S., Messer, N.*, Hartman, D.* February, 2011. Plug-in Electric Vehicles: A Practical Plan for Progress. *SPEA Insights*.

Carley, S. May, 2011. National clean energy standards: Experience from the states. *SPEA Insights*.

SELECTED WORKS IN PROGRESS

Siddiki, S., Carley, S., Zirogiannis, N., Duncan, D., Graham, J. Does dynamic federalism yield compatible policies? A study of federal and state vehicle standards. Revise and Resubmit Status at *Publius: The Journal of Federalism.*

Lane, B., Carley, S., Siddiki, S., Dumortier, J., Clark-Sutton, K.*, Krause, R., Graham, J. D. All electric vehicles are not the same: An intent to purchase analysis accounting for heterogeneity among vehicle types. Revise and Resubmit Status at *Transportation Research Part D: Transport and Environment*.

Wendling, Z.*, Warren, D.*, Rubin, B., Carley, S., Richards, K. An Energy-Economy Econometric Model for Conducting State-Level Energy Policy Analysis. Revise and Resubmit Status at *Energy Policy*.

Carley, S., Zirogiannis, N., Duncan, D., Siddiki, S., Graham, J. D. An analysis of the macroeconomic effects of 2017-2025 federal fuel economy and greenhouse gas emissions standards. *Manuscript under review*.

Carley, S., Nicholson-Crotty, S. Energy Policy Learning and Information Channels in the American States. *Manuscript under review*.

Carley, S., Yahng, L. Willingness to pay for sustainable beer. *Manuscript under review*.

Carley, S., Davies, L., Spence, D., Zirogiannis, N. Renewable Portfolio Standards, Renewable Energy Markets, and the Importance of Policy Design. *Manuscript under review*.

Ross, J., Carley, S. Efficient Siting of Nuisance Facilities Under Regulatory and Fiscal Decentralization: Empirical Evidence from the Effect of Political Borders on Wind Farms Location. *Manuscript under review*.

Duncan, D., Zirogiannis, N., Carley, S., Siddiki, S., Graham, J. D. The effect of CAFE standards on vehicle sales projections: A total cost of ownership approach. *Manuscript under review.*

Carley, S., Evans, T., Konisky, D. Vulnerability and the U.S. Energy Transition. *Manuscript under review*.

Jenn, A., Hardman, S., Carley, S., Zirogiannis, N., Duncan, D., Graham, J. D. Cost implications for automakers' compliance with emission standards from Zero Emissions Vehicle mandate. *Working paper.*

Baldwin, E., Carley, S., Nicholson-Crotty, S. The global diffusion of renewable energy policies. *Working paper.*

Zirogiannis, N., Carley, S., Duncan, D., Siddiki, S., Graham, J. D. Overcoming the shortcomings of U.S. plug-in electric vehicle policies. *Working paper.*

Siddiki, S., Carley, S., Zirogiannis, N., Duncan, D., Graham, J. D. Policy compatibility by design: The case of U.S. vehicle emissions standards. *Working paper.*

Alcorn, J., Carley, S. Exploring Renewable Energy Certificate market dynamics: What role do markets play in renewable energy growth and development? *Working paper.*

CONFERENCE PROCEEDINGS, PAPERS, AND POSTERS (CO-AUTHOR PRESENTED WORK NOT LISTED)

"A Macroeconomic Study of Federal and State Auto Regulations with Recommendations for Analysts, Regulators, and Legislators." Paper presented at the Annual Conference, U.S. Association of Energy Economics, Houston, TX, November, 2017.

"A Macroeconomic Study of Federal and State Auto Regulations with Recommendations for Analysts, Regulators, and Legislators." Paper presented at the 39th Annual Research Conference, Association for Public Policy Analysis and Management, Chicago, IL, November, 2017.

"The Global Diffusion of Renewable Energy Policies." Paper presented at the 38th Annual Research Conference, Association for Public Policy Analysis and Management, Washington, D.C., November, 2016.

"Exploring renewable energy certificate market dynamics: What role do markets play in renewable energy growth and development?" Paper presented at the International Association of Energy Economics Conference, Bergen, Norway, June, 2016.

“Policy Learning in the Context of State Energy Policy.” Paper presented at the 74th annual Midwest Political Science Association Conference, Chicago, IL, April, 2016.

“Exploring renewable energy certificate market dynamics: What role do markets play in renewable energy growth and development?” Paper presented at the 37th Annual Research Conference, Association for Public Policy Analysis and Management, Miami, FL, November, 2015.

“The Electric Vehicle Attitude-Behavior Gap: Moving Beyond the Early Adopters.” Paper presented at the 34th Annual Conference, U.S. Association of Energy Economics, Pittsburgh, PA, October, 2015.

“Global Renewable Energy Generation: An Analysis of Renewable Energy Drivers Across Gross National Income Categories.” Paper presented at the 36th Annual Research Conference, Association for Public Policy Analysis and Management, Albuquerque, NM, November, 2014.

“Global expansion of renewable energy generation: An evaluation of policy instruments.” Paper presented at the 35th Annual Research Conference, Association for Public Policy Analysis and Management, Washington, D.C., November, 2013.

“Social learning and policy diffusion: adoption, reinvention, and amendment of the renewable portfolio standard.” Paper presented at the Energy systems in Transition Conference, Karlsruhe, Germany, October, 2013.

“Global expansion of renewable energy generation: An evaluation of policy instruments.” Paper presented at the 32nd U.S. Association of Energy Economists/International Association for Energy Economists Conference, Anchorage, AK, July, 2013.

“Global expansion of renewable energy generation: An evaluation of policy instruments.” Paper presented at the annual Transatlantic Policy Consortium, The Hague, Netherlands. May 2013.

“Intent to purchase a plug-in electric vehicle: A survey of early impressions in large U.S. cites.” Conference proceeding presented at the 31st U.S. Association of Energy Economists/International Association for Energy Economists Conference, Austin, TX. November, 2012.

“Power for development: An analysis of on-the-ground experiences of distributed generation in the developing world.” Paper presented at the 33rd Annual Research Conference, Association for Public Policy Analysis and Management, Washington, D.C., November, 2011.

“NGOs and collaborative energy service provision in developing countries.” Paper presented at the American Political Science Association Conference, Seattle, WA, September 4, 2011.

“Energy-based Economic Development: From Fad to Sustainable Discipline?” Paper presented at the Seventh International Conference on Environmental, Cultural, Economic and Social Sustainability, Hamilton, New Zealand, January 7, 2011.

“Demand-side management: New perspectives for a new era.” Paper presented at the 29th U.S. Association of Energy Economists/International Association for Energy Economists Conference, Calgary, October, 2010.

“Demand-side management: New perspectives for a new era.” Paper presented at the SPEA-Speyer Workshop, Bloomington, IN, November, 2010.

"State energy policy instruments: Lessons learned from the era of state energy innovation policy." Paper presented at the 32nd Annual Research Conference, Association for Public Policy Analysis and Management, Boston, November, 2010.

"Decarbonization of the U.S. electricity sector: Are state energy policy portfolios the solution?" Poster presented at the Solar Energy Research Center's Conference, Solar Fuels and Energy Storage: The Unmet Needs, Chapel Hill, NC, January, 2010.

"Decarbonization of the U.S. electricity sector: Are state energy policy portfolios the solution?" Paper presented at the 31st Annual Research Conference, Association for Public Policy Analysis and Management, Washington, D.C., November, 2009.

"State renewable energy electricity policy: An empirical evaluation of effectiveness." Paper presented at the 30th Annual Research Conference, Association for Public Policy Analysis and Management, Los Angeles, CA, November 6, 2008.

"Evaluating the Effectiveness of State Renewable Energy Policies." Poster presented at the RTEC Sustainable Energy Symposium, Raleigh, NC, 2007.

"Tracking Social Capital Indicators using Geographic Information Systems." Presentation at the Upper Midwest Regional Planning Conference, MN, 2005. Received Best Student Presentation award.

INVITED TALKS, LECTURES, WEBINARS, OR PANEL PRESENTATIONS

2017: Innovation, Property Rights, and the Structures of Energy, Property and Environment Research Center (PERC), Bozeman, MT; Environmental Protection Agency, Ann Arbor; Environmental Protection Agency, Washington D.C.; Electricity Dialogue, Northwestern University; Association of Public Policy Analysis and Management Webinar, Washington D.C.; Workshop on Durability and Adaptability in Energy Policy, Resources for the Future; Earth and Mineral Sciences Energy Institute, Pennsylvania State University

2016: 2016 Austin Electricity Conference, University of Texas; U.S. Association of Energy Economics, dual plenary session on Transportation; South Carolina Journal of International Law and Business Symposium; University of Texas at Austin, Regional Challenges and Opportunities in Energy Transformations Workshop.

2015: Panel on National Science Foundation funding, Indiana University; U.S. Association of Energy Economics, session on Energy Economics Education; Workshop on Manufacturing and Public Policy; Mini University, Indiana University; Richard G. Lugar Center for Renewable Energy; University of Utah, S.J. Quinney College of Law, 20th Annual Stegner Symposium; University of North Carolina at Chapel Hill, Odum Institute.

2014: Kelley School of Business, Indiana University; Martin School of Public Policy and Administration, University of Kentucky; Ford School of Public Policy, University of Michigan.

2013: ARPA-E; Centre for Energy Economics and Policy, ETH Zurich; Global Mini-Conference, Indiana University; Energy Student Leaders Association, Indiana University; Energy and Climate Seminar Series, Georgetown University; International Public Affairs Association, Indiana University; 13th Annual Association of SPEA Ph.D. Students Conference, Indiana University; Kelley School of Business Renaissance Week, Indiana University.

2012: Center for Local, State, and Urban Policy, University of Michigan; School of Public and Environmental Affairs Dean's Council Meeting, Indiana University; Kelley School of Business Renaissance Week, Indiana University; Policy Lecture Series, UNC-Chapel Hill Department of Public Policy.

2011: Mini University, Indiana University; Ph.D. Student Research Seminar, School of Public and Environmental Affairs, Indiana University;

2010 Ph.D. Student Research Seminar, School of Public and Environmental Affairs, Indiana University; Ph.D. Student Research Seminar, School of Public and Environmental Affairs, Indiana University; University Research Day, University of North Carolina at Chapel Hill; Carolina Institute for the Environment Board of Visitors, University of North Carolina at Chapel Hill.
2006: Wisconsin's Bioindustry Consortium Taskforce, Madison, WI.
2005: Jefferson County Board of Supervisors, Jefferson County, WI.

PANEL CHAIR OR MODERATOR:
2017: Environmental Politics & Governance conference; Association for Public Policy Analysis and Management conference; U.S. Association of Energy Economics conference
2016: Midwest Political Science Association conference; U.S. Association of Energy Economics annual conference; Association for Public Policy Analysis and Management conference
2015: U.S. Association of Energy Economics conference; Association for Public Policy Analysis and Management conference
2014: Association for Public Policy Analysis and Management conference
2013: Association for Public Policy Analysis and Management conference; International Public Affairs Association conference; U.S. Association of Energy Economics conference
2011: U.S. Association of Energy Economics conference; Association for Public Policy Analysis and Management conference
2010: Association for Public Policy Analysis and Management conference
2006: Wisconsin Public Utility Institute conference

GUEST SEMINAR PRESENTATIONS AT INDIANA UNIVERSITY
2016: SPEA, Experience Day; SPEA, V680 Research Design
2015: SPEA, Experience Day; SPEA, E574 Energy Markets and Analysis; SPEA, V680 Research Design; Statistics, S690 Statistical Consulting
2014: SPEA, V680 Research Design
2013: SPEA, V680 Research Design; SPEA, Experience Day; Kelley School of Business, L302 Sustainability Law & Policy.
2012: SPEA, Experience Day.
2011: SPEA, V680 Research Design; SPEA, V669 Economic Development; SPEA, V160 National and International Policy; SPEA, Experience Day.
2010: SPEA, Advanced Math Camp

GRANTS
"Toward the Diffusion of Sustainable Technologies: The Case of Electric Vehicles" Co-PI with Sean Nicholson-Crotty and Saba Siddiki. National Science Foundation. $184,996. 2016-2018.

"The Siting of Energy Infrastructure: Public Perceptions and Public Finance Impacts" Co-PI with David Konisky and Steven Ansolabehere. Alfred P. Sloan Foundation. $259,900. 2016-2018.

"The U.S. Energy and Climate Transition: Aggregated Impacts of Policy on Vulnerable Populations" PI with Co-PIs Tom Evans and David Konisky. Indiana University Collaborative Research Grant. Office of the Vice Provost of Research, Indiana University. $63,437. 2016-2017.

"Consumer Willingness to Pay for Sustainability: The Case of the Brewing Industry" PI. Office of the Vice Provost of Research Award for Research Methods and Collaboration, Indiana University. $4,942. 2016.

"Study of the macro-economic impact of the light-duty vehicle corporate average fuel economy, greenhouse gas and zero-emission vehicle standards: Phases II and III" Co-PI with John Graham, Denvil Duncan, Saba Siddiki, and Nikos Zirogiannis. Alliance for Automobile Manufacturers. $590,000. 2016-2017.

"Study of the macro-economic impact of the light-duty vehicle corporate average fuel economy, greenhouse gas and zero-emission vehicle standards: Phase I" Co-PI with John Graham, Denvil Duncan, and Saba Siddiki. Alliance for Automobile Manufacturers. $202,723. 2015-2016.

"Informing Energy Policy Choices in Indiana using an Econometric and Technology Model." PI with Barry Rubin. Faculty Research Support Program, Indiana University. $72,341. 2012-2013.

"Power for Development: Sustaining Small-Scale Electricity Implementation in Africa." PI with Jennifer Brass and Lauren MacLean. Faculty Research Support Program, Indiana University. $74,484. 2012-2013.

"Exploratory Study of Risks, Benefits, and Costs of DEF and Alternatives." PI with John Graham. Navistar. $89,509. 2011-2012.

"NGO Involvement in Sustainable Energy Programs for International Development." PI with Jennifer N. Brass. Mitsui Environment Fund, Mitsui & Co., Ltd. $59,706. 2011-2012.

"Collaborative Provision of Low-Carbon Distributed Energy in Developing Countries." PI with Jennifer N. Brass. Sustainability Research Development Grant, Indiana University Office of Sustainability. $15,000. 2011-2012.

"Energy-based Economic Development." Co-PI with Adrienne Brown (PI) and Sara Lawrence (PI). RTI International R&D Grant, RTI International. $63,000. 2009-2010.

Conference Travel Grant. GPSF Travel Award, University of North Carolina at Chapel Hill. $400. 2009

Conference Travel Grant Department of Public Policy, University of North Carolina at Chapel Hill. $600. 2008.

Grant awarded for travel to Ghana, West Africa, to establish an environmental study abroad program for an East coast consortium of colleges. Environmental Studies Grant, Swarthmore College. $10,500. 2001.

HONORS AND AWARDS

Campus Catalyst Excellence in Teaching Award, Indiana University Office of Sustainability, 2017.
George I. Treyz Award for Excellence in Economic Analysis, Best Paper Award, Regional Economic Modeling, Inc. 2017.
Most Personable Faculty Award, Student Choice Award, School of Public and Environmental Affairs, Indiana University. 2016.
Outstanding Junior Faculty Award, Office of the Vice Provost for Faculty and Academic Affairs and the Office of the Vice Provost for Research, Indiana University-Bloomington. $14,500 research grant. 2013.
IU Trustees Teaching Award, Indiana University-Bloomington. 2012.
Spot Award, Research Triangle Institute International, RTP, NC. 2009.
Progress Energy Fellow, University of North Carolina at Chapel Hill. 2006-2010.
Future Faculty Fellowship, University of North Carolina at Chapel Hill. 2008.
American Planning Association Best Student Presentation Winner, Upper Midwest American Planning Association Conference. 2005.
Morris Udall Scholar, Swarthmore College. 2002.

Phillip Barley Memorial Scholar, Swarthmore College. 2002.

SELECTED PUBLICITY AND MEDIA MENTIONS

Forward Kentucky, November 13, 2017. "Did environmental rules kill mining? For coal country, that's yesterday's debate."

Science Daily, October 27, 2017. "Efforts to revive coal industry unlikely to work, may slow job growth." (Similar story printed in Science Newsline: Nature & Earth, Common Dreams, IWW Environmental Unionism Caucus, and the Indiana Daily Student)

Greenwire, August 2017. "EPA gathers consumer data as it rethinks GHG standards."

CNBC, Washington Times, IU Newsroom, March 2017. "IU research shows mileage regulations bring long-term benefits but short-term economy lag." (Reprinted in over 150 other media outlets).

Indianapolis Star, March 2017. "Solar energy in crossroads in Indiana" (Reprinted in 24 other sources).

Inside EVs, March 2016. "U.S. Cities Ranked for Plug-in Electric Car Readiness—Portland takes Top Spot." Similar news reports appear in Autocarr, Fleet Management Weekly, and Greener Ideal.

Herald Times, February 19, 2016. "IU Researchers Urge Review of Fuel Economy Standards."

WalletHub, July, 2015. "2015 Most & Least Energy-Expensive States." (Statements quoted in three subsequent news outlets)

CQ Researcher, April 2015. "Sustainability."

Indiana University Press, November 13, 2013. "Survey: Most Americans unaware of financial advantages of owning an electric car" (Reprinted by four other media outlets across the country).

Society for Risk Analysis, Press Release, October 30, 2013. "Residents weigh global benefits and local risks in views of climate change measures." (Reprinted by 289 other media outlets across the country).

Freakonomics, July 24, 2013. "How Politicians Plug Electric Cars."

Indiana University Press, July 17, 2013. "Economy edges out environment for governments plugging electric vehicles" (A variant of the article was also published in Domestic Fuel, Green Autoblog, Blog and Batter Chargers, EV World, Environmental Leader, Earth Techling, and The Green Optimistic).

Indiana Daily Student, April 4, 2013. "Awards granted to outstanding junior faculty."

Inside Higher Ed and WAMC, Northeast Radio, Academic Minute, March 14, 2013. "Dr. Sanya Carley, Indiana University—Consumer Attitude and Electric Cars."

CBS, January 7, 2013. "American Drivers Not Interested in Electric Cars."

International New York Times, International Herald Tribune, January 7, 2013. "Will 2013 be the Year of the Electric Car?"

New York Times, December 26, 2012. "Car Buyers Lack Interest in Electric Cars, Study Says."

Indianapolis Business Journal, January 2, 2013. "Report: Plug-in vehicles slow to spark interest in Indy."

Indiana University Press, December 27, 2012. "IU Study: Consumer intent to purchase electric vehicles is low, varies by city." (Reprinted in a variety of other online outlets).

Indiana University Press, September 18, 2012. "Indiana University Study: Support for Carbon Capture is extensive but not strong." (Reprinted in Science Daily, among a variety of other online outlets).

WTIU "Weekly Special," September 15, 2011. "Early Adopters."

WTIU News, July 19, 2011. "Next-Generation Electric Vehicle Appears in Bloomington."

SPEA Podcast, May, 2011. "The Future of Electric Cars."

Indiana University Press, May 23, 2011. "Journal article examines the effectiveness of state-level energy policies." (Reprinted in Indiana Ag Connection, UtilityProducts.com, Newswise, Indiana Valuation).

AOL Autos, February 23, 2011. "Are Obama's Million EV's Just Science Fiction?"

Kokomo Tribune, September 9, 2010. "19% rate hike coming: Duke Energy plans increase to help pay for $2.88B coal plant."

Indiana University Press, August 20, 2010. "Energy-based Economic Development: A Fad of Here to Stay?" (Reprinted in News Blaze, Newswise, Renewable Energy Sources, World.org)

TEACHING EXPERIENCE

V674: Energy Economics and Policy (Graduate level)
School of Public and Environmental Affairs, Indiana University.
Spring 2011, Spring 2012, Spring 2013, Spring 2014, Spring 2015, Spring 2016

V600: Capstone (Graduate level)
School of Public and Environmental Affairs, Indiana University.
Spring 2016, Spring 2018

V550: Energy Policy Seminar (Masters and Ph.D. level)
School of Public and Environmental Affairs, Indiana University.
Fall 2015, Fall 2017

V450: Research Design (Undergraduate level)
School of Public and Environmental Affairs, Indiana University.
Fall 2015, Fall 2017

E574: Energy Analysis and Markets (Graduate level)
School of Public and Environmental Affairs, Indiana University.
Fall 2010, Fall 2011, Fall 2013

V680: Research Design (Ph.D. level)
Co-instructor of a team-led course, School of Public and Environmental Affairs, Indiana University.
Fall 2011, Fall 2013, Fall 2014, Fall 2015, Fall 2016

E555: Energy Resources and Policy (Undergraduate level)
Teaching Fellow, The Department of Public Policy and the Institute for the Environment, University of North Carolina at Chapel Hill.
Spring 2009

E190H: Honors Freshman Seminar on Energy and Society (Undergraduate level)
Co-instructor, Institute for the Environment, University of North Carolina at Chapel Hill.
Spring 2009

PROFESSIONAL SERVICE

Referee and Reviewer Service*:*

American Journal of Political Science
Climate Policy
Ecological Economics
Economic Development Quarterly
Energies
Energy Economics
Energy Policy
Energy Journal
Energy Research & Social Science
Environmental and Resource Economics
Environmental Practice
Environmental Science & Technology
Ethics, Policy & Environment
Evaluation Review
Geography
Global Environmental Change
International Journal of Business and Economics
IEEE Transactions on Power Systems
J of the Assoc of Envir and Res Economists
J of Environmental Economics and Management
J of Geography and Regional Planning
J of Policy Analysis and Management
J of Policy History
J of Politics
J of Public Admin Research and Theory
National Science Foundation
Nature Energy
Nature Climate Change
PLOS One
Policy Sciences
Policy & Society
Policy Studies Journal
Public Administration Review
Publius: The Journal of Federalism
Regulation & Governance
Review of Policy Research
Renewable and Sustainable Energy Reviews
Springer Publishing
SPEA Insights
State and Local Government Review
Sustainability: Science, Practice & Policy
Transportation Letters

Transportation Research Part D: Transport and Environment

Utilities Policy

Professional, National, and State Service:

Managing Editor, *Journal of Policy Analysis and Management*, 2017-present.
Peer Review Committee Member, EPA Response Surface Methodology, 2017.
VP for Academic Affairs, U.S. Association of Energy Economics, 2018.
Secretary/Treasurer, U.S. Association of Energy Economics, 2015-2016.
Editorial Board, *Energy Research and Social Science*, 2017-2019.
Editorial Board, *Public Administration Review*, 2015-2017.
Executive Committee, Richard G. Lugar Center for Renewable Energy, 2017-present.
Editorial Board, *State and Local Government Review*, 2014-2016.
Conference student paper judge, U.S. Association of Energy Economics, 2014, 2015, 2017.
Conference poster judge, Association of Public Policy Analysis and Management, 2016, 2017.
Conference poster judge, U.S. Association of Energy Economics, 2016, 2017.
Guest editor, Special issue on the American Recovery and Reinvestment Act of 2009, *Review of Policy Research*, 2015-2016.
Finance Committee, Chair, U.S. Association of Energy Economics, 2015-2016.
Chair, Natural Resource Security, Energy, and Environmental Policy Conference Program Committee, Association of Public Policy Analysis and Management, 2015-2016.
Committee Member, Natural Resource Security, Energy, and Environmental Policy Conference Program Committee, Association of Public Policy Analysis and Management, 2013-2016.
Conference Program Committee, U.S. Association of Energy Economics, 2015-2016.
Council Member, U.S. Association of Energy Economics, 2014.
Presidential Advisor, U.S. Association of Energy Economics, 2013.
Academic Affiliate, National Renewable Energy Laboratory, 2013.
Member, Policy Choices Energy and Environment Commission, IU Public Policy Institute, 2011-2012.

University Service:

Member, Bloomington Faculty Council Research Affairs Committee, 2015-2016.
Co-Chair, Energy and the Built Environment, Indiana University, 2013-2016.
Advisory Committee, Workshop in Methods, 2013-2016.
Member, Academic Initiatives Working Group, Indiana University, 2011-2013.
Steering committee, Student Summit on a Green Economy, Indiana University, 2010.

School Service:

Chair, Policy Analysis and Public Finance Faculty Group, 2016-present.
Promotion and Tenure Committee, Indiana University Northwest, 2017.
MPA Curriculum Committee, 2017-2018.
Chair, Policy Committee, School for Public and Environmental Affairs, Indiana University, 2015-2016.
Ph.D. Public Affairs Program Committee, School for Public and Environmental Affairs, Indiana University, 2015-2016.
Chair, Environmental Policy Search Committee, School for Public and Environmental Affairs, Indiana University, 2014-2015.
Policy Committee, School for Public and Environmental Affairs, Indiana University, 2014-2016.
Budgetary Affairs Committee, School for Public and Environmental Affairs, Indiana University, 2014-2016.
Faculty Advisor, Energy Student Leaders Association, Indiana University, 2012-present.
MPA Selection Committee, School for Public and Environmental Affairs, Indiana University, 2013, 2014.

