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Efficient route of freight transport by road, evaluated with Innotransmer

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Abstract

The need to make transport more efficient in order to make it less dependent on fossil fuels, more sustainable and reduce GHG emissions is included in the guidelines of the European Union. One measure to achieve this objective has been for manufacturers to improve engine performance so as to reduce GHG emissions according to regulations EURO I to VI of commercial vehicles for the transport of goods by road. This has resulted in significant savings in the fuel bill for the transport sector; however, the choice of route remains an important element to improve efficiency. In order to make this decision it is important to take into account:

- Travel time / distance travelled / number of tolls en route.
- Layout of slopes / consumption / average speeds.
- Technical characteristics of vehicles / power / number of axles / tonnes transported.

In line with these objectives, the 2011 INNPACTO program by the Ministry of Science and Innovation approved a project called "Simulation platform for the development of innovative solutions in freight transport through high capacity roads (INNOTRANSMER, 2011)", with the aim of developing an electronic platform which enabled freight companies to assess the most efficient routes with different vehicles and tracks, in order to determine the transport configuration with the lowest consumption/cost per tonne transported in trucks, thus creating a new instrument to assess transport efficiency and GHG emissions for a certain trip.

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Keywords: efficient route; freight transport; road.

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1. Introduction

The EU has promoted efficiency in freight transport by road and the reduction of its emissions since 1988, when the first paper entitled "Towards a framework for solving environmental problems caused by the movement of heavy goods vehicles" (COM, 1998) was issued. Since then, numerous initiatives have been developed to reduce the environmental impact of transporting goods by road and reduce GHG emissions by the transport sector. In this sense, the European Commission has a Transport and Mobility strategy which promotes a clean transport system (CTS, 2011), and a significant reduction in CO_2 emissions from transport in the EU, from 80 to 95% by 2050, as it has been proven that the amount of CO_2 emissions from transport is directly related to fossil fuels burnt or consumed; therefore this objective will mean a drastic reduction in the EU's dependence on imported fossil fuels.

The Transport White Paper of March 28th, 2011 (EU, 2011) includes specific initiatives to reduce CO_2 emissions in transport by 60% in 2050 and a strategy of sustainable transport has been implemented, with actions directly affecting road freight transport:

- Alternative fuels for sustainable mobility in Europe
- Clean and energy efficient vehicles, covered by Directive 2009/33/EC of the European Parliament and of the Council of 23th April 2009 (EC, 2009), on the Promotion of Clean and Energy Efficient Road Transport Vehicles.

A key element to establish reduction targets is to measure the amount of CO_2 emitted by heavy vehicles used for road freight transport during their daily activities To that effect the "Monitoring Report of Directive 2009/33/EC on the Promotion of Clean and Energy Efficient Road Transport Vehicles" concluded on 26th October 2012 (EU, 2012), which is elaborated every two years, states that one of the main issues raised by producers in relation to industrial vehicles (heavy vehicles) is that there is still no agreement on the measurement of CO_2 emissions of such vehicles, which acts as a barrier for the application of the Directive to such vehicles. On the other hand, a similar agreement does exist for passenger cars. In the case of Spain, it is developed by the Spanish Institute for Diversification and Saving of Energy (IDAE, 2012), dependent on the Ministry of Industry, Tourism and Trade.

Furthermore, the Plan for Infrastructure, Transport and Housing (PITVI) 2012-2024, elaborated by the Ministry of Development, establishes a diagnosis of the transport system and devotes section 1.4 to the effects and impacts of transport on the environment. Section 1.4.2. sets out the sustainability and environmental effects of transport:

"... Transport remains the largest final energy consuming sector, followed by industry. Although, in the current economic climate, it is expected that demand of energy for transport will be reduced, there is a need to reorient the current model towards a more sustainable mobility."

Based on the foregoing, the INNOTRANSMER Project developed a calculation tool that assesses efficient routes based on key variables:

- Internal and inherent vehicle variables:
    - Power / capacity of the vehicle.
    - Fuel type.
    - Power transmission.
    - Vehicle resistances.
- External variables of the road and driving conditions:
    - Type of road / terrain.
    - Meteorological factors.
    - Load transported and inertia of the vehicle.

Thus, transport companies may determine travel time, fuel costs and GHG emissions for a given vehicle configuration and quantity of goods transported (route / vehicle / load) in a chosen route, in order to select the most efficient and sustainable one between a given origin and destination. This efficient transport assessment tool also allows the Administration to identify efficient routes or "green corridors" on the road network.

