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.4m

Final Model Fitting

Methane (CH_4) (Bag 1)

No. Observations: 956

No. Vehicles: 15

No. censored measurements: 0

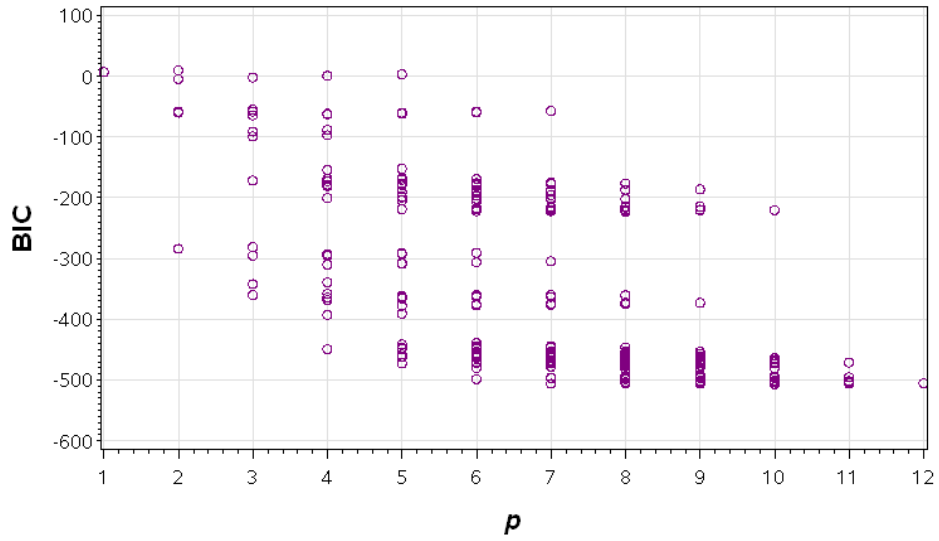
No. missing measurements: 0

No. measurements removed: 0

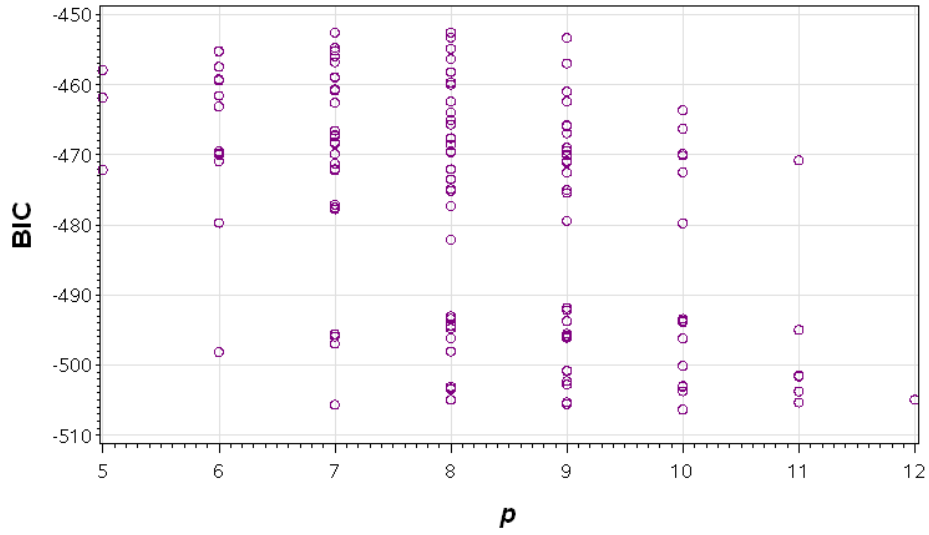
Model Type: Mixed model

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

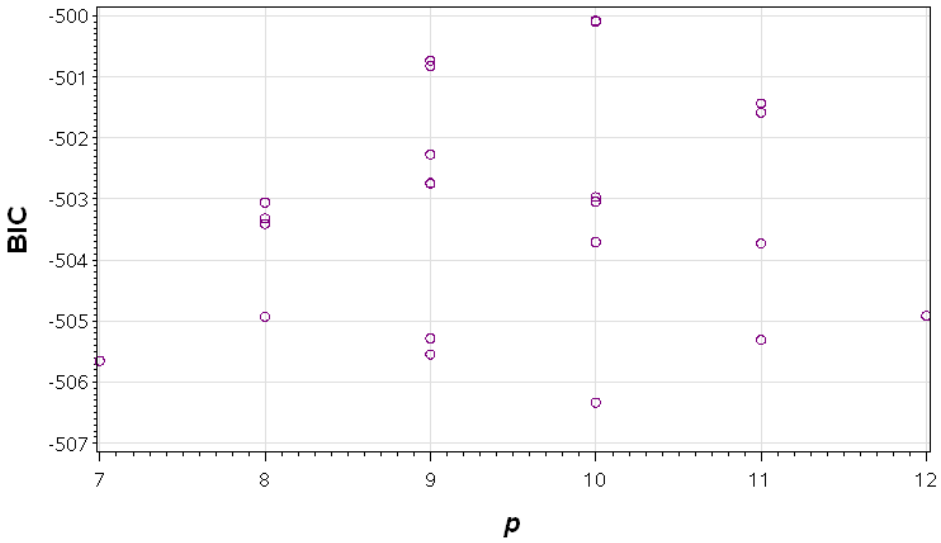
Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model (*p*) for all possible models respecting hierarchy.



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).



CH_4 (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 1-7 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	10	-506.33	•	•	•	•		•	•	•	•	•	
2	7	-505.646	•	•	•	•			•	•			
3	9	-505.54	•	•	•	•		•	•	•		•	
4	11	-505.305	•	•	•	•	•	•	•	•		•	•
5	9	-505.278	•	•	•	•	•		•	•			•
6	8	-504.925	•	•	•	•			•	•	•		
7	12	-504.911	•	•	•	•	•	•	•	•	•	•	•
8	11	-503.724	•	•	•	•	•	•	•	•	•	•	
9	10	-503.703	•	•	•	•	•		•	•	•		•
10	8	-503.404	•	•	•	•			•	•		•	
11	8	-503.314	•	•	•	•		•	•	•			
12	8	-503.053	•	•	•	•	•		•	•			
13	10	-503.043	•	•	•	•	•	•	•	•		•	
