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 H.4

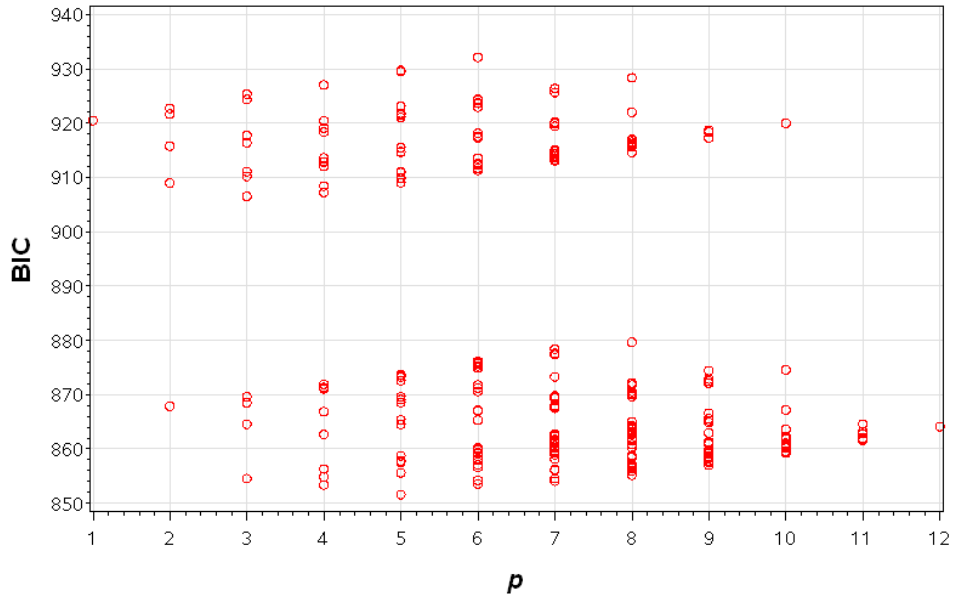
Final Model Fitting

Carbon Monoxide (CO) (Bag 2)

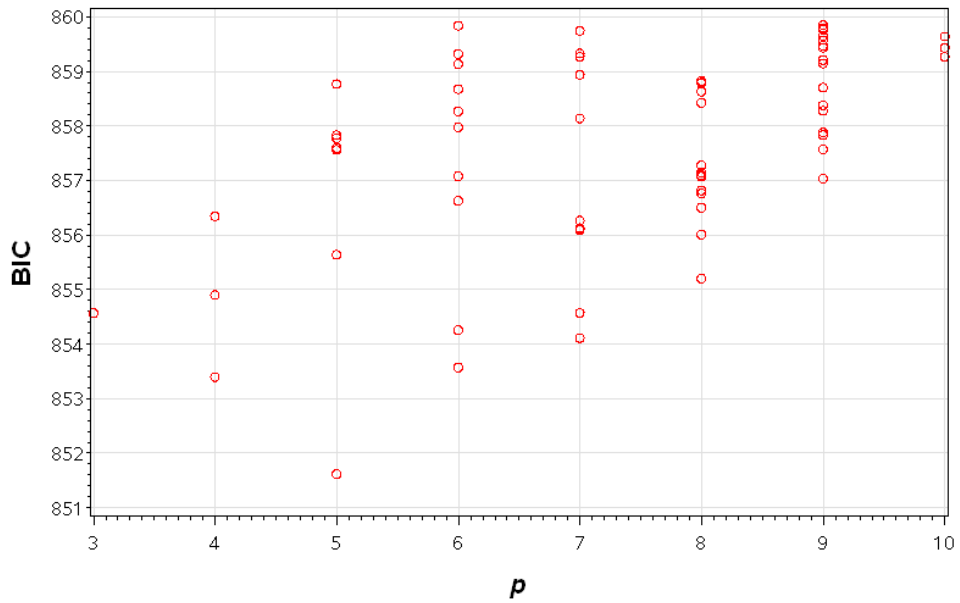
No. Observations:	956
No. Vehicles:	15
No. censored measurements:	0
No. missing measurements:	0
No. measurements removed:	0
Model Type:	Mixed model

H.4.1 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).



CO (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 × etOH	T50 × T50	etOH × Arom	etOH × RVP	etOH × T50	etOH × T90
1	5	851.62		•	•	•	•						
2	4	853.40		•	•		•						
3	6	853.58	•	•	•	•	•						
4	7	854.12	•	•	•	•	•	•					
5	6	854.26		•	•	•	•		•				
6	3	854.57		•			•						
7	7	854.58	•	•	•	•	•						•
8	4	854.90		•		•	•						
9	8	855.21	•	•	•	•	•	•					•
10	5	855.64	•	•	•		•						
11	8	856.01	•	•	•	•	•	•				•	
12	7	856.10	•	•	•	•	•			•			
13	7	856.11	•	•	•	•	•					•	
14	7	856.13	•	•	•	•	•		•				
15	7	856.27	•	•	•	•	•				•		
16	4	856.35	•	•			•						
17	8	856.51	•	•	•	•	•	•		•			
18	6	856.63	•	•	•		•						•
19	8	856.77	•	•	•	•	•	•	•				
20	8	856.82	•	•	•	•	•	•			•		
21	9	857.04	•	•	•	•	•	•				•	•
22	8	857.07	•	•	•	•	•			•			•
23	6	857.08	•	•	•		•	•					
24	8	857.10	•	•	•	•	•		•				•
25	8	857.15	•	•	•	•	•					•	•
26	8	857.28	•	•	•	•	•				•		•
27	5	857.57		•		•	•		•				
28	9	857.58	•	•	•	•	•	•		•			•
29	5	857.60	•	•		•	•						
30	5	857.78	•	•			•						•
31	5	857.84	•	•			•	•					
32	9	857.84	•	•	•	•	•	•	•				•
33	9	857.88	•	•	•	•	•	•			•		•
34	6	857.98	•	•	•		•			•			
35	7	858.14	•	•	•		•	•					•