Environmental Policy Ph.D. Exam Committee, School for Public and Environmental Affairs, Indiana University, 2013-2014.
Faculty Hiring Committee, Industrial Ecology and Life-Cycle Assessment, School for Public and Environmental Affairs, Indiana University, 2011-2012.
Faculty Hiring Committee, MPA Program Director, School for Public and Environmental Affairs, Indiana University, 2011-2012.
Member, Hiring Priorities Committee, Policy Analysis and Public Finance faculty group, School for Public and Environmental Affairs, Indiana University, 2011-2012.
Faculty Hiring Committee, Energy Policy, School for Public and Environmental Affairs, Indiana University, 2010-2011.
Committee Member, Energy Concentration, School for Public and Environmental Affairs, Indiana University, 2010-2011.
Ph.D. Dissertation Committee Member:
Adam Abelkop, 2017; Yu Zhang, 2017; Jose Iracheta, 2017; Dave Warren, 2017; Sojin Jang, 2017; Jessica Alcorn, 2016; Zach Wendling, 2016; Elizabeth Baldwin, 2015; Shuang Zhao, 2015.
Ph.D. Program Committee Member, School of Public and Environmental Affairs, Indiana University:
Arthur Ku, 2017; Michelle Lee, 2016; Yu Zhang, 2014; Jessica Alcorn, 2014; Ben Inskeep, 2013; Naveed Paydar, 2013; Chris Miller, 2012; Elizabeth Baldwin, 2012; Dave Warren, 2011; Zach Wendling, 2011; Shuang Zhao, 2010.
Honors Undergraduate or Graduate Thesis Committee Member:
Damon Smith, Indiana University, 2015; Chip Gaul, Department of Public Policy, University of North Carolina-Chapel Hill, 2011; Elinor Benami, Department of Economics, University of North Carolina-Chapel Hill, 2010; Rachel Escobar, Depart. of International Studies, University of North Carolina-Chapel Hill, 2009; Jessie Prentice-Dunn, Depart. of Public Policy, University of North Carolina-Chapel Hill, 2007.
Junior Faculty Hiring Committee, University of North Carolina-Chapel Hill, Department of Public Policy, 2008.
Student representative, University of North Carolina-Chapel Hill, Department of Public Policy, 2007-2008.
Facilitator, Environmental Studies in Ghana, University of Ghana-Legon and Swarthmore College, 2001.

PROFESSIONAL MEMBERSHIP

Association for Public Policy Analysis & Management (APPAM)
Association of Collegiate Schools of Planning (ACSP)
Brewers Association (BA)
Midwest Political Science Association (MPSA)
International Association of Energy Economists (IAEE)
United States Association for Energy Economics (USAEE)

VITA

SUJIT DAS

12305 Fort West Drive
Knoxville, Tennessee 37934

(865) 789-0299
Email: Dass@ornl.gov

EDUCATION

MBA Management Science and Computer Science, University of Tennessee 1984

MS Metallurgical Engineering, University of Tennessee, 1982

B. Tech Metallurgical Engineering, Indian Institute of Technology, Kharagpur, India, 1979. Ranked 2nd in class with Honors.

PROFESSIONAL EXPERIENCE

Sr. Research Staff Member, Energy and Transportation Science Division, Oak Ridge National Laboratory, December 1984-present.

Program manager of the cost modeling of lightweight materials and clean energy manufacturing programs for the U.S. Department of Energy. Develop, manage and lead projects for the DOE Office of Vehicle Technologies and Advanced Manufacturing Office. Responsible for a total annual budget of more than $750K consistently over the past several years and managing a team of 1-6 people per project depending on the project type. Develop cost models of advanced materials and transportation technologies and decision-making tools for several resource markets. Provide market assessments of energy efficient technologies including environmental implications for both domestic and international markets. Developed expertise in several multi-disciplinary research areas including:

- Life Cycle Assessment of Aluminum Intensive Vehicles for the Aluminum Association
- Next generation materials with energy/emissions reduction potential in the U.S. industry for DOE Advanced Manufacturing Office
- Manufacturing process modeling of high temperature stationary fuel cell systems in the 350-400 kW power range for DOE Fuel Cell Technologies Program
- Life cycle modeling of alternative lightweight engine design options for the DOE Propulsion Materials Program
- Market potential and infrastructure assessment of ethanol and hydrogen as alternative transportation fuels
- Cost modeling and life cycle analysis of advanced vehicles and lightweight materials Technologies for DOE Office of Vehicle Technologies
- Material technology assessments related to Partnership for A New Generation of Vehicles (PNGV)/Freedom Cooperative Automotive Research (FreedomCAR)
- Potential of renewable energy technologies in rural Bangladesh
- Biomass refinery analysis
- Economic analysis of advanced power electronics, electric motors, and intelligent transportation systems

- Energy efficiency of distribution transformers
- Cost of alternative fuels
- Forecasting of petroleum and uranium supplies
- Estimation of flood-stage economic damages
- The economic viability of plastics and automobile recycling
- Environmental implications of privatization of the power sector in India
- Market assessments of energy efficient technologies such as home refrigerators in India
- Inspection and Maintenance of two-wheeler vehicles in India
- Assessment of uranium resources

Visiting Fellow, Tata Energy Research Institute (TERI), New Delhi, India, October 1992-June 1993.

Developed a comprehensive, computerized, and PC-based Energy-Economic-Environment database for TERI -- the first of its kind in India and provided technical support in their ongoing energy and economic modeling activities.

Research Assistant, Energy and Economic Analysis Section, Oak Ridge National Laboratory, September 1982-December 1984.

Documented and evaluated several EIA, DOE maintained computers models, i.e., Headwater Benefit Energy Gains Model and the Petroleum Allocation Model. Developed a computer software "BIOCUT" for Economic Evaluation Model for Wood Energy Plantations.

LIST OF PUBLICATIONS

BOOK/CHAPTERS PUBLISHED

Two book chapters published in "Advanced Composite Materials for Automotive Applications: Structural Integrity and Crashworthiness," Edited by Ahmed Elmarakbi, Univ. of Sunderland, UK and published by Wiley & Sons (Aug.'13)

Chapter 3: Low Cost Carbon Fibre for Automotive Applications (Part 1: Low Cost Carbon Fibre Development);

Chapter 17: Low Cost Carbon Fibre for Automotive Applications (Part 2: Applications, Performance and Cost Reduction Models)

"Recycling and Life Cycle Issues for Lightweight Vehicles," A Book Chapter in Materials, Design and Manufacturing for Lightweight Vehicles, edited by P.K. Mallick, Woodhead Publishing Limited, pp. 309-330, 2010

"Material Use in Automobiles." A Book Chapter in Encyclopedia of Energy, published by Elsevier Inc., Vol. 3, pp. 859-869, 2004.

"Plastic Wastes: Management, Control, Recycling, and Disposal." Noyes Data Corporation, NJ (Co-Authored with U.S. Environmental Protection Agency and T. R. Curlee), 1991.

SELECTED REFERRED ARTICLES/PRESENTATIONS (Out of 60+ articles)

"Cost of Ownership and Well-to-Wheels Carbon Emissions/Oil Use of Alternative Fuels and Advanced Light-Duty Vehicle Technologies," Energy for Sustainable Development, 17(2013), pp. 626-641

Served as one of the expert reviewers for the following three recent U.S. DOT/U.S. EPA reports
Mass Reduction for Light-Duty Vehicles for Model Years 2017-2025, EDAG/The George Washington University Report, Apr. 2012
Light-Duty Technology Cost Analysis Pilot Study, FEV Draft Report, Sept. 3, 2009
An Assessment of Mass Reduction Opportunities for a 2017-2020 Model Year Vehicle Program, Lotus Engineering Inc., Mar. 2010

"Lightweighting Opportunities in the Global Automotive Industry," invited presentation at the 2011 International Automotive Lightweight Materials Development Forum, held in Chongqing, China, on Mar. 24-25,'11.(Also at the 12th IUMRS International Conference on Advanced Materials, held in Qingdao, China on Sept. 22-28, 2013)

"Importance of Economic Viability Assessment of Automotive Lightweight Materials" invited presentation at the 3rd Annual Advanced Lightweight Materials for Vehicles conference held on Aug. 11-12, '10, Detroit, MI.

"Analysis of Fuel Ethanol Transportation Activity and Potential Distribution Constraints," Transportation Research Record: Journal of the Transportation Research Board, No. 2168, Transportation Research Board of the National Academies, Washington, DC, 2010, pp. 136-145.

"Reducing GHG Emissions in the United States' Transportation Sector" Energy for Sustainable Development, 15 (2011) 117–136, May 11.

"Life Cycle Assessment of Carbon Fiber-Reinforced Polymer Composites," Intl. Journal of Life Cycle Assessment, Volume 16, Issue 3, pp. 268-282, 2011

"Battle Green," an interview article published in American Metal Market, Oct. 2010, pp. 36-40.

"Shedding Pounds On a Magnesium Diet," Automotive Engg. International, Apr. 6, 2010, pp. 34-36, interview article by Steven Ashley.

"Analysis of Fuel Ethanol Transportation Activity and Potential Distribution Constraints," Transportation Research Record: Journal of the Transportation Research Board, No. 2168, Transportation Research Board of the National Academies, Washington, DC, 2010, pp. 136-145.

"Low-Carbon Fuel Standard – Status and analytic issues," Energy Policy, vol. 38, No.1, Jan. 2010, pp. 580-591.

"Importance of Economic Viability Assessment of Automotive Lightweight Materials," invited presentation at the 3rd Annual Advanced Lightweight Materials for Vehicles," held in Detroit, MI on Aug. 11-12, 2010.

"A Comparative Life Cycle Assessment of Magnesium Front End Parts," SAE Paper No. 2010-01-0275, Society of Automotive Engineers, Warrendale, PA.

"Primary Magnesium Production Costs for Automotive Applications," Journal of Metals, Vol. 60, No. 11, 2008, pp. 51-58.

"A Systems Approach to Life Cycle Truck Cost Estimation," SAE Paper No. 2006-01-3562, Society of Automotive Engineers, Warrendale, PA.

"Automotive Lightweighting Materials Benefit Evaluation," ORNL/TM-2006/545, Oak Ridge National Laboratory, Oak Ridge, TN, Nov. 2006

"Lightweight Opportunities for Fuel Cell Vehicles," SAE Paper No. 2005-01-0007, Society of Automotive Engineers, Warrendale, PA.

"A Comparative Assessment of Alternative Powertrains and Body-in-White Materials for Advanced Technology Vehicles," SAE Paper No. 2004-01-0573, Society of Automotive Engineers, Warrendale, PA.

"Back To Basics? The Viability of Recycling Plastics by Tertiary Approaches," Working Paper #5, Program on Solid Waste Policy, School of Forestry and Environmental Studies, Yale University, New Haven, CT, September 1996. (with T. R. Curlee)

AWARDS & PROFESSIONAL ACTIVITIES

Awarded 2004 Journal of Metals Best Paper by the Mineral, Metals, and Materials Society (TMS)

Chair of Society of Automotive Engineering (SAE) Sustainable Program Development Committee (2013-2014)

Member of Transportation Research Board (TRB) Committees (2008- Present)
Transportation Economics
Alternative Transportation Fuels and Technologies

Invited Speaker on the Life Cycle Assessment of Materials by Beijing University of Technology, China
Conference Session Organizers for SAE and TRB

Peer Reviewers for Several Energy and Environmental Related Journals

Past peer reviewers for the EPA and NHTSA draft reports on the vehicle mass reduction and cost analysis of light-, medium-, and heavy-duty vehicles including:
(i) 2014 EPA Light-Duty Pickup Truck
(ii) 2015 NHTSA Costs of Medium- and Heavy-Duty Vehicle Fuel Efficiency Emission Reduction Technologies for MY 2019-2022
(iii) 2016 NHTSA Mass Reduction for Light-Duty Vehicles for MY 2017-2025

ARIZONA STATE UNIVERSITY
INDUSTRIAL ENGINEERING

DOUGLAS C. MONTGOMERY
Regents' Professor of Industrial Engineering and Statistics
ASU Foundation Professor of Engineering

EDUCATION AND EXPERIENCE

Degrees

Ph.D.	Virginia Polytechnic Institute, 1969
M.S.I.E.	Virginia Polytechnic Institute, 1967
B.S.I.E.	Virginia Polytechnic Institute, 1965

Academic Experience

1988 – Present **Regents' Professor of Industrial Engineering and ASU Foundation Professor of Engineering**, School of Computing, Informatics and Decision Systems Engineering (Program in Industrial Engineering), Arizona State University.

1984 - 1988 **John M. Fluke Distinguished Professor of Engineering**, **Director of Industrial Engineering, Professor of Mechanical Engineering**, Department of Mechanical Engineering, University of Washington.

1978 - 1984 **Professor**, School of Industrial and Systems Engineering, Georgia Institute of Technology.

1972 - 1978 **Associate Professor**, School of Industrial and Systems Engineering, Georgia Institute of Technology.

1969 - 1972 **Assistant Professor**, School of Industrial and Systems Engineering, Georgia Institute of Technology.

1967 - 1969 **Instructor**, Department of Industrial Engineering and Operations Research, Virginia Polytechnic Institute.

Industrial Experience

1966 Manufacturing/Development Engineer, Eli Lilly, Inc. Creative Packaging Division.
1963 - 1964 Process Engineer, Union Carbide Corporation.

Professional Interests

Engineering statistics, including design and analysis of experiments, statistical methods for process monitoring, control, and optimization, and the analysis of time-oriented data. The application of statistics to industrial problems, including engineering design, product and process development, and manufacturing.

Consulting Experience

Extensive consulting assignments involving projects with over 100 organizations. General area of professional experience focused on engineering applications of statistics and operations research methods. Projects have involved design of experiments and response surface methods, implementation of statistical process control, process development including characterization and optimization, time series analysis and the design of forecasting systems, empirical model building, and the design and analysis of physical distribution systems. Specific industry experience includes semiconductors and electronics, medical devices, biotechnology, consumer products, chemical and process industries, aerospace, and the service industries. Some consulting clients include Pfizer, Procter and Gamble, Intel, Motorola, AT&T, Boeing, IBM, The Coca-Cola Company, Lucent Technologies, Dial Corporation, Dow Chemicals, Amoco, Georgia-Pacific, Monsanto Chemicals, Hercules, Alcoa, and Eli Lilly.

HONORS AND AWARDS

1. Spring 2016 Outstanding Professor Award, given by the Vice Rector of Online Education Programs, Technologico de Monterrey, Mexico.
2. Spring 2015 Outstanding Professor Award, given by the Vice Rector of Online Education Programs, Technologico de Monterrey, Mexico.
3. 2015 ASU President's Award for Innovation**,** as Member**,** Vietnam Higher Engineering Education Alliance Program (HEEAP)
4. Honorary Member, American Society for Quality (at time of election, the 25th Honorary Member)
5. Fellow, American Statistical Association
6. Fellow, Royal Statistical Society
7. Fellow, Institute of Industrial and Systems Engineers
8. Elected Member, International Statistical Institute
9. Academician, International Academy for Quality
10. ASQ Reliability Division 2013 Award for Best Reliability Paper in *Quality Engineering* for the article "Experiments for Reliability Achievement"
11. Distinguished Service Medal, 2013. Given by the American Society for Quality.
12. Best paper in 2012 award from the Emerald press, for the paper, "Deploying Lean Six Sigma in a Global Enterprise – Project Identification", by B. Duarte, D.C. Montgomery, J. Fowler and J. Konopka, published in the *International Journal of Lean Six Sigma*, Vol. 3, No. 3, pp. 187-205.
13. Greenfield Medal, 2010. Given by the Royal Statistical Society, for "Contributions to the effective application of statistical methods, particularly process monitoring and optimization, quality improvement and design and analysis of experiments, and for his influential and accessible expository work."
14. American Statistical Association, 2010 Excellence in Continuing Education Course Recognition award for the course "Modern Design and Analysis of Experiments" presented at the 2009 JSM.
15. Arizona Society of Professional Engineers (Engineer's Week, 2010), Engineering Lifetime Achievement Award, 2010
16. George Box Medal, 2008. Given by the European Network for Business and Industrial Statistics (ENBIS) for lifetime contributions to the development and application of statistical methods in European business and industry.
17. Deming Lecture Award, American Statistical Association, presented at the Joint Statistical Meetings, Salt Lake City, 31 July, 2007. The presentation given accompanying the award was entitled "A Modern Framework for Enterprise Excellence".
18. Conference Honoree, Quality and Productivity Research Conference (American Statistical Association), Santa Fe, New Mexico, 4-6 June, 2007.
19. Testimonial Award, American Society for Quality, 2007, for distinguished service as Chair of the Shewhart Medal Committee, 2005-2007.
20. Lloyd S. Nelson Award, 2005. Given by the Statistics Division of the American Society for Quality for the *Journal of Quality Technology* paper having the greatest impact for professional practitioners.
21. ASU Outstanding Doctoral Mentor Award, 2004.

22. Shewell Award, 2001. Given by the Chemical and Process Industries Division of the ASQC for the best technical paper at the ASQC/ASA Fall Technical Conference, 2000.
23. Shewhart Medal, 1997. Awarded by the American Society for Quality Control for Outstanding Technical Leadership in the Field of Modern Quality Control.
24. William G. Hunter Award, 1996. Given by the Statistics Division of the American Society for Quality Control. This award is given for excellence in technical innovation and in the integration of statistics with other disciplines.
25. Brumbaugh Award, 1994. Given by the American Society for Quality Control for the best paper in a journal of the Society.
26. Shewell Award, 1993. Given by the Chemical and Process Industries Division of the ASQC for the best technical paper at the ASQC/ASA Fall Technical Conference, 1992.
27. Ellis R. Ott Award, 1992. Given by the Ellis R. Ott Foundation for the best paper on quality engineering during a two-year period.
28. Inagural W.L. Gore Lecture in Management Science, The Alfred Lerner College of Business and Economics, The University of Delaware, "Design of Experiments: New Methods and How to Use Them in Design, Development and Decision-making", 16 March 2011.
29. Invited Keynote Address, "Innovation, Statistics and Quality Technology", Forth International Conference on Lean Six Sigma, Glasgow, Scotland, 26-27 March, 2012.
30. Invited Keynote Address, "The Industrial Engineer and the Quality Improvement Sciences: Have We Missed an Opportunity?", 8th Israeli Industrial Engineering Research Conference, Beer Sheva, Israel, May 1994
31. W. J. Youden Memorial Address, "A Perspective on Models and the Quality Sciences: Some Challenges and Future Directions", presented at the 42nd Annual ASQC/ASA Fall Technical Conference October 1998.
32. Inyong Ham Distinguished Lecturer, Department of Industrial and Manufacturing Engineering, Pennsylvania State University, "Statistical Methods for Process Robustness Studies", November 11, 1999.
33. Invited Keynote Address, "Experimental Design for Process and Product Design and Development" Royal Statistical Society, Glasgow Scotland, 11 September 1998.
34. Invited Keynote Address, "The Future of Industrial Statistics", South African Statistical Association Annual Meeting, University of the Witswaterstrand, Johannesburg, South Africa, 10 November 2000.
35. Invited Keynote Address, "Some Opportunities and Challenges for Industrial Statisticians", Industrial Statistics in Action 2000, conference at the University of Newcastle-Upon-Tyne, United Kingdom, 8-10 September, 2000.
36. Isobel Loutit Invited Plenary Address on Business and Industrial Statistics, "The Modern Practice of Statistics in Business and Industry", 33rd Annual Meeting of the Statistical Society of Canada, Halifax, NS, 8-11 June 2003. This was the inaugural Isobel Loutit Address.
37. Invited Keynote Address, "Statistics and Statisticians in Today's Business World", Royal Statistical Society Conference on Business Improvement through Statistical Thinking, 21-22 April 2004, Coventry, UK.
38. Invited Keynote Address, "Statistics and the Transformation of Science, Business and Industry", 5th Annual ENBIS Conference, University of Newcastle, Newcastle-Upon-Tine, UK, 14-16 September, 2005.
39. Invited Keynote Address, "The Modern Practice of Statistics in Business and Industry" Swiss Statistics Meeting, Lucerne, Switzerland, 14-16 November, 2007.

40. Invited Keynote Address, "Modern Experimental Design and its Impact on Design for Six Sigma", Third International Conference on Six Sigma, Edinburgh, Scotland, 15-16 December, 2008.
41. Testimonial Award from the Board of Directors of the American Society for Quality Control, 2000, for Leadership and Distinguished Service as Chair of the Brumbaugh Award Committee from 1996-2000.
42. Testimonial Award from the Board of Directors of the American Society for Quality Control, 1998, for Leadership and Distinguished Service as Editor of the *Journal of Quality Technology*, 1994-1997.
43. Pritsker Award - Annual Teaching Award, Department of Industrial and Management Systems Engineering, Arizona State University, 1997
44. University Distinguished Visitor, University of Manitoba, Fall, 1994.
45. Distinguished Alumnus, Department of Industrial and Systems Engineering, Virginia Tech (Awarded 1994).
46. College of Engineering and Applied Sciences, Arizona State University, Teaching Excellence Award (Graduate), 1994.
47. Pritsker Award - Annual Teaching Award, Department of Industrial and Management Systems Engineering, Arizona State University 1994.
48. Anderson Teaching Award, Department of Industrial and Management Systems Engineering, Arizona State University, 1993.
49. Pritsker Award - Annual Teaching Award, Department of Industrial and Management Systems Engineering, Arizona State University, 1992.
50. Engineer of the Year, 1987, Puget Sound Engineering Council.
51. Industrial Engineer of the Year, 1986, Puget Sound Region Institute of Industrial Engineers.
52. Alpha Pi Mu/AIIE Outstanding Teacher Award, School of ISyE, Georgia Tech, 1976-1977.
53. Listed in *Who's Who in the American South and Southwest, American Men and Women of Science, Who's Who in Engineering.*
54. Phi Kappa Phi
55. Sigma Xi
56. Alpha Pi Mu
57. Mu Rho Sigma (Honorary Member, Va. Tech Chapter 1995)

PROFESSIONAL ACTIVITIES

1. Editor, *Quality & Reliability Engineering International*, 2000-present
2. Editor, *Journal of Quality Technology,* 1994-1997
3. Member, Technical Advisory Board, United States Golf Association, 1997-2007
4. American Society for Quality, Honorary Member
    a. Chair, Shewhart Medal Committee, 2004
    b. Chair, Brumbaugh Award Committee, 1997
    c. Member, Brumbaugh Award Committee, 1993 – 2000
    d. Member, Shewhart Medal Committee, 1997 - present
    e. Chair, Statistics Division, 1981-1982
    f. Statistics Technical Committee, 1976-1979
    g. Publications Management Board, 1977-1980, 1994-1997, 2000-present
    h. Secretary, PBM, 1979-1980

5. American Statistical Association, Fellow
    a. Founding member, Committee on Statistics in Quality and Productivity
    b. Advisory Board, Section on Physical and Engineering Sciences, 1981-1983.
6. Royal Statistical Society, Fellow
7. The Institute of Industrial and Systems Engineers, Fellow
    a. Region IV Chair, Production Planning and Control Division, 1971-1972
    b. Research and Publications Chair, Production Planning and Control Division, 1972-1973
    c. Director-Elect, Production Planning and Control Division, 1972-1973
    d. National Director, Production Planning and Control Division, 1973-1974
    e. Research Chair, Production Planning and Control Division, 1975-1976
    f. Advisory Board Member, Production Planning and Control Division, 1975-1976
    g. Program Chair, Quality Control and Reliability Division, 1975-1976
    h. Region IV Chair, Operations Research Division, 1974-1978
8. Elected Member, International Statistical Institute
9. National Academy of Science, Committee on Applied and Theoretical Statistics, Panel on Research Needs in Statistical Quality Control, 1982-1984
10. Advisory Editor in Engineering, John Wiley & Sons, Inc., 1979-1983
11. Department Editor, Applied Probability and Statistics, *IIE Transactions*, 1980-1986.
12. Book Review Editor, *Journal of Quality Technology*, 1980-1982
13. Associate Editor, *Naval Research Logistics Quarterly*, 1982-1988
14. Associate Editor, *Journal of Forecasting*, 1981-1983
15. Associate Editor, *Revue Francaise d'Automatique, d'Informatique et de Recherche Operationnelle*, 1980-1991
16. Department Editor, Quality & Reliability Engineering, *IIE Transactions*, 1992-1994
17. Editorial Board Member, *Journal of Quality Technology*, 1980-1982, 1987-present
18. Editorial Board Member, *Quality and Reliability Engineering International,* 1994-present
19. Editorial Board Member, *Quality Engineering,* 1997- present
20. Editorial Board Member, *Journal of Applied Statistics*, 2000 – present
21. Editorial Board Member, *International Journal of Experimental Design and Process Optimization*, 2009-present
22. Advisory Editor, *Quality Technology and Quantitative Management*, 2005-present
23. Editorial Board Member, *International Journal of Production Research*, 1997- 2009
24. Editorial Board Member, *Total Quality Management*, 2000-present
25. Advisory Editor, *Journal of Probability and Statistical Science*, 2002-present
26. Associate Editor, *Naval Research Logistics,* 2003-2010.
27. Referee for various journals, including: *Technometrics, Operations Research, Management Science, IIE Transactions, Operational Research Quarterly, Naval Research Logistics Quarterly, Journal of the Royal Statistical Society, Computational Statistics and Data Analysis, The American Statistician, American Institute of Chemical Engineers Transactions, Communications in Statistics, Journal of Statistical Computation and Simulation, The Engineering Economist, Computers in Industrial Engineering, Transportation Research, Journal of the American Statistical Association,* and *IEEE Transactions on Semiconductor Manufacturing*.
28. Technical manuscript reviewer for John Wiley and Sons, McGraw-Hill, Holden-Day, Marcel Dekker and Duxbury.
29. Research Proposal Reviewer for the National Science Foundation, various divisions, 1987-present
30. Chair and organizer of technical paper sessions at several conferences of IIE, ASQ, ORSA/TIMS, and the Winter Simulation Conference, 1970-1985

