

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.4n

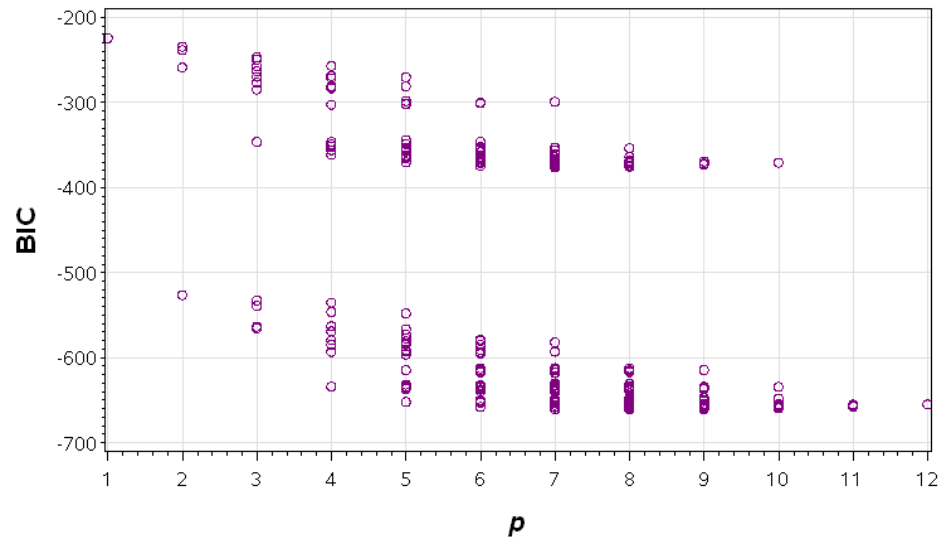
Final Model Fitting

Methane (CH₄) (Bag 2)

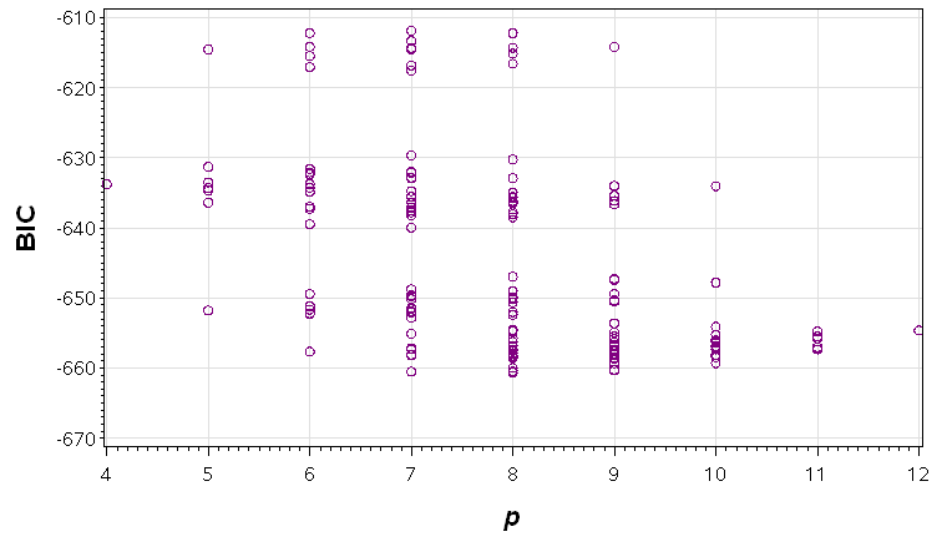
No. Observations:	956
No. Vehicles:	15
No. censored measurements:	0
No. missing measurements:	0
No. measurements removed:	0
Model Type:	Mixed model

I.4n.1 Model fitting with respect to the 11-term design model.