2. Working methodology

In assessing the cost of transport for a given route, the INNOTRANSMER Project (http://www.innotransmer.es) acquires the distance and average speed data for the route automatically from Google Maps and determines the cost of transport corresponding to that route in the tab EFFICIENT ROUTE at Fixed Cost by applying the ACOTRAM methodology of the Ministry of Development (www.fomento.es), with the values for cost per Km published periodically by the Observatory of Costs for different types of industrial vehicles:

- Articulated general cargo vehicle.
- 3-axle general cargo vehicle.
- 2-axle general cargo vehicle.
- Articulated refrigerated vehicle.
- 2-axle refrigerated vehicle.
- Dangerous Goods articulated tanker truck for gases.
- Dangerous Goods articulated tanker truck for chemicals.
- Articulated tanker truck for food products.
- Articulated tanker truck for powdered products.
- Road train (straight truck + trailer) vehicle carrier.
- Road train (straight truck + trailer).
- Articulated container vehicle.
- Articulated bulk goods vehicle.
- Articulated construction vehicle.
- Van.

Using the above variables, INNOTRANSMER determines (see Fig. 1):

- Total trip distance.
- Total time, including driving and rest times for transportation.
- Average speed.
- Fuel consumed.
- Direct costs of transport.
- CO_2 emissions, considering the diesel emission factor as 2.61 kg CO_2/litre from the data from the GHG Inventory Report (Royal Decree 1088/2010), oil density at 15°C = 833 kg/m^3.

In this first approach to the transport cost of a route or trip, it is not possible to enter customised costs for each carrier; for this reason, in a second EFFICIENT ROUTE at Variable Cost tab, each user can enter their own costs, so as to determine the direct costs in load €/km, from the following parameters (see Fig. 2):

- Direct costs incurred by the vehicle as a result of its operation; these can be divided into fixed and variable:
  - Fixed costs: are those not related to the activity performed by the vehicle fleet; these are temporary costs.
  - Variable costs: are proportional to the activity of the fleet or costs "per kilometre".
- Indirect costs which cannot be directly attributed to the operation of each vehicle, but are generated through the normal operation of the company. They include the following:
  - Infrastructure costs: amortisation and financial expenses, or rental / leasing of the facilities (offices, warehouses, etc.) of a company, maintenance and insurance costs of the infrastructure.
  - Administration / management costs: staff, office and IT equipment, communications, ...
  - Commercial costs: staff and business expenses.

Applying the ACOTRAM methodology of the Ministry of Development once again, enables the evaluation of transportation costs for a given route (excluding VAT because this concept is considered neutral).

The ACOTRAM methodology considers fuel consumption to be constant for each vehicle configuration but vehicle consumption can vary depending on the variables described above and it is a major part of the cost of transport; therefore a correct assessment of the cost of transport for a route depends on its correct determination. In INNOTRANSMER, consumptions have been introduced for different types of vehicle EURO I to VI, which the EU has regulated in multiple policies since 1970 in order to reduce fuel consumption and emissions in commercial vehicles for freight transport by road over long distances, resulting in the following types:

- EURO I (93/59/CEE) gasoil
- EURO II (96/69/CE) gasoil
- EURO III (98/69/CE S 2000) gasoil
- EURO IV (98/69/CE S 2005) gasoil

- EURO V (715/2007/CE S 2011) gasoil
- EURO VI (715/2007/CE S 2015) gasoil
- Hybrids

