

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.1e

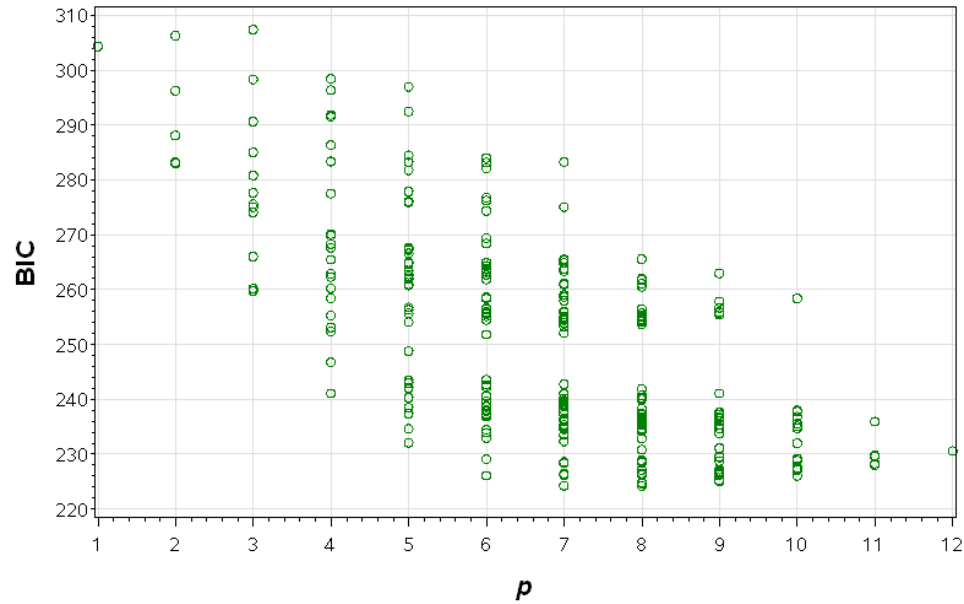
Final Model Fitting

Total Hydrocarbons (THC) (Bag 2)

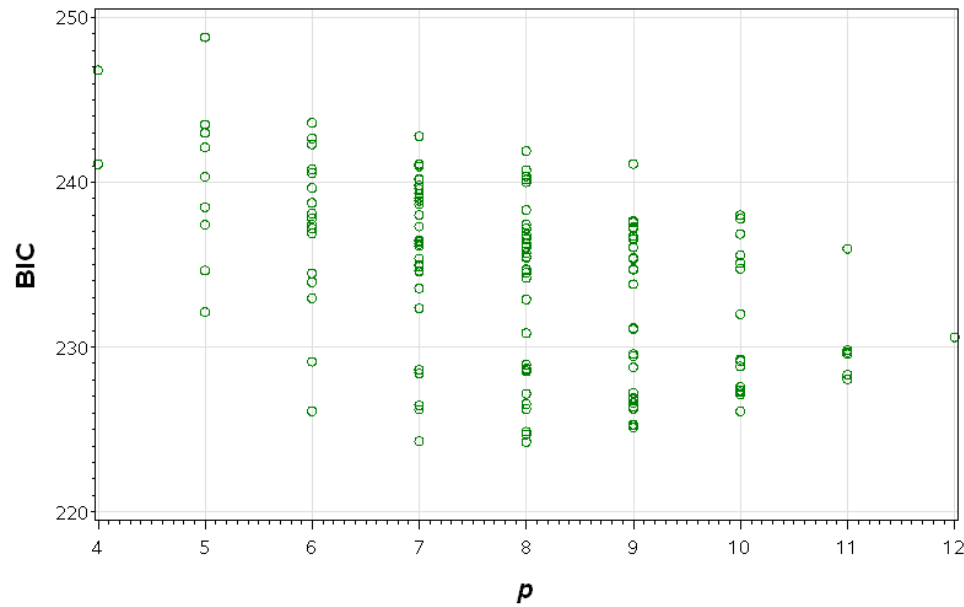
No. Observations:	832
No. Vehicles:	13 (exclude Odyssey and Sienna)
No. censored measurements:	0
No. missing measurements:	0
No. measurements removed:	0
Model Type:	Mixed model

