

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.1d

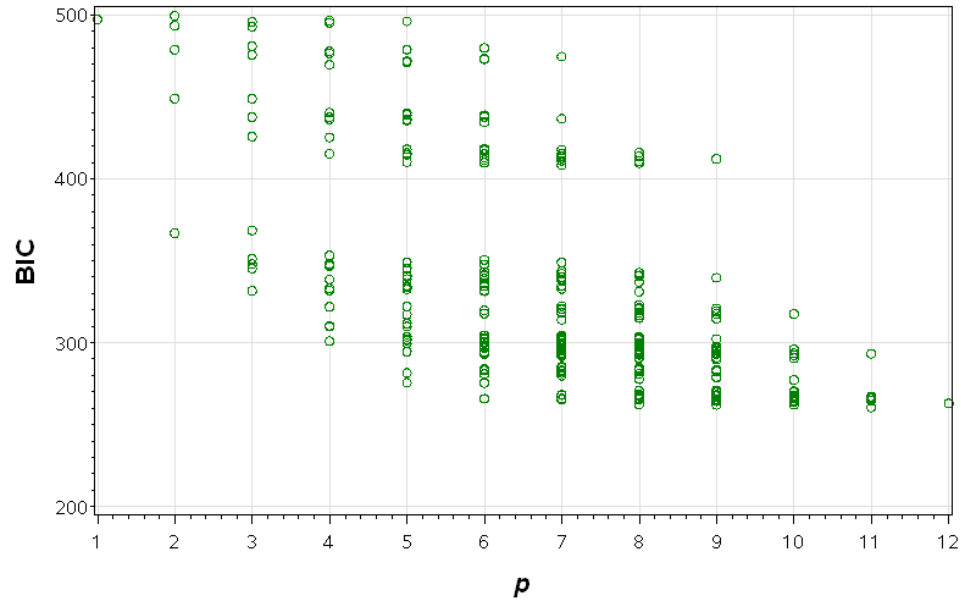
Final Model Fitting

Total Hydrocarbons (THC) (Bag 1)

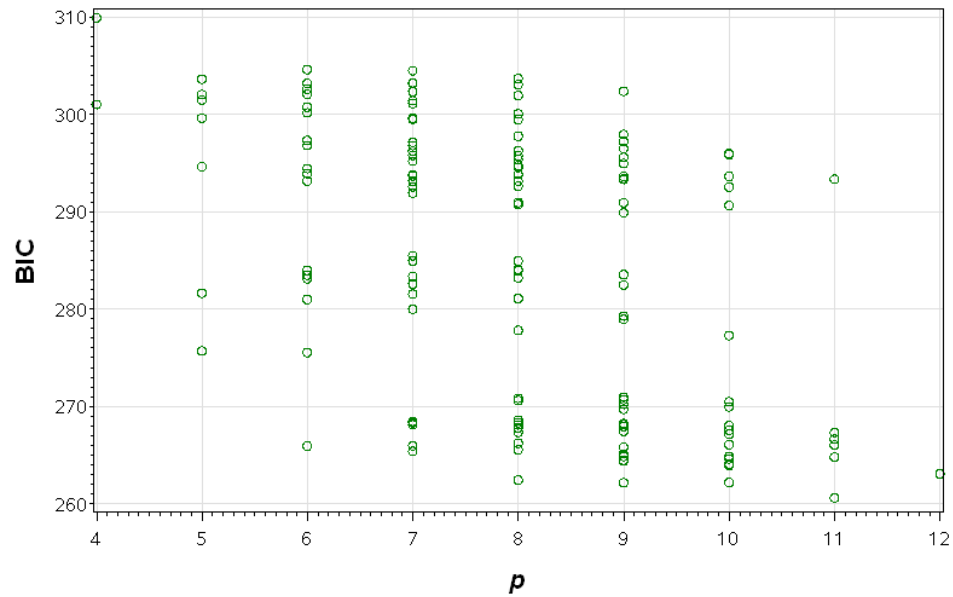
No. Observations:	956
No. Vehicles:	15
No. censored measurements:	0
No. missing measurements:	0
No. measurements removed:	0
Model Type:	Mixed model