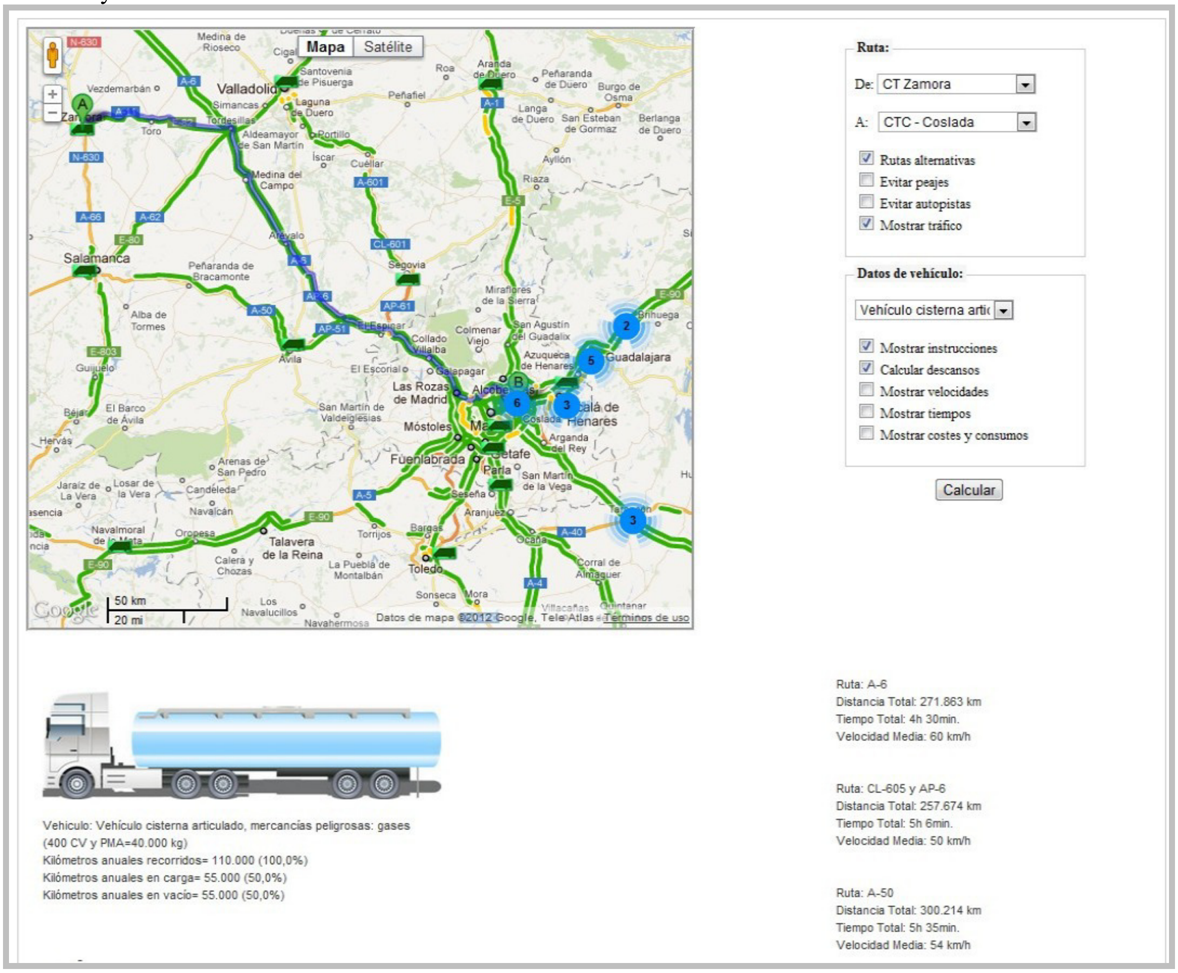

Fig 1. Example of results of the INNOTRANSMER Project

The efficient route with Custom Vehicle tab of the INNOTRANSMER project implements the calculation of transport consumption with real data provided by the manufacturers for the following vehicles and EURO types:

- MAN TGS 18.400 EEV, 400 hp (EURO V SCR)
- MAN TGX 18.400 4x2 BLS, 480 hp EURO V SCR)
- MAN TGA 18.440 XLX, 436 hp (EURO V SCR)
- Volvo FH16 750, 750 hp (EURO V SCR)
- Renault Truck Magnum 520. 18T, 519 hp (EURO V SCR)
- Scania G420, 420 hp (EURO V SCR)
- Iveco Stralis 440S45, 450 hp (EURO V SCR)

It has not been possible to extend this to other types of vehicles given the lack of information, but there is an obligation to inform consumers about the levels of fuel consumption and CO_2 emissions of new vehicles, based on Directive 1999/94/EC (Implemented by Royal Decree 837/2002, of 2nd August (BOE. 185 of 3rd August), which establishes the obligation to make available, on all new cars for sale, a mandatory information label regarding the consumption and CO_2 emissions generated per kilometre of each vehicle. It has not been published to date, although IDAE (2013) does implement it for new cars on sale in Spain.

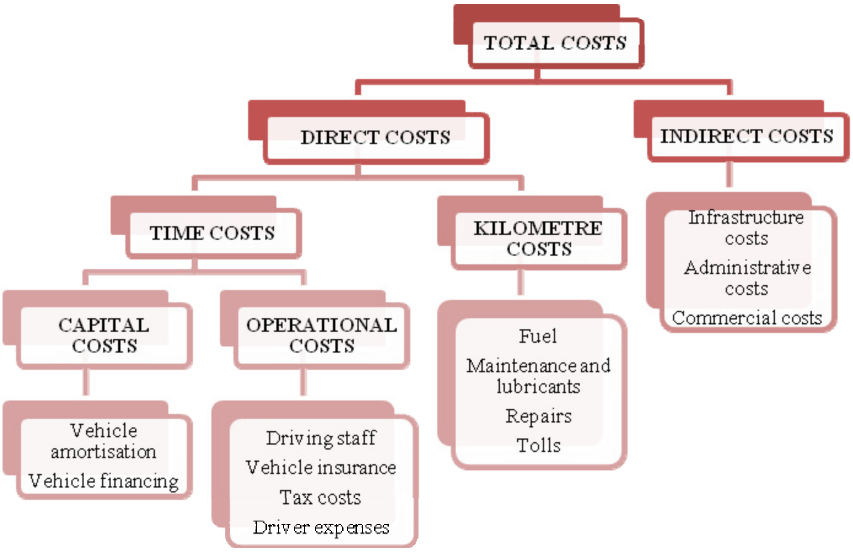

Fig 2. Different transport costs obtained from the Observatory of Transport Costs of the Ministry of Development.