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

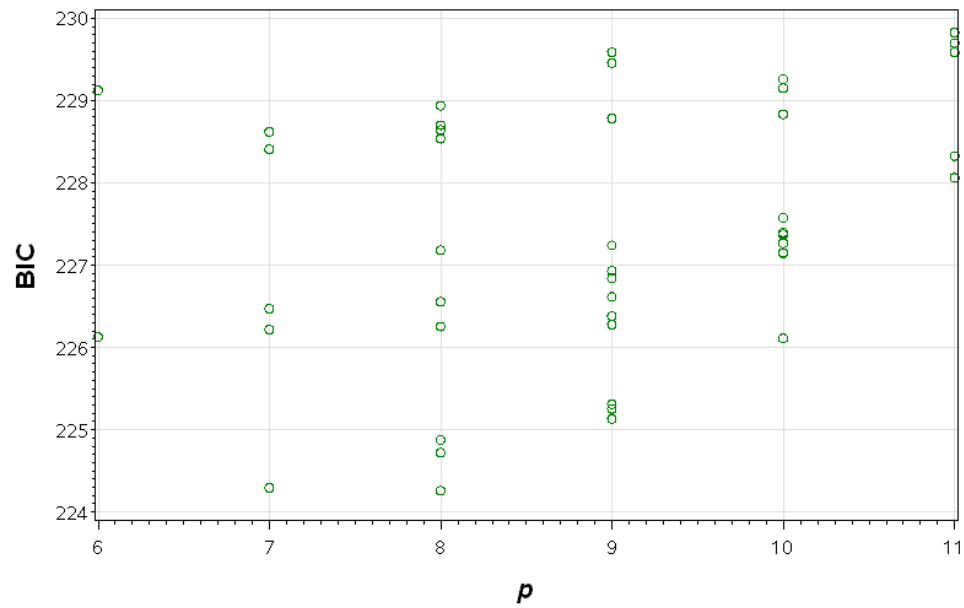
Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model (p) for all possible models respecting hierarchy.



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 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 1-5 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	etOH \times T90
1	8	224.26	*	*	*	*	*		*		*		
2	7	224.30	*	*	*	*	*		*				
3	8	224.72	*	*	*	*	*		*				*
4	8	224.88	*	*	*	*	*		*	*			
5	9	225.13	*	*	*	*	*		*	*	*		
6	9	225.26	*	*	*	*	*		*	*			*
7	9	225.32	*	*	*	*	*		*		*		*
8	10	226.11	*	*	*	*	*		*	*	*		*
9	6	226.13	*		*	*	*		*				
10	7	226.22	*		*	*	*		*		*		
11	8	226.26	*	*	*	*	*		*			*	
12	9	226.28	*	*	*	*	*		*		*	*	
13	9	226.38	*	*	*	*	*	*	*		*		
14	7	226.47	*		*	*	*		*				*
15	8	226.56	*	*	*	*	*	*	*				
16	9	226.62	*	*	*	*	*		*			*	*
17	9	226.63	*	*	*	*	*		*	*		*	
18	9	226.84	*	*	*	*	*	*	*				*
19	10	226.93	*	*	*	*	*		*	*	*	*	
20	10	226.93	*	*	*	*	*		*	*		*	*
21	8	227.01	*		*	*	*		*		*		*
22	9	227.15	*	*	*	*	*	*	*	*			
23	10	227.15	*	*	*	*	*		*		*	*	*
24	10	227.19	*	*	*	*	*	*	*	*	*		
25	10	227.24	*	*	*	*	*	*	*		*		*
26	10	227.27	*	*	*	*	*	*	*	*			*
27	11	227.38	*	*	*	*	*		*	*	*	*	*
28	11	227.40	*	*	*	*	*	*	*	*	*		*
29	7	227.58	*		*	*	*		*			*	
30	8	227.90	*		*	*	*		*		*	*	
31	7	228.07	*		*	*	*	*	*				
32	8	228.33	*		*	*	*	*	*		*		
33	8	228.41	*		*	*	*		*			*	*
34	9	228.54	*	*	*	*	*	*	*			*	
35	10	228.63	*	*	*	*	*	*	*		*	*	

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

Model Term	Notation	Model	
		Superset	SM3 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}	•	\times
etOH \times RVP	ZZ_{er}	•	\times
etOH \times T50	ZZ_{e5}	---	
etOH \times T90	ZZ_{e9}	•	\times

¹ Represents “Superset minus 3,” etc.