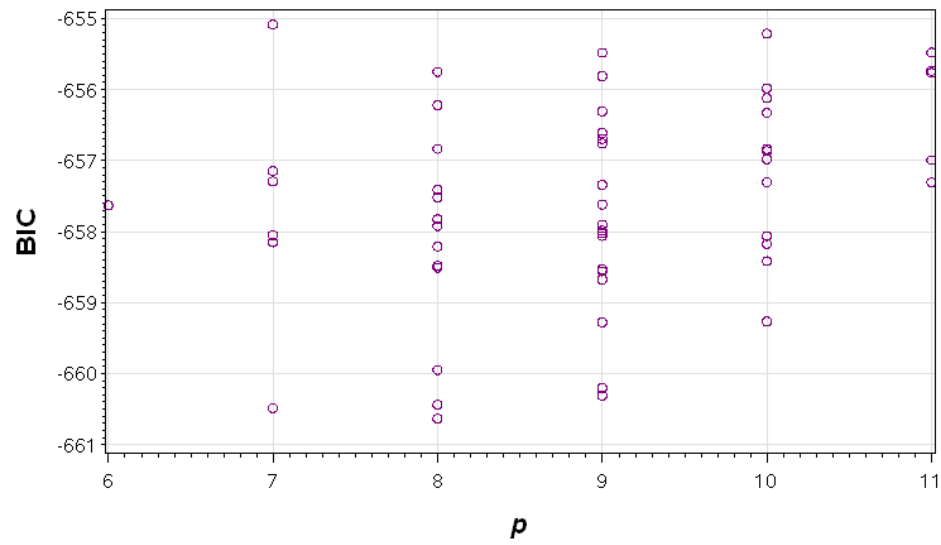
Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model (p) for all possible models respecting hierarchy.



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).



CH₄ (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	p	BIC	Design Terms									
			HCH	WCH	CHP	CHL	CHT	HCH×HCHP	CHL×CHL	WCH×HCHP	CHP×CHP	CHL×HCHP
1	8	-660.632	*	*	*	*	*		*	*		
2	7	-660.484	*	*	*	*	*		*			
3	8	-660.436	*	*	*	*	*		*		*	
4	9	-660.305	*	*	*	*	*		*	*	*	
5	9	-660.199	*	*	*	*	*		*	*		*
6	8	-659.944	*	*	*	*	*		*			*
7	9	-659.274	*	*	*	*	*		*		*	*
8	10	-659.263	*	*	*	*	*		*	*	*	*
9	9	-658.671	*	*	*	*	*		*	*		*
10	9	-658.556	*	*	*	*	*	*	*	*		
11	9	-658.529	*	*	*	*	*		*		*	*
12	8	-658.504	*	*	*	*	*		*		*	
13	8	-658.479	*	*	*	*	*		*	*		*
14	10	-658.413	*	*	*	*	*		*	*	*	*
15	8	-658.206	*	*	*	*	*	*	*			
16	10	-658.172	*	*	*	*	*		*	*		*
17	7	-658.147	*	*	*	*	*			*		
18	10	-658.061	*	*	*	*	*	*	*	*		*
19	9	-658.058	*	*	*	*	*		*	*	*	*
20	10	-658.058	*	*	*	*	*	*	*	*	*	
21	7	-658.044	*	*	*	*	*				*	
22	9	-658.019	*	*	*	*	*	*	*		*	
23	9	-657.985	*	*	*	*	*		*	*	*	
24	8	-657.918	*	*	*	*	*		*			*
25	9	-657.9	*	*	*	*	*		*		*	*
26	8	-657.823	*	*	*	*	*			*	*	
27	6	-657.629	*	*	*	*	*					
28	9	-657.614	*	*	*	*	*	*	*			*
29	8	-657.516	*	*	*	*	*				*	*
30	8	-657.407	*	*	*	*	*		*	*		
31	9	-657.339	*	*	*	*	*	*	*	*	*	
32	11	-657.303	*	*	*	*	*		*	*	*	*
33	10	-657.301	*	*	*	*	*		*	*	*	*
34	7	-657.289	*	*	*	*	*					*
35	7	-657.145	*	*	*	*	*			*		

Models fit for CH₄ (Bag 2): (all models include an intercept term).

Model Term	Notation	Model	
		Superset	SM2 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}	•	×

¹ Represents “Superset minus 2,” etc.

CH₄ (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 ¹	Dev.	d	$\Pr > \chi^2$
Superset	10	-691.760	-659.263			
SM1 ²	8	-687.712	-660.632	4.048	2	0.132

¹ A lower value indicates a better fit.

