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.2e

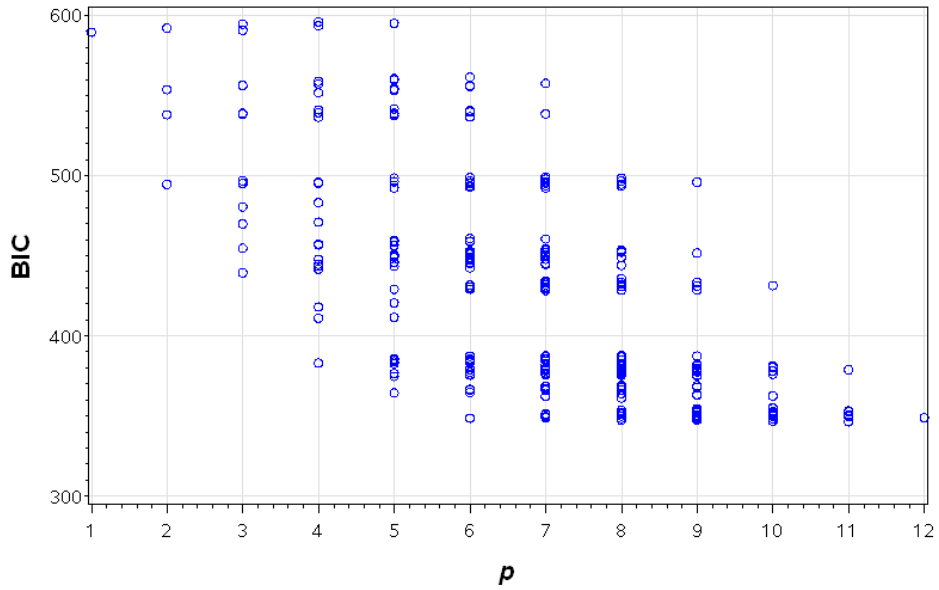
Final Model Fitting

Non-Methane Organic Gases (NMOG) (Bag 2)

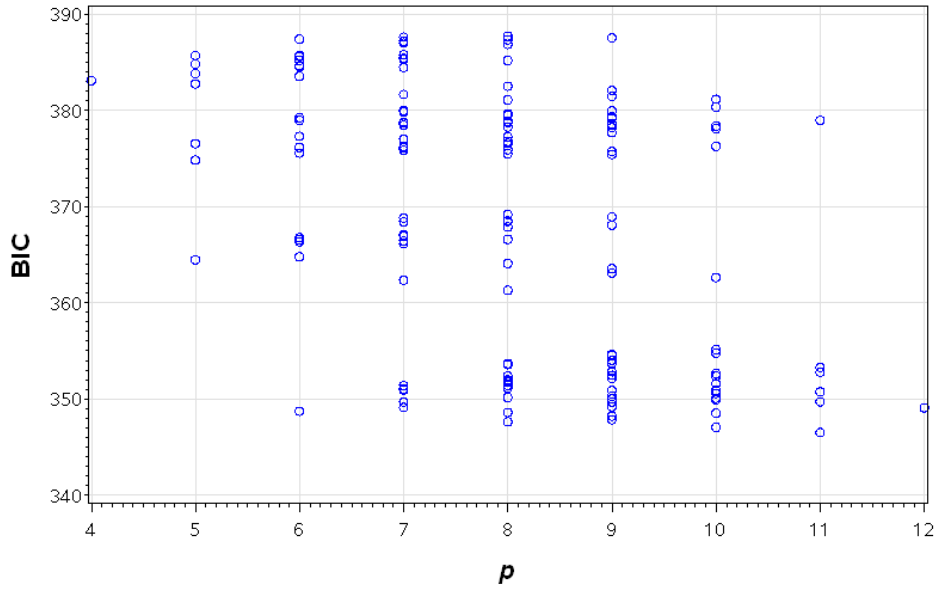
No. Observations:	832	
No. Vehicles:	13	(exclude Odyssey and Sienna)
No. censored measurements:	0	
No. missing measurements:	0	
No. measurements removed:	0	
Model Type:	Mixed model	

I.2e.1 Model fitting with respect to the 11-term design model.