Based on the manufacturer's information for this small number of industrial vehicles, the electronic access platform developed in the INNOTRANSMER Project uses the COPERT IV (2012) methodology of the European Environment Agency: "Computer Programme to Calculate Emissions from Road Transport (COPERT IV)" to calculate fuel consumption and GHG emissions (CO_2, NOx, HC and PM), of which there is greater availability of data due to society's concern for the problem of Climate Change.

3. Results

One goal of the INNOTRANSMER project is to assess the costs of freight transport by road in heavy vehicles in a real route, applying the ACOTRAM methodology of the Ministry of Development; offering users the possibility of introducing the costs structure of their transport company in order for the platform to perform the estimation of transport costs in a real route, personalised by the user. In addition, it also enables an assessment of consumption and GHG emissions for a given stretch of road by applying the COPERT IV methodology to determine consumption for different EURO types of vehicles and the percentage of cargo, compared to the calculation developed by Lopez and Sanchez (2009) in the EnerTrans Project, in order to conduct assessments of the cost of transport, with different consumptions and emissions of each type of GHG obtained with each methodology.

Using the fuel consumption obtained for each route, the calculation tool developed in the INNOTRANSMER project can make a more accurate approximation of the cost of the journey by road between an origin and a destination based on the technical data of the vehicle and the route selected. It can also establish comparisons of the consumptions based on the following calculation methods:

- Average consumption supplied by the manufacturer based on real tests.
- Consumption calculated using the EnerTrans formulation.
- Consumption calculated with COPERT IV databases.

As the average value provided by the manufacturer is constant for the whole route and independent of the amount of transported load and terrain, a comparison of fuel calculations for 34-40 t vehicles has been established using the COPERT IV methodology, which is the result of over 10 years of international cooperation in research, collecting data on consumption and emissions across Europe. COPERT IV is widely recognised and does not have a formulation for calculating the components of consumption and emissions. The mathematical formulation developed in the EnerTrans Project, is noted for its simple design, with a very reasonable response for the estimated consumption (which could be improved by taking into consideration the slopes of the route).

To validate the results of INNOTRANSMER (applying COPERT IV) a comparative study of consumption calculation has been carried out with EnerTrans, for speeds between 5 and 90 km/h for the case of an articulated vehicle where the COPERT IV model provides data for vehicles meeting the EURO regulation at different levels (in this case complying with the EURO V regulations and having SCR technology), different load levels (0%, 50%, 100%) and different slopes (-6%, -4%, -2%, 0%, 2%, 4%, 6%). The EnerTrans model provides a single formula that presents fuel consumption as a function of the Maximum Authorised Mass, payload and speed.

The results obtained are shown in Figures 3, 4 and 5 (for a 100%, 50% and 0%, load respectively). The comparison between the two models indicates a good correlation between the EnerTrans model with the 0% slope curve for all three loads.

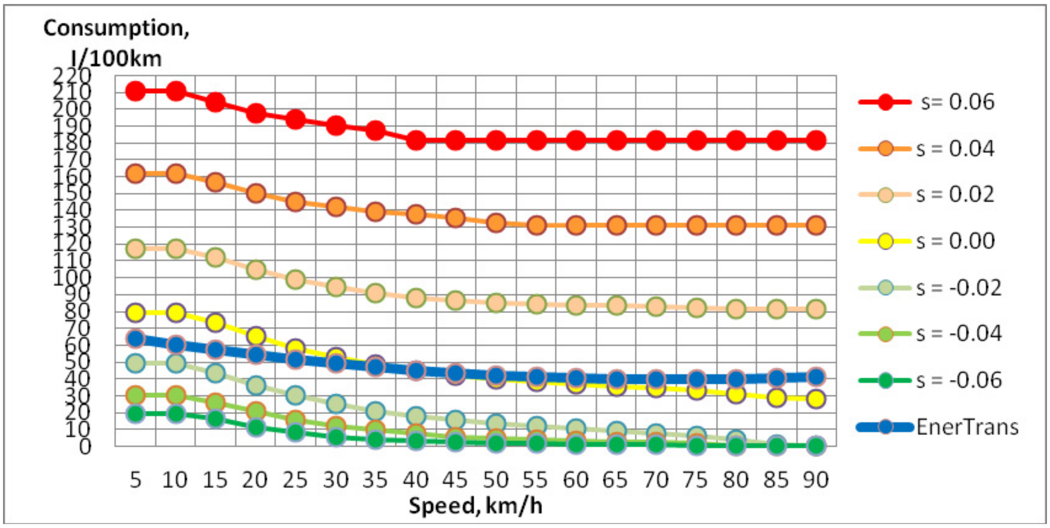

Fig. 3. Results of the Project, model COPERT IV, 34-40 tonnes, Euro V-SCR, 100% load.

