EUROPEAN MODULAR SYSTEMS PERFORMANCES COMPARISON IN FREIGHT TRANSPORT OPERATIONS

Emilio Larrodé Pellicer
Department of Mechanical Engineering, University of Zaragoza
Victoria Muerza Marín
Department of quantitative methods for business and economy, University of Zaragoza

ABSTRACT

European countries has been working in the last ten years in the implementation of high capacity vehicles in road networks. The EU allowed each member state to use combinations of cargo carriers with a modular concept, the European Modular Systems (EMS). This paper analyses the real behavior in road test of the Euro Modular vehicle of 70 tons of maximum load (called Duotrailer). A route in real conditions is used and comparisons between different vehicle typologies (Trailer, Gigatrailer and Duotrailer) in terms of fuel consumption and emissions are performed. Results in the route tested show that, as expected, the highest consumption correspond to Duotrailers. However, savings with regards to trailers are around 22 % (per ton) and 26 % (per ton and m^3), and savings with regards to Gigatrailers are around 9 % (per ton) and 23 % (per ton and m^3) considering that the charge factor is higher in Duotrailers. Although emissions are higher in Duotrailers, the load capacity is higher.

1. INTRODUCTION

Freight transport is a significant source of CO2 emissions. Hence, to find solutions to reduce the carbon footprint of road freight transport is necessary. The European Modular System (EMS) is a solution that allows combinations of existing loading units (modules) into longer and sometimes heavier vehicle combinations to be used on some parts of the road network. EMS improves road freight transport efficiency and reduces its environmental impact (Acea, s.f.).

The maximum vehicle´s dimensions and combinations, and masses are regulated in the European Council Directive 96/53/ EC revised by European Council Directive 2015/719. The EMS is defined in Article 4, Point 4. (b) of this directive as: "*Member States may allow vehicles or vehicle combinations used for goods transport which carry out certain national transport operations that do not significantly affect international competition in the transport sector to circulate in their territory with dimensions deviating from those laid down in points 1.1 , 1.2, 1.4 to 1.8 , 4.2 and 4.4 of Annex I*". Each country of the European Union have to transpose this directive to its national legislation.

Nevertheless, dimensions, masses and vehicle combinations are not uniform, as each country has taken up this directive with some modifications or different conditions (Jagelčák et al., 2019).

The experience of countries already using high capacity vehicles shows positive results, and CO2 reductions have been confirmed in practice. In the European Union, high-capacity vehicles in the form of combinations of EMS are allowed and used in Belgium, Denmark, Finland, most of the German federal states, the Netherlands, Portugal, Spain and Sweden (Acea, 2019).

The objective of this paper is to test this type of vehicles (70 t) in real conditions within a route in Spain performed by the company "Group Sesé". Consumption and emissions are analysed in comparison with different vehicle typologies (Trailer, Gigatrailer and Duotrailer).

The rest of the paper is structured as follows. Section 2 presents the background of the study. Section 3 shows the method that has been applied. Section 4 analyses the main results, and finally, Section 5 concludes the main findings.

2. BACKGROUND

In recent years, research in the development and implementation of high capacity vehicles (HCV) has increased considerably in different countries. The "International Transport Forum" in its document "High Capacity Transport. Towards Efficient, Safe and Sustainable Road Freight "(ITF, 2019) examines the experiences carried out in different countries in this regard, reviews the potential impact on road infrastructure and analyzes the consequences for other modes of transport, industry and society.

Countries such as Australia, Canada, the Netherlands, Finland, Sweden, Germany, the United States, Mexico, Argentina, New Zealand and South Africa have implemented additional regulations (e.g., additional features in vehicle performance, driver qualification, operation under special operations among others). This has allowed the deployment of these vehicles safely, with a positive impact in their public acceptance and by the Administration (Moore et al., 2014).

The precursor countries are Australia and Sweden. Since 2011, they have established different pilot tests in collaboration with the Public Administration. In turn, countries such as Australia, Canada, New Zealand and South Africa are also pioneers in the area, as they have developed Performance Based Standards.

Within the HCV are the so-called EMS. The EMS consists of the longest semi-trailer, with a maximum length of 13.6 m and the longest load support according to class C, with a maximum length of 7.82 m, allowed in the EU. This results in combinations of 25.25 m vehicles. The maximum length in the rest of Europe is 18.75 m. The EU allowed each member state to use combinations of cargo carriers with a modular concept. Sweden and Finland can combine a long and a short module, while in the rest of the EU only transport with two short or one long modules is allowed alternately. When using EMS, the volume of the three EU combinations can be transported by two combinations of EMS (TFK, 2007). See Figure 1 for more detail on this concept.

