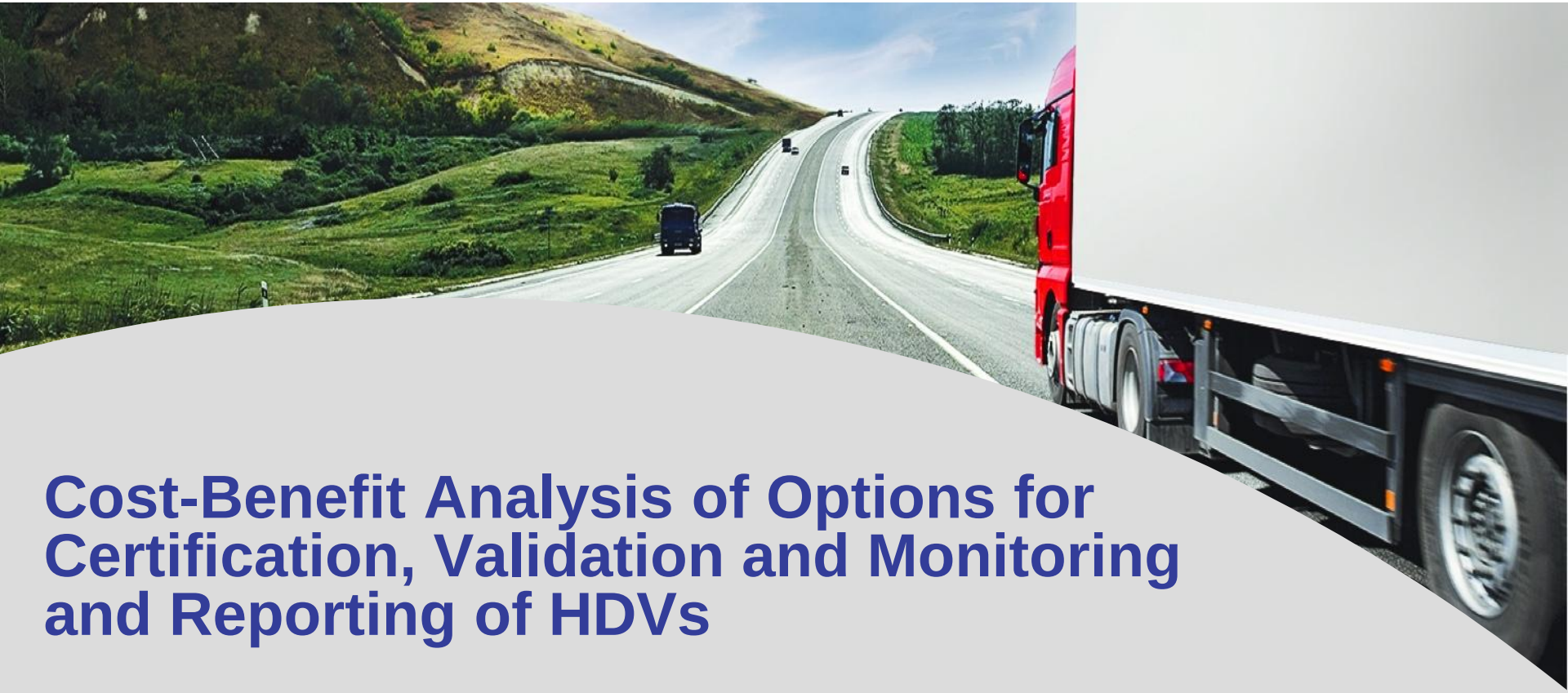

Cost-Benefit Analysis of Options for Certification, Validation and Monitoring and Reporting of HDVs

Leif-Erik Schulte
Vicente Franco

Brussels, January, 30th 2015

Overview

- Introduction
- Technical Assessment
  - CO_2 Determination Methodology (Task 1)
  - Confomity of Production / Ex-Post Validation (Task 2)
- Cost Assessment
  - CO_2 Determination Methodology (Task 1)
  - Confomity of Production / Ex-Post Validation (Task 2)

Introduction

A specific service request has been issued by the EC under Framework Service Contract CLIMA.C.2/FRA/2013/0007. The work under this contract, managed by TNO, has the following objectives:

- to identify, define and assess options for Certification, Validation, and Reporting and Monitoring of fuel consumption and CO_2 emissions from heavy-duty vehicles.
- to determine the costs of these options to the relevant stakeholders.