THC (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 ¹	Dev.	d	$\Pr > \chi^2$
Superset	10	195.334	226.113			
SM3 ²	7	201.213	224.297	5.879	3	0.118

¹ A lower value indicates a better fit.

² Best fit with respect to the 11-term design model.

THC (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.	t-value	Pr>t
Intercept	-4.6543	0.2545	13	-18.29	0.0000
Z_{ε}	0.0331	0.0120	819	2.77	0.0057
Z_{α}	-0.0194	0.0093	819	-2.09	0.0370
Z_{τ}	-0.0354	0.0106	819	-3.33	0.0009
Z_{β}	0.0476	0.0129	819	3.69	0.0002
Z_{θ}	0.0506	0.0094	819	5.39	0.0000
$ZZ_{\varepsilon\varepsilon}$	-----				
$ZZ_{\beta\beta}$	0.0334	0.0094	819	3.55	0.0004
$ZZ_{\varepsilon\alpha}$	0.0121	0.0091	819	1.33	0.1839
$ZZ_{\varepsilon\tau}$	-0.0121	0.0092	819	-1.31	0.1914
$ZZ_{\varepsilon\beta}$	-----				
$ZZ_{\varepsilon\theta}$	-0.0116	0.0092	819	-1.2600	0.2080

σ_{veh}^2	0.8406
σ_{τ}^2	0.06669

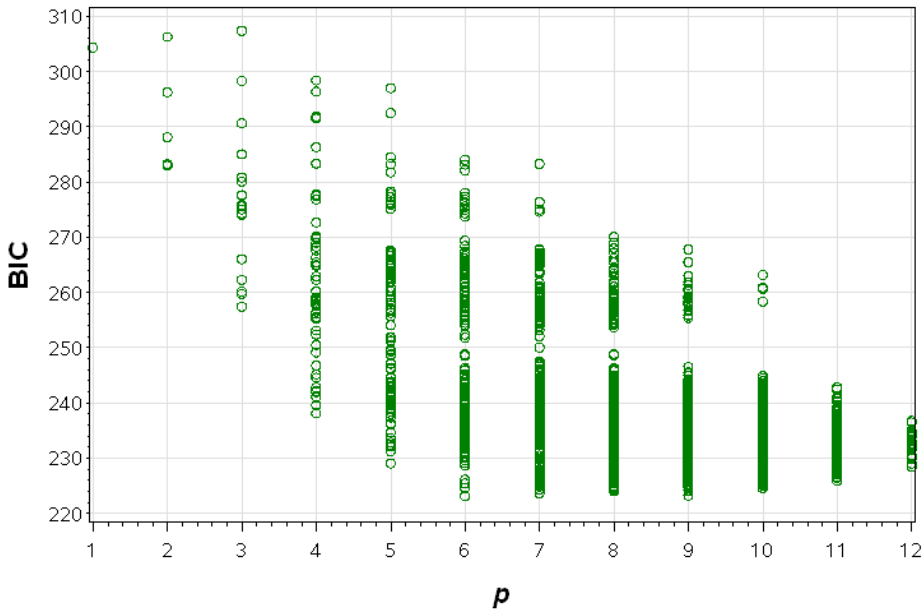
<i>Reduced Model (SM3)</i>				
Estimate	Std. Err.	d.f.	t-value	Pr>t
-4.6533	0.2541	13	-18.31	0.00000
0.0327	0.0120	819	2.73	0.0066
-0.0195	0.0093	819	-2.10	0.0360
-0.0355	0.0106	819	-3.36	0.00080
0.0501	0.0129	819	3.89	0.0001
0.0514	0.0093	819	5.54	0.00000