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

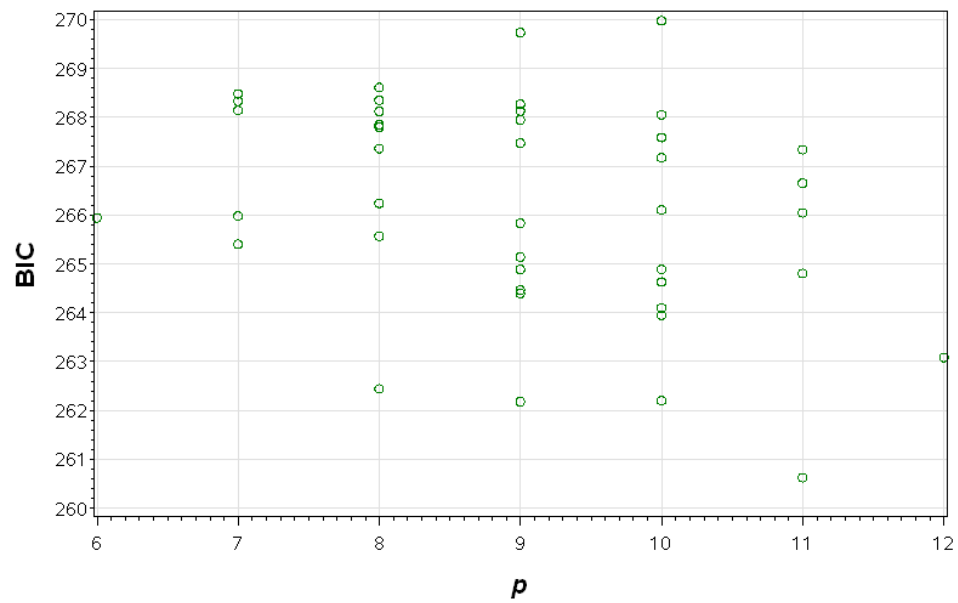
Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model (p) for all possible models respecting hierarchy.



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).



THC (Bag 1): 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 1-5 comprise the “superset” for final model-fitting).

Rank	p	BIC	Design Terms									
			etOH	Arom	RVP	T50	T90	etOH \times etOH	T50 \times T50	etOH \times Arom	etOH \times RVP	etOH \times T50
1	11	260.63	•	•	•	•	•	•	•		•	•
2	9	262.19	•	•	•	•	•		•	•		•
3	10	262.19	•	•	•	•	•	•			•	•
4	8	262.20	•	•	•	•	•		•			•
5	12	262.45	•	•	•	•	•	•	•	•	•	•
6	10	263.09	•	•	•	•	•	•	•			•
7	10	263.18	•	•	•	•	•	•	•		•	
8	9	263.61	•	•	•	•		•	•		•	
9	9	263.91	•	•	•	•	•	•	•			•
10	10	263.95	•	•	•	•	•		•	•	•	•
11	11	264.10	•	•	•	•	•	•	•		•	•
12	9	264.40	•	•	•	•	•		•		•	•
13	10	264.41	•	•	•	•	•		•	•		•
14	9	264.47	•	•	•	•	•		•			•
15	7	264.64	•	•	•	•			•	•		
16	8	264.81	•	•	•	•	•		•	•		
17	9	264.89	•	•	•	•	•	•	•		•	
18	6	264.89	•	•	•	•			•			
19	7	265.04	•	•	•	•	•		•			
20	11	265.15	•	•	•	•	•	•	•	•	•	
21	10	265.41	•	•	•	•		•	•	•	•	
22	8	265.57	•	•	•	•		•	•		•	
23	11	265.64	•	•	•	•	•	•	•	•		•
24	10	265.72	•	•	•	•	•	•	•	•		•
25	11	265.84	•	•	•	•	•		•	•	•	•
26	8	265.84	•	•	•	•		•	•	•		
27	9	265.95	•	•	•	•	•	•	•			
28	10	265.99	•	•	•	•	•		•		•	•
29	8	266.05	•	•	•	•			•	•	•	
30	8	266.06	•	•	•	•			•	•	•	
31	9	266.11	•	•	•	•	•		•	•		•
32	10	266.25	•	•	•	•	•	•	•		•	
33	8	266.30	•	•	•	•	•	•	•			
34	9	266.34	•	•	•	•	•		•	•		
35	7	266.66	•	•	•	•		•	•			

