

# **Assessing the Effect of Five Gasoline Properties on Exhaust Emissions from Light-Duty Vehicles certified to Tier-2 Standards**

## **Analysis of Data from EPA Phase 3**

**(EPAct/V2/E-89)**

### **Appendix I.3e**

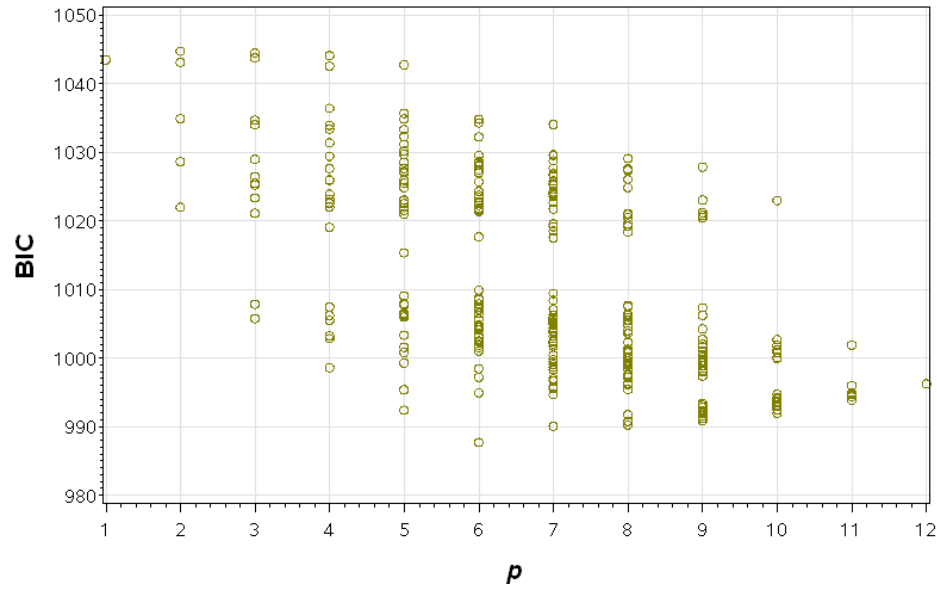
#### **Final Model Fitting**

#### **Non-Methane Hydrocarbons (NMHC) (Bag 2)**

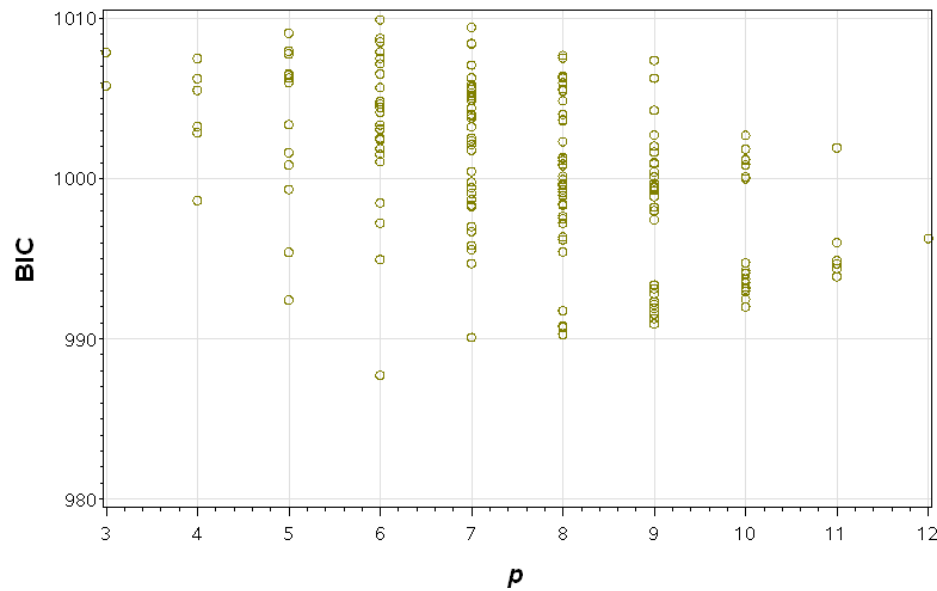
No. Observations:	832	
No. Vehicles:	13	(drop Odyssey and Siena)
No. censored measurements:	0	
No. missing measurements:	0	
No. measurements removed:	0	
Model Type:	Mixed model	