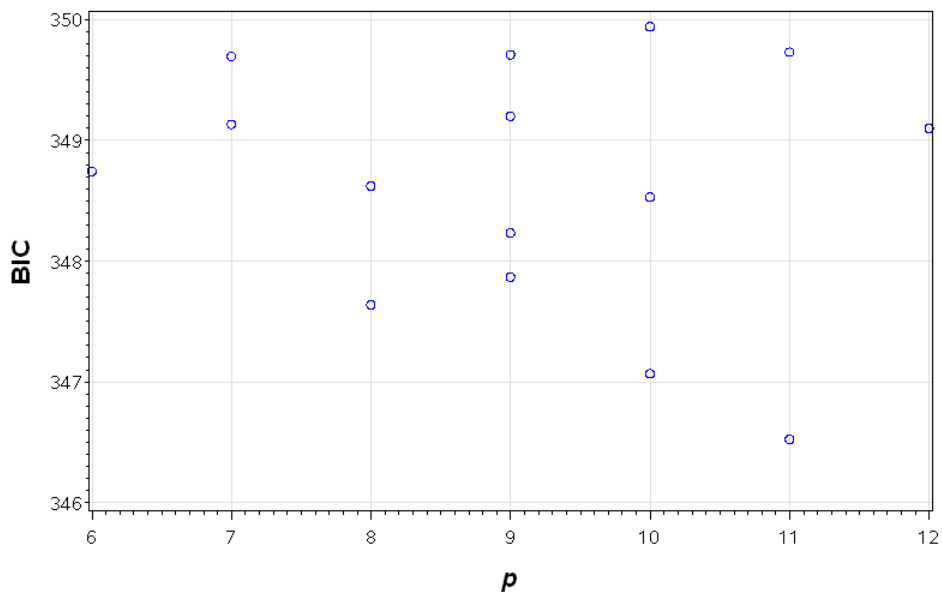
Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model (*p*) for all possible models respecting hierarchy.



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).



NMOG (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 1-8 comprise the "superset" for final model-fitting).

Rank	*p*	BIC	Design Terms										
			etOH	Arom	RVP	T50	T90	etOH × etOH	T50 × T50	etOH × Arom	etOH × RVP	etOH × T50	etOH × T90
1	9	776.93	•	•	•	•	•		•	•		•	
2	8	777.286	•	•	•	•	•		•			•	
3	8	777.584	•	•	•	•	•		•	•			
4	6	777.605		•	•	•	•		•				
5	10	777.832	•	•	•	•	•		•	•	•	•	
6	9	777.881	•	•	•	•	•		•		•	•	
7	10	777.894	•	•	•	•	•		•	•		•	•
8	7	777.94	•	•	•	•	•		•				
9	9	778.301	•	•	•	•	•		•			•	•
10	9	778.384	•	•	•	•	•		•	•	•		
11	8	778.426	•	•	•	•	•		•		•		
12	9	778.57	•	•	•	•	•	•	•	•			
13	8	778.607	•	•	•	•	•	•	•				
14	9	778.677	•	•	•	•	•		•	•			•
15	9	778.785	•	•	•	•	•	•	•		•		
16	8	779.082	•	•	•	•	•		•				•
17	10	779.09	•	•	•	•	•	•	•	•	•		
18	11	779.235	•	•	•	•	•		•	•	•	•	•
19	10	779.274	•	•	•	•	•	•	•	•		•	
20	10	779.362	•	•	•	•	•		•		•	•	•
21	10	779.566	•	•	•	•	•	•	•	•			•
22	9	779.642	•	•	•	•	•	•	•				•
23	9	779.794	•	•	•	•	•	•	•			•	
24	10	779.909	•	•	•	•	•		•	•	•		•
25	9	780.024	•	•	•	•	•		•		•		•
26	11	780.253	•	•	•	•	•	•	•	•		•	•
27	10	780.321	•	•	•	•	•	•	•		•		•
28	11	780.336	•	•	•	•	•	•	•	•	•	•	
29	10	780.446	•	•	•	•	•	•	•		•	•	
30	11	780.56	•	•	•	•	•	•	•	•	•		•
31	10	780.817	•	•	•	•	•	•	•			•	•
32	12	781.731	•	•	•	•	•	•	•	•	•	•	•
33	11	781.927	•	•	•	•	•	•	•		•	•	•
34	7	782.237	•		•	•	•		•			•	
35	8	782.744	•		•	•	•		•		•	•	

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

Model Term	Notation	Model					
		Superset	SM2[1]	SM5	SM4[2]	SM3a[3]	SM3b[4]
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}	●	×				

[1] Represents "Superset minus 2," etc.
[2] Not nested within SM5; formed by dropping etOH×Arom and etOH×T50 from SM2.
[3] Not nested within SM5 or SM4; formed by dropping etOH×Arom from SM2.
[4]Not nested within SM5, SM4 or SM3a; formed by dropping etOH×T50 from SM2.