0.0337	0.0094	819	3.59	0.00036

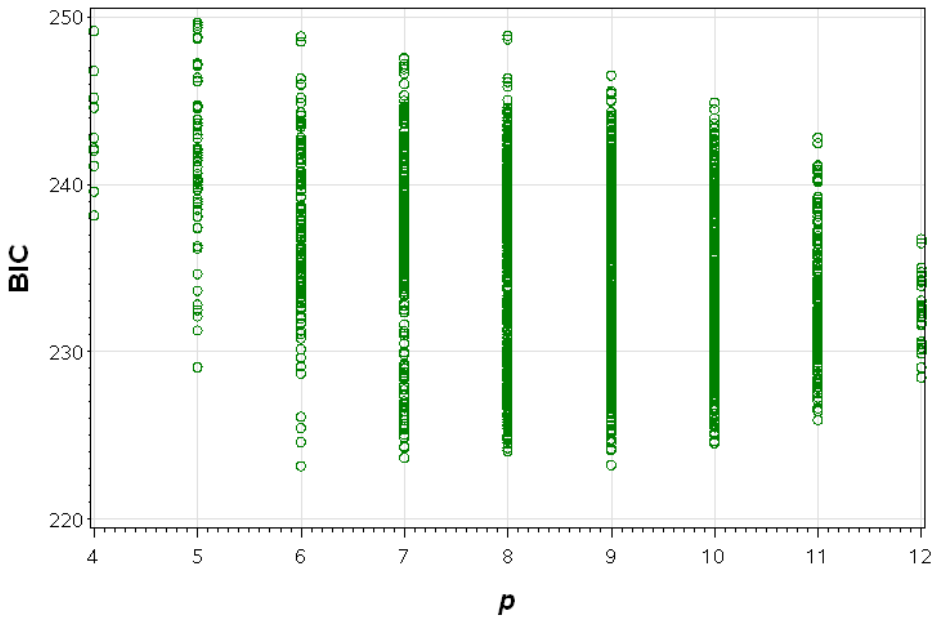
σ_{veh}^2	0.8384
σ_{τ}^2	0.06717

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

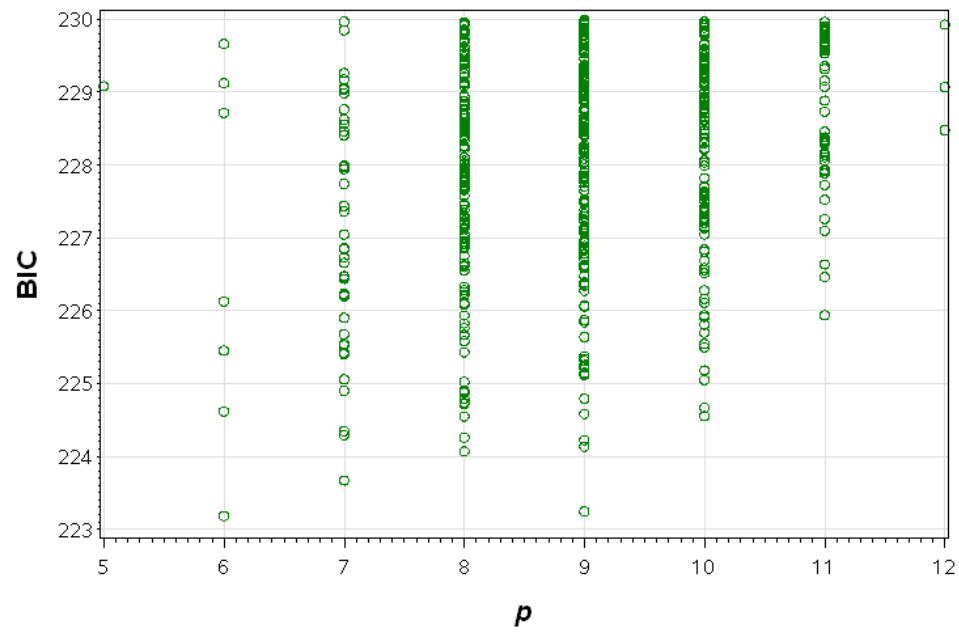
Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model (p) for all possible models respecting hierarchy.