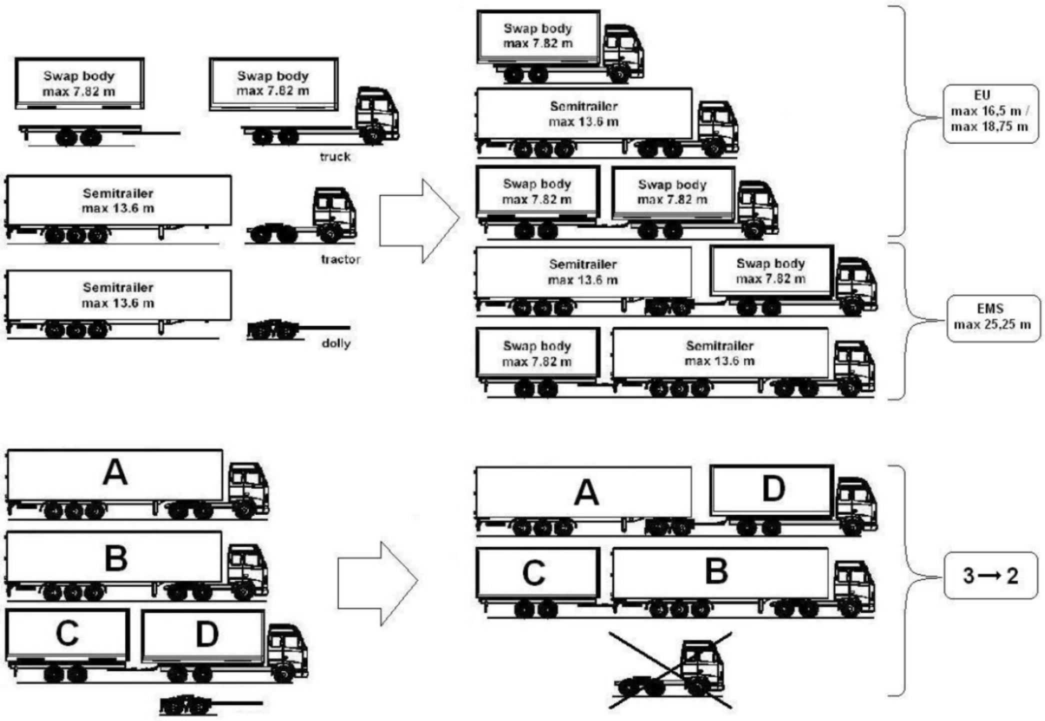


Fig. 1 – EMS configuration. Source (TFK, 2007)

In Finland, the experience in the use of high capacity vehicles nowadays includes 100 million km traveled, more than 300 km of transport annually, mixture of light cargo and food. In 2018, use of vehicles of dimensions 450x25.25 m and 60/ 64t. In 2023, it is expected to use 200x32-34m and 76t A-double vehicles and 120x 28-31m 64-76t vehicles + full trailer/ dolly + semi-trailer. As a result it is expected to obtain 25% less driving, and 15% less emissions (Lahti, 2020).

3. METHOD

The methodology proposed in this research consists of three steps: (1) the selection of the type of vehicles to be used, (2) a set of driving tests in real conditions considering a route and different load configurations, and (3) comparison in terms of consumption and CO_2 emissions.

3.1 Selection of type of vehicle

Different types (T) of vehicles were selected to compare results within a route (see Figure 2):

(1) T1: Trailer (conventional truck) of 16.50 m total length. Free movement on the Spanish road network.
(2) T2: HCV called Gigatrailer of 25.25 m total length. Free movement on the Spanish road network.
(3) T3: HCV called Duotrailer of 31.75 m total length. Subject to strict regulations and circulation under license by the Administration.

Tests were carried out with T3 vehicles (Duotrailer). Two types of Duotrailer were selected for the tests: 9 axle vehicles and 10 axle vehicles. The selection of vehicles tried to consider not only weight restrictions in Spain but also in Finland as a pioneer in the research and use of HCVs from many years. The maximum weight allowed in this country is 75 t. With this weight, a dolly of two axles is needed for the transport operation. On the other hand, tests in Spain are limited to 70 t and a one axle-dolly would be enough for the transport operation.