31. Co-chair for the 12th Annual Quality and Productivity Research Conference, Co-sponsored by ASU and Motorola Semiconductor Products, May 17-19, 1995
32. Co-chair for the 2002 Industrial Engineering Research Conference, Orlando, FL, May 2002
33. Chair for the 18th Annual Quality and Productivity Research Conference, Tempe, AZ, June, 2002
34. Invited short course presenter at the Joint Statistical Meetings, the ASQ/ASA Fall Technical Conference, the U.S. Army Design of Experiments Conference, and the Army Conference on Applied Statistics.
35. Speaker for numerous local chapters of IIE, ASA, and ASQ, 1969-present
36. Participant in several seminar programs for international visitors to Georgia Tech, 1969-1984

SERVICE ACTIVITIES

1. Arizona State University

Chair Search Committee, Industrial Engineering, 1993-94
Department Personnel Committee, 1988-1997, Chair 1996-97
Department Faculty Recruiting Committee, 1989-1993, 1996-97
Department Graduate Committee, 1996-present, Chair 1996-2001
Engineering College Personnel Committee, 1998-present
Engineering College Core Curriculum Committee, 1989-1991
Engineering College Graduate Committee, 1989-1993
Engineering College Bylaws Committee, 1995-1997
University Council on Research and Creative Activities, 1995-1998
Ira A. Fulton School of Engineering Personnel Committee, 1997-2005
Chair Search Committee, Industrial Engineering, 2003-04
SCIDSE Personnel Committee, 2011-2012

2. Georgia Institute of Technology

Advisory Committee, School of ISyE, 1980-82
Chair, Graduate Committee, School of ISyE, 1982-83
M.S. Comprehensive Exam Committee, School of ISyE, 1977-1978, 1982-1983
Undergraduate Curriculum Committee, School of ISyE, 1975-76
Chair, M.S. Comprehensive Exam Committee, School of ISyE, 1974-1975
Research Evaluation Committee, School of ISyE, 1973-1974, 1974-1975
Computer Engineering Committee, College of Engineering, 1972
Chair, Probability and Statistics Interest Group, 1971-1973
Chair, Computers and Simulation Interest Group, 1971-1972
Computer Coordinator, School of ISyE, 1970-1971
Graduate Committee, School of ISyE, 1970-1973, 1977-1979

3. Professional Development Courses Taught (Georgia Institute of Technology)

Design of Production-Inventory Systems
Design of Experiments
Materials Handling
Simulation Techniques (academic administrator, 1973)
Industrial Engineering Review (P.E. Exam)
Traffic Engineering
Statistical Methods
Statistical Design and Analysis
Design and Analysis of Experiments (academic administrator, 1978-1984)
Applied Regression Analysis (academic administrator, 1978-1984)
Sampling Methods and Statistical Analysis in Power Systems Load Research (co-administrator, 1982-1984)

4. Professional Development Courses Taught (University of Washington)

Applied Regression Analysis (academic administrator)
Design and Analysis of Experiments (academic administrator)
Statistical Process Control (academic administrator)
Process Optimization & Response Surfaces (academic administrator)

5. Professional Development Courses Taught (Arizona State University)
Instructor in ASU Master Black Belt Certification Program
Training the Trainer in Experimental Design
Introduction to Design of Experiments (also presented over NTU)
Developed on-line courses in design of experiments, regression analysis, and six sigma methods, certificate program in six sigma methods/industrial statistics, participated in numerous global outreach programs to organizations in the US and abroad

INTERNATIONAL ACTIVITIES AND CONFERENCE PARTICIPATION

1. Academic Program Reviewer, National University of Singapore, Department of Industrial and Systems Engineering, 2014, 2009.
2. Invited keynote address, "Innovation, Statistics and Quality Technology", Fourth International Conference on Lean Six Sigma, Glasgow, Scotland, 26-27 March, 2012.
3. Invited speaker, "Generating and Assessing Exact G-optimal Designs", Iassic Newton Institute for Mathematical Sciences, Cambridge, Design and Analysis of Experiments Workshop, 30 August – 2 September, 2011.
4. Invited keynote Address, "Modern Experimental Design and its Impact on Design for Six Sigma", Third International Conference on Six Sigma, Edinburgh, Scotland, 15-16 December, 2008.
5. Invited Keynote Address, "The Modern Practice of Statistics in Business and Industry" Swiss Statistics Meeting, Lucerne, Switzerland, 14-16 November, 2007.
6. Invited Keynote Address, "Statistics and the Transformation of Science, Business and Industry", 5th Annual ENBIS Conference, University of Newcastle, Newcastle-Upon-Tine, UK, 14-16 September, 2005.
7. Invited Keynote Address, Royal Statistical Society Conference on Business Improvement through Statistical Thinking, 21-22 April 2004, Coventry, UK.
8. Isobel Loutit Invited Plenary Address on Business and Industrial Statistics, 33rd Annual Meeting of the Statistical Society of Canada, Halifax, NS, 8-11 June 2003. This was the inaugural Isobel Loutit Address.
9. Invited Speaker, 6th International Conference on Teaching Statistics, Cape Town South Africa, July 2002.
10. Invited Keynote Address, South African Statistical Association Annual Meeting, University of the Witswaterstrand, Johannesburg, South Africa, November 2000.
11. Invited Keynote Address, Industrial Statistics in Action 2000 Conference at the University of Newcastle-Upon-Tyne, United Kingdom, September 2000.
12. Invited Keynote Speaker, Royal Statistical Society, Glasgow, Scotland, September 1998.
13. Invited Speaker, Congress of the International Federation of Nonlinear Analysts, Athens, Greece, July 1996.
14. Invited Keynote Speaker, 8th Israeli Industrial Engineering Conference, Beer Sheva, Israel, 1994
15. Invited Keynote Speaker, International Quality Forum, University of Texas El Paso, El Paso, Texas, 1992.

16. Invited Speaker, International Industrial Engineering Research Symposium, Monterey Institute of Technology, Monterey, Mexico 1991.
17. Chairman, Regression Methodology Session, International Forecasting Symposium, Quebec, May 1981.
18. Invited Speaker, International Symposium on Industrial Engineering, University of Regiomontana, Monterrey, Mexico, September 1980.
19. Co-Chairman and organizer, Forecasting Session; 24th International TIMS Conference, Honolulu, Hawaii, June 1979.
20. Consultant to Coca-Cola Export Corporation (includes: Coca-Cola Europe, Coca-Cola Latin America), 1974-1984.
21. Invited Speaker, Joint Meeting of Japan Operations Research Society, Japan Industrial Management Association, and Kansai Institute for Information Systems, Osaka, Japan, August 1977.
22. Invited Speaker, 6th Management Science Colloquium, Osaka University, Japan, August 1977.
23. Invited Speaker, 23rd International Management Science Conference, Athens, Greece, July 1977.
24. Invited Speaker, 2nd Interamerican Conference on Systems and Information Engineering, Mexico City, November 1974.
25. Visiting Professor of Engineering, Monterrey Institute of Technology, Monterrey, Mexico, spring quarter 1972; co-sponsored by the organization of American States.

FUNDED RESEARCH

1. Design Rules for Vertical Paper-based Immuno-Diagnostic System, Defense Threat Reduction Agency, joint with the University of Arizona School of Medicine and the University of Utah-Reno School of Medicine, 2016-2017, co-principal investigator, $188,500.
2. Science of Test, Department of Defense, 2014-2018, co-principal investigator, $485,000.
3. Science of Test, Department of Defense, 2011-2014, co-principal investigator, $385,000.
4. Collaborative Research: Efficient Experimentation for Product and Process Reliability Improvement, NSF, 2009-2012, co-principal investigator, $348,000.
5. Web-Based Active Learning Modules for Teaching Statistical Quality Control, NSF, 2009-2011, co-principal investigator, $245,000.
6. Advanced Techniques in Design of Experiments for Computational and Physical Multivariate Experiments, NASA, 2008, principal investigator, $50,000.
7. Collaborative Research: Hierarchical Modeling of Yield and Defectivity to Improve Factory Operations, NSF/SRC/ISMT, 2004-2007, co-principal investigator, $300,000.
8. Collaborative Research: Monitoring Product and Product Quality Profiles, NSF, 2004-2005, co-principal investigator, $100,000.
9. Generalized Linear Model-Based Process Control for Multivariate Measurements, National Science Foundation, 1999-2003, co-principal investigator, $211,000.
10. NSF IUERC in Quality & Reliability Engineering, 1997-2001, co-director and co-principal investigator. ASU share of annual center funding was approximately $150,000.
11. Research in Industrial Statistics (projects/graduate student research) sponsored by various organizations including Chrysler Electronics, Kellogg Corporation, SGS Thompson, and the Dial Corporation, 1996-1998, co-principal investigator, $231,000.

12. Funding for Editorial Operation of JQT, ASQC, 1994-1997, principal investigator, $315,000.
13. Graduate Education in Engineering for Women and Minorities, National Science Foundation, 1992-1997, co-principal investigator, $850,000.
14. Process Control Methodology for the Hall Process, Alcoa, 1991, principal investigator, $65,000.
15. Implementation of Design of Experiments, Allied-Signal Aerospace, 1989, principal investigator, $40,000.
16. Statistical Methods for Quality and Process Improvement, IBM Corporation, 1985-1988, principal investigator, $450,000.
17. Process Control and Optimization Studies for Substrate Manufacturing, IBM Corporation, 1985, principal investigator, $67,000.
18. Quality and Process Control in the Factory of the Future, Boeing Electronics Company, 1986, principal investigator, $25,000.
19. Statistical Modeling and Analysis in Quality Assurance, Office of Naval Research, 1979-1985, principal investigator, $320,000.
20. Determination of International Differences in Reported Fire Losses: Update and Extensions, National Fire Data Center, U.S. fire Administration, 1981, co-principal investigator, $50,000.
21. Factor Screening Designs in Computer Simulation Experiments, Office of Naval Research, 1978, principal investigator, $25,000.
22. Studies in Support of the Application of Statistical Methodology to the Design and Evaluation of Operational Tests, Department of the Army, Harry Diamond Laboratories, 1977, co-principal investigator, $45,000.
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Papers and Presentations at Meetings

193. Hill, R. R., Ahner, D, Dillard, D. and Montgomery, D. C. (2017), "Examining Potential Reductions in Wind Tunnel Testing Data Requirements", Presented at the Quality and Productivity Research Conference, Storrs, CT, June, 2017.

192. Hassler, E., Montgomery, D.C., and Silvestrini, R. (2016), "Design of Experiments for Generalized Linear Models with Random Blocks", Invited presentation at the Quality and Productivity Research Conference, Tempe, AZ 13-16 June, 2016.
191. Burke, S.E., Anderson-Cook, C.M., Borror, C.M., and Montgomery, D.C., (2016), "A Layered Pareto Front Approach to Search for the Top *N* Subpopulations in a Stockpile", Invited presentation at the Quality and Productivity Research Conference, Tempe, AZ 13-16 June, 2016.
190. Montgomery, D.C. (2016), "Modern Experimental Design or The Flight of The Phoenix", Invited plenary address at the JMP Discovery Summit Europe, Amsterdam, 15-17 March 2016.
189. Mancenido, M.V., Montgomery, D.C., and Pan, R. (2015), "Performance of Standard Mixture Designs in Modeling Ordinal Responses", presentation at the 2015 INFORMS annual meeting, Philadelphia.
188. Montgomery, D.C. (2015), "Design of Experiments: A Key to Successful Innovation", Invited presentation at the 59th Annual Fall Technical Conference, Houston, TX. 8-9 October.
187. Burke, S.E., Montgomery, D.C., Borror, C.M., and Silvestrini, R.T. (2015), "Optimal Designs for Dual Response Systems", Invited presentation at the 59th Annual Fall Technical Conference, Houston, TX. 8-9 October.
186. Weese, M.L., Montgomery, D.C. and Ramsey, P.J. (2015), "Analysis Strategies for Definitive Screening Designs", Invited presentation at the 59th Annual Fall Technical Conference, Houston, TX. 8-9 October.
185. Montgomery, D.C. (2015), "Modern Experimental Design or The Flight of The Phoenix", Invited plenary address at the JMP Discovery Summit, San Diego, CA, 14-17 September 2015.
184. Ramsey, P., Weese, M., and Montgomery, D.C. (2015), "Model Selection Strategies for Definitive Screening Designs Using JMP Pro and R", Invited presentation at the JMP Discovery Summit, San Diego, CA, 14-17 September 2015.
183. Montgomery, D.C. (2015), "Teaching Design of Experiments to Engineers and Scientists", invited presentation at the Design and Analysis of Experiments Conference 2015, Cary NC, 4-6 March 2015.

182. Mancendito, M., Montgomery, D.C., and Pan, R. (2014), "Modeling Ordered Categorial Responses in Mixture Expoeriments", Invited presentation at the 58th Annual Fall Technical Conference, Richmond, Va., 2-3 October.

181. Stone, B.B., Montgomery, D.C., Silvestrini, R., and Jones, B. (2014), "No Confounding Designs of 20 and 24 Runs: Alternatives to Resolution IV Screening Designs", Invited presentation at the 58th Annual Fall Technical Conference, Richmond, Va., 2-3 October.

180. Montgomery, D.C. (2014), "The Contribution of Six Sigma to the Development of Statistical Thinking in the Workplace", Invited presentation at the 9th International Conference on Teaching Statistics, Flagstaff, AZ, 13-18 July.

179. Montgomery, D.C. (2014), "Innovation, Six Sigma and Quality Technology", Invited presentation at the 2014 Joint Research Conference, Seattle, Washington, 24-26 June.

178. Shinde, S.M., Montgomery, D.C. and Jones, B. (2013), "Projection Properties of No-Confounding Designs for Six, Seven, and Eight Factors in Sixteen Runs", invited presentation at the 57th annual Fall Technical Conference, San Antonio, Texas, 18 October 2013.

177. Montgomery, D.C. (2013), "Stu Hunter's Contributions to Statistics and Quality Engineering", invited presentation at the 57th annual Fall Technical Conference, San Antonio, Texas, 17 October 2013.

176. Jones, B. and Montgomery, D.C. (2013), invited short course, "Recent Developments in Design of Experiments", presented at the 57th annual Fall Technical Conference, San Antonio, Texas, 16 October 2013.

175. Jones, B. and Montgomery, D.C. (2013), "Stu Hunter's Contributions to Statistics and Quality Engineering", invited presentation in the *Technometrics* session, Joint Statistical Meetings, Montreal, Canada, August 2013.

173. Montgomery, D.C. (2013), "Stu Hunter's Contributions to Statistics and Quality Engineering", invited presentation at the conference honoring Stu Hunter's 90th birthday, Amsterdam, March 2013.

172. Chen, Y., Montgomery, D.C., Fowler, J., and Pfund, M. (2013), "Using Regression Splines to Parameterize Composite Dispatching Rules", presented at the 43rd International Confernce on Computers and Industrial Engineering, 16-18 October, 2013, Hong Kong.

171. Hassler, E., Montgomery, D.C., and Silvestrini, R. (2013), "Bayesian D-Optimal Design Issues for Generalized Linear Models", invited presentation at the 11th Workshop on Intellegent Statistical Quality Control, Sydney, Australia, 20-23 August, 2013.

170. Rigdon, S., Pan, R., Montgomery, D.C. and Borror, C.M. (2012), "Design of Experiments for Reliability Improvement", invited presentation at the 56th Annual Fall Technical Conference, St. Louis, MO, 3-4 October, 2012.

169. Timmer, D., Gonzalez, Montgomery, D.C. and Borror, C.M. (2012), "DOE Education Strategies", invited presentation at the 56th Annual Fall Technical Conference, St. Louis, MO, 3-4 October, 2012.

168. Montgomery, D.C. (2012), "Methods and Applications of Generalized Linear Models", one-day short course presented at the 56th Annual Fall Technical Conference, St. Louis, MO, 3 October, 2012.

167. Montgomery, D.C. (2012), "Experiments with Physical and Resource Constraints", Invited presentation at the 2012 Joint Statistical Meetings, 28 July – 2 August, San Diego, CA.

166. Montgomery, D.C. (2012), "Innovation, Statistics and Quality Technology", Invited keynote address presented at the Fourth International Conference on Lean Six Sigma, Glasgow, Scotland, 26-27 March, 2012

165. Timmer, D., Gonzalez, M., Borror, C. and Montgomery, D.C. (2011), "Web-Based Active Learning Laboratories for Teaching Control Charts", presented at the 55^{th} Annual Fall Technical Conference, Kansas City, October 13-14, 2011.

164. Krueger, D. and Montgomery, D.C. (2011). "Integrating CART and Generalized Linear Models for Improving process Understanding", presented at the 55^{th} Annual Fall Technical Conference, Kansas City, October 13-14, 2011.

163. Montgomery, D.C. (2011), "Generating and Assessing Exact G-optimal Designs" , Invited presentation at the Iassic Newton Institute for Mathematical Sciences, Cambridge, Design and Analysis of Experiments Workshop, 30 August – 2 September, 2011.

162. Montgomery, D.C. (2011), "Design of Experiments: New Methods and How to Use Them in Design, Development and Decision-making", Inaugural W.L. Gore lecture at the Alfred Lerner College of Business and Economics, The University of Delaware, 16 March 2011.

161. Shinde, S. and Montgomery, D.C. (2010), "Analysis Methods for Non-regular Fractional Factorial Designs, presented at the INFORMS Annual Meeting, Austin Texas, 7 – 10 November.

160. Monroe, E., Pan, R., Montgomery, D.C., Borror, C.M., and Anderson-Cook, C.M. (2010), "Sensitivity Analysis of Optimal Designs for Accelerated Life Testing", *Journal of Quality Technology* invited paper session, INFORMS Annual Meeting, Austin Texas, 7 – 10 November.

159. Jones, B. and Montgomery, D.C. (2010), "Workshop on Modern Experimental Design Methods", presented at the 2010 Army Conference on Applied Statistics" Cary, NC, 18-19 October.

157. Johnson, R.T., Montgomery, D.C., Jones, B., and Parker, P.A. (2010), "Comparing Computer Experiments for Fitting High-Order Polynomial Models", invited presentation at the *Journal of Quality Technology* Session at the 54^{th} Annual Fall Technical Conference, Birmingham, Alabama, 7-8 October.

156. Fish, B.R., Rigdon, S.E., Borror, C.M., Montgomery, D.C. and Pan, R. (2010), "Optimal Designs for Multifactor Life Testing Experiments", invited presentation at the 10^{th} International Workshop on Intelligent Statistical Quality Control, Seattle, WA 18-20 August.

155. Johnson, R.T., Montgomery, D.C. and Kennedy, K.S. (2010), "Hybrid Space-Filling Designs for Computer Experiments", invited presentation at the 10^{th} International Workshop on Intelligent Statistical Quality Control, Seattle, WA 18-20 August.

154. Rigdon, S.E., Montgomery, D.C., Pan, R., and Borror, C.M. (2010), "Optimal Design for Multi-Factor Life-Testing Experiments", presented at the Joint Statistical Meetings, Vancouver BC, Canada, 31 July-5 August.

153. Montgomery, D.C. (2010), "A New Framework for Teaching Design of Experiments", Invited Panel Discussion on Future Developments in Experimental Design at the Joint Statistical Meetings, Vancouver BC, Canada, 31 July-5 August.

152. Laungrungrong, B., Borror, C.M., and Montgomery, D.C. (2009), "Multivariate Poisson-Distributed Control Charts", 53rd Annual Fall Technical Conference, Indianapolis, 7-10 October.

151. Capehart, S.R., Kulahci, M, Keha, A., and Montgomery, D.C. (2009), "Designing Fractional Factorial Split-Plot Experiments using Integer Programming", 53rd Annual Fall Technical Conference, Indianapolis, 7-10 October.

150. Montgomery, D.C. (2009), "Critical Components of a Quality and Reliability Engineering Graduate Program", presentation and panel discussion at the INFORMS annual meeting, San Diego CA, 11-14 October.

149. Montgomery, D.C. (2009),"Panel Discussion: Information and Messages from Editors of QSR Journals", presented at the INFORMS annual meeting, San Diego CA, 11-14 October.

148. Montgomery, D.C. (2009), "Generating and Assessing Exact *G*-Optimal Designs: (Is it worth it?)", invited presentation at the Joint Statistical Meetings, 3 August, Washington, DC.

147. Montgomery, D.C. (2009), "Modern Experimental Design methods and Their Impact on Business and Industry", invited tutorial session at the INFORMS Regional Conference, 24 April, Tempe AZ.

146. Jones, B. Johnson, R.T., and Montgomery, D.C. (2009), "Comparing Space Filling Designs for Gaussian Process Models", presented at the INFORMS Regional Conference, 24 April, Tempe AZ.

145. Broyles, J.R., Cochran, J.K., and Montgomery, D.C. (2009), "A Markov Decision Process for Hospital Inpatient Staffing", presented at the INFORMS Regional Conference, 24 April, Tempe AZ.

144. Montgomery, D.C. (2008), "Modern Experimental Design and its Impact on Design for Six Sigma", Invited keynote Address at the Third International Conference on Six Sigma, Edinburgh, Scotland, 15-16 December, 2008.

143. Johnson, R.T., Montgomery, D.C., and Jones, B. (2008), "Comparing Designs used for Fitting Gaussian process Models", invited presentation at the 52nd Annual Fall Technical Conference, Phoenix, AZ, 9-10 October, 2008.

142. Krueger, D. and Montgomery, D.C. (2008), "Semiconductor Yield Modeling using Generalized Linear Models", invited presentation at the 52nd Annual Fall Technical Conference, Phoenix, AZ, 9-10 October, 2008.

141. Montgomery, D. C. (2008), "Some Experiences with Designing Experiments", Friday Luncheon Address, 52nd Annual Fall Technical Conference, Phoenix, AZ, 9-10 October, 2008.

140. Montgomery, D.C. (2008), "Statistical Design Techniques for Robust Design", invited presentation at the European Conference on Design of Experiments, Antwerp, Belgium, January, 2008.

139. Montgomery, D.C. (2007), "A Modern Framework for Enterprise Excellence", Deming Lecture, presented at the Joint Statistical Meetings, Salt Lake City, 31 July.