14	10	-503.037	•	•	•	•	•	•	•	•			•
15	10	-502.965	•	•	•	•	•		•	•		•	•
16	9	-502.745	•	•	•	•		•	•	•	•		
17	9	-502.734	•	•	•	•			•	•	•	•	
18	9	-502.266	•	•	•	•	•		•	•	•		
19	11	-501.58	•	•	•	•	•	•	•	•	•		•
20	11	-501.43	•	•	•	•	•		•	•	•	•	•
21	9	-500.816	•	•	•	•	•		•	•		•	
22	9	-500.73	•	•	•	•	•	•	•	•			
23	10	-500.091	•	•	•	•	•	•	•	•	•		
24	10	-500.077	•	•	•	•	•		•	•	•	•	
25	6	-498.114	•	•	•	•			•				
26	8	-498.028	•	•	•	•	•		•				•
27	7	-496.925	•	•	•	•			•		•		
28	10	-496.179	•	•	•	•	•	•	•			•	•
29	8	-496.142	•	•	•	•		•	•			•	
30	9	-496.084	•	•	•	•	•		•		•		•
31	9	-495.926	•	•	•	•		•	•		•	•	
32	7	-495.891	•	•	•	•			•			•	
33	9	-495.731	•	•	•	•	•		•			•	•
34	7	-495.578	•	•	•	•	•		•				
35	7	-495.529	•	•	•	•		•	•				

Models fit for CH_4 (Bag 1): (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 1," etc.

CH_4 (Bag 1): 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	12	-542.823	-504.911			
SM1[2]	10	-538.826	-506.330	3.997	2	0.136

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

CH_4 (Bag 1): Coefficients and Tests of Effect for the Superset and Reduced Models, with respect to the 11-term design model.