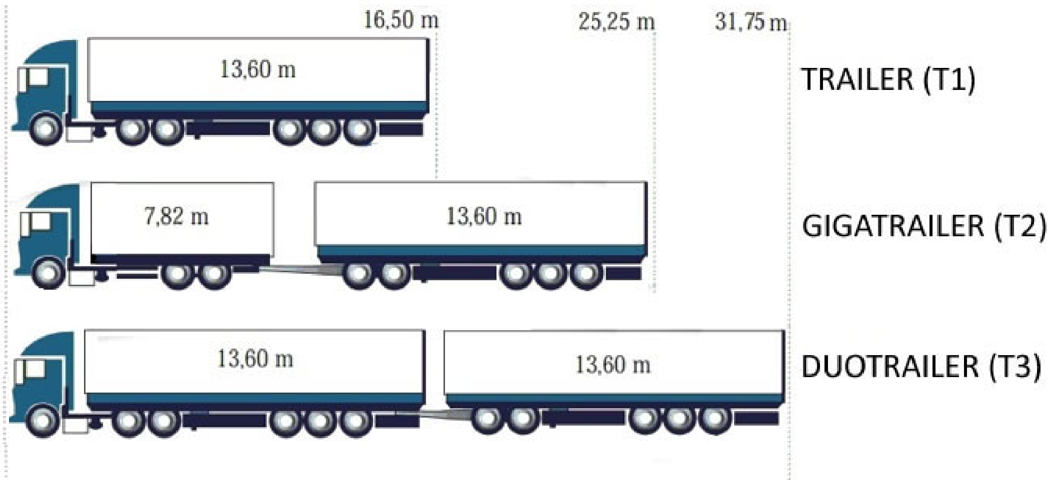
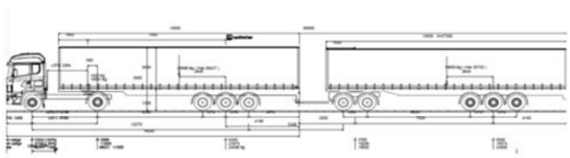
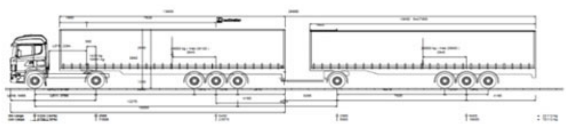


Fig. 1 – Comparison of vehicles within the route used for tests

The characteristics of the Duotrailer vehicles in terms of power, maximum authorised mass (MAM), technically permissible maximum masses (TPMM), and total length of the Duotrailer are shown in Figure 3 according to the tractor unit, semitrailer 1, dolly and semitrailer 2.



10 axle Duotrailer set



9 axle Duotrailer set

Typology	Power (kW) Tractor unit (T)	MAM (kg)	TPMM (kg)	MAM (kg) Semitrailer 1 (S1)	MAM (kg) Dolly (D)	MAM (kg) Semitrailer 2 (S2)	Total length (m)	Total number of axles
T3.1	383/427/464	18,000	70,000	35,000	Two axles 18,000	35,000	31.750	10
T3.2	383/427/464	18,000	70,000	35,000	One axle 10,000	35,000	31.750	9

Fig. 2 – Weights and dimensions of the used vehicles (Duotrailer)

Three vehicle configurations (VC) have been used in the tests (see Table 1).

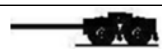
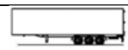
Vehicle Configuration	T	S1	D	S2
				
VC1	580 CV (2 axles)	3 axles	2 axles	3 axles
VC2	580 CV (2 axles)	3 axles	1 axle	3 axles
VC3	520 CV (2 axles)	3 axles	1 axle	3 axles

Table 1 – Identification of the vehicles used in the tests

3.2 Driving tests in real conditions

The transport company Group Sesé in Spain performed the tests in real operation. A route was chosen for the use of the Duotrailer vehicle: Azuqueca- Martorell (round trip) with a distance of 552 km (each trip). A load of 13.5 t was transported (30% use of the vehicle). A set of conditions for the vehicles has been stablished:

(1) **Characteristics of the set of vehicles:**

(1a) Tests with 9-axle and 10-axle vehicles.

- Resistance to advance, specific consumption.
- Manoeuvrability, interaction with infrastructure.

(1b) Tests with two available tractor units: 520 CV and 580 CV.

- Optimize energy efficiency.
- Emissions.

(2) **Characteristics of the type of route:**

(2a) Tests with different distances long and short routes.

- Average consumption.
- Energy efficiency.