138. Montgomery, D.C. (2007), "Statistics and Science, Business and Industry", Invited keynote presentation at the JMP Users' Conference, Cary NC, 13 June 2007.
137. Montgomery, D. C. (2007), "Teaching DOX: Some Adventures and Lessons Learned", Invited Plenary Presentation at the ASA Quality and Productivity Research Conference, Santa Fe, New Mexico, 4 June 2007.
136. Montgomery, D. C. (2006), "Logistic Regression", invited short course given at the 50th Annual ASA/ASQ Fall Technical Conference, Columbus OH, October, 2006
135. Montgomery, D. C. (2006), "Comparison and Evaluation of Designs", invited presentation at the Joint Statistical Meetings, Seattle, WA, August, 2006.
134. Montgomery, D. C. (2006), "The Impact of Statistics on Science, Business and Industry", invited Keynote Address, meeting of the International Statistical Institute, Lima, Peru, January, 2006.
133. Montgomery, D. C. (2005), "Some Trends in Six-Sigma Education", invited presentation at the 49th Annual ASA/ASQ Fall Technical Conference, St. Louis MO, 20-21 October, 2005.
132. Lawson, C. A. and Montgomery, D. C. (2005), "Business Process Characterization using Categorical Data Models", invited presentation at the 49th Annual ASA/ASQ Fall Technical Conference, St. Louis MO, 20-21 October, 2005.
131. Montgomery, D. C. (2005), "Criteria for Designing Experiments: Some Practical Considerations", invited presentation at the Los Alamos National Labs Design and Analysis of Experiments Conference, Santa Fe, NM,.11-14 October, 2005.
130. Montgomery, D. C. and Goldfarb, H. B. (2005),"Graphical Methods for the Evaluation of Mixture and Mixture-Process Designs", invited presentation in the 50th anniversary of mixture experiments session, Joint Statistical Meetings, Minneapolis, MN, 7-11 August, 2005.
129. Montgomery, D. C. (2005), "Statistics and the Transformation of Science, Business and Industry", invited keynote presentation at the 5th Annual ENBIS Conference, University of Newcastle, Newcastle-Upon-Tine, UK, 14-16 September, 2005.
128. Park, You-Jin, Richardson, D. E., Borror, C. M., Anderson-Cook, C. M., and Montgomery, D. C. (2004), "Prediction Variance Properties of Second-Order Response Surface Designs for Cuboidal Regions", invited paper presented at the 48th ASA/ASQ Fall Technical Conference, Roanoke, VA, 14-15 October.
127. Robinson, T. J., Wulff, S. S., Montgomery, D. C., and Kurhi, A. I (2004), "A Response Surface Approach to Robust Parameter Design using Generalized Linear Models", invited paper presented at the 48th ASA/ASQ Fall Technical Conference, Roanoke, VA, 14-15 October.
126. Heredia-Langner, A., Montgomery, D. C., Carlyle, W. M., and Borror, C. M. (2004), "Model-Robust Optimal Designs: A Genetic Algorithm Approach", invited paper presented in the *Journal of Quality Session* at the 48th ASA/ASQ Fall Technical Conference, Roanoke, VA, 14-15 October.
125. Chung, J., Goldfarb, H. B., and Montgomery, D. C. (2004), "Statistical Designs for Mixture-Process Variable Experiments with Control and Noise Variables", invited paper presented at the 48th ASA/ASQ Fall Technical Conference, Roanoke, VA, 14-15 October.
124. Holcomb, D. R., Montgomery, D. C., and Lurponglukana, N. (2004), "A Bootstrap Method for Determining Active factors in Unreplicated Factorial Designs", invited paper presented at the 48th ASA/ASQ Fall Technical Conference, Roanoke, VA, 14-15 October.

123. Woodall, W. H., Spitzner, D., Montgomery, D. C., and Gupta, S. (2004), "Using Control Charts to Monitor Product and Process Quality Profiles", invited presentation at the Joint Statistical Meetings, Toronto, CA 8-12 August.
122. Kowalski, K. M., Vining, G. G., Montgomery, D. C. and Borror, C. M. (2004), Modeling the Process Mean and Variance from a CCD", contributed paper presentation at the Joint Statistical Meetings, Toronto, CA 8-12 August.
121. Montgomery, D. C., Jearkpaporn, D., Runger, G. C., and Borror, C. M. (2004), "Monitoring Mean Shifts for Multistage Processes using Generalized Linear Models", invited presentation at the Joint Statistical Meetings, Toronto, CA 8-12 August.
120. Montgomery, D. C. (2004), "Six Sigma: New Directions for DOX", invited presentation at the 2004 Quality and Productivity Research Conference, 19-21 May, Durham, NC.
119. Montgomery, D. C. (2004), "Designing Experiments: Some Adventures and Lessons Learned", invited seminar at the Industrial Statistics Research Center, University of Newcastle-Upon-Tyne, 23 April, Newcastle-Upon-Tyne, UK.
118. Montgomery, D. C. (2004), "Statistics and Statisticians in Today's Business World", keynote address, Royal Statistical Society Conference on Business Improvement Through Statistical Thinking, 21-22 April, Coventry, UK.
117. Goldfarb, H. B., Anderson-Cook, C. M., Borror, C. M., and Montgomery, D. C. (2003), "Graphical Methods to Assess the Prediction Capability of Mixture and Mixture-Process Designs", invited presentation at the 47th Annual ASA/ASQ Fall Technical Conference, El Paso, TX, 16-17 October 2003.
116. Drain, D. C., Borror, C. M., Montgomery, D. C., and Anderson-Cook, C. M. (2003), "The Effect of Correlated Noise Variables on Designed Experiments", invited presentation at the 47th Annual ASA/ASQ Fall Technical Conference, El Paso, TX, 16-17 October 2003.
115. Burdick, R. K., Borror, C. M., and Montgomery, D. C. (2003), "A Review of Methods for Measurement Systems Capability Analysis", invited presentation at the *Journal of Quality Technology* session, 47th Annual ASA/ASQ Fall Technical Conference, El Paso, TX, 16-17 October.
114. Kowalski, S., Vining, G.G., Montgomery, D.C., and Borror, C.M. (2003), Modifying a Central Composite Design to Model the Mean and Variance Within a Split-Plot Structure", invited presentation at the Joint Statistical Meetings, San Francisco, CA 3-7 August 2003.
113. Robinson, T. J., Myers, R. H., and Montgomery, D. C. (2003), "Analysis Considerations in Industrial Split-Plot Experiments when the Responses are Non-normal", invited presentation at the Joint Statistical Meetings, San Francisco, CA, 3-7 August 2003.
112. Montgomery, D.C., Burdick, R. K., Sebert, D.M., Shah, H. K., Molnau, W., Lawson, C., Zenzen, F., and Holcomb, D. R. (2003), "Teaching Six-Sigma Concepts in a University Setting", invited presentation at the Joint Statistical Meetings, San Francisco, CA 3-7 August 2003.
111. Drain. D. C., Montgomery, D. C., and Borror, C.M. (2003), "The Application of Hybrid Heuristic Optimization in Design of Experiments", invited presentation at the Joint Statistical Meetings, San Francisco, CA 3-7 August 2003.
110. Montgomery, D. C. (2003), "The Modern Practice of Statistics in Business and Industry", the Isobel Loutit Invited Plenary Address on Business and Industrial Statistics, 33rd Annual Meeting of the Statistical Society of Canada, Halifax, NS, 8-11 June 2003.
109. Jearkpaporn, D., Eastman, S. A., Gonzalez-Altamirano, G., Holcomb, D. R., Heredia-Langner, A., Borror, C. M., and Montgomery, D. C. (2003), "Using Supersaturated Designed

Experiments for Factor Screening and Robustness Analysis in the Design of a Semiconductor Clock Circuit “, contributed paper presented at the 2003 ASA Quality and Productivity Research Conference, Yorktown Heights, NY, 21-23 May 2003.

108. Anderson-Cook, C. M., Ozol, A., Myers, R. H., and Montgomery, D. C. (2003), “Fraction of Design Space Plots for Generalized Linear Models”, invited paper presented at the 2003 ASA Quality and Productivity Research Conference, Yorktown Heights, NY, 21-23 May 2003.
107. Goldfarb, H. B., Borror, C. M., Montgomery, D. C., and Anderson-Cook, C. M. (2003), “Graphical Methods to Assess the Prediction Capability of Mixture and Mixture-Process Designs”, invited paper presented at the 2003 ASA Quality and Productivity Research Conference, Yorktown Heights, NY, 21-23 May 2003.
106. Montgomery, D. C. (2003), “Research Needs in Experimental Design”, Invited Presentation at the Journal Editors’ Session, INFORMS National Meeting, San Jose, CA, 18-20 November 2002.
105. Janakirim, M. and Montgomery, D.C. (2002), “Integrating Engineering Process Control and Statistical Process Control for Effective APC for Semiconductor Processes”, Invited Presentation at the ASQ/ASA Fall Technical Conference, Valley Forge, PA, 17-18 October 2002.
104. Jearkpaporn, D., Montgomery, D. C., Runger, G. C., and Borror, C. M. (2002), “Process Monitoring for Correlated Gamma Distributed Variables using GLM Based Control Charts”, Invited Presentation at the ASQ/ASA Fall Technical Conference, Valley Forge, PA, 17-18 October 2002.
103. Montgomery, D. C. (2002), “Education of Future (Industrial) Statistical Consultants”, Invited Presentation at the Joint Statistical Meetings, New York, 11-15 August 2002.
102. Kowalski, S., Borror, C. M., and Montgomery, D. C. (2002), “The Path of Steepest Ascent in Split-Plot Experiments”, Contributed Presentation at the Joint Statistical Meetings, New York, 11-15 August 2002.
101. Montgomery, D. C. (2002), “Teaching Experimental Design to Engineers: Some Experiences and Advice”, Invited Presentation at the 6th International Conference on Teaching Statistics, Cape Town, South Africa, 7-12 July 2002.
100. Fowler, J. A. and Montgomery, D. C. (2002), “The Future of the IERC”, Presentation at the Industrial Engineering Research Conference, Orlando, Florida, 18-19 May 2002.
99. Montgomery, D. C. (2002), “Some Thoughts About Research”, Invited Presentation at the First IIE Doctoral Colloquium, Industrial Engineering Research Conference, Orlando, Florida, 18-19 May 2002.
98. Montgomery, D. C. (2002), “A Retrospective on Response Surface Methodology”, invited presentation at the Virginia Tech Conference on RSM in Honor of Professor Raymond H. Myers, Blacksburg, Virginia, 19-20 April 2002.
97. Wisnowski, J. W., Runger, G. C., and Montgomery, D. C. (2001), “Enhanced Analysis of Factorial Designs with Regression Trees”, Invited Presentation at the 45th Annual Fall Technical Conference, 18-19 October, Toronto, Canada.
96. Skinner, K. R., Runger, G. C., and Montgomery, D. C. (2001), Multivariate Control Charts for Discrete Data”, Invited Presentation at the 45th Annual Fall Technical Conference, 18-19 October, Toronto, Canada.
95. Montgomery, D. C. (2001), Invited Panelist for the Session “The 50th Anniversary of Response Surface Methodology”, 45th Annual Fall Technical Conference, 18-19 October, Toronto, Canada.

94. Holcomb, D. R., Jr. and Montgomery, D. C. (2001), “Some Difficulties in Analyzing Plackett-Burman Design with Interactions”, Invited Presentation at the 45th Annual Fall Technical Conference, 18-19 October, Toronto, Canada.
93. Heredia-Langner, A., Carlyle, W. M., and Montgomery, D. C. (2001), “Genetic Algorithms for the Construction of D-Efficient Designs”, Invited Presentation at the 45th Annual Fall Technical Conference, 18-19 October, Toronto, Canada.
92. Rejavelu, G., Montgomery, D. C., and Vining, G. G. (2001), “Graphical Design Evaluation Techniques for Constrained Mixture Experiments”, Invited Presentation at the 45th Annual ASQ/ASA Fall Technical Conference, 18-19 October, Toronto, Canada.
91. Heredia-Langner, A., Carlyle, W. M., and Montgomery, D. C. (2001), “Model-Robust Optimal Designs Using Genetic Algorithms”, Invited Presentation at the Joint Statistical Meetings, 5-9 August, Atlanta GA.
90. Myers, R. H. and Montgomery, D. C. (2001), “Analysis of Designed Experiments using GLMs”, Invited presentation at the Joint Statistical Meetings, Atlanta GA, 5-9 August.
89. Myers, R. H. and Montgomery, D. C. (2001), “Generalized Linear Models and Response Surface Methods”, Invited presentation at the ASA Quality and Productivity Research Conference, Austin TX, 22-25 May.
88. Holcomb, D. R., Montgomery, D. C., and Carlyle, W. M. (2000), “Supersaturated Designs in Product Design and Development”, Invited presentation at the 44th Annual ASQC/ASA Fall Technical Conference, Minneapolis, MN, 12-13 October, 2000.
87. Somerville, S. E., Montgomery, D. C., and Runger, G. C. (2000), “Filtering and Smoothing Methods for Mixed Particle Count Distributions”, Invited presentation at the 44th Annual ASQ/ASA Fall Technical Conference, Minneapolis, MN, 12-13 October, 2000.
86. Wisnowski, J. W., Simpson, J. R., Montgomery, D. C., and Runger, G. C. (2000), “Regressor Variable Selection for Contaminated Data Sets”, Invited presentation at the 44th Annual ASQ/ASA Fall Technical Conference, Minneapolis, MN, 12-13 October, 2000.
85. Montgomery, D. C., Loredo, E. N., Jearkpaporn, D., and Testik, M. C. (2000), “Experimental Designs for Constrained Regions”, Invited presentation at the 44th Annual ASQ/ASA Fall Technical Conference, Minneapolis, MN, 12-13 October, 2000.
84. Montgomery, D. C. (2000), “Some Opportunities and Challenges for Industrial Statisticians” (Invited Keynote Address), Industrial Statistics in Action 2000, conference at the University of Newcastle-Upon-Tyne, United Kingdom, 8-10 September, 2000.
83. Lewis, S. M., Montgomery, D. C. and Myers, R. H. (1999), “The Analysis of Designed Experiments using Generalized Linear Models”, Invited presentation at the 43rd Annual Fall Technical Conference, Houston Texas, October 14-15.
82. Carlyle, W. M., Montgomery, D. C. and Runger, G. C. (1999), “Optimization Problems and Methods in Quality Control and Improvement”, *Journal of Quality Technology* session - invited presentation at the 43rd Annual Fall Technical Conference, Houston Texas, October 14-15.
81. Borror, C. M., Keats, J. B. and Montgomery, D. C. (1999), “Control Charts for Low Rates of Process Nonconformance”, Invited presentation at the 43rd Annual Fall Technical Conference, Houston Texas, October 14-15.
80. Lanning, J., Montgomery, D. C. and Runger, G. C. (1999), “Adaptive Methods for Monitoring Fractionally Sampled Multiple Stream Processes”, Invited presentation at the 43rd Annual Fall Technical Conference, Houston Texas, October 14-15.

79. Wisnowski, J. W., Montgomery, D. C. and Simpson, J. R. (1999), "A Comparative Analysis of Multiple Outlier Detection Procedures in the Linear Regression Model", Invited presentation at the 43rd Annual Fall Technical Conference, Houston Texas, October 14-15.
78. Montgomery, D. C. (1999), "Statistical Methods for Process Robustness Studies", Inyong Ham Distinguished Lecture, Department of Industrial and Manufacturing Engineering, Pennsylvania State University, November 11.
77. Montgomery, D. C. (1999), "Statistical Methods for Achieving Six-Sigma Results", Invited presentation at the Pharmaceutical and Medical Device Industries Conference on Six-Sigma, Institute of International Research, Philadelphia, PA, September 23-24.
76. Vining, G. G., Kowalski, S. L. and Montgomery, D. C. (1999), "Hard-to-Change Design Variables in a Response Surface Setting", Invited presentation at the Joint Statistical Meetings, Baltimore, MD, August 8-12
75. Montgomery, D. C. (1999), "Multiple Response Optimization Methods", Invited presentation at the Joint Statistical Meetings, Baltimore, MD, August 8-12**.**
74. Montgomery, D. C. (1998), "A Perspective on Models and the Quality Sciences: Some Challenges and Future Directions", W. J. Youden Memorial Address presented at the 42nd Annual ASQ/ASA Fall Technical Conference, 22-23 October, Corning, NY.
73. Zimmer, L. S., Montgomery, D. C., and Runger, G. C. (1998), "Some Guidelines for the Application of Adaptive Control Charts", Invited presentation at the 42nd Annual ASQC/ASA Fall Technical Conference, 22-23 October, Corning, NY.
72. Borror, C. M., Montgomery, D. C., and Myers, R. H. (1998), "Optimal Design Strategies for Experiments Involving Noise Variables", Invited presentation at the 42nd Annual ASQC/ASA Fall Technical Conference, 22-23 October, Corning, NY.
71. Montgomery, D. C. (1998), "Some Challenges and Opportunities for Industrial Statisticians" Invited presentation at a Panel Discussion on Emerging Issues and Directions in Quality Improvement, INFORMS, Seattle Washington, 27 October.
70. Montgomery, D. C. (1998), "Designed Experiments for Product and Process Development: Some Examples", Invited presentation at INFORMS, Seattle Washington, 27 October.
69. Montgomery, D. C. (1998), "Experimental Design for Process and Product Design and Development" Invited Keynote Address, Royal Statistical Society, Glasgow Scotland, 11 September.
68. Montgomery, D. C. and Vining, G. G. (1998), "Methods and Applications of Generalized Linear Models", Invited Short Course presented for the Section on Engineering and Physical Sciences, Joint Statistical Meetings, Dallas, TX, 11 August.
67. Montgomery, D. C. (1998), "Some Challenges for Industrial Statisticians", Invited Presentation at the Joint Statistical Meetings, Dallas, TX, 10 August.
66. Montgomery, D. C. (1997), "Generalized Linear Models and Designed Experiments", Invited plenary presentation at the Applied Probability and Statistics Day, Johns Hopkins University Applied Physics Laboratory**,** 18 October, Laurel, MD.
65. Sebert, D. M., Montgomery, D. C., and D. A. Rollier (1997), "Identifying Multiple Outliers and Influential Subsets in Linear Regression: A Clustering Approach", presented at the 41st Annual ASQ/ASA Fall Technical Conference, 16-17 October, Baltimore, MD.
64. Montgomery, D. C. (1997), "Some Aspects of Generalized Linear Models for Designed Experiments", Plenary Address, Nineteenth Annual Midwest Biopharmaceutical Statistics Workshop, Ball State University, Muncie, Indiana.

63. Montgomery, D. C. (1997), "Response Surface Methodology", invited tutorial presented at the Southern California American Statistical Association Applied Statistics Workshop, Long Beach, California.
62. Montgomery, D. C., and G. C. Runger (1996), "Multivariate Control Charts and Process Monitoring", invited short course at the ASQ/ASA Fall Technical Conference, Scottsdale, AZ, (sponsored by the Statistics Division of ASQ).
61. Montgomery, D. C. (1996), "Multiple Response Optimization Methods," invited presentation at the 2nd Congress of the International Federation of Nonlinear Analysts, Athens, Greece.
60. Montgomery, D. C. (1995), "Response Surface Methods and Designs," invited short course at the ASQC/ASA Fall Technical Conference, St. Louis, MO, (sponsored by the Statistic Division of ASQC).
59. Montgomery, D. C. (1994), "Regression Analysis," invited short course at the ASQC/ASA Fall Technical Conference, Birmingham, Alabama, (sponsored by the Statistics Division of ASQC).
58. Montgomery, D. C. (1994), "Design of Experiments," invited short course at the 40th U.S. Army Design of Experiments Conference, U.S. Military Academy, West Point, NY.
57. Montgomery, D. C. (1994), "Statistical Process Control for the Process Industries," invited short course at the Joint Statistical Meetings, Toronto, Canada, (sponsored by the Quality and Productivity Section of ASA).
56. Mastrangelo, C. M., and D. C. Montgomery (1994), "Shift Detection Properties of Moving-Centerline EMWA Control Schemes", presented at the IIE Research Conference, Atlanta, GA.
55. Montgomery, D. C. (1994), "The Industrial Engineer and the Quality Improvement Sciences: Have We Missed an Opportunity?", invited Keynote Address at the 8th Israeli Industrial Engineering Conference, Beer Sheva, ISRAEL.
54. Montgomery, D. C. (1994), "Strategies for Integrating Statistical Process Control and Engineering Process Control", presented at the Conference on Computer Integrated Manufacturing in the Process Industries, Rutgers University.
53. Montgomery, D. C. (1993), "Planning, Conducting, and Analyzing Industrial Experiments," invited presentation at the 49th Annual Conference on Applied Statistics, Atlantic City, NJ.
52. Montgomery, D. C. (1993), "Solutions for Customer-Driven Quality Problems with Design of Experiments", invited tutorial at the Fall ORSA/TIMS Conference.
51. J. B. Keats, D. C. Montgomery, G. C. Runger, and W. S. Messina (1993), "Strategies for Integrating Statistical Process Control with Feedback (PID) Controllers", presented at the ASQ/ASA Fall Technical Conference, Rochester, NY.
50. Del Castillo, E. and D. C. Montgomery (1993), "Methods for Finite-Horizon Process Control: "Q" Charts and Alternative Techniques", presented at the ASQ/ASA Fall Technical Conference, Rochester, NY.
49. Montgomery, D. C. and J. A. Heinsman (1993), "Optimization of Product Formulation Using Mixture Experiments," invited presentation at the ORSA/TIMS Conference, Chicago, IL.
48. Montgomery, D. C., C. M. Mastrangelo and C. A. Lowry (1993), "Statistical Process Monitoring for Aluminum Smelting," invited presentation at the 10th Annual Quality and Productivity Research Conference, Knoxville, TN.
47. Montgomery, D. C., C. M. Mastrangelo and C. A. Lowry (1992), 'Statistical Process Monitoring for Dynamic Systems," invited presentation at the IIE Research Conference, Los Angeles, CA.

46. Montgomery, D. C. and J. E. Taggart (1993), "Selection of a Second-Order Response Surface Design," invited presentation at the SAS Users Group International Conference, New York.
45. Coleman, D. E. and D. C. Montgomery (1992), "A Systematic Approach to Planning for a Designed Industrial Experiment," invited paper, *Technometrics* Session, ASQ/ASA Fall Technical Conference, Philadelphia, PA.
44. Mastrangelo, C. M. and D. C. Montgomery (1992), "Characterization of a Moving Centerline EWMA Control Chart," invited presentation at the ASQCASA Fall Technical Conference, Philadelphia, PA.
43. Montgomery, D. C. and S. R. Voth (1991), "Some Practical Aspects of Designing Mixture Experiments." Invited presentation at the ASQ/ASA Fall Technical Conference, Lexington, KY.
42. Montgomery, D. C. and C. M. Mastrangelo (1990), "Statistical Process Control Methods for Autocorrelated Data." Invited paper, JQT Session, ASQ/ASA Fall Technical Conference, Richmond, VA.
41. Montgomery, D. C. (1984), "Economic Models and Statistical Process control," invited presentation at the Joint Statistical Meetings, Philadelphia, PA.
40. Montgomery, D. C. (1984), "Design of Experiments in Development and Manufacturing Engineering," invited presentation at the 3rd Annual IBM Corporate Quality Conference, Austin, TX.
39. Montgomery, D. C. (1984), "Improving Quality and Productivity in Manufacturing with Design of Experiments," invited presentation at the 10th Annual IBM Design of Experiments Conference, Lexington, Kentucky.
38. Montgomery, D. C. (1984), "Sampling Procedures for Monitoring Service Contracts," invited paper given at the Spring ORSA Meeting, San Francisco, Calif.
37. Montgomery, D. C. and F. D. Baker (1983), "Statistical Modeling of Soybean Growth," Workshop on Crop Simulation, University of Illinois, Urbana-Champaign, Illinois.
36. Montgomery, D. C. (1983), "The Effect of Nonnormality on Acceptance Sampling Plans for Variables," presented at a Meeting of the National Academy of Science, Washington, D.C.
35. Montgomery, D. C. and D. J. Friedman (1982), "An Evaluation of Biased Estimators for Prediction," invited paper given at the Joint Statistical Meetings, Cincinnati, Ohio.
34. Montgomery, D. C. (1982), "Some Hazards of Using Regression Analysis as a Statistical Tool for Load Research," invited paper given at the AEIC Load Research Conference, Atlanta, Georgia.
33. Montgomery, D. C. (1981), "Cost Based Acceptance Sampling Plans and Process Control Schemes," invited paper presented at the AIIE Fall Technical Conference, Washington, D. C., also in Conference Proceedings.
32. Montgomery, D. C. (1981), "Regression Analysis - Some Aspects of its Use in Load Research," invited paper given at the AEIC Load Research Conference, Atlanta, Georgia.
31. Montgomery, D. C. and E. A. Peck (1981), "The Multicollinearity Problem in Regression," invited tutorial session at the Southeast Institute for Decision Sciences Meeting, Orlando, Florida, February 1980; also in Conference Proceedings.
30. Montgomery, D. C. and G. Weatherby (1979), "Factor Screening Methods in Computer Simulation," presented at the Winter Simulation Conference, San Diego, Calif., also in Conference Proceedings.