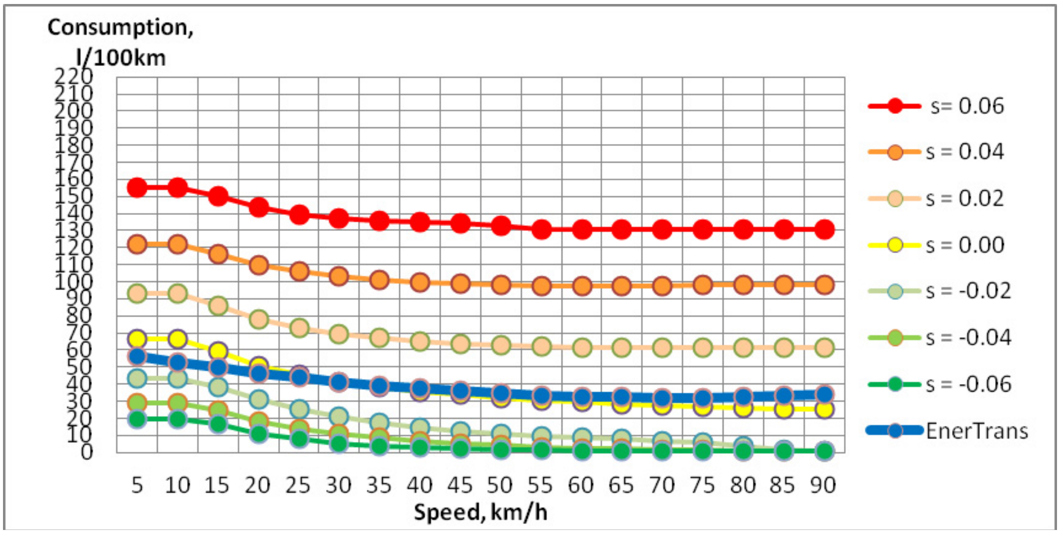

Fig. 4. Results of the Project, model COPERT IV, 34-40 tonnes, Euro V-SCR, 50% load.

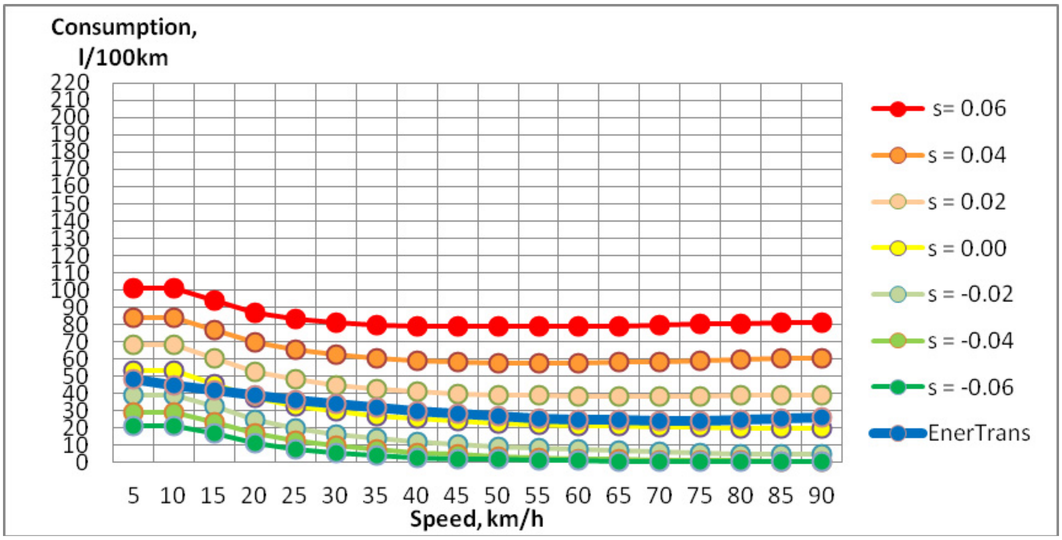

Fig. 5. Results of the Project, model COPERT IV, 34-40 tonnes, Euro V-SCR, 0% load.