Tasks

- Task 1 Certification (TüV NORD)
- Task 2 Ex-post validation (TüV NORD)
- Task 3 Monitoring and reporting (TNO)
- Task 4-6 Costs for tasks 1-3 (ICCT)
- Task 7 Stakeholder consultation (ICCT)

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  - CO_2 Determination Methodology (Task 1)
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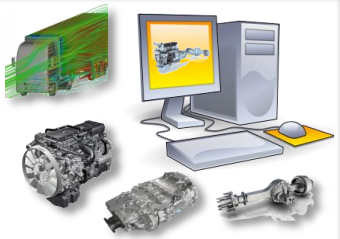
CO_2 Determination Methodology

Overview

Options

D1	D2	D3	D4	D5
				

Simulation based Engine Testing (HILS)

Real Driving

Chassis Dyno

Reduced Testing Effort and Simulation

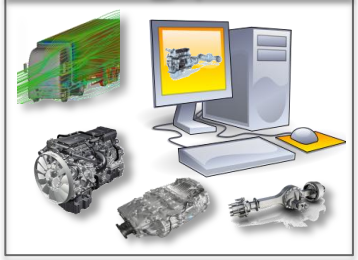
Component Testing and Simulation (baseline option)

CO_2 Determination Methodology

Component Testing and Simulation

Options

D1



D2

D3

D4

D5

Pros

+ Determination of vehicle specific CO_2 emission / fuel consumption
+ High accuracy possible if use of default is minimized
+ Easy determination of CO_2 emissions / fuel consumption for different mission profiles and payloads
+ No driver influence
+ Good repeatability and reproducibility (vs. mismatch . . .)

Cons

- Possible mismatch between simulation and reality (cycle, gear change, etc.)
- Possible operating errors of tool or data handling
- High testing effort on component level

CO_2 Determination Methodology

Reduced Testing Effort and Simulation

Options

D1

D2

D3

D4

D5

Pros

+ Lower effort compared to baseline option

Cons

- Loss of accuracy
- Loss of technology driver
- Similar to (large) family concept

Option for niche products?

CO_2 Determination Methodology

Chassis Dyno Testing

Options

D1 D2 **D3** D4 D5

Pros

+ Real operation of complete system
+ Laboratory conditions (ambient)

Cons

- Family approach needed
- Driver influence
- Repeatability / Reproducability
- Availability of test benches
- No technology driver for single components

CO_2 Determination Methodology

Real Driving

Options

D1

D2

D3

D4

D5

Pros

+ Real operation of complete system under real conditions

Cons

- Family approach needed
- Limited to poor repeatability, reproducability, comparability
- No technology driver for single components

CO_2 Determination Methodology

Simulation based Engine Testing (HILS)

Options

D1

D2

D3

D4

D5

Pros

+ High accuracy
+ Dynamic behaviour of engine included
+ Comparable option to D1 and D2

Cons

- High engine testing effort
- Family approach could become necessary to limit effort

CO_2 Determination Methodology
Summary

		Costs	Timeline	Comparability between vehicles	Technical feasibility	Accuracy	Stakeholder preference	Notes
D1	**Simulation and component testing**							Preferred by both industrial and non-industrial stakeholders
D2	**Simulation and reduced effort component testing**							Alternative for niche vehicles. Lowest total estimated cost.
D3	**Chassis dynamometer testing**							Alternative for ex-post validation due to better real world representation of whole vehicle. Fleet coverage is diminished in comparison to simulation options (D1, D2 and D5).
D4	**On-road testing (PEMS / fuel flow meters)**							Alternative for ex-post validation due to best real-world representation of whole vehicle. Fleet coverage is diminished in comparison to simulation options (D1, D2 and D5). Least preferred option from industrial stakeholders.
D5	**Simulation and transient engine testing**							Alternative for hybrids. Highest total estimated costs.