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

CH₄ (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	-5.7080	0.2722	15	-21.0	0.000000
Z_e	0.05859	0.006829	941	8.58	0.000000
Z_a	-0.09846	0.005308	941	-18.5	0.000000
Z_r	-0.02053	0.006080	941	-3.38	0.00076
Z_5	0.04321	0.007399	941	5.84	0.000000
Z_9	0.02539	0.005359	941	4.74	0.000002
ZZ_{ee}	---	---	---	---	---
ZZ_{55}	0.01248	0.005381	941	2.32	0.021
ZZ_{ea}	0.008520	0.005183	941	1.64	0.10
ZZ_{er}	-0.007004	0.005258	941	-1.33	0.18
ZZ_{e5}	---	---	---	---	---
ZZ_{e9}	-0.006794	0.005260	941	-1.29	0.20

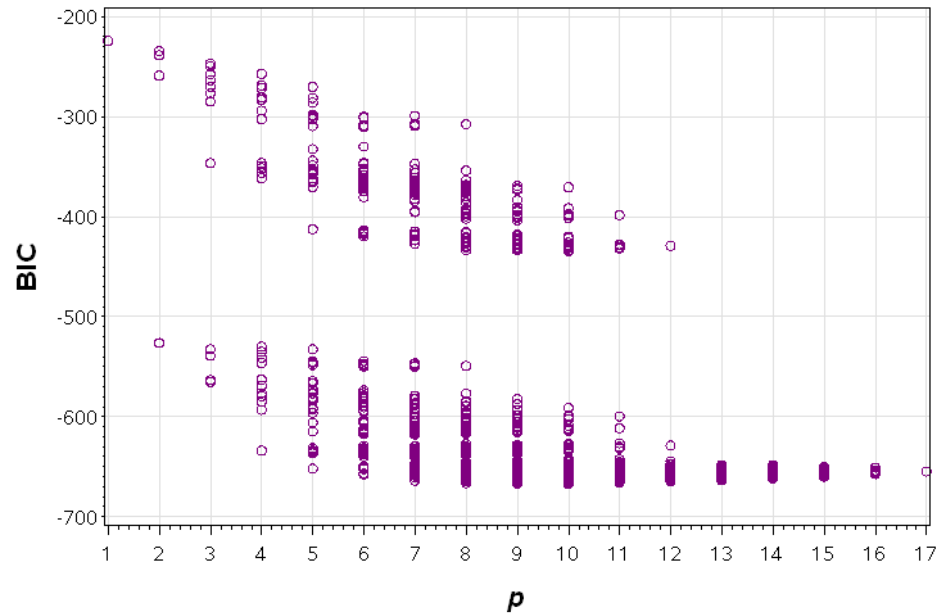
σ_{veh}^2	1.1109
σ_{ε}^2	0.02507

<i>Reduced Model (SM2)</i>				
Estimate	Std. Err.	d.f.	<i>t</i> -value	Pr> <i>t</i>
-5.7075	0.2722	15	-21.0	0.000000
0.05860	0.006839	941	8.57	0.000000
-0.09836	0.005317	941	-18.5	0.000000
-0.02049	0.006036	941	-3.39	0.00072
0.04394	0.007393	941	5.94	0.000000
0.02575	0.005290	941	4.87	0.000001
---	---	---	---	---
0.01227	0.005379	941	2.28	0.023
0.008769	0.005185	941	1.69	0.091
---	---	---	---	---