Regarding the different technologies to reduce emissions, the results of the calculation of seven different technologies have been compared: Conventional, EURO I, EURO II, EURO III, EURO IV EGR, EURO V EGR and EURO V SCR (whose formulas are available in the COPERT IV model), with the single formula of EnerTrans. In this comparison the slope does not change (always 0%), but the payload does (performed for three load levels, 100%, 50% and 0%, respectively). (see Figs. 6, 7 and 8).

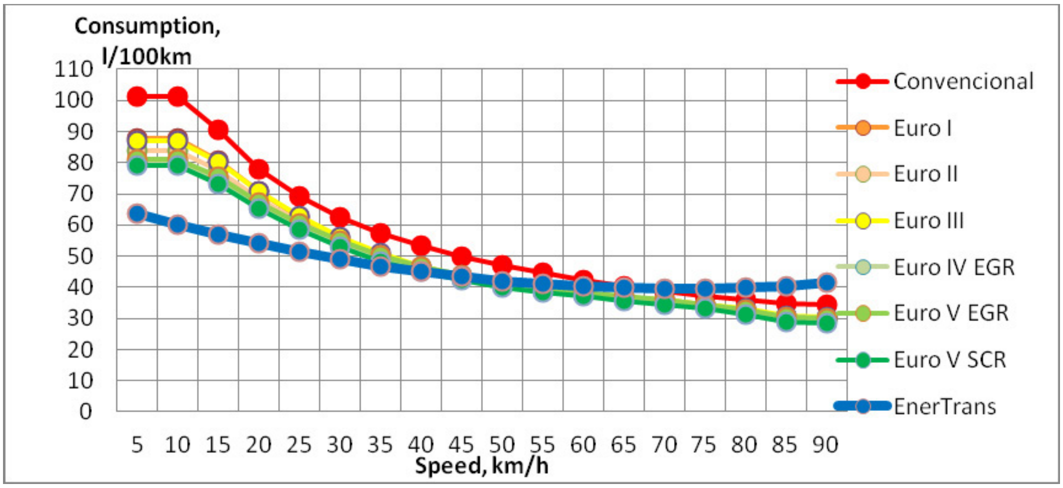

Fig. 6. Comparison of Project outcomes with different technologies, COPERT IV model, 34-40 tonnes, slope = 0%, 100% load.

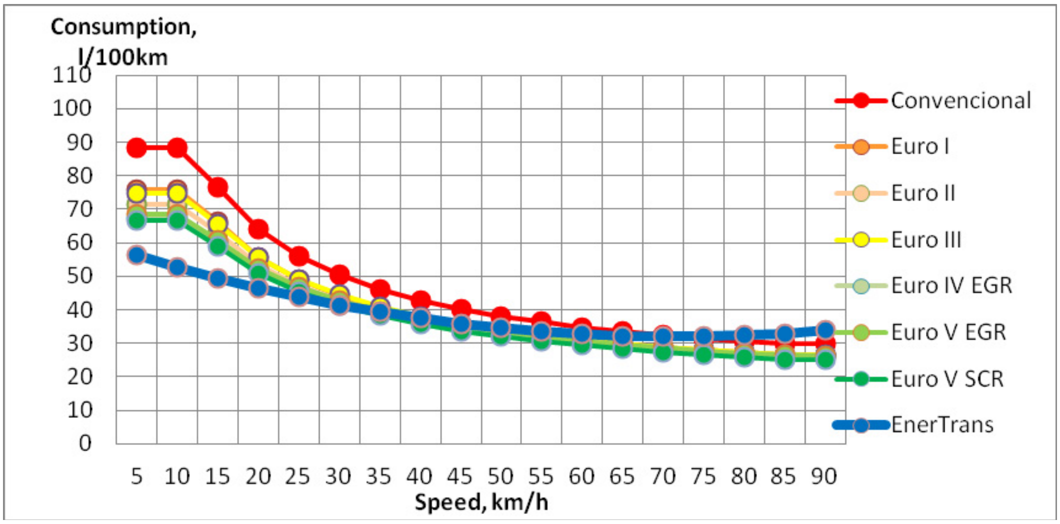

Fig. 7. Comparison of Project outcomes with different technologies, COPERT IV model, 34-40 tonnes, slope = 0%, 50% load.

Finally, the COPERT IV model implemented in INNOTRANSMER has been tested and calibrated with information on the Euro Truck Test (Maroto, 2009). In this test, eight sections (4 outbound and 4 return) from the route between Munich and Milan have been documented, with the following types of truck competing:

- DAF FT XF105.460.
- MAN TGX 18.440 4x2 BLS-EL.
- Mercedes Actros 1848 LS.
- Scania R 420 LA 4x2 MNA EURO 5.
- Volvo FH 460 4x2 T.