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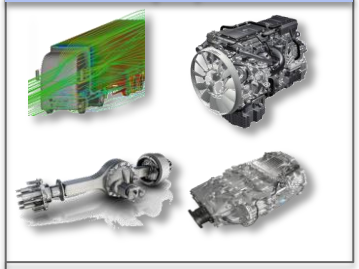
Confomity of Production / Ex-Post Validation

Overview

Confomity of Production

Ex-Post Validation

P1



P2

P3

Vehicle specific CoP
- SiCo
- Real Driving

Process specific CoP

Comoponent specific CoP

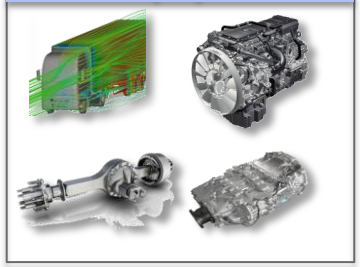
Confomity of Production / Ex-Post Validation

Component specific

Confomity of Production

Ex-Post Validation

P1



P2

P3

Pros

+ Direct quality control on component level
+ Use of simplified test procedures possible

Cons

- No control of the complete process, e.g. operating error during certification
- Transfer of responsibility to component supplier => number of involved parties / administrative burden

Confomity of Production / Ex-Post Validation

Process specific

Confomity of Production

Ex-Post Validation

P1

P2

P3

Pros

+ Control of complete process
+ Only few values to control

Cons

- No simplification of component test procedures possible
- Further CoP levels needed to identify components causing non-conformity

Confomity of Production / Ex-Post Validation

Vehicle specific

Confomity of Production

Ex-Post Validation

P1

P2

P3

Pros

+ Identification of misuse / handling errors of VECTO

Cons

- Real driving requires high conformity factors for CoP due to poor repeatability, reproducability
- Further CoP levels needed to identify single components causing non-conformity

Confomity of Production / Ex-Post Validation
Summary

		Costs	Timeline	Comparability between vehicles	Technical feasibility	Accuracy (depends on D option)	Stakeholder preference	Notes
P1	**Component-specific CoP**							Preferred option for OEMs and TAA and Technical Services.
P2	**Process-specific CoP**							
P3	**Vehicle-specific CoP**							Preferred option for research bodies, consultancies and NGOs. Least preferred option for industrial stakeholders.

Certification related Issues

Non-Standard Bodies/Trailers/Semi-Trailers a

Current status (Lot3): 1-Stage certification on basis of standard bodies/trailers/semi-trailers

Vehicle Combinations

Source: DAF

Multi-Stage

Manufacturer A

Manufacturer B

Source: Mercedes Benz

Certification of non-standard bodies/trailers/semi-trailers to stipulate introduction of fuel/CO_2 efficient bodies/trailers/semi-trailers

Certification related Issues

Non-Standard Bodies/Trailers/Semi-Trailers and Multi-Stage

Certification of non-standard bodies/trailers/semi-trailers to stipulate introduction of fuel/CO_2 efficient bodies/trailers/semi-trailers

Option 1
Complete VECTO Simulation

Body/Trailer/Semi-Trailer Config.

Chassis Identification

Component Testing

Air Drag (Testing or CFD)

VECTO Vehicle Energy Consumption Calculation Tool

with original OEM input data and updated air drag

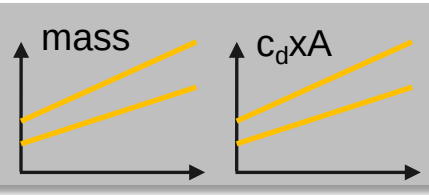
Option 2
Table values

Body/Trailer/Semi-Trailer Config.

Chassis Identification

Component Testing

Air Drag (Testing or CFD)



influence on CO_2 / FC from first stage certification

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- Costs of certification
- Costs of CoP
- Conclusions and recommendations

Costs of certification

Methodology

1. Determining which cost components are relevant to the option
2. Evaluating the cost associated with each component (as a synthesis of several different sources)
3. Aggregating and allocating the costs for each option (based on the number of times that each cost component is required for each vehicle certified or sold)