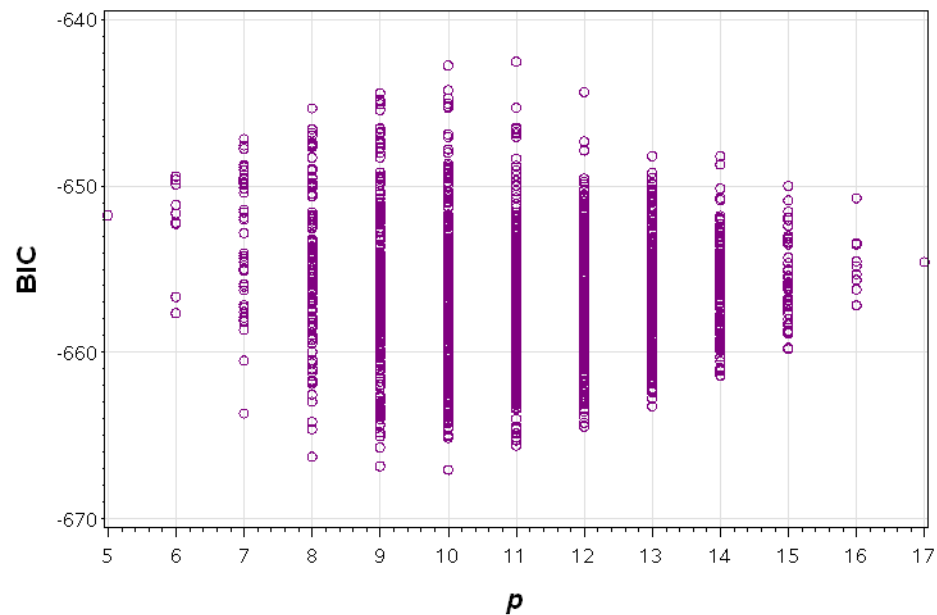
σ_{veh}^2	1.1108
σ_{ε}^2	0.02518

I.4n.2 Model Fitting with respect to the 16-term extended Model.

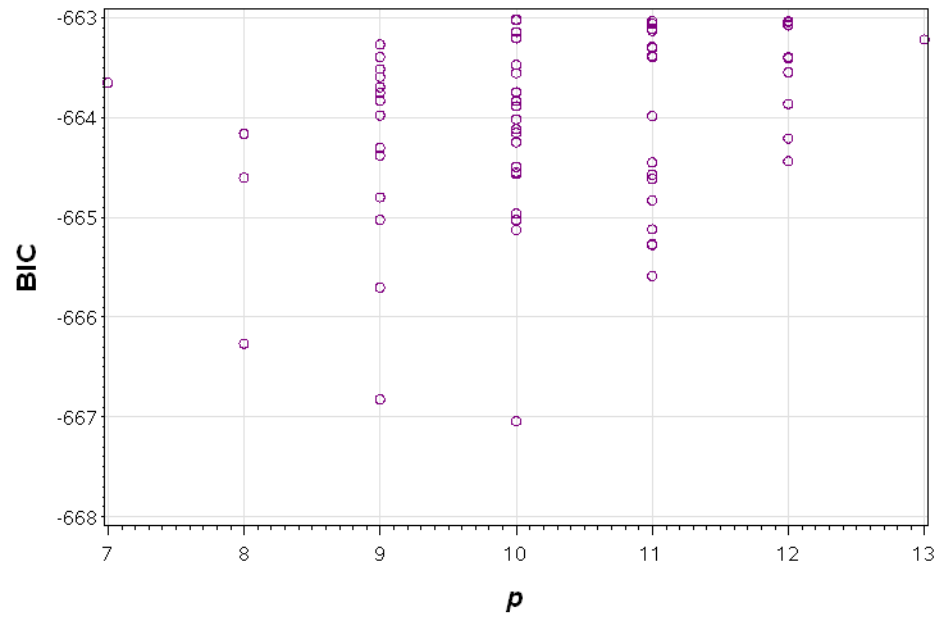
Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model (p) for all possible models respecting hierarchy.



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).