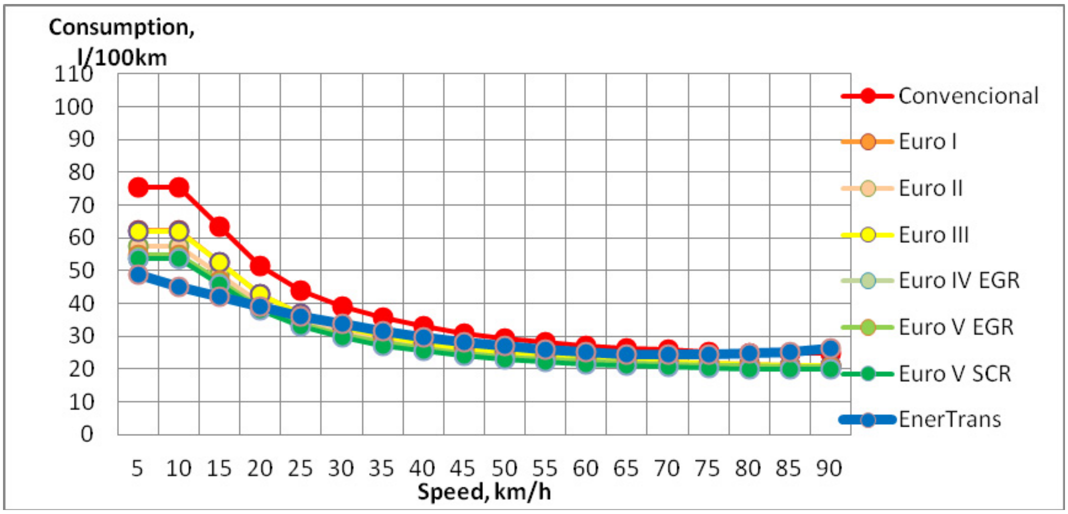

Fig. 8. Comparison of Project outcomes with different technologies, COPERT IV model, 34-40 tonnes, slope = 0%, 0% load.

The results are detailed in Maroto (2009), where all vehicles had EURO V SCR technology, test weight of 40,000 kg and power between 420 and 476 hp. The vehicle simulated by INNOTRANSMER was an articulated vehicle, 34-40 t, EURO V-SCR, 100% load, 460 hp, travelling the same route as the real vehicles.

As shown in Figure 9, there was a reasonable correlation between the data obtained by the simulation and the actual vehicles, both regarding time and consumption.

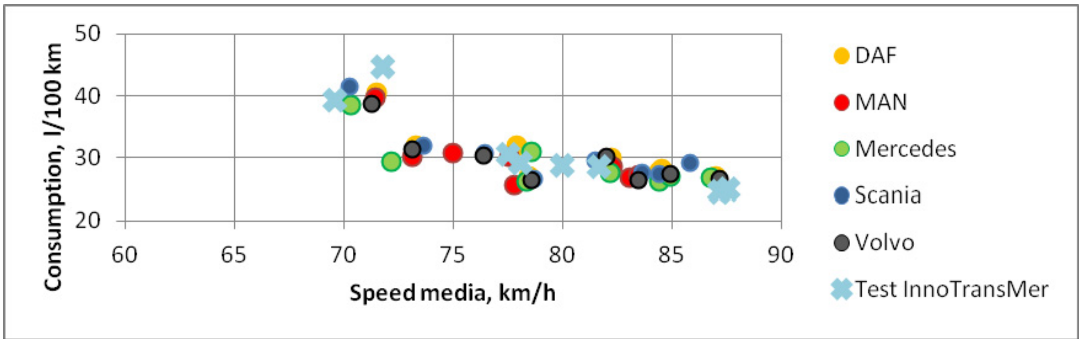

Fig. 9..Comparison between actual consumption versus COPERT IV

The largest differences were observed in those routes with marked differences in altitude (stretches with a considerable slope), where the simulator returned greater consumption and longer times (see Table 1). This is partly due to the approximation of the altitudes (sometimes inaccurate) provided by the Google service, which we have attempted to compensate during the calculation.

Table 1. Results obtained by the actual vehicles, Maroto (2009).