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

Fit Parameters				*Test with respect to Previous Model*		
Model	*p*	-2ln*L*	BIC[1]	Dev.	*d*	Pr>χ^2
Superset	11	745.891	779.235			
SM2[2]	9	748.716	776.930	2.825	2	0.244
SM5	6	757.086	777.605	8.370	3	0.0390
SM4[3]	7	754.855	777.940	6.140	2	0.0464
SM3a[3]	8	751.636	777.286	2.920	1	0.0875
SM3b[3]	8	751.934	777.584	3.219	1	0.0728

[1] A lower value indicates a better fit.
[2] Best fit with respect to the 11-term design model.
[3] Not nested within previous model; test with respect to SM2.

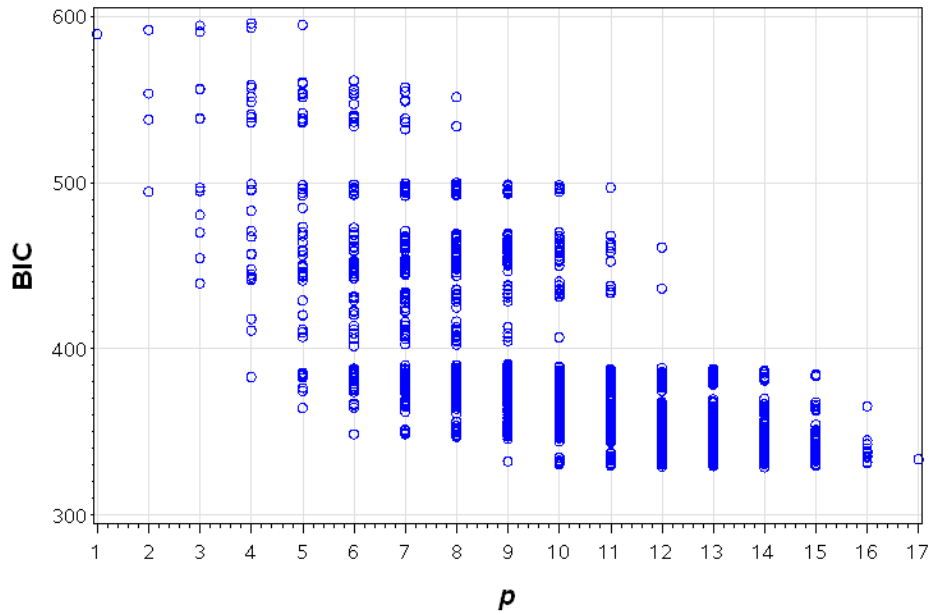
NMOG (Bag 2): Coefficients and Tests of Effect for the Superset and Reduced Models, with respect to the 11-term design model.

Effect	*Full Model (superset)*					*Reduced Model (SM2)*				
	Estimate	Std. Err.	d.f.	*t* -value	Pr>*t*	Estimate	Std. Err.	d.f.	*t* -value	Pr>*t*
Intercept	-5.2370	0.2562	13	-20.4	0.00000	-5.2360	0.2560	13	-20.4	0.00000
Z_e	0.02684	0.01675	819	1.60	0.11	0.02673	0.01676	819	1.59	0.11
Z_a	0.03630	0.01306	819	2.78	0.0056	0.03634	0.01308	819	2.78	0.0056
Z_r	-0.04775	0.01489	819	-3.21	0.0014	-0.04786	0.01475	819	-3.24	0.0012
Z_5	0.04777	0.01810	819	2.64	0.0085	0.04915	0.01807	819	2.72	0.0067
Z_9	0.07197	0.01314	819	5.48	0.00000	0.07252	0.01295	819	5.60	0.00000
ZZ_{ee}	---	---	---	---	---	---	---	---	---	---
ZZ_{55}	0.05379	0.01451	819	3.71	0.00022	0.05349	0.01452	819	3.68	0.00025
ZZ_{ea}	0.02087	0.01271	819	1.64	0.10	0.02171	0.01269	819	1.71	0.088
ZZ_{er}	-0.01429	0.01291	819	-1.11	0.27					
ZZ_{e5}	0.02592	0.01439	819	1.80	0.072	0.02586	0.01440	819	1.80	0.073
ZZ_{e9}	-0.01393	0.01292	819	-1.08	0.28					

