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Publishable Executive Summary

The general objective of WP6 is to demonstrate, validate and analyse the feasibility of the AEROFLEX innovations. The innovations being part of WP6 are the WP2 distributed powertrain technology called Advanced Energy Management PowerTrain (AEMPT), WP3 advanced vehicle aerodynamics (AeroLoad) and WP4 Smart Loading Units (SLU).

Based on the measurement protocols and test matrix defined in the deliverable 6.3, WP6 has carried out the indicated testing activities to obtain and evaluate the reference results.

The first phase of the testing activities described in this report are performed on the following reference vehicles also called test cases:

Vehicle classification	Configuration	Name	Role
Zero-case vehicle		Zero-case (4x2)	Standard vehicle selected as reference to compare all the innovations developed on the Aeroflex project.
Reference vehicles	  	EMS1 reference AEMPT (6x2) EMS1 reference Aeroload (6x2) Reference Aeroload (4x2)	EMS1 standard vehicles configuration selected as baseline to directly compare the EMS1 improvements developed on the Aeroflex project. Reference baseline vehicle to compare the Aeroload innovations.
Advanced reference vehicles	 	Advanced reference AEMPT (4x2) Advanced reference AeroLoad (4x2)	Semitrailers developed on previous EU Transformers project and improved on Aeroflex project. Tested as advanced reference vehicle to identity the benefits of its current configuration.
Control vehicle		Control vehicle (4x2)	To obtain accurate fuel consumption results and be able to carry out a long testing campaign as defined in SAE protocols, it has included the control vehicle to identify possible deviation of the fuel consumption results caused for external conditions. Test use-cases 1 and 2.

According to the test programme the following activities called test use-cases are carried out:

- Test use-case 1: Fuel consumption tests at steady-state speed on high speed test track
- Test use-case 2: Fuel consumption tests on the public road, called Fraga route.
- Test use-case 3: Air drag on test track
- Test use-case 4: Vehicle dynamics measurements on test track

The objective of the testing activities described above is to identify the reference results on the following KPI's defined in deliverable 6.1 to be compared to the second test phase results of the demonstrator vehicles:

- Fuel consumption efficiency
  - Fuel consumption [l/km] (Energy consumption)
  - Fuel consumption [l/tonne-km] (Energy efficiency)
  - Average vehicle speed [km/h]
- Aerodynamic efficiency
  - Air drag reduction factor [-]
- Safety standards
  - Startability
  - Gradeability
  - Acceleration capability
  - Low-speed swept path width
  - Tail swing
  - Static rollover threshold
  - Rearward amplification
  - Directional stability under braking
  - High-speed transient off-tracking (HSTO)
  - Yaw damping
  - 360º Circle

The initial part of the test campaign was focused on provide baseline of fuel consumption results in reference (advances) vehicles. Thus, the comparisons done cover only the reference vehicles. The following table shows the fuel consumption results obtained [l/100km], taken as reference the Zero-case vehicle.

	TEST USE CASE 1				TEST USE CASE 2			
	50% Load Weight		GCW Weight		50% Load Weight		GCW Weight	
	Result	Confidence interval	Result	Confidence interval	Result	Confidence interval	Result	Confidence interval
Zero-case	**Ref.1**	0.6%	**Ref.2**	0.4%	**Ref.3**	0.8%	**Ref.4**	0.2%
Adv. Ref. AEMPT vs MAN Zero-case	**1.8%**	1.1%	**0.5%**	0.3%	**-4.4%**	3.0%	**-5.9%**	1.2%
EMS 1 Ref. AEMPT vs MAN Zero-case	**29.9%**	3.2%	**30.0%**	0.6%	**36.9%**	0.5%	**31.9%**	1.7%
Ref. Aeroload vs MAN Zero-case	**-10.2%**	1.0%	**-11.1%**	1.0%	**-7.8%**	1.0%	**-11.8%**	0.3%
Adv. Ref. Aeroload vs MAN Zero-case	**-14.0%**	0.9%	**-17.6%**	0.4%	**-6.1%**	2.2%	**-13.9%**	1.1%
EMS 1 Ref. Aeroload vs MAN Zero-case	**22.2%**	1.4%	**18.3%**	1.4%	**31.9%**	1.1%	**23.2%**	0.7%

Table 1. Test use case 1 and 2. Fuel consumption zero case comparative (l/100km)

After analysing the results obtained in each vehicle configuration (three runs for each test use-case 1 and 2 and load configuration). We consider that the repeatability and accuracy of the results fulfils the requirements of the project and provides a good reference to compare with the prototype vehicles to be evaluated in the second testing campaign.