		DAF		MAN		MERCEDES		SCANIA		VOLVO	
	km	Consu.	Time	Consu.	Time	Consu.	Time	Consu.	Time	Consu.	Time
STAGE 1											
Schweiten.-Angath	134.4	40.25	98.03	38.30	98.02	37.03	98.11	39.73	98.95	40.55	98.29
km/h		82.26		82.27		82.19		81.50		82.04	
l/100 km		29.95		28.50		27.55		29.56		30.17	
Effectiveness		1.37		1.44		1.49		1.38		1.36	
STAGE 2											
Angath - Laimburg	190.6	61.11	156.00	57.62	156.34	56.19	158.42	60.88	155.28	59.90	156.40
km/h		73.31		73.15		72.19		73.65		73.12	
l/100 km		32.06		30.23		29.48		31.94		31.43	
Effectiveness		1.14		1.21		1.22		1.15		1.16	
STAGE 3											
Laimburg - Monte Alto	139.2	37.62	106.42	35.66	107.38	36.41	106.59	37.15	106.13	36.74	106.32
km/h		78.48		77.78		78.36		78.70		78.56	
l/100 km		27.03		25.62		26.16		26.69		26.39	
Effectiveness		1.45		1.52		1.50		1.47		1.49	
STAGE 4											
Monte Alto - Milano	97.7	27.22	69.41	26.17	70.57	25.70	69.41	26.84	69.45	26.75	69.00
km/h		84.45		83.07		84.45		84.41		84.96	
l/100 km		27.86		26.79		26.31		27.47		27.38	
Effectiveness		1.52		1.55		1.61		1.54		1.55	
STAGE 5											
Milano - Monte Alto	97.7	27.51	69.33	26.52	70.20	26.45	69.01	27.06	70.10	25.88	70.20
km/h		84.55		83.50		84.94		83.62		83.50	
l/100 km		28.16		27.14		27.07		27.70		26.49	
Effectiveness		1.50		1.54		1.57		1.51		1.58	
STAGE 6											
Monte Alto - Laimburg	139.2	44.48	107.20	42.89	111.36	42.98	106.29	42.92	109.23	42.27	109.29
km/h		77.91		75.00		78.58		76.46		76.42	
l/100 km		31.95		30.81		30.88		30.83		30.37	
Effectiveness		1.22		1.22		1.27		1.24		1.26	
STAGE 7											
Laimburg - Angath	179.0	72.42	150.17	71.04	150.26	69.11	152.74	74.37	152.82	69.16	150.60
km/h		71.52		71.48		70.32		70.28		71.31	
l/100 km		40.46		39.69		38.61		41.55		38.64	

Effectiveness		0.88		0.90		0.91		0.85		0.92	
STAGE 8											
Angath - Munich	107.5	29.04	74.10	28.81	75.33	28.76	74.30	31.36	75.12	28.56	73.98
km/h		87.04		85.62		86.81		85.86		87.19	
l/100 km		27.01		26.80		26.75		29.17		26.57	
Effectiveness		1.61		1.60		1.62		1.47		1.64	
TOTAL											
Munich-Mailand-	1085.3	339.61	830.70	327.02	839.50	323.10	834.90	338.12	837.10	330.85	834.10
km/h		78.39		77.57		77.99		77.79		78.07	
l/100 km		31.29		30.13		29.77		31.15		30.48	
Effectiveness		1.25		1.29		1.31		1.25		1.28	

4. Conclusions

In the “INNOTRANSMER Project” there has been compared the theoretical fuel consumption of an industrial heavy vehicle (truck) of 34-40 Tn., evaluated with two methodologies of theoretical calculation: ‘COPERT IV’ and ‘EnerTrans’, for speeds between 5 and 90 km/h. The methodology of fuel’s calculation of consumption with ‘COPERT IV’ requires a larger number of variables for its application: vehicle’s EURO regulations, load level (0%, 50%, 100%), different speed and outstanding of the road (- 6%, 4%, 2%, 0%, 2%, 4%, 6%). On the other hand, the methodology of fuel’s calculation of consumption with ‘EnerTrans’ is easier to apply, its mathematical formulation needs: the MMA (Maximum Authorized Mass), the useful load, and the speed. The results obtained in the calculation of consumptions of fuel is a correlation between ‘COPERT IV’ and ‘EnerTrans’, when the layout of the road is flat (slope 0%) in the three load conditions (0%, 50%, 100%) and different when it intervenes (in) the slopes of the road layout.

Selected ‘COPERT IV’’s methodology for calculating the fuel’s consumption in ‘INNOTRANSMER’, there have been compared the results obtained on a path of the ‘Euro Truck Test 2009’ truck with 34-40 tons., EURO V-SCR, 100% load, 460 CV, with actual fuel consumption data of participating trucks in ‘Euro truck Test 2009’ (Eco Challenge); where all participants were similar to INNOTRANSMER trucks. The fuel’s consumptions calculated with INNOTRANSMER are similar to the trucks participants in the Euro Truck Test 2009, which demonstrates the reliability of the fuel’s calculation of consumptions that INNOTRANSMER realizes; although it should be noted deviations in sections with bigger steep path, which facilitates INNOTRANSMER higher fuel consumption, this is not 100% attributable to ‘COPERT IV’’s methodology, but the calculation of altitudes that INNOTRANSMER realizes of the path from Google Maps.

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