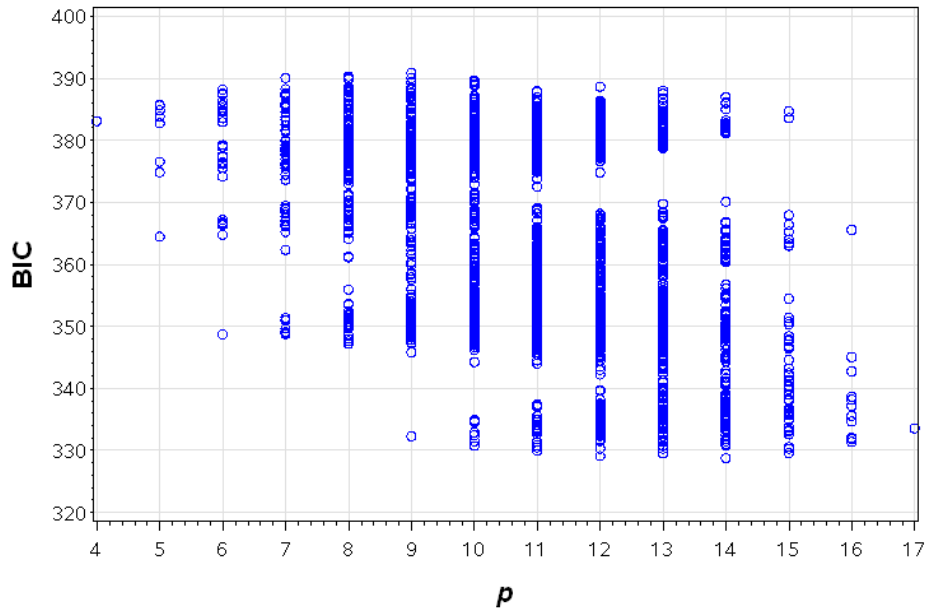
σ^2_{veh}	0.8514	σ^2_{veh}	0.8502
σ^2_{ε}	0.1306	σ^2_{ε}	0.1310

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

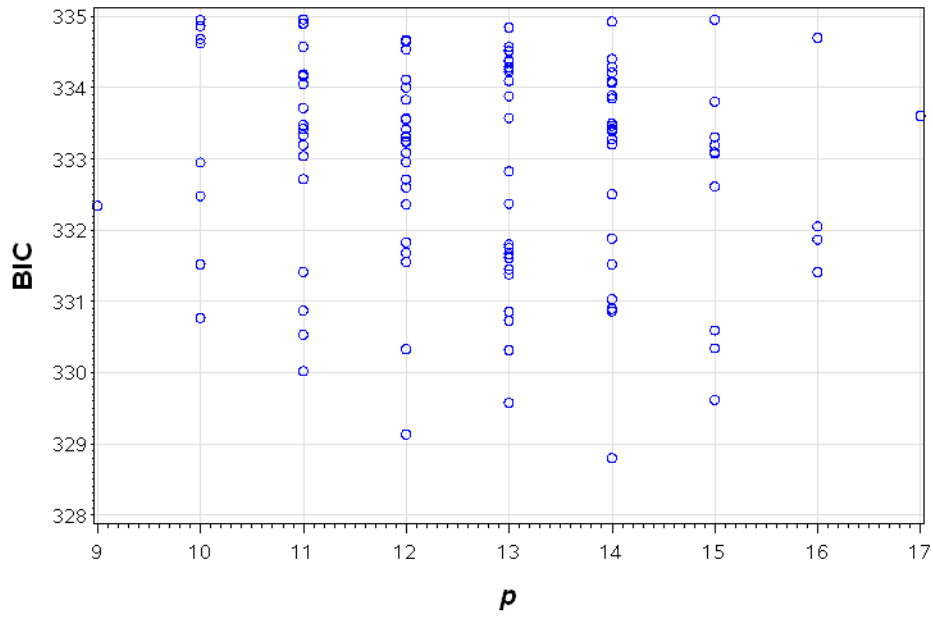
Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model (*p*) for all possible models respecting hierarchy.



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).



NMOG (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 1-5 comprise the "superset" for final model-fitting).