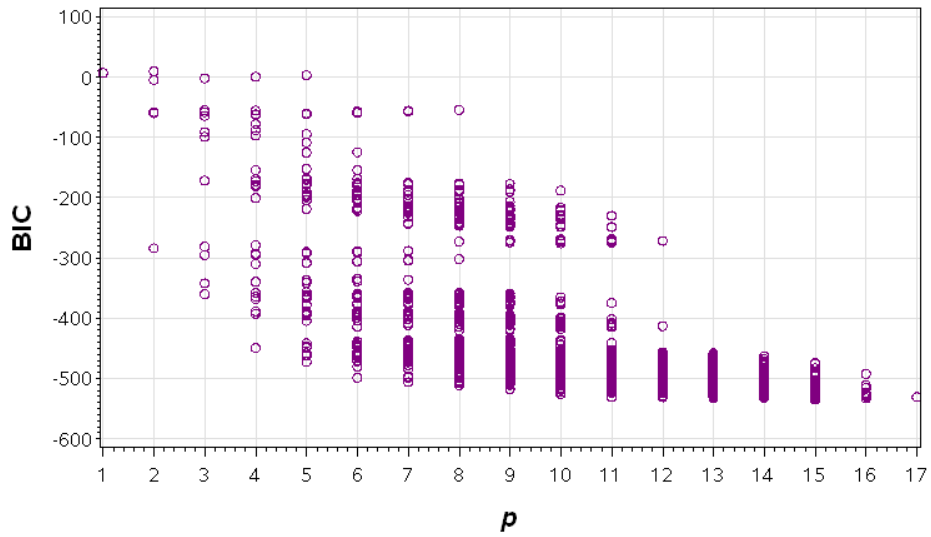
Effect	*Full Model (superset)*					*Reduced Model (SM2)*				
	Estimate	Std. Err.	d.f.	*t* -value	Pr>*t*	Estimate	Std. Err.	d.f.	*t* -value	Pr>*t*
Intercept	-3.0072	0.1380	15	-21.8	0.00000	-3.0074	0.1381	15	-21.8	0.00000
Z_e	0.06938	0.00841	941	8.25	0.00000	0.06994	0.008428	941	8.30	0.00000
Z_a	-0.1055	0.005865	941	-18.0	0.00000	-0.1053	0.005876	941	-17.9	0.00000
Z_r	-0.03439	0.006698	941	-5.13	0.00000	-0.03275	0.006627	941	-4.94	0.00000
Z_5	0.07516	0.008449	941	8.90	0.00000	0.07554	0.008465	941	8.92	0.00000
Z_9	0.003600	0.005867	941	0.61	0.54					
ZZ_{ee}	0.02814	0.01129	941	2.49	0.013	0.02844	0.01131	941	2.51	0.012
ZZ_{55}	0.05185	0.008457	941	6.13	0.00000	0.05170	0.008474	941	6.10	0.00000
ZZ_{ea}	0.02049	0.005737	941	3.57	0.00037	0.02088	0.005745	941	3.63	0.00029
ZZ_{er}	0.008907	0.005852	941	1.52	0.13	0.01082	0.005779	941	1.87	0.062
ZZ_{e5}	0.02983	0.01212	941	2.46	0.014	0.03048	0.01213	941	2.51	0.012
ZZ_{e9}	0.01138	0.005759	941	1.98	0.048					