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

Model Term	Notation	Model		
		Superset	SM3[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}	●	×	

[1] Represents "Superset minus 3," etc.

CO (Bag 2): Model fitting history, starting with the 8-term superset model.

Fit Parameters				*Test with respect to Previous Model*		
Model	*p*	-2ln*L*	BIC[1]	Dev.	*d*	Pr>χ^2
Superset	9	828.049	857.838			
SM3	6	831.913	853.577	3.864	3	0.277
SM4[2]	5	832.664	851.620	0.751	1	0.386

[1] A lower value indicates a better fit.
[2] Best fit with respect to the 11-term design model.

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

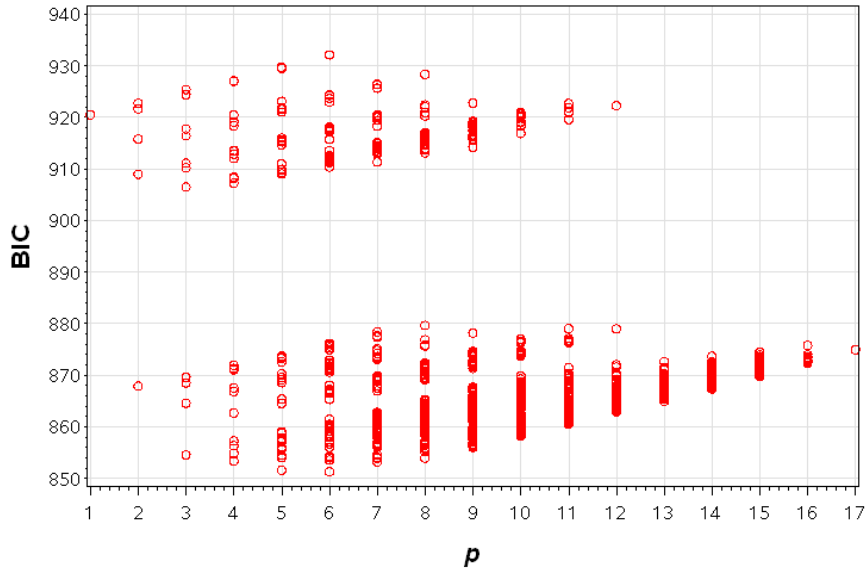
Effect	*Full Model (superset)*					*Reduced Model (SM4)*				
	Estimate	Std. Err.	d.f.	*t*-value	Pr>*t*	Estimate	Std. Err.	d.f.	*t*-value	Pr>*t*
Intercept	-1.3899	0.3578	15	-3.88	0.0015	-1.3893	0.3578	15	-3.88	0.0015
Z_e	0.01949	0.01567	941	1.24	0.21					
Z_a	0.09453	0.01195	941	7.91	0.00000	0.0913	0.0118	941	7.76	0.0000
Z_r	0.03769	0.01351	941	2.79	0.0054	0.0299	0.0122	941	2.45	0.0144
Z_5	0.03936	0.01655	941	2.38	0.018	0.0261	0.0123	941	2.12	0.0342
Z_9	0.04214	0.01190	941	3.54	0.00042	0.0440	0.0118	941	3.73	0.0002
ZZ_{ee}	0.01713	0.01220	941	1.40	0.16					
ZZ_{55}	-0.003339	0.01205	941	-0.277	0.78					
ZZ_{ea}	---	---	---	---	---					
ZZ_{er}	---	---	---	---	---					
ZZ_{e5}	---	---	---	---	---					
ZZ_{e9}	-0.01487	0.01161	941	-1.28	0.20					