29. Montgomery, D. C. (1979), "Methods for Combining Forecasts," presented at the 24th International TIMS Conference, Honolulu, Hawaii.
28. Johnson, L. A. and D. C. Montgomery (1979), "Forecasting Methods in Production and Operations Management," invited paper presented at the 24th International TIMS Conference, Honolulu, Hawaii.
27. Simms, E. D. and D. C. Montgomery (1977), "The Use of Discriminant Analysis for Risk Assessment in Operational Testing," Presented at the 16th Annual U.S. Army Operations Research Symposium, Ft. Lee, Virginia.
26. Russ, S. W., Jr., D. C. Montgomery, and H. M. Wadsworth, Jr. (1977), "A Cost Optimal Approach to Selection of Experimental Designs for Operational Testing Under Conditions of Constrained Sample Size," Presented at the 16th Annual U.S. Army Operations Research Symposium, Ft. Lee, Virginia.
25. Friese, W. F., Jr., and D. C. Montgomery (1977), "A Cost-Optimal Approach to Selecting a Fractional Factorial Design," presented at the 16th Annual U.S. Army Operations Research Symposium, Ft. Lee, Virginia, also in Conference Proceedings.
24. Montgomery, D. C. (1977), "Procedures for Optimizing and Integrating Production and Distribution Operations," invited paper presented at the 6th Management Science Colloquium, Osaka University, Osaka, Japan.
23. Johnson, L. A. and D. C. Montgomery (1977), "Forecasting with Prediction Limits," invited paper presented at the 23rd International TIMS Conference, Athens, Greece.
22. Montgomery, D. C. and V. M. Bettencourt, Jr. (1976), "A Review of Multiple Response Surface Methods in Computer Simulation," invited paper presented at the Fall ORSA/TIMS National Meeting, Miami, Florida.
21. Brown, E. L. and D. C. Montgomery (1975), "An Application of Network Simulation to Operational Testing and Evaluations," presented at the 14th Annual U.S. Army Operations Research Symposium, Ft. Lee, Virginia, also in Conference Proceedings.
20. Johnson, L. A. and D. C. Montgomery (1975), "Forecasting and Time Series Analysis," seminar presented at the 3rd Annual AIIE Fall Systems Engineering Conference, Las Vegas.
19. Johnson, L. A. and D. C. Montgomery (1975), "Planning Lot Size Production for Inventory," invited paper presented at the Fall ORSA/TIMS National Meeting, Las Vegas.
18. Gearing, D. V., R. G. Heikes and D. C. Montgomery (1975), "Development of an Economic Model of Moving Average Control Charts," presented at the Fall 1975 ORSA/TIMS National Meeting, Las Vegas.
17. Montgomery, D. C., R. G. Heikes, and Y. G. Yap (1975), "A Comparison of Two Adaptive Forecasting Systems," presented at the 47th National ORSA Meeting, Chicago, Illinois.
16. Cummings, J. M., B. B. McCra, D. C. Montgomery and R. G. Heikes (1974), "Repairing Response Surface Designs to Minimize Bias," presented at the 46th National ORSA Meeting, San Juan, Puerto Rico.
15. Montgomery, D. C. (1974), "Experimental Design Techniques for Computer Simulation," invited paper at the Second Interamerican Conference on Information and Systems Engineering, Mexico City.
14. Marsh, J. D. and D. C. Montgomery (1974), "Scheduling Jobs with Sequence Dependent Setup Times on Parallel Machines," presented at the 45th National ORSA Meeting, Boston, Massachusetts.

13. Johnson, L. A. and D. C. Montgomery (1974), "On Dynamic Production Planning Models," invited paper presented at the Distinguished Scholars Seminar, Southeast Institute of Decision Sciences Meeting, New Orleans, Louisiana, also in Conference Proceedings.
12. Montgomery, D. C. and C. K. Hudson (1973), "Use of Equiradial Designs in Response Surface Methodology," presented at the 44th National ORSA Meeting, San Diego, California.
11. Heikes, R. G., D. C. Montgomery and J. Young (1973), "Alternate Process Models in the Economic Design of T2 Control Charts," presented at the 44th National ORSA Meeting, San Diego, California, subsequently published in *AIIE Transactions*.
10. Alt, F. B., J. J. Goode, D. C. Montgomery and H. M. Wadsworth (1973), "Variable Control Charts for Multivariate Data," invited paper presented at the American Statistical Association Meeting, New York.
9. Marsh, J. D and D. C. Montgomery (1973), "Optimal Procedures for Scheduling Jobs with Sequence-Dependent Changeover Times on Parallel Processors," invited paper presented at the AIIE Annual Conference, Chicago, Illinois.
8. Montgomery, D. C. and D. M. Evans (1972), "Second Order Response Surface Designs in Digital Simulation," invited paper presented at the 41st National ORSA Meeting, New Orleans, Louisiana, a revised version of this paper was subsequently published in *Simulation*.
7. Montgomery, D. C. and P. J. Klatt (1972), "Minimum Cost Multivariate Quality Control Tests," invited paper presented at the AIIE Annual Conference, Anaheim, California, also in Conference Proceedings and subsequently published in *AIIE Transactions*.
6. Montgomery, D. C. and H. M. Wadsworth (1972), "Some Techniques for Multivariate Quality Control Applications," invited paper presented at the American Society for Quality Control Annual Conference, Washington, D.C., also in Conference Proceedings.
5. Montgomery, D. C. (1971), "Stochastic Capacity Decision Models for Production Facilities," invited paper presented at the AIIE Annual Conference, Boston, Massachusetts, also in Conference Proceedings.
4. Montgomery, D. C. (1970), "Expectations of Young Engineers from Their Employers and Professional Societies," invited paper presented at the 13th International Meeting of APICS, Cincinnati, Ohio.
3. Fabrycky, W. J., V. Chachra and D. C. Montgomery (1970), "A Simulation Study of Three Classes of Job-Shop Sequencing Rules," invited paper presented at the 13th International Meeting of APICS, Cincinnati, Ohio.
2. Ghare, P. M. and D. C. Montgomery (1969), "Flow Management in Transportation Networks," invited paper presented at the 5th International Conference on Operations Research, Venice, Italy, also in Conference Proceedings.
1. Montgomery, D. C. (1970), "Evolutionary Operation and Machine Center Capacity Control in Job-Shop Systems," contributed paper presented at the 11th American Meeting of TIMS, Los Angeles, California.

Other Publications

59. Montgomery, D.C. and Anderson-Cook, C.M. (2016), “In Memory of Connie M. Borror”, Obituary in *Quality Engineering*, Vol. 28, No. 3, pp. 247-248.
58. Montgomery, D.C. (2016), “Why Do Lean Six Sigma Projects Sometimes Fail?”, editorial in *Quality and Reliability Engineering International*, Vol. 32, No. 4, pp. 1279.

57. Montgomery, D.C. (2016), "Collecting Data", editorial in *Quality and Reliability Engineering International*, Vol. 32, No. 2, pp. 333.
56. Montgomery, D.C. (2015), "Show Me the Money", editorial in *Quality and Reliability Engineering International*, Vol. 31, No. 8, pp. 1303.
55. Montgomery, D.C. (2015), "Robert Vincent (Bob) Hogg", editorial in *Quality and Reliability Engineering International*, Vol. 31, No. 4, pp. 555.
54. Montgomery, D.C. (2015), "A.V. Feigenbaum", editorial in *Quality and Reliability Engineering International*, Vol. 31, No. 2, pp. 163.
53. Montgomery, D.C. (2014), "Big Data and the Quality Profession", editorial in *Quality and Reliability Engineering International*, Vol. 30, No. 4, pp. 447.
52. Montgomery, D.C. (2014), "Lean Six Sigma and Promoting Innovation", editorial in *Quality and Reliability Engineering International*, Vol. 30, No. 1, pp. 1.
51. Montgomery, D.C. (2013), "Lean Six Sigma and Quality Management", editorial in *Quality and Reliability Engineering International*, Vol. 29, No. 7, pp. 935.
50. Montgomery, D.C. (2013), "2013: The International Year of Statistics", editorial in *Quality and Reliability Engineering International*, Vol. 29, No. 3, pp. 305.
49. Montgomery, D.C. (2013), "The Quality, Reliability and Statistical Engineering Profession in the 21st Century", editorial in *Quality and Reliability Engineering International*, Vol. 29, No. 1, pp. 1.
48. Montgomery, D.C. (2012), "Giants of Quality – W. Edwards Deming", editorial in *Quality and Reliability Engineering International*, Vol. 28, No. 3, pp. 247-248.
47. Montgomery, D.C. (2011), "Giants of Quality – Walter Shewhart", editorial in *Quality and Reliability Engineering International*, Vol. 27, No. 8, pp. 979.
46. Montgomery, D.C. (2011), "Innovation and Quality Technology", editorial in *Quality and Reliability Engineering International*, Vol. 27, No. 6, pp. 733-734.
45. Montgomery, D.C. (2011), The Principles of Testing", *The ITEA Journal*, invited editorial, Vol 32, No. 3, pp. 231-234.
44. Montgomery, D.C. (2010), "The 25th Anniversary Volume of *Quality and Reliability Engineering International*", editorial in *Quality and Reliability Engineering International*, Vol. 26, No. 1, pp. 1-2.
43. Montgomery, D.C. (2009), "Computer Modelling", editorial in *Quality and Reliability Engineering International*, Vol. 25, No. 6, pp. 645.
42. Montgomery, D.C. (2009), "It's a Great Time to be a Statistician", editorial in *Quality and Reliability Engineering International*, Vol. 25, No. 4, pp. 379-380.
41. Tiwari, M.K., Antony, J., and Montgomery, D. C. (2008), "Editorial Note for the Special Issue on Effective Decision Support to Implement Lean and Six Sigma Methodologies in the Manufacturing and Service Sectors", *International Journal of Production Research*, Vol. 46, No. 23, pp. 6563-6566.
40. Montgomery, D.C. (2008), "Applications of Design of Experiments in Engineering", editorial in *Quality and Reliability Engineering International*, Vol. 24, pp. 501-502.
39. Montgomery, D.C. (2008), "Does Six Sigma Stifle Innovation?", editorial in *Quality and Reliability Engineering International*, Vol. 24, pp. 249.

38. Montgomery, D.C. (2008), "A Retrospective on Volume 23 of *Quality and Reliability Engineering International*", editorial in *Quality and Reliability Engineering International*, Vol. 24, pp. 1-2.
37. Montgomery, D.C. (2007), "SPC Research – Current Trends", editorial in *Quality and Reliability Engineering International*, Vol. 23, pp. 515-516.
36. Montgomery, D. C. (2006), "Designed Experiments in Process Improvement", editorial in *Quality and Reliability Engineering International*, Vol. 22, No. 8, pp. 863-864.
35. Montgomery, D. C. (2006), "Analyzing and Improving Measurement Systems: A Key to Effective Decision-Making", editorial in *Quality and Reliability Engineering International*, Vol. 22, No. 3, pp. 237-238.
34. Montgomery, D. C. and Brombacher, A.C. (2006), "Carol J. Feltz and David Newton", editorial in *Quality and Reliability Engineering International*, Vol. 22, No. 2, pp. i.
33. Brombacher, A. C. and Montgomery, D. C. (2005), "News from Newcastle: Product Quality from a Customer Perspective", editorial in *Quality and Reliability Engineering International*, Vol. 21, No. 8, pp. iii.
32. Montgomery, D. C. (2005), "Generation III Six Sigma", editorial in *Quality and Reliability Engineering International*, Vol. 21, No. 6, pp. iii-iv.
31. Montgomery, D. C. (2005), "Changing of the Guard", editorial in *Quality and Reliability Engineering International*, Vol. 21, No. 1, pp. iii.
30. Montgomery, D. C. (2004), "Selecting the Right Improvement Projects", editorial in *Quality and Reliability Engineering International*, Vol. 20, No. 7, pp. iii-iv.
29. Montgomery, D. C. (2004), "Improving Business Performance: Project-by-Project", editorial in *Quality and Reliability Engineering International*, Vol. 20, No. 4, pp. *iii.*
28. Montgomery, D. C. (2003), "Corporate Ethics and Quality", editorial in *Quality and Reliability Engineering International*, Vol. 19, No. 6, pp. *iii-iv.*
27. Montgomery, D. C. (2003), "Quality Improvement and Economic Growth", editorial in *Quality and Reliability Engineering International*, Vol. 19, No. 3, pp. *iii.*
26. Montgomery, D. C. (2003), review: *The Mahalanobis-Taguchi Strategy*, G. Taguchi and R. Jugulum, in: *Journal of Quality Technology*, Vol. 35, No. 2.
25. Montgomery, D. C. (2003), "Education for Industrial Statisticians", editorial in *Quality and Reliability Engineering International*, Vol. 19, No. 1.
24. Montgomery, D. C. (2002), "Changing Roles for the Industrial Statistician", editorial in *Quality and Reliability Engineering International*, Vol. 18, No. 5.
23. Montgomery, D. C. (2002), "Research in Industrial Statistics – Part II", editorial in *Quality and Reliability Engineering International*, Vol. 18, No. 2.
22. Montgomery, D. C. (2001), "Research in Industrial Statistics – Part I", editorial in *Quality and Reliability Engineering International*, Vol. 17, No. 6.
21. Montgomery, D. C. (2001), "Beyond Six-Sigma", editorial in *Quality and Reliability Engineering International*, Vol. 17, No. 4.
20. Montgomery, D. C. (2001), "Some Thoughts on ISO/QS Registration", editorial in *Quality and Reliability Engineering International*, Vol. 17, No. 1.
19. Borror, C. M., Montgomery, D. C., and Runger, G. C. (2000), "Statistical Experimental Design – Some Recent Advances and Applications", editorial in *Quality and Reliability Engineering International*, Vol. 16, No. 5.

18. Montgomery, D. C. (2000), "The Present State of Industrial Statistics", editorial in *Quality and Reliability Engineering International*, Vol. 16, No. 4.
17. Montgomery, D. C. (2000), "A Meeting for Industrial Statisticians", editorial in *Quality and Reliability Engineering International*, Vol. 16, No. 2.
16. Montgomery, D. C. (1988), "Experimental Design and Product and Process Development," *Manufacturing Engineering*, Vol. 101, No. 3, September.
15. Heikes, R. G. and D. C. Montgomery (1981), "Productivity is Enhanced by Statistical Quality Control," *Industrial Engineering*, Vol. 13, No. 3.
14. Montgomery, D. C. (1981), review: *Dynamic Regression: Theory and Algorithm*s, M. H. Pearson and L. J. Slater, in: *Journal of Quality Technology*, Vol. 13, No. 1.
13. Montgomery, D. C. (1980), review: *Practical Experiences with Modeling and Forecasting Time Series*, G. M. Jenkins, In: *Journal of Quality Technology*, Vol. 12, No. 1.
12. Montgomery, D. C. (1977), review: *Statistical Methods for Digital Computers*, K. Enslein, A. Ralstan and H. S. Wolf, eds., in: *TIMS Interfaces*.
11. Montgomery, D. C. (1977), review: *Fundamentals of Finite Mathematics*, R. L. Childress, in: *Interfaces*, Vol. 8, No. 1.
10. Montgomery, D. C. (1975), review: *Engineering Mathematics*, A. C. Bajapi, L. R. Mustoe and D. Walker, In: *Industrial Engineering*, Vol. 7, No. 1.
9. Montgomery, D. C. (1975), review: *Industrial Systems: Planning, Analysis, and Control*, David D. Bedworth, in: *Industrial Engineering*, Vol. 7, No. 1.
8. Johnson, L. A. and D. C. Montgomery (1973), review: *An Introduction to Production and Inventory Control*, and *Production and Inventory Control: Theory and Practice*, R. W. Van Ness and W. Monhemius, in: *Industrial Engineering*, Vol. 5, No. 12.
7. Montgomery, D. C. (1970), review: *An Illustrated Guide to Linear Programming*, S.I. Gass, in: *Industrial Engineering*, Vol. 12, No. 8.
6. Montgomery, D. C. (1970), review: *Theory of Games and Strategies*, Levin and DesJardins, in: *Industrial Engineering*, Vol. 2, No. 7.
5. Montgomery, D. C. (1969), review: *Queuing Theory*, J. A. Panico, in: *Industrial Engineering*, Vol. 1.
4. Montgomery, D. C. (1968), review: *Fundamentals of Operations Research*, Ackoff and Sasieni, *The Journal of Industrial Engineering*, Vol. 19, No. 7.
3. Montgomery, D. C. (1968), review: *Operations Research and the Design of Management Information Systems*, J. F. Pierce, ed., *The Journal of Industrial Engineering*, Vol. 19, No. 4.
2. Montgomery, D. C. (1971), "Simulation Predicts Product Behavior," *Machine Design*.
1. Montgomery, D. C. and W. L. Berry (Editors) (1974), *Production Planning and Control: Concepts, Techniques and Systems*, Production Planning and Control Division Monograph No. 1, American Institute of Industrial Engineers.

RESEARCH STUDENTS SUPERVISED

Ph.D. Dissertations

68. Sarah E. Burke, "Optimal Design of Experiments for Dual-Response Systems"

67. Michelle V. Mancenido, “Categorical Responses in Mixture Experiments”, co-advisor with Rong Pan
66. Edgar Hassler, “Bayesian D-Optimal Design Issues and Optimal Design Construction for Generalized Linear Models with Random Effects”, co-advisor with Rachel Silvestrini
65. Azadeh Adibi, “A P-Value Approach for Phase II Profile Monitoring”, co-advisor with Connie M. Borror.
64. Brian B. Stone, “No-Confounding Designs of 20 and 24 Runs for Screening Experiments and a Design Selection Methodology”, co-advisor with Rachel Silvistrini.
63. Kathryn S. Kennedy, “Bridging the Gap Between Space-Filling Designs and Optimal Designs: Designs for Computer Experiments”, co-advisor with Rachel Silvistrini.
62. Shilpa M. Shinde, “Projection Properties and Analysis Methods for Six-to-Fourteen Factor No-Confounding Designs in 16 Runs”.
61. Richard B. Abelson, “The Development of a Validated Clinically Meaningful Endpoint for the Evaluation of Tear Film Stability as a Measure of Ocular Surface Protection in the Diagnosis and Treatment of Dry Eye Disease”.
60. Joseph M. Juarez, “Accelerated Life Testing of Electronic Circuit Boards with Applications in Lead-Free Design”.
59. Brett Duarte, “An Analytical Approach to Lean Six Sigma Deployment Strategies: Project Identification and Prioritization", co-advisor with John Fowler.
58. Dana C. Krueger, “Semiconductor Yield Modeling using Generalized Linear Models”.
57. Busaba Laungrungrong, “Multivatiate Charts for Multivariate Poisson-Distributed Data”.
56. Shilpa Gupta, “Profile Monitoring – Control Chart Schemes for Monitoring Linear and Low-Order Polynomial Profiles”.
55. Tae-Yeon Cho, “Mixture-Process Variable Design Experiments with Control and Noise Variables within a Split-Plot Structure”.
54. James R. Broyles, “Markovian Model of Patient Throughput in Hospitals: A Regression and Decision Process Approach”, co-advisor with Jeff Cochran.
53. Eric M. Monroe, “Optimal Experimental Designs for Accelerated Life Tests with Censoring and Constraints”, co-advisor with Rong Pan.
52. Rachel T. Johnson, “Experimental Designs for Computer Experiments”, co-advisor with John Fowler.
51. Capehart, S. R., “Designing Fractional Factorial Split-Plot Experiments Using Integer Programming”, co-advisor with Murat Kulahci.
50. Myrta Rodriguez, “Evaluation and Construction of Optimal Experimental Designs for Fitting Response Surface Models”, co-advisor with Connie Borror.
49. Ashraf Almimi, “Split-Plot Designs: Follow-Up Experiments, Missing Observations, and Model Adequacy Checking”, co-advisor with Murat Kulahci.
48. Russell Elias, “Demand Model Management: A Model-Based Expert System for the Forecasting of Semiconductor Product”.
47. Peter J. Chung, “Mixture-Process Experiments with Continuous and Categorical Noise Variables”.
46. Cathy Lawson, “Business Process Characterization using Categorical Data Models”.
45. You-Jin Park, “Application of Genetic Algorithms in Response Surface Optimization Problems”.

44. Duangporn Jearkpaporn, "Multivariate Process Monitoring using Generalized Linear Models", co-advisor with G. C. Runger.
43. David C. Drain, "Response Surface Methods for Experiments Involving Correlated Noise Variables".
42. Heidi B. Goldfarb, "Mixture-Process Experiments with Control and Noise Variables".
41. Katina R. Skinner, "Multivariate Process Control for Discrete Data", co- advisor with G. C. Runger.
40. Alejandro Heredia-Langner, "Genetic Algorithms in Quality Control Problems", co- advisor with W. M. Carlyle.
39. Elvira N. Loredo, "Annual Electrical Peak Load Forecasting Methods with Measures of Prediction Error".
38. Mani Janakiram, "Statistical and Engineering Process Control Integration Strategies for Constrained Controllers".
37. Harendra Shah, "Impact of Correlated Responses on the Desirability Function", co- advisor with W. M. Carlyle.
36. Geetha Rajavelu, "Graphical Design Evaluation Techniques for Constrained Mixture Experiments".
35. Lisa Custer, "Augmenting Experimental Designs: Approaches and Comparisons".
34. Kelly G. Canter, "Screening Methods for Life Cycle Inventory Models", co-advisor with W. M. Carlyle.
33. Don R. Holcomb, Jr., "Supersaturated Experiments for use in Product Development", co-advisor with W. M. Carlyle.
32. Leonard A. Perry, "Partition Experimental Designs for Sequential Processes".
31. Teri Reed Rhoads, "An Investigation of Strategies for Multivariate Monitoring of Continuous Processes".
30. Daniel R. McCarville, "Test Guard Band Probability Models and Strategies for Optimization".
29. Wisnowski, James W., "Multiple Outliers in Regression: Detection Methods, Robust Estimation, and Variable Selection", co-advisor with G. C. Runger.
28. Steven E. Somerville, "Filtering and Monitoring Methods for Univariate and Multiple Stream Processes", co-advisor with G. C. Runger.
27. Jeffrey W. Lanning, "Methods for Monitoring Fractionally Sampled Multiple Stream Processes", co-advisor with G. C. Runger.
26. Connie M. Borror, "Response Surface Methods for Experiments Involving Noise Variables".
25. Sharon L. Lewis, "Analysis of Designed Experiments using Generalized Linear Models".
24. Wade E. Molnau, "Economic Statistically Constrained Design of the Multivariate Exponentially Weighted Moving Average Control Chart", co-advisor with G. C. Runger.
23. Lora S. Zimmer, "Contributions to Adaptive Control Charts", co-advisor with G. C. Runger.
22. Daryl J. Hauck, "Extensions to Regression Adjustment Techniques in Multivariate Process Monitoring", co-advisor with G. C. Runger.
21. Dale J. Kennedy, "Development and Analysis of Stochastic Environmental Life Cycle Assessment Inventory Modeling", co-advisor with D. A. Rollier.
20. David M. Sebert, "A Clustering Approach to Finding Multiple Outliers in Linear Regression".

19. Carole Shlaes, "Use of Chance-Constrained Programming Techniques to Determine Optimal Insurance Deductible Levels", co-advisor with J. B. Keats.
18. James R. Simpson, "New Methods and Comparative Evaluations for Robust and Biased-Robust Regression Estimation".
17. Jose Andere-Rendon, "Computer-Aided Robust Design of Mixture Experiments Based on Bayesian D-Optimality," co-advisor with D. A. Rollier.
16. Diane Schaub, "Experimental Design Strategy: An Application to Rapid Prototyping of Aerospace Parts".
15. Sharad S. Prabhu, "Adaptive Sample Size and Adaptive Sampling Interval Schemes for an X-Bar Control Chart".
14. Christina M. Mastrangelo, "Statistical Process Monitoring for Autocorrelated Data".
13. Enrique Del Castillo, "Some Models and Methods for Statistical Process Control in Short-Run Manufacturing Systems".
12. William S. Messina, "Strategies for the Integration of Engineering Process Control and Statistical Process Control," co-advisor with J. B. Keats.
11. James C. C. Torng, "The Economic Statistical Design of Variables Control Charts with an Application to Exponentially Weighted Moving Average Charts," co-advisor with J. K. Cochran.
10. D. Y. Kim, "Economic Statistical Design and Analysis for the Poisson CUSUM Control Chart," co-advisor with J. B. Keats.
9. M. K. Chua, "A Control Scheme for Multivariate Quality Control".
8. John S. Gardiner, "Statistical Process Control Methods for Detecting Small Process Shifts with Applications to Integrated Circuit Manufacturing".
7. Steven A. Yourstone, "Real-Time Process Quality Control in a Computer-Integrated Manufacturing Environment".
6. David J. Friedman, "An Evaluation of Biased Estimators in Prediction".
5. Rickey A. Kolb, "Robustness of Current Methodologies for the Analysis of Contingency Tables with Respect to Small Expected Cell Values".
4. Ginner Weatherby, "Aggregation, Disaggregation and Combination of Forecasts".
3. Joseph D. Marsh, Jr., "Scheduling Parallel Processors".
2. Michael P. Deisenroth, "On Simulation Methodology in Vehicular Traffic Flow".
1. Ronald G. Askin, "The Combination of Biased and Robust Estimation Techniques in Multiple Regression Models".

M.S. Theses and MS Statistics Projects

48. Archana Krishnamoorthy, "Analysis of No-Confounding Designs using the Dantzig Selector."
47. Jeanne Huddleston, "Harm During Hospitalizations for Heart Failure: Adverse Events as a Reliability Measure of Hospital Policies and Procedures", co-advisor John Fowler.
46. Dean S. Hoskins, "D-Optimal Designs with Interaction Coverage", MS Statistics Project.
45. Shilpa Madhavan Shinde, "Statistical Analysis and Optimization of a Microfluidic Mixing Process Based on the Bubble-Induced Acoustic Microstreaming Principle for a Gene Expression Assay."