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 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 \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	7	223.18	*		*	*	*		*								*	
2	10	223.25	*	*	*	*	*		*	*	*				*			
3	8	223.67	*	*	*	*	*		*								*	
4	9	224.07	*	*	*	*	*		*	*							*	
5	11	224.14	*	*	*	*	*		*	*	*				*		*	
6	11	224.23	*	*	*	*	*		*	*	*				*			*
7	8	224.26	*	*	*	*	*		*		*							
8	7	224.30	*	*	*	*	*		*									
9	8	224.35	*		*	*	*		*		*						*	
10	9	224.55	*	*	*	*	*		*		*						*	
11	11	224.56	*	*	*	*	*		*	*	*	*			*			
12	10	224.59	*	*	*	*	*		*	*			*					*
13	8	224.62	*		*	*	*		*								*	*
14	11	224.67	*	*	*	*	*		*	*	*		*		*			
15	8	224.72	*	*	*	*	*		*				*					
16	9	224.74	*	*	*	*	*		*				*				*	
17	9	224.79	*	*	*	*	*		*		*						*	
18	11	224.80	*	*	*	*	*		*	*	*				*	*		
19	8	224.88	*	*	*	*	*		*	*								
20	8	224.90	*	*	*	*	*		*									*
21	9	224.91	*	*	*	*	*		*	*								*
22	10	225.03	*	*	*	*	*		*	*					*		*	
23	11	225.05	*	*	*	*	*	*	*	*	*				*			
24	8	225.06	*		*	*	*		*				*					*
25	10	225.12	*	*	*	*	*		*	*	*							*
26	9	225.13	*	*	*	*	*		*	*	*							
27	11	225.15	*	*	*	*	*		*	*	*			*	*			
28	12	225.18	*	*	*	*	*		*	*	*		*		*			*
29	10	225.22	*	*	*	*	*		*	*	*						*	
30	12	225.24	*	*	*	*	*		*	*	*			*	*		*	
31	9	225.26	*	*	*	*	*		*	*			*					
32	9	225.32	*	*	*	*	*		*		*		*					
33	10	225.34	*	*	*	*	*		*		*		*					*
34	12	225.38	*	*	*	*	*		*	*	*				*	*		*
35	8	225.41	*		*	*	*		*			*					*	

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

Model Term	Notation	Model		
		Superset	SM1 ¹	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}	---		
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.”

THC (Bag 2): Model fitting history, starting with the 15-term superset model.

Fit Parameters				Test with respect to Previous Model		
Model	p	$-2\ln L$	BIC ¹	Dev.	d	$\text{Pr} > \chi^2$
Superset	11	190.795	224.139			
SM1 ²	10	192.466	223.245	1.671	1	0.196
SM4 ³	7	203.136	226.220	10.670	3	0.0137

¹ A lower value indicates a better fit.

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

³ Fit because the linear term for Aromatics appears insignificant in The superset model; therefore, dropped aromatics and its interactions. Test results indicate that these three terms contribute to fit.

THC (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	-4.6543	0.2543	13	-18.30	0.00000
Z_{θ}	0.03492	0.01196	819	2.92	0.0036
Z_{α}	-0.01558	0.00977	819	-1.59	0.11
Z_{γ}	-0.02774	0.01171	819	-2.37	0.018
Z_{β}	0.05069	0.01302	819	3.89	0.00011
Z_{ρ}	0.05841	0.01024	819	5.71	0.00000
$ZZ_{\theta\theta}$	---				
$ZZ_{\beta\beta}$	0.03340	0.009377	819	3.56	0.00039
$ZZ_{\theta\alpha}$	0.02800	0.01215	819	2.30	0.022
$ZZ_{\theta\gamma}$	-0.01880	0.01011	819	-1.86	0.063
$ZZ_{\theta\beta}$	---				
$ZZ_{\theta\rho}$	---				
$ZZ_{\alpha\gamma}$	---				
$ZZ_{\alpha\beta}$	0.02841	0.01486	819	1.91	0.056
$ZZ_{\alpha\rho}$	---				
$ZZ_{\beta\rho}$	0.01303	0.01007	819	1.29	0.20
$ZZ_{\gamma\rho}$	---				
σ_{veh}^2	0.8395				
σ_z^2	0.06632				

<i>Reduced Model (SM1)</i>				
Estimate	Std. Err.	d.f.	t-value	Pr>t
-4.6543	0.25427	13	-18.30	0.00000
0.03470	0.01198	819	2.90	0.0039
-0.01968	0.00926	819	-2.13	0.034
-0.02641	0.01168	819	-2.26	0.024
0.05122	0.01303	819	3.93	0.00009
0.06077	0.01008	819	6.03	0.00000
0.03392	0.00938	819	3.62	0.00032
0.02892	0.01215	819	2.38	0.017
-0.02184	0.00985	819	-2.22	0.027
0.03112	0.01473	819	2.11	0.035
σ_{veh}^2	0.8395			
σ_z^2	0.66460			