(2b) Route profile (flat profiles and mountain profiles).

- Energy consumption.

(3) Characteristics of the type of merchandise.

(3a) Type of heavy good.

- Powers, consumption and emissions.

(3b) Type of bulky and light merchandise.

Tests were scheduled along 2018 and 2019. The schedule can be seen in Figure 3. A total number of 150 test were performed.

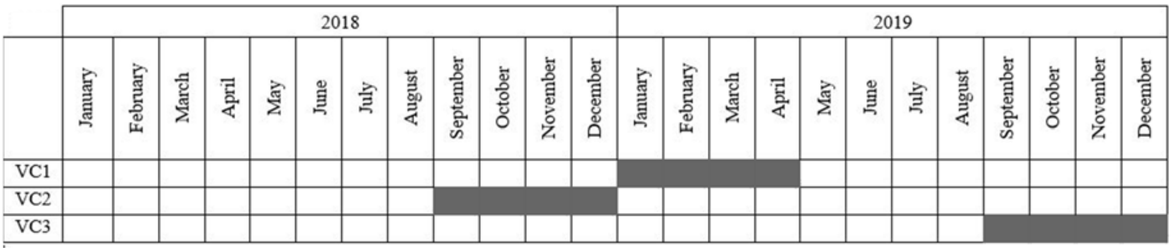


Fig. 3 – Tests schedule

3.3 Comparison of consumptions and CO_2 emissions

A matrix of cases is constructed. The calculation of consumptions has initially considered the following conditions:

- Condition 1: Influence of meteorological conditions:
  - Action of the wind.
  - Consumptions.
  - Ultrasonic wind speed measurement sensors.
- Condition 2: Influence of traffic conditions.
  - Heavy traffic or slow traffic
  - Average consumption.
  - Variation of speed conditions.
  - Considerable increase in braking and acceleration.
- Condition 3: Influence of driving type.
  - Average consumption of vehicles.
  - Short distance routes.
  - Transport of heavy merchandise.

To limit the number of tests to be carried out, the working intervals of each of the factors that were taken into account were established and the following working hypotheses were adopted:

(1) Hypotheses regarding the type of vehicle (HVE):

- Type of connection:
  - HVE1: Dolly of two axles (10-axle Duotrailer).
  - HVE2: Dolly of one axle (9-axle Duotrailer).

- Type of tractor (T):
  - HVET1: 520 CV (383 kW).
  - HVET2: 580 CV (427 kW).

(2) Hypotheses regarding the route (HR):

- Distance (HRD):
  - HRD1: Route of short distance traveled (<600 km).
  - HRD2: Route of long distance traveled (>600 km).
- Profile (HRP):
  - HRP1: Profile of the route with strong ramps accumulated (> 12%).
  - HRP2: Profile of the route with accumulated average ramps (> 5% and <12%).
  - HRP3: Profile of the route with slight accumulated ramps (<5%).

(3) Hypotheses regarding the merchandise (HM):

- Volume transport (HMV): ≤ 33% of maximum payload.
- Load volume (HML): medium load transport (> 33% of maximum payload) and full load transport (> 66% of maximum payload).

(4) Existence of externalities:

- Wind forces.
- Traffic congestion.
- Stressed driving.

The analysis of emissions was performed by using EcoTransIT (https://www.ecotransit.org/calculation.es.html) calculation tool. The tool provides information of emissions in terms of CO2, CO2 equivalent, NO2, non-methane hydrocarbons, particles and distances. In this research, we focus on CO2 emissions.

4. RESULTS

Table 2 shows the average results in terms of consumption for the route tested using Duotrailers (T3). It can be seen that, on average, consumption is higher for the transport from Martorell to Azuqueca than the road trip even if average payload transported is lower. This is due to the profile of the route.

	Azuqueca-Martorell	Martorell-Azuqueca
Average consumption (l/100km)	39.10	41.47
Average distance traveled (km)	552	552
Average payload transported (t)	14.25	12.75
Average charge factor	2.50	2.60

Table 2 – Average consumption results for T3 in the route tested

Table 3 shows a comparison between T1, T2 and T3 in the same route in terms of consumption savings. However, it has to be highlighted that different charge factors have been considered as the tests have been performed in real operation. The highest consumption correspond to T3 vehicles (Duotrailer). However, savings with regards to T1 vehicles are around 22 % (per ton) and 26 % (per ton and m^3) (mean), and savings with regards to T2 are around 9 % (per ton) and 23 % (per ton and m^3) (mean) considering that the charge factor is higher in T3 vehicles.