σ^2_{veh}	0.2853
σ^2_{ε}	0.03001

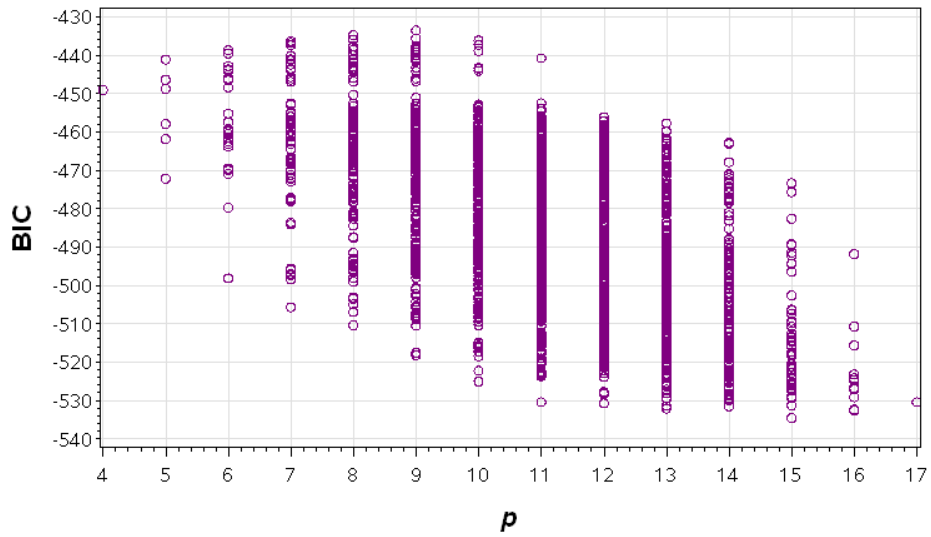
σ^2_{veh}	0.2855
σ^2_{ε}	0.03014

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

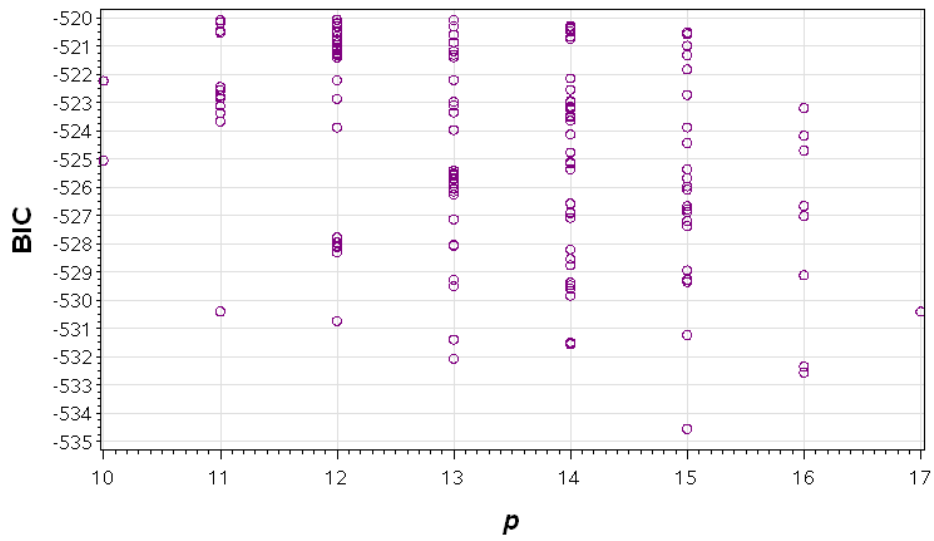
Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model (*p*) for all possible models respecting hierarchy.



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).



CH_4 (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 1-8 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	15	-534.546	•	•	•	•	•	•	•	•		•	•	•	•	•	•	
2	16	-532.551	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
3	16	-532.341	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•
4	13	-532.065	•	•	•	•	•		•	•			•	•	•	•	•	
5	14	-531.548	•	•	•	•	•	•	•	•			•	•	•	•	•	
6	14	-531.484	•	•	•	•	•	•	•	•		•	•	•		•	•	
7	13	-531.384	•	•	•	•	•	•	•	•		•	•			•	•	
8	15	-531.224	•	•	•	•	•	•	•	•	•	•	•	•		•	•	
9	12	-530.726	•	•	•	•	•		•	•			•	•		•	•	
10	17	-530.397	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
11	11	-530.391	•	•	•	•	•		•	•			•			•	•	
12	14	-529.83	•	•	•	•	•	•	•	•	•	•	•			•	•	
13	14	-529.57	•	•	•	•	•		•	•	•		•	•	•	•	•	
14	13	-529.491	•	•	•	•	•	•	•	•			•	•		•	•	
15	14	-529.458	•	•	•	•	•	•	•	•		•	•		•	•	•	
16	14	-529.368	•	•	•	•	•		•	•		•	•	•	•	•	•	
17	14	-529.357	•	•	•	•	•		•	•			•	•	•	•	•	•
18	15	-529.338	•	•	•	•	•	•	•	•		•	•	•	•	•		•
19	15	-529.277	•	•	•	•	•	•	•	•		•	•	•		•	•	•
20	13	-529.262	•	•	•	•	•		•	•	•		•	•		•	•	
21	15	-529.258	•	•	•	•	•	•	•	•	•		•	•	•	•	•	
22	16	-529.107	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
23	15	-528.932	•	•	•	•	•	•	•	•			•	•	•	•	•	•
24	14	-528.751	•	•	•	•	•	•	•	•		•	•			•	•	•
25	14	-528.529	•	•	•	•	•	•	•	•	•		•	•		•	•	
26	12	-528.297	•	•	•	•	•		•	•		•	•			•	•	
27	14	-528.194	•	•	•	•	•	•	•	•		•	•	•	•	•		
28	12	-528.121	•	•	•	•	•		•	•	•		•			•	•	
29	12	-528.07	•	•	•	•	•	•	•	•			•			•	•	
30	13	-528.062	•	•	•	•	•		•	•		•	•	•		•	•	
31	13	-528.024	•	•	•	•	•		•	•			•	•		•	•	•
32	12	-527.945	•	•	•	•	•		•	•			•		•	•	•	
33	12	-527.773	•	•	•	•	•		•	•			•			•	•	•
34	12	-527.751	•	•	•	•	•	•	•	•		•	•			•		
35	15	-527.366	•	•	•	•	•	•	•	•	•	•	•		•	•	•	