Models fit for THC (Bag 1): (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 \times etOH	ZZ_{ee}	•	•
T50 \times T50	ZZ_{55}	•	•
etOH \times Arom	ZZ_{ea}	•	•
etOH \times RVP	ZZ_{er}	•	\times
etOH \times T50	ZZ_{e5}	•	•
etOH \times T90	ZZ_{e9}	•	•

¹ Represents “Superset minus 1,” etc.

THC (Bag 1): 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 ¹	Dev.	d	$\Pr > \chi^2$
Superset	12	225.176	263.089			
SM1 ²	11	225.426	260.631	0.250	1	0.62
¹ A lower value indicates a better fit. ² Best fit with respect to the 16-term extended model.						

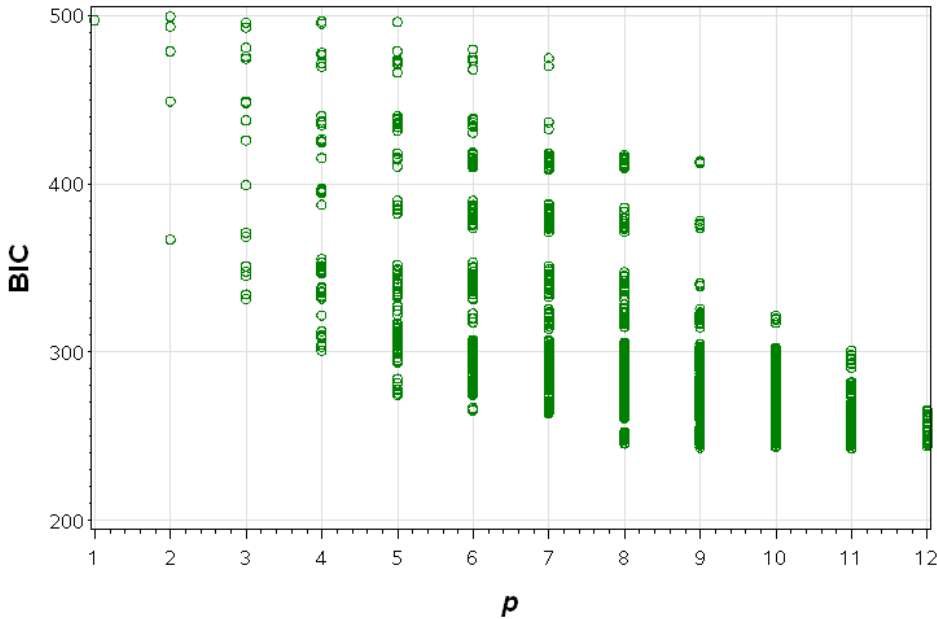
THC (Bag 1): Coefficients and Tests of Effect for the Superset and Reduced Models, with respect to the 11-term design model.