### I.3e.1 Model fitting with respect to the 11-term design model.

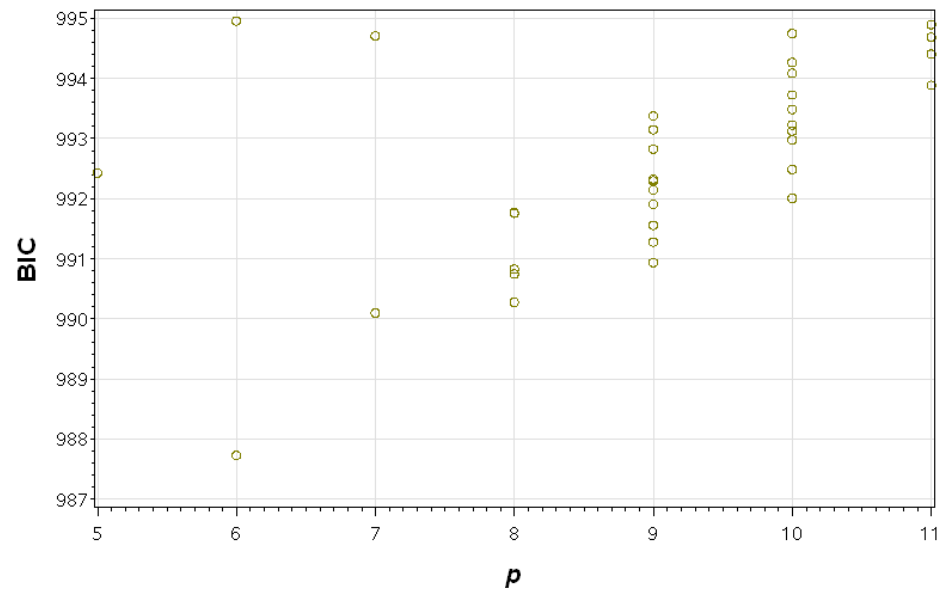
**Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for all possible models respecting hierarchy.**



**Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for all possible models respecting hierarchy (CLOSEUP of previous figure).**



**Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for all possible models respecting hierarchy (CLOSEUP of previous figure).**



**NMHC (Bag 2):** Number of terms (*p*), Goodness-of-fit (BIC) and terms included in the 35 best-fitting candidate models (out of a total of 294 possible models with hierarchy). (Terms included in models ranked 1-6 comprise the “superset” for final model-fitting).

Rank	<i>p</i>	BIC	Design Terms										
			etOH	Arom	RVP	T50	T90	etOH x etOH	T50 x T50	etOH x Arom	etOH x RVP	etOH x T50	etOH x T90
1	6	987.73		•	•	•	•		•				
2	7	990.10	•	•	•	•	•		•				
3	8	990.28	•	•	•	•	•		•	•			
4	8	990.75	•	•	•	•	•		•			•	
5	8	990.83	•	•	•	•	•		•		•		
6	9	990.94	•	•	•	•	•		•	•		•	
7	9	991.28	•	•	•	•	•		•	•	•		
8	9	991.56	•	•	•	•	•		•		•	•	
9	8	991.76	•	•	•	•	•		•				•
10	8	991.77	•	•	•	•	•	•	•				
11	9	991.91	•	•	•	•	•		•	•			•
12	10	992.01	•	•	•	•	•		•	•	•	•	
13	9	992.15	•	•	•	•	•	•	•	•			
14	9	992.30	•	•	•	•	•	•	•		•		
15	9	992.33	•	•	•	•	•		•			•	•
16	5	992.43			•	•	•		•				
17	10	992.49	•	•	•	•	•		•	•		•	•
18	9	992.83	•	•	•	•	•		•		•		•
19	10	992.98	•	•	•	•	•	•	•	•	•		
20	10	993.13	•	•	•	•	•	•	•	•		•	
21	9	993.15	•	•	•	•	•	•	•			•	
22	10	993.23	•	•	•	•	•		•	•	•		•
23	9	993.38	•	•	•	•	•	•	•				•
24	10	993.49	•	•	•	•	•		•		•	•	•
25	10	993.73	•	•	•	•	•	•	•	•			•
26	11	993.89	•	•	•	•	•		•	•	•	•	•
27	10	994.09	•	•	•	•	•	•	•		•	•	
28	10	994.27	•	•	•	•	•	•	•		•		•
29	11	994.41	•	•	•	•	•	•	•	•	•	•	
30	11	994.69	•	•	•	•	•	•	•	•		•	•
31	7	994.71	•		•	•	•		•			•	
32	10	994.75	•	•	•	•	•	•	•			•	•
33	11	994.90	•	•	•	•	•	•	•	•			•
34	6	994.96	•		•	•	•		•				
35	5	995.41		•	•	•	•						