Costs of certification

Cost structure for “D” options: assumptions

Assumption	Rationale
The estimated costs are referred to **vehicle OEMs**	Vehicle OEMs have a key position in the value chain. This assumption enables the allocation of estimated cost to vehicle sales by means of commercial HDV databases.
Segmentation of vehicle OEMs	*Two different tiers of vehicle OEMs were defined* to investigate the changes in the impact of the regulation with the size of OEMs.
Time horizon	The commercial lifetime of a vehicle variant was required for the calculation of annual costs of determination options. The lifetime was determined to be approximately five years, and the commercial lifetime of vehicle families was determined to be ten years.
The costs of testing tyres and auxiliaries are not included	Tyre manufacturers already determine the rolling resistance coefficient of tyres according to EC 458/2011. Auxiliaries were excluded due to the uncertainty about nature of tests and lack of cost data.
Marginal cost of simulations	The cost of simulation covers all the relevant runs necessary for the given vehicle. Simple modifications of the simulation file and subsequent re-runs do not bring about additional costs.

Cost structure for “D” options: data sources

Data source	Primary use
Stakeholder questionnaire	Identification of cost components associated to certification. Estimation of **capital investments** required for each “D” option, as well as the individual costs of the **relevant physicals tests** and simulations.
Structured interviews	Further refinement of the cost components and estimates gathered from the stakeholder questionnaire.
Database IHS1 (IHS 2013)	Estimation of the average variant-to-manufacturer ratios. Estimation of average commercial lifetime. Estimation of cost allocation ratios (**Q coefficients**): average model family-to-variant and transmission-to-variant ratios.
Database IHS2 (IHS 2012a)	Database on European HDV engine production, including forecasts up until 2018. Yields engine-to-variant, transmission-to-variant and other relevant ratios for the allocation of costs to vehicle variants).
Database IHS3 (IHS 2012b)	Database on European HDV chassis production, including forecasts up until 2018. Yields estimates for unique tractor bodies and commercial lifetime and lifetime sales of models.

Costs of certification

Generic cost structure for “D” options

	Variable costs	Fixed costs
Direct costs	**Air drag**: cost of performing an air drag test. This may be a physical air drag test (constant speed test, options D3, D4) or a CFD simulation (relevant to option D2) [EUR/test or simulation]	**Staff training**: costs incurred [additional annual person-hours multiplied by an estimate of hourly training costs]
	Transmission: cost of performing a transmission test to determine the power transmission efficiency for all gears [EUR/test]	
	Axle: cost of performing an axle test to determine the power transmission efficiency [EUR/test]	**Additional staff**: costs incurred [additional number of staff required multiplied by an estimate of annual staff costs]
	Engine: cost of performing a modal engine test to determine a steady-state fuelling rate map (options D1, D2) or a transient test (D5)	
	VECTO: cost of entering the relevant data to the simulation tool and running the simulation according to the requirements of the regulation (using the tool’s “declaration mode”; this is a desktop activity) [EUR/vehicle simulated; marginal cost of simulation runs is negligible]	
Indirect costs	No indirect variable costs were identified within the scope of the analysis.	**Other:** Lump estimate of indirect fixed costs [EUR p.a.]

Costs of certification

Estimated costs for option D1 (baseline): *transition* costs

Cost type	Item costs				Transition costs					
					Large manufacturers			Medium manufacturers		
	Cost component	Cost type	Estimated Cost	Base	Q	Q * C	Q * C / VS	Q	Q * C	Q * C / VS
Direct variable costs	air drag	test	€ 10 000	component	132.0	1 320 000	€ 34.46	53.3	532 500	€ 29.63
	transmission	test	€ 20 000	component	39.0	780 000	€ 20.36	31.3	625 000	€ 34.77
	axle	test	€ 6 250	component	3.5	21 875	€ 0.57	3.5	21 875	€ 1.22
	engine	test	€ 5 325	component	39.0	207 675	€ 5.42	31.3	166 406	€ 9.26
	VECTO	simulation	€ 100	certified vehicle	1 609.7	160 967	€ 4.20	1 066.0	106 600	€ 5.93
	RRC	default	€ -	component	-	-	€ -	-	-	€ -
	auxiliaries	default	€ -	component	-	-	€ -	-	-	€ -
	Total direct variable costs			manufacturer	-	2 490 517	€ 65.02	-	1 452 381	€ 80.81
Fixed costs	Cost component	Cost type	Estimated Cost	Base	Large manufacturers			Medium manufacturers		
					Q	Q * C * N	Q * C * N / VS	Q	Q * C * N	Q * C * N / VS
	Training	estimate	€ 600	manufacturer	16.3	29 250	€ 0.76	5.7	10 293	€ 0.57
	Additional staff	estimate	€ 60 000	manufacturer	2.5	450 000	€ 11.75	0.9	158 358	€ 8.81
	Other	estimate	€ 200 000	manufacturer	1.0	600 000	€ 15.66	0.4	211 145	€ 11.75
	Total direct/indirect fixed costs			manufacturer	-	1 079 250	€ 28.17	-	379 796	€ 21.13
Grand total					-	3 569 767	€ 93.19	-	1 832 178	€ 101.94