Effect	<i>Full Model (superset)</i>				
	Estimate	Std. Err.	d.f.	t-value	Pr>t
Intercept	-0.8663	0.0944	15	-9.18	0.00000
Z_{θ}	0.0555	0.0127	941	4.36	0.00001
Z_{α}	0.0678	0.0089	941	7.64	0.00000
Z_{τ}	-0.0439	0.0101	941	-4.33	0.00002
Z_{β}	0.1296	0.0128	941	10.14	0.00000
Z_{ρ}	0.0178	0.0089	941	2.01	0.04481
$ZZ_{\theta\theta}$	0.0452	0.0171	941	2.64	0.00834
$ZZ_{\beta\beta}$	0.0742	0.0128	941	5.80	0.00000
$ZZ_{\theta\alpha}$	0.0183	0.0087	941	2.11	0.03542
$ZZ_{\theta\tau}$	0.0044	0.0089	941	0.50	0.61726
$ZZ_{\theta\beta}$	0.0460	0.0183	941	2.51	0.01227
$ZZ_{\rho\theta}$	0.0208	0.0087	941	2.38	0.01729
σ_{veh}^2	0.1325				
σ_{τ}^2	0.06870				

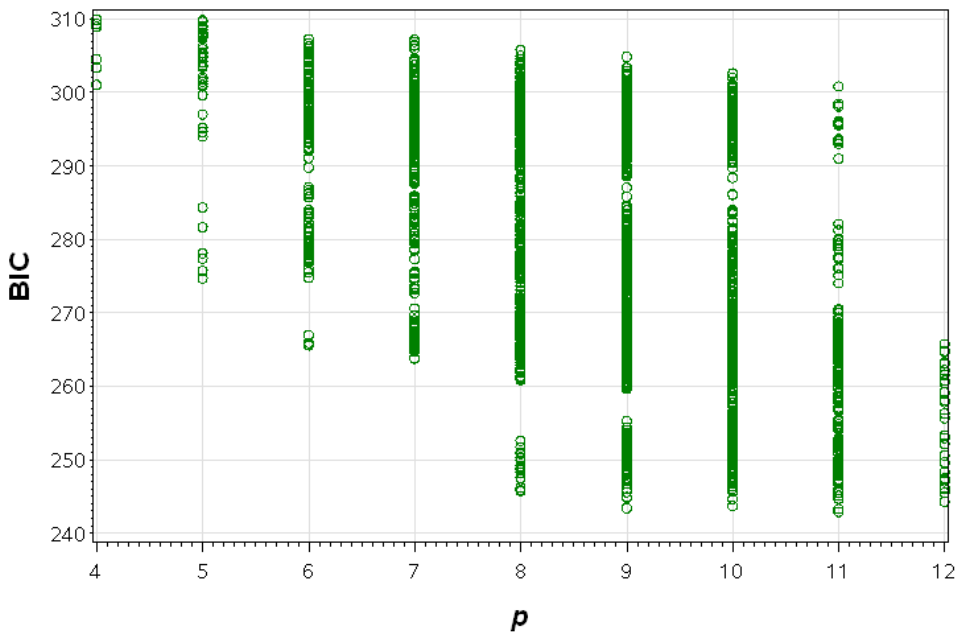
<i>Reduced Model (SM1)</i>				
Estimate	Std. Err.	d.f.	t-value	Pr>t
-0.8664	0.0944	15	-9.18	0.00000
0.0548	0.0127	941	4.33	0.00002
0.0676	0.0089	941	7.62	0.00000
-0.0445	0.0101	941	-4.43	0.00001
0.1288	0.0127	941	10.15	0.00000
0.0183	0.0088	941	2.07	0.03898
0.0436	0.0168	941	2.60	0.00959
0.0736	0.0128	941	5.77	0.00000
0.0179	0.0087	941	2.07	0.03857
0.0445	0.0181	941	2.46	0.01409
0.0214	0.0086	941	2.49	0.01294
σ_{veh}^2	0.1325			
σ_{τ}^2	0.06872			

I.1d.2 Model Fitting with respect to the 16-term extended Model.