**Models fit for NMHC (Bag 2): (all models include an intercept term).**

Model Term	Notation	Model		
		Superset	SM3 <sup>1</sup>	SM4
etOH	$Z_e$	•	•	×
Arom	$Z_a$	•	•	•
RVP	$Z_r$	•	•	•
T50	$Z_5$	•	•	•
T90	$Z_9$	•	•	•
etOH × etOH	$ZZ_{ee}$	---	---	---
T50 × T50	$ZZ_{55}$	•	•	•
etOH × Arom	$ZZ_{ea}$	•	×	
etOH × RVP	$ZZ_{er}$	•	×	
etOH × T50	$ZZ_{e5}$	•	×	
etOH × T90	$ZZ_{e9}$	---	---	---

<sup>1</sup> denotes “Superset minus 3,” etc.

**NMHC (Bag 2): Model fitting history, starting with the 10-term superset model.**

Fit Parameters				<i>Test with respect to Previous Model</i>		
Model	$p$	$-2\ln L$	BIC <sup>1</sup>	Dev.	$d$	$\Pr > \chi^2$
Superset	10	961.229	992.008			
SM3	7	967.013	990.098	5.785	3	0.123
SM4 <sup>2</sup>	6	967.211	987.730	0.197	1	0.657

<sup>1</sup> A lower value indicates a better fit.

<sup>2</sup> Best fit with respect to the 11-term design model.

**NMHC (Bag 2): Coefficients and Tests of Effect for the Superset and Reduced Models, with respect to the 11-term design model.**

Effect	<i>Full Model (superset)</i>				
	Estimate	Std. Err.	d.f.	<i>t</i> -value	Pr> <i>t</i>
Intercept	-5.3253	0.2738	13	-19.45	0.00000
$Z_e$	0.009380	0.01907	819	0.492	0.62
$Z_a$	0.03825	0.01488	819	2.57	0.010
$Z_r$	-0.05762	0.01685	819	-3.42	0.00066
$Z_5$	0.04836	0.02061	819	2.35	0.019
$Z_9$	0.08329	0.01480	819	5.63	0.00000
$ZZ_{ee}$	---	---	---	---	---
$ZZ_{55}$	0.05627	0.01653	819	3.41	0.00069
$ZZ_{ea}$	0.02106	0.01447	819	1.46	0.15
$ZZ_{er}$	-0.01776	0.01453	819	-1.22	0.22
$ZZ_{e5}$	0.02222	0.01638	819	1.36	0.18
$ZZ_{e9}$	---	---	---	---	---

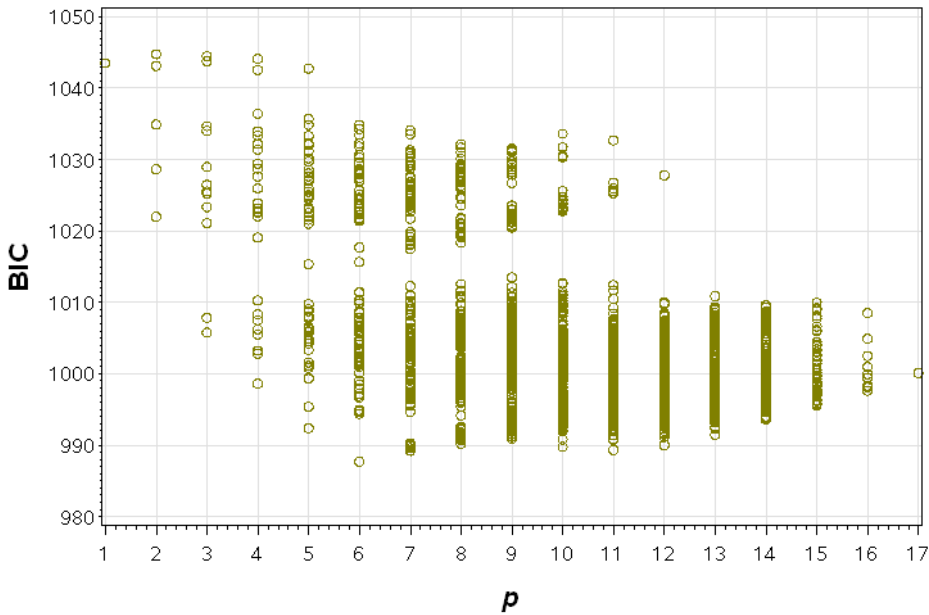
$\sigma_{veh}^2$	0.9722
$\sigma_{\varepsilon}^2$	0.1695