CH₄ (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	<i>p</i>	BIC	Design Terms											Extended Terms				
			εOH	Arom	RVP	T50	T90	εOH × εOH	T50 × T50	εOH × Arom	εOH × RVP	εOH × T50	εOH × T90	Arom × RVP	Arom × T50	Arom × T90	T50 × T90	RVP × T90
1	10	-667.041	•	•	•	•	•		•	•						•	•	
2	9	-666.822	•	•	•	•	•		•	•						•		
3	8	-666.263	•	•	•	•	•		•							•		
4	9	-665.701	•	•	•	•	•		•							•	•	
5	11	-665.585	•	•	•	•	•		•	•	•					•	•	
6	11	-665.274	•	•	•	•	•		•	•						•	•	
7	11	-665.265	•	•	•	•	•		•	•		•				•	•	
8	10	-665.124	•	•	•	•	•		•	•	•					•		
9	11	-665.117	•	•	•	•	•	•	•	•						•	•	
10	10	-665.026	•	•	•	•	•		•	•						•		
11	10	-665.024	•	•	•	•	•		•	•							•	
12	9	-665.023	•	•	•	•	•			•		•				•		
13	10	-664.96	•	•	•	•	•		•	•		•				•		
14	11	-664.827	•	•	•	•	•		•	•						•	•	
15	9	-664.797	•	•	•	•	•		•		•					•		
16	11	-664.614	•	•	•	•	•		•	•	•					•		
17	8	-664.601	•	•	•	•	•			•						•		
18	11	-664.568	•	•	•	•	•		•	•						•	•	
19	10	-664.563	•	•	•	•	•	•	•	•						•		
20	10	-664.543	•	•	•	•	•		•	•						•		
21	10	-664.491	•	•	•	•	•		•		•					•	•	
22	11	-664.448	•	•	•	•	•		•	•				•		•	•	
23	12	-664.436	•	•	•	•	•		•	•	•				•	•		
24	9	-664.377	•	•	•	•	•		•			•				•		
25	9	-664.302	•	•	•	•	•		•	•							•	
26	10	-664.246	•	•	•	•	•			•		•				•	•	
27	12	-664.207	•	•	•	•	•		•	•	•					•	•	
28	8	-664.16	•	•	•	•	•					•				•		
29	10	-664.151	•	•	•	•	•		•	•						•		
30	10	-664.114	•	•	•	•	•		•	•				•		•		
31	10	-664.016	•	•	•	•	•		•	•	•						•	
32	11	-663.984	•	•	•	•	•		•	•	•		•				•	
33	9	-663.976	•	•	•	•	•		•						•	•		
34	10	-663.884	•	•	•	•	•		•			•				•	•	
35	12	-663.861	•	•	•	•	•		•	•	•	•				•	•	

Models fit for CH₄ (Bag 2): (all models include an intercept term).

Model Term	Notation	Model	
		Superset	SM1
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}	---	---
Arom \times RVP	ZZ_{ar}	---	---
Arom \times T50	ZZ_{a5}	---	---
Arom \times T90	ZZ_{a9}	---	---
T50 \times T90	ZZ_{59}	•	•
RVP \times T90	ZZ_{r9}	•	•

¹ Denotes “Superset minus 1,” etc.

CH₄ (Bag 2): 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	11	-700.789	-665.585			
SM1 ²	10	-699.537	-667.041	1.252	1	0.263

¹ A lower value indicates a better fit.

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

CH₄ (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.	<i>t</i> -value	Pr> <i>t</i>
Intercept	-5.7078	0.2722	15	-21.0	0.000000
Z_e	0.06063	0.006873	941	8.82	0.000000
Z_a	-0.09260	0.005608	941	-16.5	0.000000
Z_r	-0.02135	0.006033	941	-3.54	0.00042
Z_5	0.04424	0.007413	941	5.97	0.000000
Z_9	0.02510	0.005324	941	4.71	0.000003
ZZ_{ee}	---	---	---	---	---
ZZ_{55}	0.01445	0.005496	941	2.63	0.0087
ZZ_{ea}	0.01015	0.005202	941	1.95	0.051
ZZ_{er}	-0.005907	0.005277	941	-1.12	0.26
ZZ_{e5}	---	---	---	---	---
ZZ_{e9}	---	---	---	---	---
ZZ_{ar}	---	---	---	---	---
ZZ_{a5}	---	---	---	---	---
ZZ_{a9}	---	---	---	---	---
ZZ_{59}	0.01241	0.005994	941	2.07	0.039
ZZ_{r9}	-0.01034	0.005802	941	-1.78	0.075
σ^2_{veh}	1.111				
σ^2_{ε}	0.02483				

<i>Reduced Model (SM1)</i>				
Estimate	Std. Err.	d.f.	<i>t</i> -value	Pr> <i>t</i>
-5.7076	0.2722	15	-21.0	0.000000
0.06076	0.006877	941	8.84	0.000000
-0.09211	0.005595	941	-16.5	0.000000
-0.02082	0.006018	941	-3.46	0.00056
0.04477	0.007403	941	6.05	0.000000
0.02445	0.005295	941	4.62	0.000004
---	---	---	---	---
0.01398	0.005483	941	2.55	0.011
0.01047	0.005198	941	2.01	0.044
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
0.01374	0.005879	941	2.34	0.020
-0.009921	0.005794	941	-1.71	0.087
σ^2_{veh}	1.1109			
σ^2_{ε}	0.02486			