Rank	*p*	BIC	Design Terms											Extended Terms				
			etOH	Arom	RVP	T50	T90	etOH × etOH	T50 × T50	etOH × Arom	etOH × RVP	etOH × T50	etOH × T90	Arom × RVP	Arom × T50	Arom × T90	T50 × T90	RVP × T90
1	11	775.72	•	•	•	•	•		•	•	•	•			•			
2	12	776.56	•	•	•	•	•		•	•	•	•			•	•		
3	9	776.93	•	•	•	•	•		•	•		•						
4	10	777.25	•	•	•	•	•		•	•		•			•			
5	8	777.29	•	•	•	•	•		•			•						
6	12	777.49	•	•	•	•	•		•	•	•	•	•		•			
7	11	777.50	•	•	•	•	•	•	•	•	•				•			
8	12	777.52	•	•	•	•	•		•	•	•	•			•		•	
9	10	777.54	•	•	•	•	•		•	•		•					•	
10	8	777.58	•	•	•	•	•		•	•								
11	6	777.61		•	•	•	•		•									
12	10	777.61	•	•	•	•	•		•	•	•				•			
13	12	777.64	•	•	•	•	•		•	•	•	•			•			•
14	10	777.83	•	•	•	•	•		•	•	•	•						
15	9	777.88	•	•	•	•	•		•		•	•						
16	10	777.89	•	•	•	•	•		•	•		•	•					
17	7	777.94	•	•	•	•	•		•									
18	9	778.06	•	•	•	•	•		•			•					•	
19	12	778.07	•	•	•	•	•		•	•	•	•		•	•			
20	11	778.08	•	•	•	•	•		•	•		•			•		•	
21	9	778.12	•	•	•	•	•		•	•							•	
22	10	778.12	•	•	•	•	•		•	•		•						•
23	13	778.16	•	•	•	•	•		•	•	•	•			•	•		•
24	12	778.21	•	•	•	•	•	•	•	•	•	•			•			
25	11	778.30	•	•	•	•	•		•	•		•	•		•			
26	9	778.30	•	•	•	•	•		•			•	•					
27	9	778.38	•	•	•	•	•		•	•	•							
28	7	778.40		•	•	•	•		•								•	
29	8	778.43	•	•	•	•	•		•		•							
30	13	778.53	•	•	•	•	•		•	•	•	•			•	•	•	
31	10	778.56	•	•	•	•	•		•	•		•				•		
32	9	778.57	•	•	•	•	•	•	•	•								
33	8	778.61	•	•	•	•	•	•	•									
34	12	778.62	•	•	•	•	•	•	•	•	•				•	•		
35	8	778.65	•	•	•	•	•		•								•	

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

Model Term	Notation	Model	
		Superset	SM1[1]
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}	---	---

[1] denotes "Superset minus 1, etc."

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

Fit Parameters				*Test with respect to Previous Model*		
Model	*p*	-2ln*L*	BIC[1]	Dev.	*d*	Pr>χ^2
Superset	12	740.652	776.561			
SM1	11	742.372	775.716	1.720	1	0.190

[1] A lower value indicates a better fit.
[2] Best fit with respect to the 16-term extended model.

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

Effect	*Full Model (superset)*					*Reduced Model (SM1)*				
	Estimate	Std. Err.	d.f.	*t* -value	Pr>*t*	Estimate	Std. Err.	d.f.	*t* -value	Pr>*t*
Intercept	-5.2367	0.2562	13	-20.44	0.00000	-5.2369	0.2561	13	-20.45	0.00000
Z_e	0.03387	0.01709	819	1.98	0.048	0.02947	0.01677	819	1.76	0.079
Z_a	0.03531	0.01302	819	2.71	0.007	0.03540	0.01303	819	2.72	0.0067
Z_r	-0.03371	0.01637	819	-2.06	0.040	-0.03415	0.01639	819	-2.08	0.0375
Z_5	0.06201	0.01940	819	3.20	0.001	0.05338	0.01827	819	2.92	0.0036
Z_9	0.08917	0.01429	819	6.24	0.000	0.08637	0.01414	819	6.11	0.00000
ZZ_{ee}	---	---	---	---	---	---	---	---	---	---
ZZ_{55}	0.05562	0.01452	819	3.83	0.000	0.05652	0.01451	819	3.89	0.00011
ZZ_{ea}	0.04671	0.01711	819	2.73	0.006	0.04544	0.01710	819	2.66	0.0080
ZZ_{er}	-0.03051	0.01391	819	-2.19	0.029	-0.02795	0.01379	819	-2.03	0.043
ZZ_{e5}	0.03208	0.01458	819	2.20	0.028	0.03080	0.01456	819	2.12	0.035
ZZ_{e9}	---	---	---	---	---	---	---	---	---	---
ZZ_{ar}	---	---	---	---	---	---	---	---	---	---
ZZ_{a5}	0.04751	0.02095	819	2.27	0.024	0.04528	0.02090	819	2.17	0.031
ZZ_{a9}	0.01833	0.01397	819	1.31	0.190					
ZZ_{59}	---	---	---	---	---	---	---	---	---	---
ZZ_{r9}	---	---	---	---	---	---	---	---	---	---
σ^2_{veh}	0.8516					σ^2_{veh}	0.8507			
σ^2_{ε}	0.1298					σ^2_{ε}	0.1300			