To provide additional information of the influence of the vehicle payload in the fuel consumption results and as defined in the KPI's list, the evaluation and comparison of the results in l/tonne km obtained in each vehicle is detailed in the following table.

	TEST USE CASE 1				TEST USE CASE 2			
	50% Load Weight		GCW Weight		50% Load Weight		GCW Weight	
	Result	Confidence interval	Result	Confidence interval	Result	Confidence interval	Result	Confidence interval
Zero-case	**Ref.1**	0,6%	**Ref.2**	0,4%	**Ref.3**	0,8%	**Ref.4**	0,2%
Adv. Ref. AEMPT vs MAN Zero-case	**2.1%**	1.1%	**9.1%**	0.3%	**-4.2%**	3.0%	**-4.6%**	1.2%
EMS 1 Ref. AEMPT vs MAN Zero-case	**-17.5%**	3.2%	**-10.2%**	0.6%	**-13.1%**	0.5%	**-8.8%**	1.7%
Ref. Aeroload vs MAN Zero-case	**-10.2%**	1.0%	**-4.8%**	1.0%	**-7.7%**	1.0%	**-5.5%**	0.3%
Adv. Ref. Aeroload vs MAN Zero-case	**-13.6%**	0.9%	**1.0%**	0.4%	**-5.8%**	2.2%	**5.5%**	1.1%
EMS 1 Ref. Aeroload vs MAN Zero-case	**-22.4%**	1.4%	**-16.4%**	1.4%	**-16.2%**	1.5%	**-13.0%**	0.7%

Table 2. Test use case 1 and 2. Fuel consumption zero case comparative (l/tonne km)

EMS1 vehicles have the greatest benefit when comparing consumption results in l/tonne km

In public route tests (Fraga route), the type of vehicle has an important influence on the average speed of the route, so it is important to evaluate the differences obtained on the different test cases as a KPI. This information is not considered confidential; thus, the following table shows directly the reference vehicles average speed results obtained for the repetitions done in each route and the deviations taking as reference the Zero-case.

	TEST USE CASE 2					
	50% Load Weight			GCM Weight		
	Average speed (km/h)	Difference	Confidence interval	Average speed (km/h)	Difference	Confidence interval
Zero-case	**74.5**	**---**	0.3%	**73.7**	**---**	1.6%
Adv. Ref. AEMPT vs MAN Zero-case	**76.1**	**2.1%**	0.7%	**75.3**	**2.2%**	1.4%
EMS 1 Ref. AEMPT vs MAN Zero-case	**73.3**	**-1.7%**	1.0%	**71.9**	**-2.4%**	1.5%
Ref. Aeroload vs MAN Zero-case	**74.9**	**0.6%**	0.6%	**73.4**	**-0.4%**	1.2%
Adv. Ref. Aeroload vs MAN Zero-case	**74.9**	**0.5%**	0.6%	**73.8**	**0.2%**	1.1%
EMS 1 Ref. Aeroload vs MAN Zero-case	**74.9**	**0.5%**	1.2%	**73.5**	**-0.3%**	1.6%

Table 3. Test use-case 2. Average speed comparative

Based on the results obtained in this first phase of the fuel consumption tests on the reference vehicles, WP6 calibrated and validated the simulation models used in the assessment framework to be ready to quantify the impact of the AEROFLEX innovations for various relevant logistic applications (as part of deliverable 6.6).

The aim of the test use-case 3 is to measure the aerodynamic resistance of the vehicles by measuring the torque applied to the drive wheels at high and low speed and compare them. During the test, the air velocity, its yaw angle and the vehicle speed are measured and considered in order to obtain a result of the influence of the wind on the vehicle.