Models fit for CH_4 (Bag 1): (all models include an intercept term).

Model Term	Notation	Model	
		Superset	SM2
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}	●	×

CH_4 (Bag 1): Model fitting history, starting with the 15-term superset model.

Fit Parameters				*Test with respect to Previous Model*		
Model	p	-2ln$L$	BIC[1]	Dev.	d	Pr>χ^2
Superset	17	-581.850	-530.397			
SM2[2]	15	-580.583	-534.546	1.267	2	0.531

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

CH_4 (Bag 1): Coefficients and Tests of Effect for the Superset and Reduced Models, with respect to the 16-term extended 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	-3.0065	0.1380	15	-21.8	0.000000	-3.0068	0.1380	15	-21.8	0.000000
Z_e	0.09137	0.009954	941	9.18	0.000000	0.08877	0.009439	941	9.40	0.000000
Z_a	-0.09725	0.006246	941	-15.6	0.000000	-0.09816	0.006199	941	-15.8	0.000000
Z_r	-0.02406	0.008404	941	-2.86	0.0043	-0.02455	0.008296	941	-2.96	0.0032
Z_5	0.10813	0.01109	941	9.75	0.000000	0.1059	0.01067	941	9.92	0.000000
Z_9	0.006944	0.006434	941	1.08	0.28	0.008573	0.006196	941	1.38	0.17
ZZ_{ee}	0.03479	0.01160	941	3.00	0.0028	0.03133	0.01113	941	2.81	0.0050
ZZ_{55}	0.06151	0.009467	941	6.50	0.000000	0.05882	0.008899	941	6.61	0.000000
ZZ_{ea}	0.03944	0.009387	941	4.20	0.000029	0.03977	0.009181	941	4.33	0.000016
ZZ_{er}	0.005566	0.006365	941	0.87	0.38					
ZZ_{e5}	0.03118	0.01226	941	2.54	0.011	0.02883	0.01205	941	2.39	0.017
ZZ_{e9}	0.02377	0.007526	941	3.16	0.0016	0.02655	0.006892	941	3.85	0.00013
ZZ_{ar}	0.02957	0.01017	941	2.91	0.0037	0.02791	0.009975	941	2.80	0.0052
ZZ_{a5}	0.02268	0.01133	941	2.00	0.046	0.02585	0.01075	941	2.41	0.016
ZZ_{a9}	0.03032	0.006365	941	4.76	0.000002	0.03072	0.006248	941	4.92	0.000001
ZZ_{59}	0.02094	0.008467	941	2.47	0.014	0.02280	0.007557	941	3.02	0.0026
ZZ_{r9}	-0.005353	0.007195	941	-0.744	0.46					
σ^2_{veh}	0.2853					σ^2_{veh}	0.2853			
σ^2_{ε}	0.02879					σ^2_{ε}	0.02883			