<i>Reduced Model (SM4)</i>				
Estimate	Std. Err.	d.f.	<i>t</i> -value	Pr> <i>t</i>
-5.3253	0.2734	13	-19.48	0.00000
0.03987	0.01476	819	2.70	0.0071
-0.05881	0.01555	819	-3.78	0.00017
0.04548	0.01567	819	2.90	0.0038
0.08202	0.01478	819	5.55	0.00000
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0.04774	0.01487	819	3.21	0.00137
---	---	---	---	---

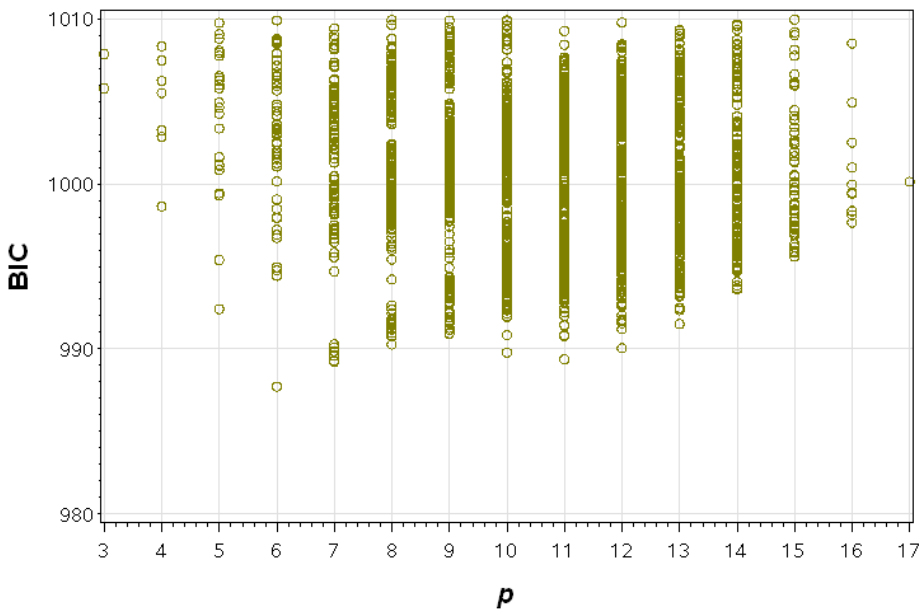
$\sigma_{veh}^2$	0.9691
$\sigma_{\varepsilon}^2$	0.1708