Costs are allocated to individual *vehicle sold*

Cost of certification

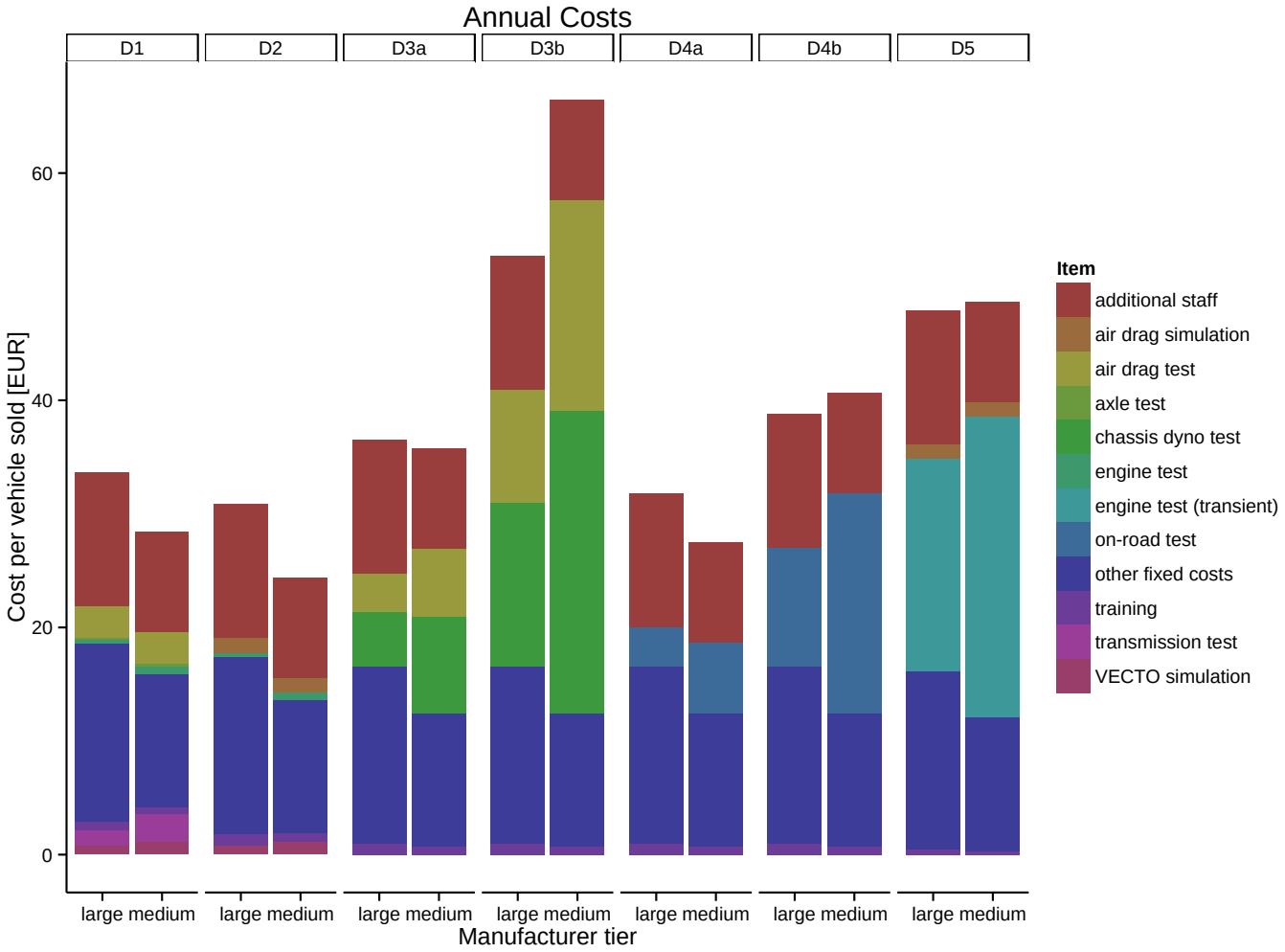
Estimated costs for option D1 (baseline): *annual* costs