44. Andrea M. Archer, “Bootstrap Confidence Regions on the Optimum Point of a Quadratic Response Surface”, MS Statistics Project.
43. Jiahong Li, “Comparisons of Prediction Variance Properties of Six-to Ten-Factor CCD and CCD Min Res V Response Surface Designs”, MS Statistics Project.
42. Nuttha Lurponglukana, “Using a Bootstrap Method to Determine Active Factors in an Unreplicated Factorial Experiment”.
41. Amy K. Volpe, “Fitting Response Surface Models with Mixed Effects using Generalized Linear Mixed Models”, MS Statistics Project.
40. Diane E. Richardson, “Variance Dispersion Studies of Second Order Response Surface Designs in Cuboidal Regions”, MS Statistics Project.
39. Russell J. Elias, “Demand Signal Modeling: A Model-Based Approach to the Forecasting of Future Product Demand”, co - advisor J. B. Keats.
38. Duangporn Jearkpaporn, “Using Half-Normal Plots to Identify Important Factors in Screening Experiments Analyzed with the Generalized Linear Model”.
37. Sharlyn R. Stocker, “Measurement Capability with Wear Out”, co-advisor, George C. Runger.
36. John A. Druyor, “An Investigation of Linear Screening and Prediction Accuracy in Constrained Mixture Experiments”.
35. Pamela A. Okamoto, “Parameter Estimation from Hazard Plots using Robust Regression Techniques”, co-advisor with J. B. Keats.
34. M. J. Yatskievych, “Integrating Statistical Process Control with Feedforward Control,” co-advisor with J. B. Keats.
33. Richard D. Scranton, “Enhancements to the Multivariate Exponentially Weighted Moving Average Control Chart,” co - advisor J. B. Keats.
32. Steven E. Somerville, "Process Capability Ratios and Non-normal Distributions".
31. Daniel R. McCarville, "Defect Levels and Losses due to Gauge Error".
30. James E. Taggart, "A Comparison of Some Second-Order Response Surface Designs Based on Rotability and Prediction Variance".
29. Nora B. Peterschmidt, "Comparison of Regression Estimates in Mixture Experiments".
28. Sheila R. Voth, "Leverage, Multicollinearity and Bias in Response Surface Designs for Mixtures".
27. Robert Gilby, "A Wald Sequential Ratio Test, Modified to Ignore Small Shifts in the Process Variable".
26. Christina M. Mastrangelo, "Statistical Process Control Methods for Autocorrelated Data".
25. Deborah Garner, "Regression Diagnostics for Influence with Many Influential Cases".
24. Timothy G. Fields, "Nonlinear Programming Techniques for the Multiple Response Problem".
23. Beth Quay, "Investigation of Methods for Determining Influential Data Points in Regression Analysis".
22. Ronda K. Martin, "Interactive Regression Diagnostics".
21. Margaret Panagos, "Economic Design of the $\bar{x}$ Chart for Two Process Models".
20. Richard Matteson, "Minimum Bias Estimation of the Slope of a Response Surface".
19. Joseph F. Mance, "Economic Design of Fraction Defective Control Charts to Maintain Current Control of a Process".
18. Phillip J. Klatt, "Design of Control Charts for the Mean Vector of a Multivariate Normal Process".

17. A. K. Keswani, "Single Item Inventory Models for Back Orders and Lost Sales".
16. Mari Krista Jones, "A Comparison of Direct Smoothing with Short Term Forecasting Techniques for Periodic Data".
15. James M. Jerkins, "Some Algorithms for Nonlinear Regression".
14. William F. Friese, "A Cost Optimal Approach to Selecting a Fractional Factorial Design".
13. Claude K. Hudson, "Use of the Class of Equiradial Designs as Second Order Response Surface Designs".
12. David E. Ferguson, "The Development of an Adaptive Prediction and Control System".
11. Daniel M. Evans, Jr., "The Use of Second Order Response Surface Designs in Digital Simulation".
10. Joseph M. Cummings, "Repairing Response Surface Experiments to Minimize Bias".
9. Geneveive M. Cruz, "A Statistical Approach to the Combination of Forecasts".
8. Philip V. Coyle, "An Adaptation of Bayesian Statistical Methods to the Determination of Optimal Sample Sizes for Operational Testing".
7. Elwyn L. Brown, "An Application of Simulation Networking Techniques in Operational Test Design and Evaluation".
6. Jimmie K. Boles, "A GPSS II Simulation of an Air Defense Problem".
5. Joan S. Horwitz, "A Mathematical Model of an Epidemic Process".
4. Richard Harris, "Economic Design of T2 Control Charts for Multivariate, Multi-State Processes".
3. Timothy G. Fields, "Nonlinear Programming Techniques for the Multiple Response Problem".
2. Robert M. Baker, "An Application of Bayesian Statistical Methods in the Determination of Sample Size for Operational Testing in the U.S. Army".
1. Frank B. Alt, "Some Aspects of Multivariate Statistical Control Charts".

DOUGLAS C. MONTGOMERY
Biographical Data

Dr. Douglas C. Montgomery is Regents' Professor and the ASU Foundation Professor of Engineering at Arizona State University. He held the John M. Fluke Distinguished Chair in Engineering, was the Director of Industrial Engineering and Professor of Mechanical Engineering at the University of Washington in Seattle. He was a Professor of Industrial & Systems Engineering at the Georgia Institute of Technology. He holds BSIE, MS and Ph.D. degrees from Virginia Polytechnic Institute.

Professor Montgomery's professional interests are in industrial statistics, including design of experiments, quality control, applications of linear models, and time series analysis and forecasting. He also has interests in operations research and statistical methods applied to modeling and analyzing manufacturing systems. He has lectured extensively throughout the Americas, Europe and the Far East. He was a Visiting Professor of Engineering at the Monterey Institute of Technology in Monterey, Mexico, and a University Distinguished Visitor at the University of Manitoba. Professor Montgomery has conducted basic research in empirical stochastic modeling, process control, and design of experiments. The Department of Defense, the Office of Naval Research, the National Science Foundation, the United States Army, and private industry have sponsored his research. He has supervised 66 doctoral dissertations and more than 40 MS theses and MS Statistics projects.

Professor Montgomery is an author of thirteen textbooks that have appeared in over 35 English editions and numerous foreign languages, including *Design and Analysis of Experiments,* 8th edition (2012), *Introduction to Statistical Quality Control*, 7th edition (2012), *Generalized Linear Models,*2nd edition (2010, with R. H. Myers, G. G. Vining and T.J. Robinson), *Engineering Statistics*, 5th edition (2011, with G. C. Runger and N. F. Hubele), *Applied Statistics and Probability for Engineers,* 5th edition (2011, with G.C. Runger), *Introduction to Linear Regression Analysis,* 5th edition (2012, with E. A. Peck and G. G. Vining), and *Response Surface Methodology,*3rd edition (2009, with R. H. Myers and C.M. Anderson-Cook). He has edited or coauthored seven other research books or edited volumes. His research papers have appeared in many journals, including the *Journal of Quality Technology, Technometrics*, *Management Science*, *Naval Research Logistics Quarterly*, *IIE Transactions, Journal of the Royal Statistical Society, Communications in Statistics, IEEE Transactions on Reliability, Quality and Reliability Engineering International, IEEE Transactions on Semiconductor Manufacturing, Quality Engineering, Operational Research Quarterly*, *International Journal of Production Research*, *Journal of Spacecraft and Rockets*, and *Transportation Research.* He is a past Editor of the *Journal of Quality Technology* and one of the current chief editors of *Quality and Reliability Engineering International*. He has served as the Applied Probability and Statistics Department Editor and as the Quality and Reliability Engineering Department Editor for *IIE Transactions.* He is a member of the Editorial Board of the *Journal of Quality Technology,* the *Journal of Applied Statistics*, *Quality Engineering,* the *Journal of Probability and Statistical Science*, and *Quality Technology and Quantitative Management*.

Professor Montgomery's industrial experience includes engineering assignments with Union Carbide Corporation and Eli Lilly and Company. He also has extensive consulting experience with many national and international organizations.

Professor Montgomery is an Honorary Member of the American Society for Quality, a Fellow of the American Statistical Association, a Fellow of the Royal Statistical Society, a Fellow of the Institute of Industrial Engineers, an Elected Member of the International Statistical Institute, and an Elected Academician of the International Academy for Quality. He has held several national offices in ASQ, ASA, and IIE. He is a member of the honorary societies Phi Kappa Phi, Sigma Xi, Mu Sigma Rho, and Alpha Pi Mu. He received the Deming Lecture Award from the American Statistical Association. He is a recipient of the Shewhart Medal, the Distinguished Service Medal, the William G. Hunter Award, the Brumbaugh Award, the Lloyd S. Nelson Award, and two Shewell Awards from the American Society for Quality, the George Box Medal from ENBIS, the Greenfield Medal from the Royal Statistical society, and the Ellis R. Ott Award. He has also received several outstanding teaching awards, including the Arizona

State University Engineering College Graduate Teaching Excellence Award in 1994. He was named an ASU Outstanding Doctoral Mentor in 2004.

Appendix B. Charge Letter

3040 E. Cornwallis Road • PO Box 12194 • Research Triangle Park, NC 27709-2194 • USA
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October 30, 2017

Dr. Sanya Carley
School of Public and Environmental Affairs
Indiana University
1315 E. 10th Street
Bloomington, IN 47405

SUBJECT: Peer Review of EPA's Response Surface Equation Report

Dear Dr. Carley,

RTI International has been contracted by EPA to facilitate a peer review of their Response Surface Methodology Report. You have been selected to participate on this panel and your conflict of interest evaluation is complete. RTI will compensate you $3,000 for your services.

This charge letter contains specific questions to guide you in your review, the review schedule, and details about the materials we would like you to send us by the end of the three-week review period. Additionally, you should receive the peer review materials in the same email that delivered this letter.

Background

EPA's Office of Transportation and Air Quality has developed a statistical approach to access results from the Advanced Light-Duty Powertrain and Hybrid Analysis (ALPHA) model. To demonstrate the credibility of the methodology and gain acceptance in the light-duty automotive community, EPA has decided to initiate an independent peer review.

The ALPHA model is a full vehicle simulation model which is used to assess the effectiveness of different technology packages in vehicles. Effectiveness values from ALPHA act as robust inputs to the Optimization Model for Reducing Emissions of Greenhouse Gases from Automobiles (OMEGA) as well as the overall rulemaking process.

Because operating the ALPHA model in real time to conduct full vehicle simulations is cost- and time-prohibitive, EPA has developed a method of deriving the necessary effectiveness values using a statistical methodology known as a Response Surface Model (RSM). An RSM is used to computationally synthesize a large set of simulation outputs to derive response surface equations (RSE). The derived RSEs can then be used in place of running the ALPHA model in real time.

Charge Questions

For this review, EPA is looking for the reviewer's opinion of the use of response surface modeling to access the results of the ALPHA model for use in the OMEGA model. *The ALPHA and OMEGA models themselves are not part of the review and no independent data analysis is required.*

EPA would like you to consider the questions below to help define the scope of the review. You are not expected to respond to the questions individually; instead, they should be considered a guide for your response.

General Questions and Issues to Consider

1. EPA's overall approach to applying response surface modelling to accessing ALPHA model results and whether the resulting response surface equations provide accurate and robust inputs for the OMEGA model.
2. Reasonableness of any assumptions, implicit or explicit, contained in EPA's execution of the methodology.
3. Clarity, completeness and accuracy of the technical application of response surface modelling; and
4. Any recommendations for specific improvements to the functioning or the quality of the methodology.

In your review, please identify any recommendations that would improve the methodology, clearly distinguishing between specific improvements that can be readily made using available data and literature, and improvements that are more theoretical or exploratory, which would rely on data or literature not readily available to the EPA. Comments should be detailed enough that EPA readers or others familiar with the report can understand the comments' relevance to the Response Surface Equation Report.

Schedule

The schedule for this peer review is as follows:

- October 30th, 2017: Charge letter distributed to reviewers
- October 31st, 2017: Peer Review Kick-Off Call
- Date TBD: Mid-review conference call
- November 22nd, 2017: Comment/review due via email to Kyle Clark-Sutton at kcs@rti.org.

Materials

Upon completion of your review, you should submit your report under a cover letter that states:

1) Your name

2) The name and address of your organization
3) A statement of any real or perceived conflict(s) of interest.

Should you have any questions or concerns, feel free to contact me via phone at 919-541-5874 or by email. In addition, the EPA project manager for this effort is Jeff Cherry and he may be reached at 734-214-4371 or cherry.jeff@epa.gov.

For any questions about the review process itself, please contact Ruth Schenk in EPA's Quality Office, National Vehicle and Fuel Emissions Laboratory at 734-214-4017 or schenk.ruth@epa.gov.

Thanks for your participation!

Sincerely,

Kyle Clark-Sutton
Research Economist, RTI International
(919) 541-5784
kcs@rti.org

Appendix C. Sanya Carley Comments

November 16, 2017

Kyle Clark-Sutton
Research Economist
RTI International

RE: Peer Review of EPA's Response Surface Equation Report

Dear Mr. Clark-Sutton,

Thank you for the invitation to conduct a peer review of the EPA's Response Surface Equation Report. I am an associate professor in the School of Public and Environmental Affairs at Indiana University. My work address is presented below.

Please find a summary of my review enclosed in this submission package. These comments and recommendations are based on my understanding of Response Surface Methodology, cost-effectiveness of different vehicle technology packages, the use of input parameters and the operation of the OMEGA model, and U.S. fuel economy and greenhouse gas emissions standards for light-duty vehicles between 2017 and 2025.

To the best of my knowledge, I have no real or perceived conflicts of interest in conducting this review. I have conducted research with colleagues on the macroeconomic implications of U.S. fuel economy and greenhouse gas emissions standards. As part of this effort, my colleagues and I recreated the EPA's OMEGA model and used it to generate estimates of vehicle prices. This research was funded by the Alliance of Automobile Manufacturers but the work was conducted independently of the funding organization. I disclosed this potential conflict of interest to the EPA when they were in the process of seeking peer reviewers and it was determined at the time to not be a conflict.

Please do not hesitate to contact me with further questions about my review, or if there are other questions that I could address that would assist with the process.

Sincerely,

Sanya Carley
Associate Professor
Chair, Policy Analysis and Public Finance
School of Public and Environmental Affairs
Indiana University
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812-856-0920
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Enclosure: A summary of review comments and recommendations

PEER REVIEW

EPA RESPONSE SURFACE METHODOLOGY REPORT

Sanya Carley
School of Public and Environmental Affairs
Indiana University
November 16, 2017

I. SUMMARY

This document summarizes my review of the "EPA Report on the Implementation of Response Surface Methods to Reproduce ALPHA Modeling Results in the OMEGA Model Preprocess" and all supporting modeling outputs provided in the review package. The proposed response surface method (RSM) will be used to replicate simulation modeling in a manageable time frame, and generate technology effectiveness estimates to be used in the Environmental Protection Agencies' (EPA) Optimization Model for reducing Emissions of Greenhouse gases from Automobiles (OMEGA). The OMEGA model, in turn, is an optimization model used to generate light-duty vehicle technology cost estimates that comply with emissions standards, as used for the Final Rulemaking for the 2017-2025 greenhouse gas emissions standards (OMEGA v1.4.1) and more recently the Technical Assistance Report of 2022-2025 standards (OMEGA v1.4.56).

After a thorough review of the report and supporting documentation, my general impression is that response surface statistical methods are an appropriate and efficient approach to generate data needed to populate the OMEGA model. The RSM is an analysis tool that is increasingly accepted in engineering and other disciplines, and subjected to rigorous peer review. An analysis of the model performance in this specific case also leads me to believe that the RSM approach is highly accurate, and capable of generating results that match the significantly more time-intensive ALPHA simulations.

II. OVERVIEW OF APPROACH

The general approach to the use of RSM is as follows. The modeler uses the ALPHA model to evaluate all combinations of engines, transmissions, road loads, and vehicle types to produce a design of experiments. The design of experiments is then entered into the response surface equation modeling program, a standard statistical modeling software program, JMP from SAS. The response surface equations are then generated using this statistical program. Using four different input parameters—mass reduction, aero drag reduction, rolling resistance reduction, and transmission type—and the response surface equations, the modeler then compares the results between the RSM outputs and the design of experiments from the ALPHA simulations, and assesses the quality of the fitted model as well as the accuracy of the model to predict the experimental results. The output of the RSM is converted into a spreadsheet of vehicle effectiveness to be used in the OMEGA model, as designed to match the former spreadsheets used with the lumped parameter model.

All of these steps are clearly described, and in greater detail, in the "EPA Report on the Implementation of Response Surface Methods to Reproduce ALPHA Modeling Results in the OMEGA Model Preprocess" report. This process, as outlined, is appropriate and matches standard procedures.

III. APPROPRIATENESS OF THE APPROACH

A. RSM as an Accepted Approach

RSM is a set of mathematical and statistical techniques that allows one to fit a polynomial model to data. RSM can account for several different independent variables (also referred to as factors or operating parameters), that can vary at the same time over a set of experimental runs. RSM can be used to develop the functional relationship between an outcome of interest (or a "response") and several different independent variables, so as to simultaneously optimize the values of these variables. The errors in RSM are assumed to be random.

Response Surface Methodology was first introduced by Box and Wilson in 1951 (Box and Wilson, 1951). Since its inception, but particularly beginning it in the early 1970s, it has been applied to a range of complex topics, such as automobiles and impact load conditions (e.g., Avelle et al. 2002), water desalination (e.g., Boubakri et al., 2014), and food industry processes (see Yolmeh and Jafari, 2017 for a comprehensive review of this literature), among many other topics.

Figure 1 graphs the number of different types of studies that have used RSM since it was first introduced, according to a search within the Scopus database. This graph demonstrates that engineering studies are the most common applications of the method, followed closely by biochemistry and agricultural/biological sciences. Figure 2 shows the same data but over time, between the 1961 and 2016. This figure demonstrates that the majority of studies that used RSM in the earliest years of the methodology were immunology and microbiology studies. The use of the methodology has grown significantly over time within various chemistry disciplines as well as, more recently, engineering disciplines.

Figure 1. Number of Published RSM Articles by General Category of Study, 1951-2017

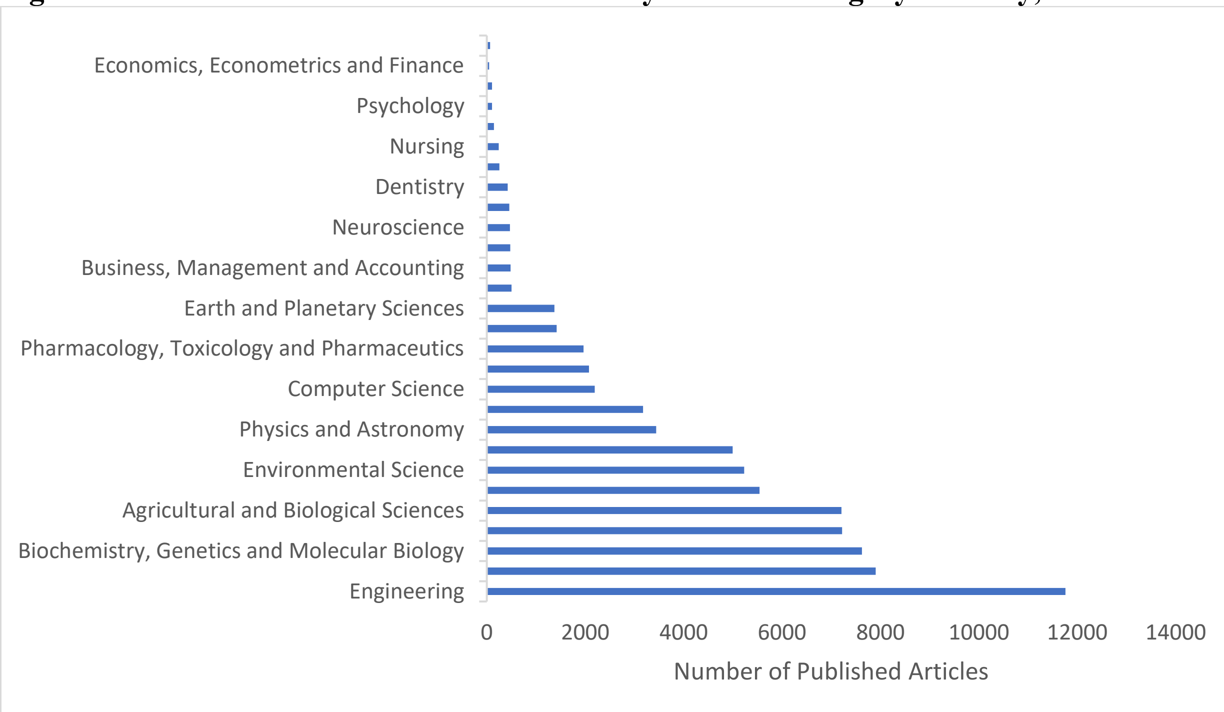
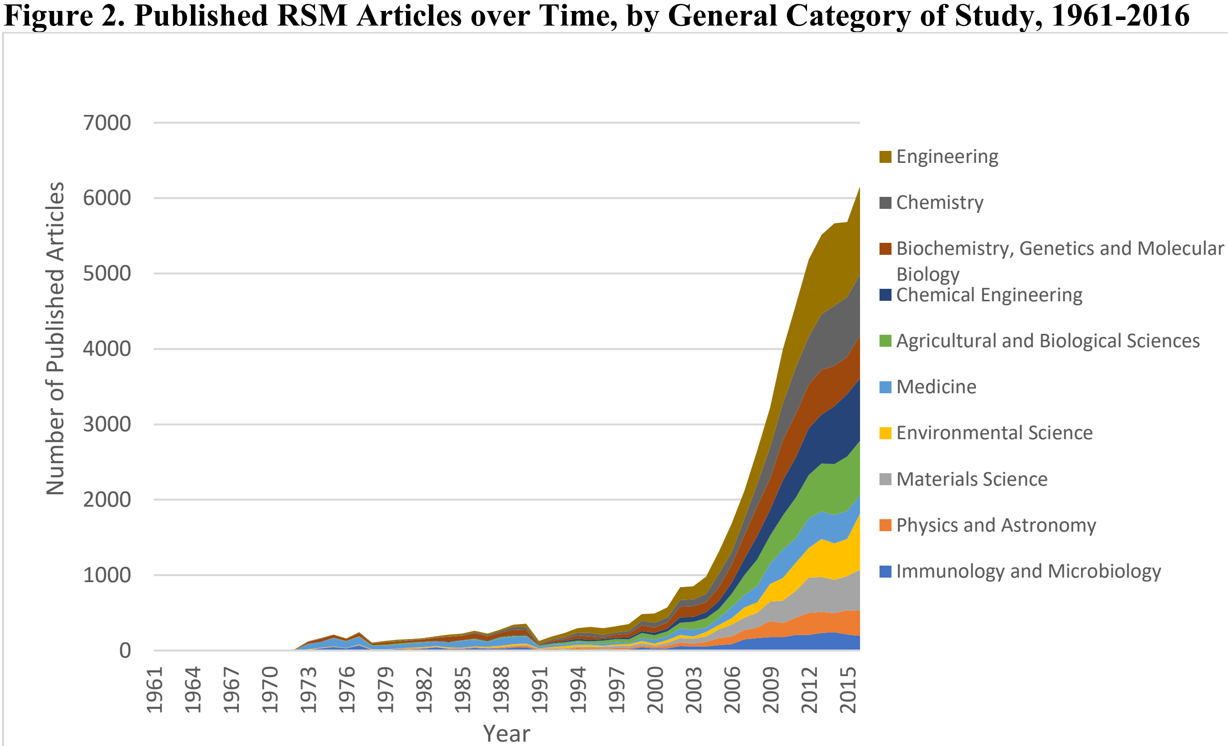


Figure 2. Published RSM Articles over Time, by General Category of Study, 1961-2016



B. Timing and Practical Considerations

The execution time of the RSM is similar to that associated with the former lumped parameter model, and significantly faster than running the ALPHA model. This modeling efficiency allows for real-time input parameter generation for the OMEGA model, and also allows the EPA—and others that choose to replicate EPA results—to use standard computing equipment. These conditions also have implications for the EPA budget, since running the RSM will not require additional financial resources.

C. Response Surface Modeling Process

To perform the RSM analysis, the modelers use a standard software package for this purpose, the JMP Classical Response Surface Design Model. This software is highly flexible, able to generate equations with the appropriate functional form, and assess which independent variables should be included.

IV. VALIDATION OF THE MODELING OUTPUTS

A. Validation of Modeling Results

a. *Model Performance*

A standard test that is used to evaluate the performance of the model is a goodness-of-fit estimate. The EPA has confirmed that they obtained sufficiently high R^2 values for all of their model runs.

b. *Comparison of Output to ALPHA Modeling Output*

There are a variety of performance metrics that one could use to assess response surface equation accuracy and adequacy. For this review, I evaluated the size of the residuals, the percent error, and the distribution of the residuals.