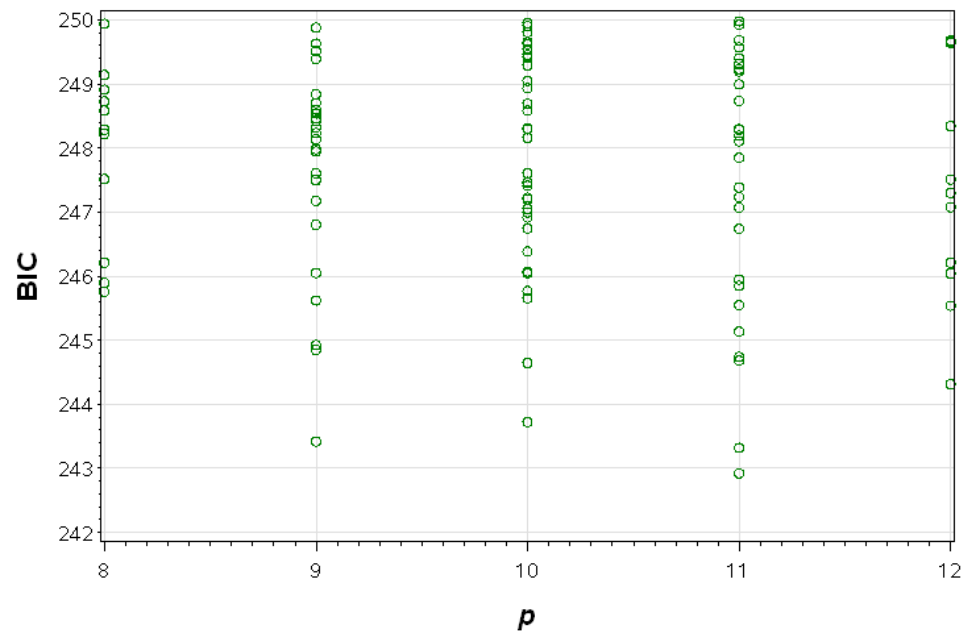
Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model (p) for all possible models respecting hierarchy.



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).



THC (Bag 1): 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 \times etOH	T50 \times T50	etOH \times Arom	etOH \times RVP	etOH \times T50	etOH \times T90	Arom \times RVP	Arom \times T50	Arom \times T90	T50 \times T90	RVP \times T90
1	14	242.93	*	*	*	*	*	*	*	*		*	*	*		*	*	
2	15	243.32	*	*	*	*	*	*	*	*		*	*	*	*	*	*	
3	12	243.42	*	*	*	*	*		*	*			*	*		*	*	
4	13	243.73	*	*	*	*	*	*	*	*			*	*		*	*	
5	15	244.32	*	*	*	*	*	*	*	*	*	*	*	*		*	*	
6	14	244.65	*	*	*	*	*	*	*	*			*	*	*	*	*	
7	13	244.69	*	*	*	*	*	*	*	*		*	*			*	*	
8	15	244.74	*	*	*	*	*	*	*	*		*	*	*		*	*	*
9	13	244.86	*	*	*	*	*		*	*			*	*	*	*	*	
10	11	244.93	*	*	*	*	*		*	*			*			*	*	
11	16	245.14	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*
12	16	245.54	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
13	14	245.55	*	*	*	*	*	*	*	*	*		*	*		*	*	
14	11	245.63	*	*	*	*	*		*	*			*	*		*	*	
15	13	245.66	*	*	*	*	*		*	*	*		*	*		*	*	
16	10	245.76	*	*	*	*	*		*				*			*	*	
17	12	245.77	*	*	*	*	*	*	*	*			*	*		*	*	
18	13	245.85	*	*	*	*	*	*	*	*		*	*	*		*	*	
19	11	245.90	*	*	*	*	*		*				*	*	*	*	*	
20	14	245.95	*	*	*	*	*	*	*	*		*	*	*	*	*	*	
21	16	246.05	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
22	14	246.05	*	*	*	*	*	*	*	*			*	*		*	*	*
23	13	246.05	*	*	*	*	*		*	*			*	*	*	*	*	*
24	13	246.08	*	*	*	*	*		*	*		*	*	*		*	*	
25	14	246.22	*	*	*	*	*	*	*	*	*	*	*	*		*	*	
26	11	246.22	*	*	*	*	*		*				*		*	*	*	
27	13	246.39	*	*	*	*	*	*	*	*			*	*	*	*	*	
28	13	246.74	*	*	*	*	*	*	*	*	*		*	*		*	*	
29	12	246.75	*	*	*	*	*	*	*			*	*			*	*	
30	12	246.81	*	*	*	*	*		*	*			*	*	*	*	*	
31	12	246.92	*	*	*	*	*	*	*	*			*			*	*	
32	15	247.00	*	*	*	*	*	*	*	*			*	*	*	*	*	*
33	13	247.05	*	*	*	*	*	*	*			*	*	*		*	*	
34	15	247.07	*	*	*	*	*	*	*	*	*		*	*	*	*	*	
35	14	247.08	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	