Cost type	Item costs				Annual costs					
					Large manufacturers			Medium manufacturers		
	Cost component	Cost type	Estimated Cost	Base	Q'	Q' * C	Q' * C / VS	Q'	Q' * C	Q' * C / VS
Direct variable costs	air drag	test	€ 10 000	component	10.6	105 783	€ 2.76	4.9	48 835	€ 2.72
	transmission	test	€ 20 000	component	2.5	50 874	€ 1.33	2.2	43 519	€ 2.42
	axle	test	€ 6 250	component	1.2	7 292	€ 0.19	0.9	5 469	€ 0.30
	engine	test	€ 5 325	component	2.5	13 545	€ 0.35	2.2	11 587	€ 0.64
	VECTO	simulation	€ 100	certified vehicle	321.9	32 193	€ 0.84	213.2	21 320	€ 1.19
	RRC	default	€ -	component	-	-	€ -	-	-	€ -
	auxiliaries	default	€ -	component	-	-	€ -	-	-	€ -
	Total direct variable costs			manufacturer	-	209 688	€ 5.47	-	130 729	€ 7.27
					Large manufacturers			Medium manufacturers		
Fixed costs	Cost component	Cost type	Estimated Cost	Base	Q'	Q' * C * N	Q' * C * N / VS	Q'	Q' * C * N	Q' * C * N / VS
	Training	estimate	€ 600	manufacturer	16.3	29 250	€ 0.76	5.7	10 293	€ 0.57
	Additional staff	estimate	€ 60 000	manufacturer	2.5	450 000	€ 11.75	0.9	158 358	€ 8.81
	Other	estimate	€ 200 000	manufacturer	1.0	600 000	€ 15.66	0.4	211 145	€ 11.75
	Total direct/indirect fixed costs			manufacturer	-	1 079 250	€ 28.17	-	379 796	€ 21.13
Grand total					-	1 288 938	€ 33.65	-	510 525	€ 28.40