Table 1 displays the first two performance metrics, along with additional detail about the model runs. The first column designates the vehicle type, of which there are six. The second column designates the powertrain category, of which there are four. The combination of six vehicle types of four powertrain categories results in 24 different categories of model runs. The observation count is the number of ALPHA runs with all allowable combinations of the independent variables that stay within parameter bounds. The next four columns provide statistics for the residual (the difference between the dependent variable of the response surface equation and the ALPHA simulation). The final column displays the percent error, or the deviation between the experimental ALPHA values and the predicted RSM values for a determined set of conditions.

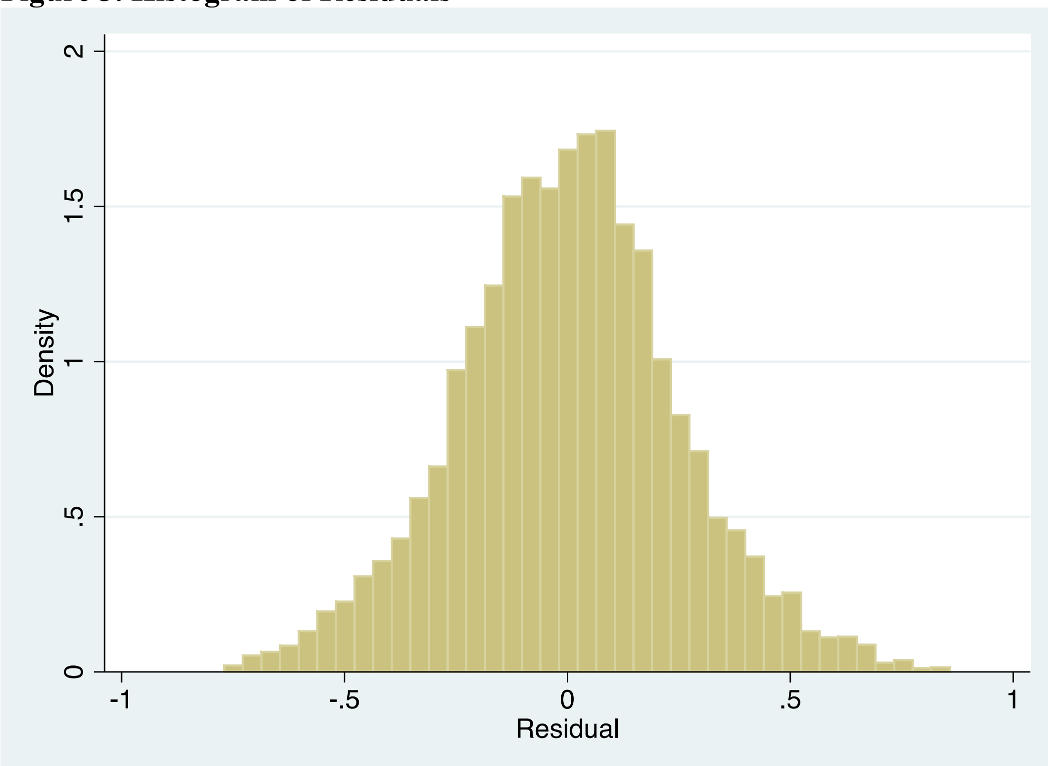
These statistics confirm that the predicted values have excellent accuracy. The average residual is 0.0013 and the average percent error is -0.0004 percent. All combinations of vehicle type and powertrain perform similarly. The combination that has the highest residual is the High Power/Weight 2014 Atkinson.

Table C-1. RSM Performance Metrics

Vehicle Type	Powertrain Category	Obs	Average Residual	Residual Standard Deviation	Residual Min	Residual Max	% Error
Low Power/Weight -- Low Road Load	2014 GDI	375	-2.5E-10	0.19	-0.51	0.60	-2.4E-08
Low Power/Weight -- Low Road Load	2014 Atkinson	371	6.5E-03	0.20	-0.51	0.41	-2.9E-05
Low Power/Weight -- Low Road Load	2020 Atkinson	375	2.3E-10	0.18	-0.52	0.40	-3.1E-08
Low Power/Weight -- Low Road Load	2020 24 Bar Turbo	375	3.9E-10	0.18	-0.65	0.50	7.7E-08
Medium Power/Weight -- Low Road Load	2014 GDI	375	6.1E-11	0.14	-0.40	0.50	4.8E-08
Medium Power/Weight -- Low Road Load	2014 Atkinson	375	5.7E-10	0.26	-0.57	0.69	-3.7E-07
Medium Power/Weight -- Low Road Load	2020 Atkinson	375	3.1E-11	0.18	-0.43	0.48	-4.0E-07
Medium Power/Weight -- Low Road Load	2020 24 Bar Turbo	375	5.0E-11	0.28	-0.73	0.55	-8.9E-07
High Power/Weight	2014 GDI	351	-1.1E-02	0.25	-0.58	0.57	4.1E-05
High Power/Weight	2014 Atkinson	313	0.42	0.35	-0.69	0.70	-1.8E-04
High Power/Weight	2020 Atkinson	340	8.1E-04	0.32	-0.65	0.64	5.8E-07
High Power/Weight	2020 24 Bar Turbo	375	3.0E-11	0.23	-0.69	0.68	3.3E-07
Lower Power/Weight -- High Road Load	2014 GDI	325	2.5E-10	0.17	-0.49	0.59	1.2E-08
Lower Power/Weight -- High Road Load	2014 Atkinson	274	2.5E-10	0.17	-0.38	0.41	7.3E-08
Lower Power/Weight -- High Road Load	2020 Atkinson	285	-1.6E-12	0.11	-0.29	0.33	4.7E-08
Lower Power/Weight -- High Road Load	2020 24 Bar Turbo	375	5.5E-11	0.15	-0.43	0.35	4.2E-07
Medium Power/Weight -- High Road Load	2014 GDI	332	9.7E-05	0.21	-0.52	0.50	2.5E-06
Medium Power/Weight -- High Road Load	2014 Atkinson	280	-3.4E-11	0.23	-0.58	0.65	-2.9E-08
Medium Power/Weight -- High Road Load	2020 Atkinson	282	1.1E-10	0.21	-0.60	0.63	2.2E-08
Medium Power/Weight -- High Road Load	2020 24 Bar Turbo	363	-9.9E-03	0.28	-0.59	0.65	4.7E-05
Truck	2014 GDI	357	-3.5E-03	0.27	-0.58	0.58	7.4E-06
Truck	2014 Atkinson	315	-1.4E-02	0.38	-0.77	0.78	6.2E-05
Truck	2020 Atkinson	336	-1.2E-03	0.38	-0.77	0.86	1.4E-05
Truck	2020 24 Bar Turbo	358	2.2E-02	0.36	-0.74	0.78	-6.8E-05
All vehicle types	All powertrain categories	8257	1.3E-03	0.25	-0.77	0.86	-4.1E-06

I also plotted the residuals to see if they fit a normal distribution, as suggested by Bezerra et al. (2008). Figure 3 presents a histogram of all residuals across the 8,257 model runs. The distribution appears normal. I also looked at the histograms for all vehicle types, powertrain technologies, and vehicle type-powertrain combinations separately (not shown here). These plots provide no cause for concern.

Figure 3. Histogram of Residuals



B. The Design of Experiments

The RSM output is compared to the ALPHA modeling output, which assumes that the ALPHA output (the design of experiments) is accurate. I have no reason to believe that this is cause for concern, however, since the ALPHA model has already gone through thorough rigorous peer review (see https://nepis.epa.gov/Exe/ZyPdf.cgi?Dockey=P100PUKT.pdf). The peer reviewers found the ALPHA model to be highly reliable and accurate.

V. RECOMMENDATIONS

A. Design of Experiments

A future extension of model validation could be an assessment of the RSM output with actual testing data. One should assume that the results would be similar to the estimates of comparison between ALPHA and RSM, however, since the EPA's previous work found that ALPHA estimates were within the margin of 3% error as compared to actual vehicle performance testing.

B. Transparency

As stated in the report, one of the benefits of the RSM is "increased transparency regarding synthesis of ALPHA simulation into OMEGA modeling". It is not entirely clear to me how the use of RSM will increase transparency. But I strongly encourage and support full transparency of modeling inputs, outputs, processes, and supporting information.

References

Avalle, M., Chiandussi, G., Belingardi, G. 2002. Design optimization by response surface methodology: application to crashworthiness design of vehicle structures. *Structural and Multidisciplinary* Optimization 24, 325-332.

Bezerra, M.A., Santelli, R.E., Oliveira, E.P., Villar, L.S., Escaleira, L.A. 2008. Response surface methodology (RSM) as a tool for optimization in analytical chemistry. Talanta 76, 965-977.

Boubakri, A., Hafiane, A., Bouguecha, S.A.T. 2014. Application of response surface methodology for modeling and optimization of membrane distillation desalination process. *Journal of Industrial and Engineering Chemistry* 20, 3163-3169.

Box, G.E., Wilson, K. 1951. On the experimental attainment of optimum conditions. *Journal of the Royal Statistical Society. Series B (Statistical Methodology*) 13(1), 1-45.

Yolmeh, M., Jafari, S.M. 2017. Applications of response surface methodology in the food industry processes. *Food Bioprocess Technology* 10, 413-433.

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Appendix D. Sujit Das Comments

Sujit Das
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(865)789-0299 dass@ornl.gov

November 17, 2018

Kyle Clark-Sutton
Research Economist, RTI International
3040 Cornwallis Road
PO Box 12194, Research Triangle Park, NC 27709

RE: Peer Review of *EPA's Response Surface Equation Report*

Dear Mr. Clark-Sutton:

Thank you for inviting me to conduct a peer review of *EPA's Response Surface Equation Report.* I have completed the review.

Enclosed with this letter is a summary of my review comments and recommendations. These comments are made on the basis of the current state of science as I understand it. To the best of knowledge, I have no real or perceived conflicts of interest in conducting this review.

Please feel free to contact me should you have any questions or need additional regarding this review.

Sincerely,

Sujit Das

Enclosure: A summary of review comments and recommendations

PEER REVIEW COMMENTS

EPA RESPONSE SURFACE MODEL (RSM)

Sujit Das

Oak Ridge National Laboratory

12305 Fort West Drive, Knoxville, TN 37934

November 22, 2017

Peer Review of EPA Response Surface Model (RSM)

1. The industry standard statistical software JMP from SAS has the design of experiments and design generation capabilities besides being interactive and visual and thereby justifies its use towards the development of Response Surface Equations. Unlike SAS (which is command-driven), JMP has a graphical user interface to explore data visually. JMP is the tool of choice for scientists, engineers and other data explorers in almost every industry and government sector. It combines dynamic data visualization with powerful statistics, in memory and on the desktop. Interactive and visual, JMP reveals insights that raw tables of numbers or static graphs tend to hide.

2. RSM approach has demonstrated clearly an effective use of the large scale simulations from the already validated full vehicle simulation model ALPHA. It definitely serves the intended appropriate and accurate means of assessing technology packages by means of the efficient transposition of full-vehicle simulation results into OMEGA inputs. RSM design concept is very similar to the design of LPM which was used for each Light-duty Greenhouse Gas rulemaking, from the 2009 FRM through the 2016 Proposed Determination. The RSEs allows any ALPHA run to be derived at a similar speed as the current spreadsheet LPM. A similar user-friendly and execution time LPM front end used for RPM is definitely an advantage, but it needs to be customized for RPM which is limited to only a combination of few technology options (i.e., for specific vehicle type and powertrain model with user-specific inputs for mass reduction, aero drag reduction, rolling resistance reduction, and transmission type) compared to LPM, for a large number of RPM users.

3. Response surface methodology (RSM) explores the relationships between several explanatory variables and one or more response variables. A sequence of designed experiments (DOE) was used, i.e., the main idea of RSM to obtain an optimal response. A DOE used in this case was based on an automated process that is configured to produce a complete set of ALPHA results for all combinations of engines, transmissions, roadloads, and vehicle types to be used in the OMEGA analysis. It is a relatively easy statistical model to estimate and apply, even when little is known about the process. It maximizes the production of a special substance by optimization of operational factors. A factorial experiment or a fractional factorial design generally used to

estimate RSE process has generated as series of equations from a complete set of ALPHA data for each vehicle type and powertrain model. A second-degree RSE polynomial model was developed for each 24 vehicle cases based on a combination of 6 vehicle types and 4 powertrain types in the present analysis.

4. A comparison of CO_2 results between RSE and ALPHA has confirmed the validity of the data transfer between these two models thereby proving the accuracy of the technical application of response surface modeling. A total of 21 results (only 2020_TURB24 was available for LPW_LRL vehicle) out of total 24 vehicle types were examined for the RSM validation. Residuals were found to be between a narrow range of -1.0 and 1.0 gCO_2/mile in all cases. The line slope of the plot of results of ALPHA and RSE was also found to be 45^o and thus has ensured the validity of data transfer between them. In addition, as the physics behind the Mass, Aero, and Roll are quite linear in reality, and so CO_2 emission impacts of any values between the range of these parameters were also found to be reasonable using the RSE results.

5. Section 6. Baseline Vehicle Adaptation needs further details in terms of the necessary process steps for adjusting the effectiveness of a baseline vehicle to match the ALPHA model. The adjustment approach for the baseline vehicle adaptation is an interesting one as it allows ~ 50 alternative options to consider in a baseline vehicle.

6. Since the RSE final output is CO_2 emissions provided to the OMEGA model with the technology alternatives necessary to produce the most cost-effective path for compliance, a short discussion of it will be useful for unfamiliar users.

7. A description of three different transmission types considered and denoted by numerals (i.e., 2, 4, & 5) would be useful. An appropriate justification needs to be included why other two types, i.e., 1 and 3 were not considered for the RSM DOE analysis.

8. It is unclear why the assumed vehicle mass reduction value is not actually reflected in the ALPHA spreadsheets provided, e.g., for 2020 TURB24 vehicle, 3109.15 lbs and 2961.3 lbs Test Weight have been assumed for a mass reduction of 5% and 10%, respectively, for a baseline vehicle Test Weight of 3257 lbs? Similar level of difference was found in all 21 different vehicle type/powertrain considered for RSM.

9. The draft report mentions about six vehicle types in OMEGA analysis and four powertrain categories in the ALPHA. It is unclear about the consistency in the number of vehicle types and powertrain categories between these two tools and thereby to what extent does the current RSM cover the overall analysis scope of the OMEGA technology options?

10. In spite of the fact that there are four independent variables, i.e., mass reduction, aerodynamic drag reduction, rolling resistance reduction, and transmission type have been used for the development of RSE equations, but +50 ALPHA data variables have been included in the several vehicle spreadsheets provided. It'd be good to provide the description of each of the ALPHA variables for an understanding of impacts of the four major dependent variables considered.

11. As the RSE "Effectiveness" implementation is expanded beyond the currently limited six vehicles, four powertrains, and three transmission type options provided, the user-friendliness in terms of inputs should be kept in mind. Using the current framework provided as an example, it is difficult for a novice user to perform a quick analysis. Specifically, a discussion on the "Baseline Vehicle Adaptation" procedure needs to be included in the documentation, when all original LPM technology options are also available for RSM for the baseline vehicle adaptation. Some Comments/Warning should be included if the results are invalid for transmission cases 1 & 3 as is the case now. The inputs for Vehicle Type, Model, and Transmission in Column A should be interlinked with the corresponding numeric value in Column B on this worksheet.

12. It'd be useful for the EPA draft report completeness to provide some background information on the models and tools used in EPA's light-duty Greenhouse Gas (GHG) rulemakings for unfamiliar audience.

13. Not sure whether any model validation was done in terms of using the model to predict the response for one or more combinations of design factors that were not used to build the RSM models? What agreements between the two results were found for such a validation?

14. Overall, the quality of RSE methodology appears to be reasonable for the four independent variables considered. The validity of this methodology need to reexamined if it is expanded to a higher number of independent variables in the future.

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Appendix E. Doug Montgomery Comments

Douglas C. Montgomery
3841 East Talowa Street
Phoenix AZ 85044
480.496.8872
30 November 2017

Kyle Clark-Sutton
Research Economist, RTI International
3040 Cornwallis Road
PO Box 12194, Research Triangle Park, NC 27709

RE: Peer Review of *EPA's Response Surface Equation Report*

Dear Mr. Clark-Sutton:

Thank you for asking me to participate in a peer review of *EPA's Response Surface Equation Report.* I have completed the requested review.

Previously I have sent you a summary of my review comments and recommendations. These comments are made on the basis of the current state of science as I understand it. To the best of my knowledge, I have no real or perceived conflicts of interest in conducting this review.

Please feel free to contact me should you have any questions or need additional regarding this review.

Sincerely,

Douglas C. Montgomery

ALPHA is the acronym for the Advanced Light-Duty Powertrain and Hybrid Analysis full vehicle simulation model developed to study greenhouse gas emissions from vehicle internal combustion engines. This is a validated model that has been shown to provide accurate prediction of emissions for various combinations of engines and vehicle types. However, running the ALPHA model is very time-consuming. In situations like this a standard industry practice is to replace the computer model with a statistical model that can be executed more quickly but which has comparable accuracy in prediction. Such a statistical model is usually called a metamodel.

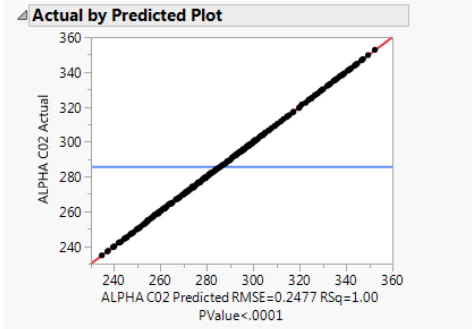
A widely used approach to creating the statistical metamodel is to conduct a designed experiment on the computer model investigating factors of interest to the analysts and then fit the model to the data resulting from the experiment. Response surface methodology (RSM) is a standard technique for this purpose.

This report is a review of the RSM models produced for the ALPHA simulation model. There are 24 models representing a range of powertrain and vehicle types. For each RSM model I was furnished with a spreadsheet that contained the designed experiment that was performed on that configuration of the ALPHA model, along with the observed responses, the predicted responses from the RSM model, and the residuals. For these experiments the inputs factors for the design include Mass Reduction, Aero Drag Reduction, Rolling Resistance Reduction, and Transmission type. The experiments used were variations of standard factorial designs. Response surface models were fit to the experimental results to produce the spreadsheet outputs that I was given.

I investigated the adequacy of the RSM models by first analyzing the residuals from these models in the spreadsheets that were provided. I constructed normal probability plots of the residuals and plots of the residuals versus the predicted response. These plots investigate the normality of the response variable and the equality of variance assumption, both of which are standard RSM assumptions. The normality assumption is of only moderate importance since the underlying statistical methodology is robust to all but severe departures from normality. The equal variance assumption is more important, and moderate to large departures from this assumption may require remedial measure such as the use of variance-stabilizing transformation. A few of the normal probability plots exhibited very small potential departures from normality but nothing severe enough to call model validity into question. Similarly, some of the plots of residuals versus the predicted response exhibited a non-random pattern, but none of the patterns were serious enough to question the equal variance assumptions. It is also worth noting that the model residuals ae extremely small as all models provide extremely good fits to the data obtained from the simulation model.

I selected a subset of the 24 models for further investigation. I loaded the experimental designs for these models into JMP PRO V 13 and performed my own RSM analysis, fitting the standard second-order model. The results for one of these RSM model from spreadsheet HPW 1026 2017a tab 2014 GDI are discussed below. This is typical of the results I obtained for all models that I investigated.

Plot of actual versus predicted response:



The points in this plot lie almost exactly along a straight line, indicating excellent agreement between the simulation model output and the predicted value from the second-order RSM model.

Summary of fit and analysis of variance for the RSM model:

Summary of Fit

RSquare	0.999925
RSquare Adj	0.999921
Root Mean Square Error	0.247653
Mean of Response	285.8269
Observations (or Sum Wgts)	351

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	14	273407.37	19529.1	318414.8
Error	336	20.61	0.061332	Prob > F
C. Total	350	273427.97		<.0001*

The R^2 statistic for the model exceeds 0.99, indicating that most of the variability in the sample data (in excess of 99%) is explained by the RSM model. Also, the R^2-adjusted statistic is also in excess or 0.99. R^2-adjusted is a reflection of potential overfitting; that is including terms not really important in the model just to inflate the ordinary R^2. When these two statistics are in close agreement as they are here there is likely to be no substantial issue with overfitting. The analysis of variance indicates that the model contains at least one statistically significant term.

RSM Model Parameters Estimates:

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	382.68894	0.075154	5092.1	<.0001*
Mass	-201.7124	0.190516	-1059	<.0001*
Aero	-52.06903	0.190476	-273.4	<.0001*
Roll	-53.30226	0.189323	-281.5	<.0001*
Trans	-18.23885	0.012694	-1437	<.0001*
(Mass-0.10085)*(Mass-0.10085)	8.0152892	3.191378	2.51	0.0125*
(Mass-0.10085)*(Aero-0.09715)	-10.63205	2.735951	-3.89	0.0001*
(Aero-0.09715)*(Aero-0.09715)	-5.158863	3.177543	-1.62	0.1054
(Mass-0.10085)*(Roll-0.09886)	50.490674	2.751456	18.35	<.0001*
(Aero-0.09715)*(Roll-0.09886)	-6.814333	2.723004	-2.50	0.0128*
(Roll-0.09886)*(Roll-0.09886)	-3.497919	3.169082	-1.10	0.2705
(Mass-0.10085)*(Trans-3.68091)	23.883683	0.149944	159.28	<.0001*
(Aero-0.09715)*(Trans-3.68091)	0.4606774	0.150692	3.06	0.0024*
(Roll-0.09886)*(Trans-3.68091)	0.626202	0.149753	4.18	<.0001*
(Trans-3.68091)*(Trans-3.68091)	0.5810956	0.014437	40.25	<.0001*

The second –order model contains 15 parameters; an intercept, four main effects, six 2-factor interactions, and four quadratic terms. The parameter estimates display indicates that all but two of these terms are statistically significant at the 0.05 level. However, in RSM we usually think that it's the order of the model that is most important so we often do not remove non-significant terms from the model unless there are many of them. That is not the case here.

The PRESS Statistic

In model validation it is important that the model both fit the sample and that it provide good predictions of new data. The PRESS (Prediction Error Sum of Squares) statistic, reported below, is a standard one-sample-at-a-time cross-validation used to assess potential prediction performance.

Press

Press	Press RMSE
22.448639323	0.2528957

Notice that the PRESS statistic is very similar to the residual sum of squares from the analysis of variance. An R^2-like prediction error statistic can be computed from PRESS simply by replacing the residual sum of squares in the equation for R^2 by PRESS. This gives:

$$R^2_{\text{Prediction}} = 1 - \frac{PRESS}{TotalSS} = 1 - \frac{22.449}{273428} = 0.9999$$

We would expect the RSM model to explain in excess of 99% of the variability in data produced by the simulation model. This is excellent validation of potential prediction performance.

Summary of Conclusions

I conclude that the RSM approach has produced statistical metamodels that are an excellent alternative to the APLHA simulation model. So long as they are used to interpolate over the ranges of the four factor used in their construction I expect that they will be excellent alternatives to the ALPHA simulation procedure.

Appendix F. Response Surface Report

EPA Report on the Implementation of Response Surface Statistical Methods to Reproduce ALPHA Modeling Results in the OMEGA Model Preprocess

J. Cherry

March 2017

1 Background:

For the Light-Duty (LD) Greenhouse Gas (GHG) rulemakings created by the Environmental Protection Agency (EPA) including the MY 2012-2016 and MY 2017-2025 Final Rules, estimates for the effectiveness of vehicle technologies have played an important role as a robust input into the overall rulemaking analysis process and as input to EPA's Optimization Model for reducing Emissions of Greenhouse gases from Automobiles (OMEGA).

For each Light-duty Greenhouse Gas rulemaking, from the 2009 FRM through the 2016 Proposed Determination, EPA has applied a combination of full-vehicle simulation modeling and a Lumped Parameter Model (LPM). The LPM methodology has been continuously developed, refined, and calibrated throughout each of these rulemakings to reflect the latest technology developments and comments received regarding the application of the LPM. The National Academy of Sciences (NAS) reviewed the application of the LPM in their 2011 and 2015 reports on technologies available for reducing fuel consumption and found the LPM to be robust and to accurately predict the overall effectiveness of combinations of technology. While EPA continues to believe that the LPM is an appropriate and accurate means of assessing technology packages, the efficient transposition of full-vehicle simulation results into OMEGA inputs has historically required many hours of manual calibration, that has not been well understood by our stakeholders.

In response to comments received from stakeholders and in an effort to reduce the manual interpretation and calibration of the LPM, EPA is considering replacing the LPM with an industry standard statistical methodology. This methodology, commonly known as a Response Surface Model (RSM), computationally is able to synthesize large numbers of simulations and distill the outputs into an equation which represents the effectiveness of technology packages. This latest process to reproduce these technology effectiveness estimates in real time for OMEGA is the subject of this report. First, some history of the process for reference.