### I.3e.2 Model Fitting with respect to the 16-term extended Model.

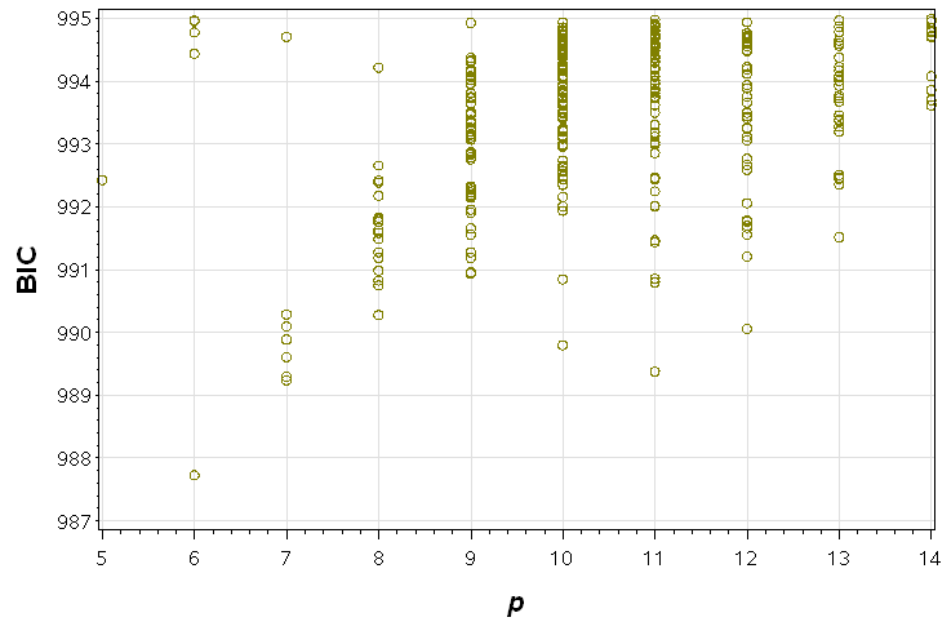
Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for all possible models respecting hierarchy.



Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for subset of models respecting hierarchy (CLOSEUP of previous figure).



**Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for subset of models respecting hierarchy (CLOSEUP of previous figure).**





NMHC (Bag 2): Number of terms ( $p$ ), Goodness-of-fit (BIC) and terms included in the 35 best-fitting candidate models (out of a total of 2,964 possible models with hierarchy). (Terms included in models ranked 1-7 comprise the “superset” for final model-fitting).

Rank	$p$	BIC	Design Terms											Extended Terms				
			$\epsilon$ OH	Arom	RVP	T50	T90	$\epsilon$ OH $\times$ $\epsilon$ OH	T50 $\times$ T50	$\epsilon$ OH $\times$ Arom	$\epsilon$ OH $\times$ RVP	$\epsilon$ OH $\times$ T50	$\epsilon$ OH $\times$ T90	Arom $\times$ RVP	Arom $\times$ T50	Arom $\times$ T90	T50 $\times$ T90	RVP $\times$ T90
1	6	987.73		•	•	•	•		•									
2	7	989.24		•	•	•	•		•								•	
3	7	989.3		•	•	•	•		•									•
4	11	989.38	•	•	•	•	•		•	•	•	•			•			
5	7	989.61		•	•	•	•		•									
6	10	989.8	•	•	•	•	•		•	•	•							
7	7	989.89		•	•	•	•		•						•			
8	12	990.06	•	•	•	•	•		•	•	•	•				•	•	
9	7	990.1	•	•	•	•	•		•									
10	8	990.28	•	•	•	•	•		•	•								
11	7	990.29		•	•	•	•		•						•			
12	8	990.75	•	•	•	•	•		•				•					
13	11	990.8	•	•	•	•	•		•	•	•				•	•		
14	8	990.83	•	•	•	•	•		•		•							
15	10	990.85	•	•	•	•	•		•	•			•			•		
16	11	990.86	•	•	•	•	•	•	•	•	•				•			
17	9	990.94	•	•	•	•	•		•	•			•					
18	9	990.96	•	•	•	•	•		•	•						•		
19	8	990.99		•	•	•	•		•							•		•
20	9	991.19	•	•	•	•	•		•	•								•
21	8	991.19		•	•	•	•		•							•	•	
22	12	991.21	•	•	•	•	•		•	•	•	•			•			•
23	8	991.28		•	•	•	•		•								•	•
24	9	991.28	•	•	•	•	•		•	•	•							
25	11	991.44	•	•	•	•	•		•	•	•				•			•
26	11	991.47	•	•	•	•	•		•	•	•			•	•			
27	8	991.49	•	•	•	•	•		•									•
28	13	991.52	•	•	•	•	•		•	•	•	•			•	•		•
29	12	991.56	•	•	•	•	•		•	•	•	•	•		•			
30	9	991.56	•	•	•	•	•		•		•	•						
31	8	991.59	•	•	•	•	•		•								•	
32	8	991.63		•	•	•	•		•					•		•		
33	8	991.63		•	•	•	•		•					•			•	
34	8	991.63		•	•	•	•		•					•				•
35	9	991.66	•	•	•	•	•		•	•							•	