σ^2_{veh}	1.9182
σ^2_{ε}	0.1250

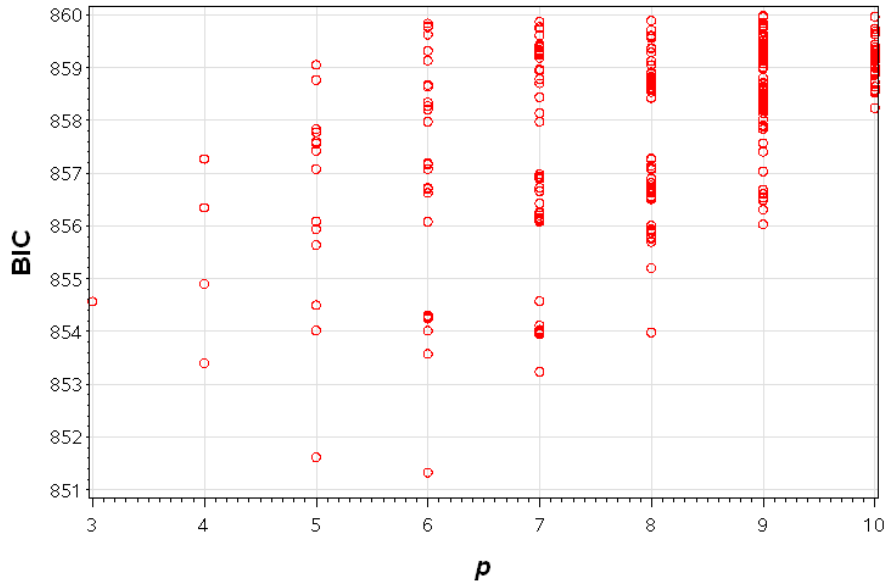
σ^2_{veh}	1.9187
σ^2_{ε}	0.1256

H.4.2 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).



CO (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	6	851.33		•	•	•	•										•	
2	5	851.62		•	•	•	•											
3	7	853.24	•	•	•	•	•										•	
4	4	853.40		•	•		•											
5	6	853.58	•	•	•	•	•											
6	7	853.95		•	•	•	•		•								•	
7	8	853.99	•	•	•	•	•	•									•	
8	7	853.99		•	•	•	•										•	•
9	7	854.01		•	•	•	•							•			•	
10	6	854.02		•	•	•	•							•				
11	5	854.02		•		•	•										•	
12	7	854.03		•	•	•	•									•	•	
13	7	854.04		•	•	•	•								•		•	
14	7	854.12	•	•	•	•	•	•										
15	6	854.25		•	•	•	•											•
16	6	854.26		•	•	•	•		•									
17	6	854.29		•	•	•	•									•		
18	6	854.31		•	•	•	•								•			
19	5	854.50		•	•		•							•				
20	3	854.57		•			•											
21	7	854.58	•	•	•	•	•						•					
22	4	854.90		•		•	•											
23	8	855.21	•	•	•	•	•	•					•					
24	5	855.64	•	•	•		•											
25	8	855.70	•	•	•	•	•			•							•	
26	8	855.77	•	•	•	•	•					•					•	
27	8	855.77	•	•	•	•	•		•								•	
28	8	855.79	•	•	•	•	•						•				•	
29	8	855.88	•	•	•	•	•									•	•	
30	8	855.91	•	•	•	•	•				•						•	
31	8	855.93	•	•	•	•	•							•			•	
32	8	855.94	•	•	•	•	•										•	•
33	8	855.94	•	•	•	•	•								•		•	
34	5	855.95		•	•		•									•		
35	8	856.01	•	•	•	•	•	•				•						

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

Model Term	Notation	Model		
		Superset	SM3[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 3, etc."

CO (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	10	826.828	859.325			
SM3	7	828.868	853.241	2.040	3	0.564
SM4[2]	6	829.667	851.331	0.798	1	0.37

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

CO (Bag 2): 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 (SM4)*				
	Estimate	Std. Err.	d.f.	*t*-value	Pr>*t*	Estimate	Std. Err.	d.f.	*t*-value	Pr>*t*
Intercept	-1.3897	0.3579	15	-3.88	0.0015	-1.3895	0.3579	15	-3.88	0.0015
Z_e	0.01931	0.01588	941	1.22	0.22					
Z_a	0.10080	0.01262	941	7.98	0.00	0.09800	0.01237	941	7.92	0.00000
Z_r	0.03490	0.01350	941	2.58	0.01	0.02839	0.01220	941	2.33	0.020
Z_5	0.03835	0.01672	941	2.29	0.02	0.02484	0.01229	941	2.02	0.043
Z_9	0.04201	0.01187	941	3.54	0.00	0.04177	0.01186	941	3.52	0.00045
ZZ_{ee}	0.01660	0.01227	941	1.35	0.18					
ZZ_{55}	-0.00342	0.01239	941	-0.28	0.78					
ZZ_{ea}	---	---	---	---	---	---	---	---	---	---
ZZ_{er}	---	---	---	---	---	---	---	---	---	---
ZZ_{e5}	---	---	---	---	---	---	---	---	---	---
ZZ_{e9}	---	---	---	---	---	---	---	---	---	---
ZZ_{ar}	---	---	---	---	---	---	---	---	---	---
ZZ_{a5}	---	---	---	---	---	---	---	---	---	---
ZZ_{a9}	---	---	---	---	---	---	---	---	---	---
ZZ_{59}	0.02133	0.01321	941	1.61	0.11	0.02177	0.01256	941	1.73	0.083
ZZ_{r9}	0.00025	0.01295	941	0.02	0.98					
σ^2_{veh}	1.9197					σ^2_{veh}	1.9196			
σ^2_{r}	0.1248					σ^2_{r}	0.12520			