1.1 History:

One method for determining the effectiveness value for a vehicle technology package required for an OMEGA analysis would be to run a validated full vehicle simulation. In practice, robust full vehicle simulations require a considerable set of data and a finite amount of time to execute for each simulation. During a typical analysis cycle, many thousands of simulations are performed. For example, preprocessing data for an OMEGA run requires approximately one million technology package results that would require several days to execute on a modern computer. This situation along with the lack of a complete set of engine maps, transmission maps, and other validated data required for such simulations during the analysis for the MY 2012-2016 Final Rule required an alternative solution.

In response to this need, EPA combined an extensive library of full vehicle simulation data, test data, and public literature to create the Lumped Parameter Model (LPM). Historically, the LPM has been implemented as a spreadsheet method to provide vehicle technology package effectiveness values in the preprocessing phase for the OMEGA model. The LPM was originally based on the techniques for combining (lumping) various vehicle technologies into their various loss categories as detailed in a SAE paper by General Motors (2002-01-0628). This lumping process results in a first-principles energy balance accounting for the various synergies and disynergies as the technologies are merged to reduce double counting and missed efficiencies. The result is a final effectiveness value to represent the changed efficiency of the vehicle as the result of the additional (or subtracted) technologies. An example of these loss categories is shown in Figure 6 and the original Excel version of the LPM is shown in Figure 7.

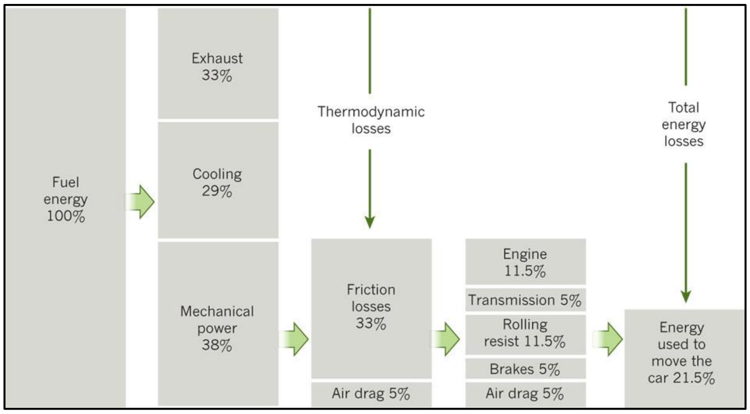


FIGURE 6 – EXAMPLE LOSS CATEGORIES IN A LIGHT DUTY VEHICLE

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Vehicle Energy Effects Estimator

Vehicle type: Standard Car Family

Description: Technology picklist
Package: Z

	Indicated Energy							Heat Lost To Exhaust & Coolant			
	Brake Energy					Engine Friction					
	Vehicle Mass	Road Loads: Drag	Road Loads: Tires	Parasitics	Gearbox, T.C.						
	Inertia Load	Aero Load	Rolling Load	Access Losses	Trans Losses	Friction Losses	Pumping Losses	Ind Eff Losses	Second Law	Check	
Baseline % of fuel	13.0%	4.0%	4.0%	1.8%	4.2%	6.6%	4.4%	32.0%	30.0%	100.0%	OK
Reduction	0%	16%	8%	64%	33%	16%	75%				
% of original fuel	13.0%	3.4%	3.7%	0.8%	3.3%	5.6%	1.1%	31.8%	30%		

	Indicated Efficiency	Mech Efficiency	Brake Efficiency	Drivetrain Efficiency	Fuel Efficiency	Road Loads
Baseline	38.0%	71.1%	27.0%	77.8%	21.0%	100.0%
New	38.2%	82.5%	31.5%	87.2%	27.5%	95.4%

Current Results	
72.9%	Fuel Consumption
27.1%	**FC Reduction**
37.2%	FE Improvement
N/A	**Diesel FC Reduction**

Original friction/brake ratio Based on PMEP/IMEP >>>> (GM study)	PMEP Losses	Brake Efficiency
	11%	27%
	=71.1% mech efficiency	

Technology	Independent FC Estimate		Loss Category	Implementation into estimator	User Picklist Include? (0/1)	Gross FC Red	
Aero Drag Reduction	3.0%		Aero	16% aero (cars), 10.5% aero (trucks)	1	3.0%	
Rolling Resistance Reduction	1.5%		Rolling	8% rolling	1	1.5%	
Low Fric Lubes	0.5%		Friction	2% friction	1	0.5%	
EF Reduction	2.0%		Friction	8.5% friction	1	2.0%	
ICP	2.0%		Pumping	12% pumping, 38.2% IE, -2% fric	0	0.0%	
DCP	3.0%	total VVT	Pumping	18.5% pumping, 38.2% IE, -2% fric	0	0.0%	Pick one
CCP	3.0%	total VVT	Pumping	18.5% pumping, 38.2% IE, -2% fric	1	3.0%	
Deac	6.0%		Pumping, friction	39% pumping	0	0.0%	
DVVL	4.0%		Pumping	30% pumping, -3% friction	1	4.0%	Pick one
CVVL	5.0%		Pumping	37% pumping, -3% friction	0	0.0%	
Camless	10.0%		Pumping	76% pumping, -5% friction	0	0.0%	
GDI	1.5%		Ind Eff	38.6% Ind Eff	0	0.0%	
Turbo/Dnsize	6.0%		Pumping	39% pumping	0	0.0%	
5-spd	2.5%		Trans, pumping	22% pumping, -5% trans	0	0.0%	Pick one or 6-spd
CVT	6.0%		Trans, pumping	46% pumping, -5% trans	0	0.0%	
ASL	1.5%		Pumping	9.5% pumping	1	1.5%	
Agg TC Lockup	0.5%		Trans	2.5% trans	1	0.5%	
6-spd auto	5.5%		Trans, pumping	42% pumping, -5% trans	1	5.5%	Or #44/45
AMT	6.5%		Trans	35% trans (increment)	1	6.5%	
42V S-S	7.5%		F, P, A	13% friction, 19% pumping, 38% access	1	7.5%	
12V acc + Imp alt	1.5%		Access	18% access	0	0.0%	Or #53
EPS	1.5%		Access	18% access	1	1.5%	
42V acc + imp alt	3.0%		Access	36% access	1	3.0%	Or #51
HCCI dual-mode	11.0%		Ind. Eff, pumping	41% IE, 25% pumping	0	0.0%	
GDI (lean)	10.5%		Ind. Eff, pumping	40% IE, 38% pumping	0	0.0%	
Diesel - LNT	30.0%	over gas	Ind Eff, pumping	48% IE, 85% pumping, -13% friction	0	0.0%	Pick one
Diesel - SCR	30.0%	over gas	Ind Eff, pumping	46% IE, 80% pumping, -13% friction	0	0.0%	
Opt. E25	8.5%		Ind. Eff, pumping	39% IE, 40% pumping	0	0.0%	
						33.6%	

FIGURE 7 - ORIGINAL LPM SPREADSHEET

The LPM user interface consisted of selecting a vehicle type and various technology combinations (see arrows in Figure 7) to calculate the final result in percent. In practice the spreadsheet was used twice, first to calculate a percentage effectiveness improvement using the technologies on a baseline vehicle, and second to calculate a percentage effectiveness improvement with additional technologies applied to the same baseline vehicle. This process was automated to provide approximately fifty improvements for each baseline vehicle as input to the OMEGA model.

The LPM was validated for present day vehicles and technologies by comparing the results to test data from various EPA databases and a contract with Ricardo Inc. provided another set of simulation results for validating present and future technologies. For the regulatory activities associated with the

Light-duty Greenhouse Gas Midterm Evaluation (MTE), the LPM has also been calibrated with results from EPA's full-vehicle simulation model, ALPHA.

2 Development of ALPHA:

After the completion of the MY 2017-2025 LD Final Rule, EPA began an extensive project to benchmark a wide variety of engines, transmissions, and vehicles to create the Advanced Light-Duty Powertrain and Hybrid Analysis (ALPHA) full vehicle simulation model based on the existing GEM model used for heavy duty compliance purposes. The intent of this project was for the ALPHA model to be fully functional, validated, and peer reviewed for use during the MY 2017-2025 LD Final Rule Midterm Evaluation (MTE) process.

As the MTE progressed, the ALPHA model matured and was capable of providing most of the technology package effectiveness values needed for the OMEGA analysis. With the ALPHA model results being applied widely across EPA's analyses, the LPM quickly became less a model and more a repeater of ALPHA model results. For the Proposed Determination phase of the MTE, EPA recognized that a more efficient and less complex method could be developed to access ALPHA results directly. In addition, EPA now has the capability to perform large scale simulation using ALPHA and the application of these large-scale simulation results requires a more streamlined and less manual process. EPA considered several alternatives for its future analyses with respect to the application of simulation results. Figure 8 illustrates some possible methods to accomplish this task.

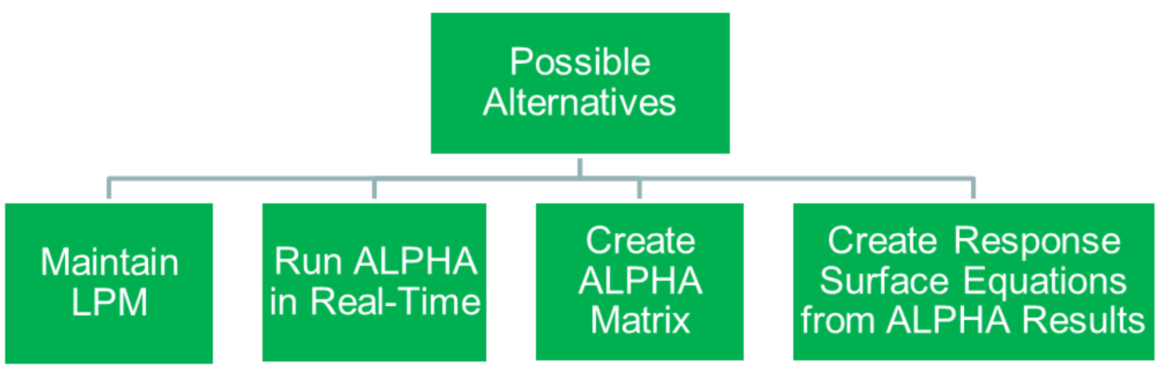

FIGURE 8 – POSSIBLE ALTERNATIVES TO ACCESS ALPHA RESULTS

Discussion for each alternative:

- Maintain LPM:
  - The LPM was originally designed to generate values - not to match several models simultaneously resulting in a significant increase in complexity and maintenance. While EPA feels that the LPM continues to be a robust and accurate tool, the calibration and maintenance of the tool is manually intensive.
- Run ALPHA in Real-Time:
  - Running ALPHA in real-time would be the ideal solution, however, as discussed earlier, the execution time would be prohibitive.
- Create full ALPHA Matrix of results:

- The execution time would be prohibitive initially unless significant budget and resources are dedicated for access to a complex cloud or supercomputing system. This process would have to be repeated for any additions or changes to the ALPHA model and would impact sensitivity analyses depending on scenario.

- Create Response Surface Equations (RSEs) from ALPHA results:
  - The RSEs allow any ALPHA run to be derived at a similar speed as the current spreadsheet LPM.
  - Requires no programming or calibration – A simple check sheet verifies RSE alignment with ALPHA results.
  - An overnight batch job producing several thousand ALPHA results is sufficient to create a set of RSEs.
  - This method was chosen and is described in the following sections.

3 New Method for OMEGA Preprocess:

Given the above discussion along with the ALPHA model now capable of providing most of the needed effectiveness data, the LPM is no longer required and can be replaced with industry standard Response Surface Equations. This technique allows any combination of the ALPHA full vehicle simulations to be accessed in real time to assemble the necessary effectiveness data for the OMEGA Model.

This process begins by instructing the ALPHA model to execute a Design Of Experiments (DOE) to provide the necessary inputs to the RSE. The DOE used for this task is an automated process that is configured to produce a complete set of ALPHA results for all combinations of engines, transmissions, roadloads, and vehicle types to be used in the OMEGA analysis. The DOE generates thousands of modeling results to populate the statistical RSE generation tool. EPA adheres to a "Performance Neutral" methodology for all rulemaking simulation work as described in Chapter 2 of the Technical Support Document (TSD) of the Proposed Determination (PD) phase of the MTE[1]. Several ALPHA runs are executed per table point and the run closest to the same performance as the base vehicle is selected to ensure the DOE is populated with "Performance Neutral" results. For this example, the inputs to the RSE include Mass Reduction, Aero Drag Reduction, Rolling Resistance Reduction, and Transmission type. A small sample of the 21,000+ ALPHA results used to generate the RSE for vehicle type MPW_LRL is shown in Table 2.

---

[1] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100Q3L4.pdf

Mass Reduction	Aero Reduction	Rolling Reduction	Transmission Type	CO2 g/mi
5%	10%	15%	4	215.7
5%	10%	20%	4	213.4
5%	15%	0%	4	219.9
5%	15%	5%	4	217.9
5%	15%	10%	4	215.6
5%	15%	15%	4	213.3
5%	15%	20%	4	211.1
5%	20%	0%	4	217.6
5%	20%	5%	4	215.4
5%	20%	10%	4	213.2
5%	20%	15%	4	210.9
5%	20%	20%	4	208.8
0%	0%	0%	5	222.8
0%	0%	5%	5	220.4
0%	0%	10%	5	218.3
0%	0%	15%	5	215.9
0%	0%	20%	5	213.7
0%	5%	0%	5	220.5
0%	5%	5%	5	218.1
0%	5%	10%	5	215.9
0%	5%	15%	5	213.8
0%	5%	20%	5	211.3
0%	10%	0%	5	218.2
0%	10%	5%	5	215.9
0%	10%	10%	5	213.7
0%	10%	15%	5	211.4
0%	10%	20%	5	209.0
0%	15%	0%	5	216.0
0%	15%	5%	5	213.8
0%	15%	10%	5	211.3
0%	15%	15%	5	208.8
0%	15%	20%	5	207.0
0%	20%	0%	5	213.5
0%	20%	5%	5	211.2
0%	20%	10%	5	208.9
0%	20%	15%	5	206.6
0%	20%	20%	5	204.6

TABLE 2 – SMALL SAMPLE OF ALPHA RESULTS FOR VEHICLE TYPE MPW_LRL

4 RSE Generation:

The next phase of the RSE process generates a series of equations from a complete set of ALPHA data for each vehicle type and powertrain model. The sets of data used in this process are shown in Figure 11. EPA used the industry standard statistical software JMP from SAS[2] to create the response surface equations. The complete table of ALPHA results for a particular vehicle type and powertrain model is entered and an example Response Surface Equation result is shown in Figure 9.

220.667785899048+-14.9927683931428*((Mass-0.1)/0.1)+-4.89195006285714*((Aero-0.1)/0.1)+-4.37358584114285*((Roll-0.1)/0.1)+-18.64483848*((Trans-3)/2)+((((Mass-0.1)/0.1)*(Aero-0.1))/0.1)*-0.0912061119999999+((((Mass-0.1)/0.1)*(Roll-0.1))/0.1)*0.405110426666666+((((Aero-0.1)/0.1)*(Roll-0.1))/0.1)*0.0391345333333341+((((Mass-0.1)/0.1)*(Trans-3))/2)*1.52171338742856+((((Aero-0.1)/0.1)*(Trans-3))/2)*0.17252074057143+((((Roll-0.1)/0.1)*(Trans-3))/2)*0.22308929142857+((((Mass-0.1)/0.1)*(Mass-0.1))/0.1)*-0.158016769523809+((((Aero-0.1)/0.1)*(Aero-0.1))/0.1)*0.0321151047619073+((((Roll-0.1)/0.1)*(Roll-0.1))/0.1)*0.00802461333332157+((((Trans-3)/2)*(Trans-3))/2)*-1.66503986133335

FIGURE 9 – EXAMPLE RSE FOR VEHICLE TYPE = MPW_LRL AND MODEL = 2014_GDI

Throughout this process, the ALPHA results are compared to the RSE results as shown in Figure 10 to ensure the validity of the data transfer from ALPHA and RSE equation implementation. An added benefit of this comparison is the verification that the ALPHA model results are smooth and predictable as expected.

[2] https://www.jmp.com/en_us/software/data-analysis-software.html

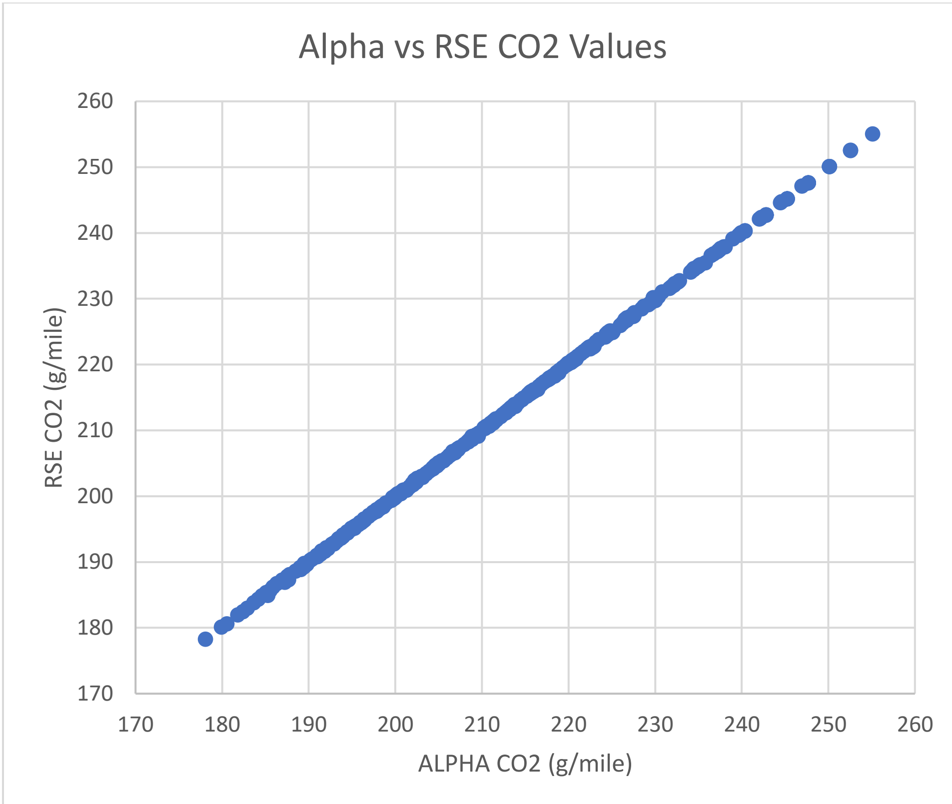

FIGURE 10 – ALPHA VS RSE CO2 VALUES

5 Practical Implementation:

The practical implementation of the RSE method uses a similar effectiveness spreadsheet and user interface format as before replacing the LPM with methods described in this document. This similar format and user interface avoided disruptive modifications to the existing OMEGA preprocess and continues the practicality of a visual tool for verification purposes and transparency for stakeholders. The new effectiveness tool has been reduced to a single spreadsheet tab labeled "Effectiveness" as the LPM and associated equations no longer exist.

5.1 RSE Layout

The current OMEGA analysis consists of six vehicle types based on power to weight ratio and road loads:

- Low Power/Weight – Low Road Load (Typical Small Car)
- Medium Power/Weight – Low Road Load (Typical Standard Car)
- High Power/Weight (Typical Large Car)
- Low Power/Weight – High Road Load (Typical Small SUV)
- Medium Power/Weight – High Road Load (Typical Large SUV)
- Truck (Typical Full Size Pickup)

The current ALPHA model consists of four powertrain categories:

- 2014 GDI (2014_GDI)
- 2014 Atkinson (2014_ATK2)
- 2020 Atkinson (2020_ATK2)
- 2020 24 Bar Turbo (2020_TURB24)

The six vehicle types combined with the four model categories result in twenty-four RSEs as shown in Figure 11.

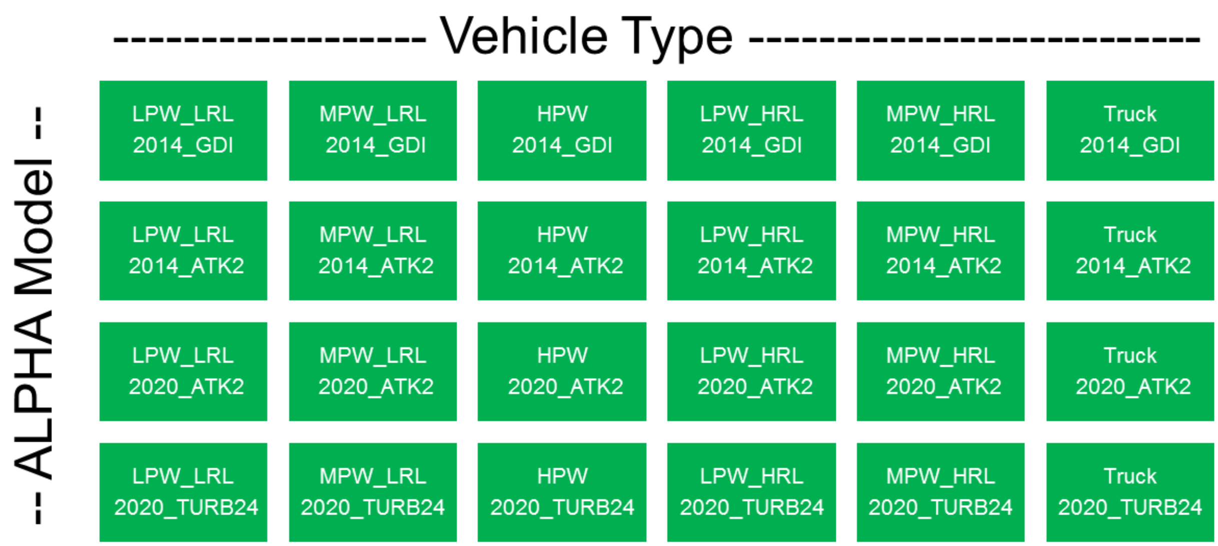

FIGURE 11 – RSE LAYOUT

5.2 Process Summary

A summary of the process is shown in Figure 7. Simply stated, the inputs are applied to the selected RSE and the corresponding ALPHA CO2 value is generated.

FIGURE 12 – RSE IMPLEMENTATION SUMMARY

5.3 Example Case

An example case of the "Effectiveness" RSE in shown in Figure 13. The Vehicle Type selection and Model selection determine the appropriate RSE to be used. In this example the RSE equation in Figure 9 (MPW_LRL 2014_GDI) has been selected with the inputs:

- Mass Reduction = 5%
- Aero Drag reduction = 15%
- Rolling Resistance reduction = 5%
- Transmission = TRX21 (4)

THE RESULTING VALUE FROM THE RSE IS CALCULATED AS SHOWN IN FIGURE 13 CLOSELY MATCHING THE ALPHA VALUE FROM THE RSE INPUT TABLE IN TABLE 3.

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Vehicle Type	
MPW_LRL	2
Model	
2014_GDI	1
Transmission	
TRX21	4

Current CO2 Results

Vehicle Type	CO2
LPW_LRL	201.2
MPW_LRL	217.9
HPW	289.0
LPW_HRL	241.6
MPW_HRL	307.6
Truck	341.2
RS Result	217.9
Final Result	217.9

Exemplar Vehicle Characteristics

Rated Power	190	hp
Rated Torque	191	ft-lb
ETW	3626	lb
50mph RL	11.4	hp
P/W	0.052399	hp/lb
Null CO2	296.3105	g/mi

FIGURE 13 – EXAMPLE CASE

TABLE 3 – EXAMPLE ALPHA RESULT FROM RSE INPUT TABLE

Mass Reduction	Aero Reduction	Rolling Reduction	Transmission Type	CO2 g/mi
5%	10%	15%	4	215.7
5%	10%	20%	4	213.4
5%	15%	0%	4	219.9
5%	15%	5%	4	217.9
5%	15%	10%	4	215.6

Comparisons of execution time has shown the RSE method is similar to the LPM including the overhead of the automation system. The added benefits include:

- Elimination of LPM programming and calibration
- Increased transparency regarding synthesis of ALPHA simulation into OMEGA modeling
- Real-Time extraction of ALPHA results with the ability to quickly represent the latest available benchmarking and simulation data in greenhouse gas analyses.
- Ability for stakeholders to readily reproduce the RSEs based on ALPHA simulations and/or their own large-scale simulation results.
- Vast speed improvement over executing ALPHA in Real-Time allowing the OMEGA analysis to run on standard EPA computing equipment without additional resources or budget.

6 Conclusion

EPA's Lumped Parameter Model has been a robust tool for estimating the effectiveness of light-duty vehicle technology packages to reduce greenhouse gas emissions. While EPA continues to believe that the continued application of the LPM would provide accurate assessments, we also recognize that the required manual calibration of the LPM and the associated interpretation of ALPHA full-vehicle simulation could be improved. EPA considered several alternatives in considering the future development or replacement of the LPM. EPA has found the most efficient approach is to replace the LPM with statistically derived Response Surface Equations. EPA believes this change in methodology will allow the agency to more readily access large-scale simulation results, improve the robustness of the analyses, and improve transparency in the OMEGA process.