Models fit for THC (Bag 1): (all models include an intercept term).

Model Term	Notation	Model		
		Superset	SM2 ¹	SM6
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 2, etc.”

THC (Bag 1): Model fitting history, starting with the 15-term superset model.

Fit Parameters				<i>Test with respect to Previous Model</i>		
Model	p	$-2\ln L$	BIC ¹	Dev.	d	$\Pr > \chi^2$
Superset	16	196.798	245.543			
SM2 ²	14	199.598	242.927	2.800	2	0.247
SM6	10	229.637	262.134	30.039	4	0.0000048

¹ A lower value indicates a better fit.

² Best fit with respect to the 16-term extended model.

THC (Bag 1): 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>					<i>Reduced Model (SM2)</i>				
	Estimate	Std.Err.	d.f.	t-value	Pr> t	Estimate	Std.Err.	d.f.	t-value	Pr> t
Intercept	-0.8653	0.09410	15	-9.20	<0.0001	-0.8658	0.09407	15	-9.20	<0.0001
Z _e	0.07607	0.01436	941	5.30	<0.0001	0.06794	0.01342	941	5.06	<0.0001
Z _a	0.08474	0.009469	941	8.95	<0.0001	0.08344	0.00943	941	8.85	<0.0001
Z _r	-0.03584	0.01264	941	-2.83	0.0047	-0.04669	0.01016	941	-4.60	<0.0001
Z ₅	0.1602	0.01622	941	9.88	<0.0001	0.1490	0.01446	941	10.30	<0.0001
Z ₉	0.01582	0.009786	941	1.62	0.11	0.01434	0.009179	941	1.56	0.12
ZZ _{ee}	0.04604	0.01708	941	2.69	0.0072	0.04065	0.01677	941	2.22	0.016
ZZ ₅₅	0.0818	0.01354	941	6.04	<0.0001	0.07555	0.01299	941	5.82	<0.0001
ZZ _{ea}	0.03790	0.01415	941	2.68	0.0075	0.02297	0.008769	941	2.62	0.0090
ZZ _{er}	0.006772	0.009678	941	0.700	0.48					
ZZ _{e5}	0.03790	0.01839	941	2.06	0.040	0.03426	0.01827	941	1.87	0.061
ZZ _{e9}	0.04627	0.01053	941	4.39	<0.0001	0.04782	0.01048	941	4.56	<0.0001
ZZ _{ar}	0.03977	0.01517	941	2.62	0.0089	0.02553	0.01206	941	2.12	0.035
ZZ _{a5}	0.02101	0.01724	941	1.22	0.22					
ZZ _{a9}	0.02087	0.009634	941	2.17	0.031	0.02260	0.009506	941	2.38	0.018
ZZ ₅₉	0.05255	0.01161	941	4.53	<0.0001	0.05004	0.01147	941	4.36	<0.0001
ZZ _{r9}	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
σ^2_{veh}	0.1317					0.1317				
σ^2_{ε}	0.06667					0.06687				