Costs are allocated to individual *vehicle sold*

Cost of certification

Estimated costs for all options: *annual* costs

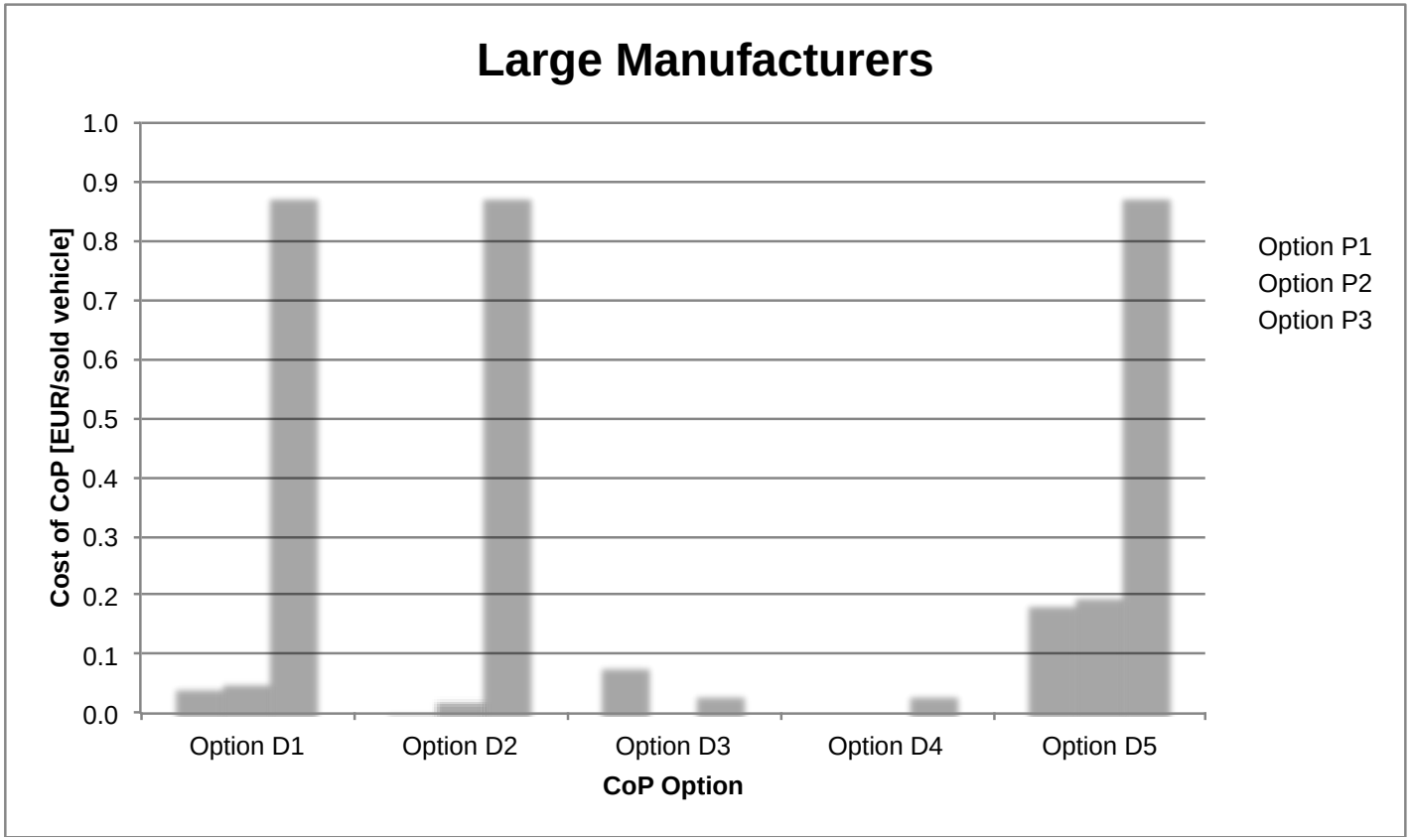


Cost structure for “P” options: assumptions

Assumption	Rationale
Option P1: Component-specific CoP	Option P1 relies on ensuring that the input data for the simulation of CO_2 emissions is valid (it therefore applies to options D1, D2 and D5). This option is based on the assumption that, if the specifications of the different components conform to the data delivered for the certification of the vehicle, then the certified vehicle is in conformity. It was assumed that **one percent of components would be retested**.
Option P2: Process-specific CoP	Option P2 consists of replicating the CO_2 determination process, including retesting components and rerunning the simulation for a portion of certified vehicles. It was assumed that **one percent of component tests and simulations would be repeated**. The process-specific CoP was determined to be **unsuitable for options D3 and D4**, as these options do not rely on simulations.
Option P3: Vehicle-specific CoP	Option P3 relies on confirming a vehicle’s CO_2 emission value based on **PEMS on-road measurements or measurements on a test track**. Under determination options D1, D2, and D5, **one percent of the certified vehicles would be tested**. Under options D3 and D4, **ten percent of vehicle families would be retested**.

Costs of CoP

Estimated costs of “P” options



Conclusions and recommendations

“D” options

1. Options D1 (baseline) and D2 (simplified baseline) are the most cost-effective, provide the best fleet coverage.
2. Options D3 and D4 only comparable in cost to D1, D2 if a broad family concept is adopted (there is a tradeoff between cost an fleet coverage).
3. Option D5 is not cost-effective due to the large number of transient engine tests it requires.

Conclusions and recommendations

“P” options

1. For similar levels of coverage, options P1 (component-specific) and P2 (process-specific) are vastly more cost-efficient than option P3 (vehicle-specific conformity of production).
2. The cost-effectiveness of simulation approaches (options D1, D2) are carried over to CoP.
3. The estimated additional costs per sold vehicle are EUR 0.05 and 0.07 for large and medium manufacturers (1% coverage).

Thank you for your attention