The results of the following table are given as a percentage of variation from the average of the zero case and each one of the results of the different tests.

	TEST USE CASE 3	
	Result	Confidence interval
Zero-case	**Ref.1**	0.1%
Adv. Ref. AEMPT vs MAN Zero-case	**-4.1%**	1.5%
EMS 1 Ref. AEMPT vs MAN Zero-case	**20.9%**	1.6%
Adv. Ref. Aero 1 vs MAN Zero-case	**-11.0%**	1.6%
Adv. Ref. Aero 2 vs MAN Zero-case	**-20.6%**	0.8%
Adv. Ref. Aero 3 vs MAN Zero-case	**-23.8%**	2.1%
EMS 1 Ref. Aeroload vs MAN Zero-case	**5.3%**	0.8%

Table 4. Test use-case 3. Airdrag comparative

The improvements between the several advance references are in line with which it could be expected. At the same time, due the EMS1 (6x2) vehicle characteristics, the airdrag results obtained are worse than the standard 4x2 + semi-trailer configuration.

The reference dynamic results are done on a EMS1 reference vehicle according to the Australian Performance Based Standards. The low and high-speed KPIs are quantified for the respective manoeuvres in the clockwise and anti-clockwise direction. All the KPIs of the test vehicle are summarized above, which is the average of the performance achieved by the test vehicle in clockwise and anti-clockwise directions.

Key Performance Indicators	Average performance achieved	PBS Level achieved
1. Startability, [% grade]	15	1
2. Gradeability-A, [% grade]	18	2
3. Gradeability-B, [km/h]	> 70	2
4. Acceleration capability, [s]	15.6	1
5. Directional stability under braking: (a) Average deceleration, [g] (b) Maximum lane-width, [m]	 0.37 2.9	Acceptable
6. Frontal swing: (a) Maximum frontal swing (FS_{max}), [m] (b) Difference of maxima (DOM), [m] (c) Maximum of difference (MOD), [m]	 0.47 0.33 0.32	Acceptable
7. Tail swing at entry (TS_{entry}), [m]:	0.20	1
8. Low-speed swept path width (SPW): (a) 90 degree, [m] (b) 360 degree, [m]	 6.67 7.85	 1 2
9. Rearward amplification (RA), [-]	1.54	Acceptable
10. High-speed transient off-tracking ($HSTO$): (a) Overshoot, [m] (b) Undershoot, [m]	 0.09 -0.01	1
11. Yaw damping coefficient (YD), [-]	0.37	Acceptable
12. Static rollover threshold (SRT), [g]	> 0.47	Acceptable

Table 5: Test use-case 4. Dynamic results

Sections 1 to 5 are directly taken from test data. Section 6 to 12 are obtained by performing PBS tests (as per the specification) with the validated vehicle model for determining the KPIs final values.
PBS level are listed from 1 to 4, being the Level 1 the better and Level 4 the worse. Main part of the KPI's evaluated stays inside the Level 1 and 2 and passes the criteria in acceptable where is only indicated a minimum value to reach.

These results will be taken as reference and compared on EMS1 and EMS2 prototype vehicles in order to determine the possible improvements on the dynamic standards.

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Project partners:

#	Partner	Partner Full Name
1	MAN	MAN TRUCK & BUS AG
2	DAF	DAF Trucks NV
3	IVECO	IVECO S.p.A
4	SCANIA	SCANIA CV AB
5	VOLVO	VOLVO TECHNOLOGY AB
6	CRF	CENTRO RICERCHE FIAT SCPA
7	UNR	UNIRESEARCH BV
8	SCB	SCHMITZ CARGOBULL AG
9	VEG	VAN ECK BEESD BV
10	TIRSAN	TIRSAN TREYLER SANAYI VE TICARET A.S.
11	CREO	CREO DYNAMICS AB
12	MICH	MANUFACTURE FRANCAISE DES PNEUMATIQUES MICHELIN
13	WABCO	WABCO Europe BVBA-SPRL
14	CHALM	CHALMERS TEKNISKA HOEGSKOLA AB
15	DLR	DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV
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17	HAN	STICHTING HOGESCHOOL VAN ARNHEM ENNIJMEGEN HAN
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