**Models fit for NMHC (Bag 2): (all models include an intercept term).**

Model Term	Notation	Model		
		Superset	SM4 <sup>1</sup>	SM8
etOH	$Z_e$	•	•	×
Arom	$Z_a$	•	•	•
RVP	$Z_r$	•	•	•
T50	$Z_5$	•	•	•
T90	$Z_9$	•	•	•
etOH × etOH	$ZZ_{ee}$	---	---	---
T50 × T50	$ZZ_{55}$	•	•	•
etOH × Arom	$ZZ_{ea}$	•	•	×
etOH × RVP	$ZZ_{er}$	•	•	×
etOH × T50	$ZZ_{e5}$	•	•	×
etOH × T90	$ZZ_{e9}$	---	---	---

Arom × RVP	$ZZ_{ar}$	•	×	
Arom × T50	$ZZ_{a5}$	•	•	•
Arom × T90	$ZZ_{a9}$	•	×	
T50 × T90	$ZZ_{59}$	•	×	
RVP × T90	$ZZ_{r9}$	•	×	

<sup>1</sup> Denotes “Superset minus 4,” etc.

**NMHC (Bag 2): Model fitting history, starting with the 9-term superset model.**

Fit Parameters				<i>Test with respect to Previous Model</i>		
Model	$p$	$-2\ln L$	BIC <sup>1</sup>	Dev.	$d$	$\Pr > \chi^2$
Superset	15	952.581	996.185			
SM4 <sup>2</sup>	11	956.038	989.382	3.457	4	0.484
SM8	7	967.210	990.295	11.172	4	0.025

<sup>1</sup> A lower value indicates a better fit.

<sup>2</sup> Best fit with respect to the 16-term extended model.

**NMHC (Bag 2): Coefficients and Tests of Effect for the Superset and Reduced Models, with respect to the 16-term extended model.**

Effect	<i>Full Model (superset)</i>				
	Estimate	Std. Err.	d.f.	t -value	Pr>t
Intercept	-5.3250	0.2740	13	-19.4	0.00000
$Z_e$	0.02885	0.02218	819	1.30	0.19
$Z_a$	0.04286	0.01594	819	2.69	0.0073
$Z_r$	-0.03307	0.02098	819	-1.58	0.12
$Z_5$	0.07846	0.02673	819	2.93	0.0034
$Z_9$	0.09945	0.01660	819	5.99	0.00000
$ZZ_{ee}$	---	---	---	---	---
$ZZ_{55}$	0.06524	0.01810	819	3.60	0.00
$ZZ_{ea}$	0.06090	0.02371	819	2.57	0.010
$ZZ_{er}$	-0.03344	0.01630	819	-2.05	0.041
$ZZ_{e5}$	0.02558	0.01745	819	1.47	0.14
$ZZ_{e9}$	---	---	---	---	---
$ZZ_{ar}$	0.01733	0.02569	819	0.67	0.50
$ZZ_{a5}$	0.06319	0.02923	819	2.16	0.031
$ZZ_{a9}$	0.02290	0.01620	819	1.41	0.16
$ZZ_{59}$	0.00490	0.01743	819	0.28	0.78
$ZZ_{r9}$	-0.01760	0.01679	819	-1.05	0.29
$\sigma_{veh}^2$	0.9734				
$\sigma_{\varepsilon}^2$	0.1677				

<i>Reduced Model (SM4)</i>				
Estimate	Std. Err.	d.f.	t -value	Pr>t
-5.3256	0.2739	13	-19.4	0.00000
0.01334	0.01909	819	0.70	0.48
0.03743	0.01483	819	2.52	0.012
-0.03909	0.01865	819	-2.10	0.036
0.05566	0.02080	819	2.68	0.0076
0.09799	0.01610	819	6.09	0.00000
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0.05909	0.01652	819	3.58	0.00037
0.05087	0.01946	819	2.61	0.0091
-0.03153	0.01569	819	-2.01	0.045
0.02865	0.01657	819	1.73	0.084
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0.05429	0.02379	819	2.28	0.023
$\sigma_{veh}^2$	0.9723			
$\sigma_{\varepsilon}^2$	0.1684			