		Typologies of vehicles				
	T1(410 CV gas)	T1(450 CV)	T2 (580 CV)	T3 (520 CV)	T3 (580 CV)	T3 (580 CV)
Consumption (l/100km)	24.8	27.1	39.5	38	40.80	41.48
Saving per ton (%)	-	-	13.66	25.1	19.63	20.29
Saving per ton and m^3 (%)	-	-	2.9	29.90	24.87	23.52
Real charge factor	-	-	1.5 (theoretical)	2.53	2.5	2.5

Table 3 – Comparison of consumptions and savings between vehicles

Figure 4 shows a comparison in terms of mass transported and the unladen mass of the vehicles used. Although T3 vehicles (Duotrailer) are heavier, they transport nearly twice load.

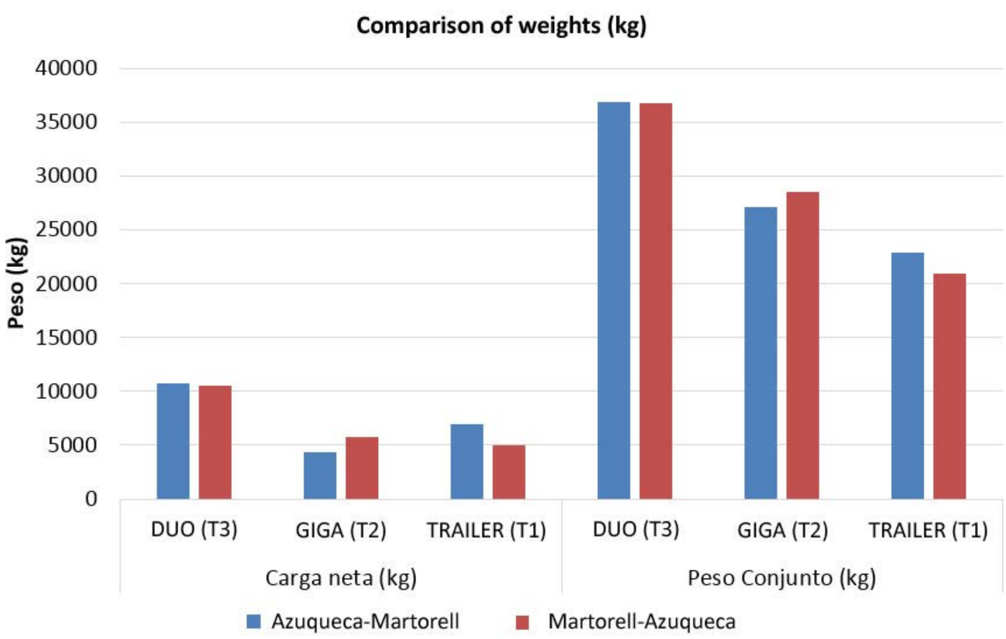


Fig. 4 – Comparison of weights of the vehicles used

Figure 5 shows the differences in total emissions between the three types of vehicles. T3 vehicles (Duotrailer) are the most polluting.

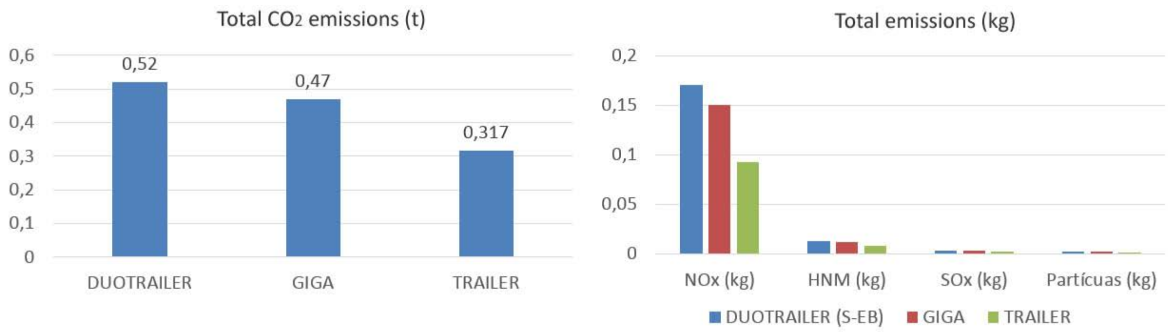


Fig. 5 – Difference of emissions in the vehicles used

Representando las emisiones de CO_2 en función de la masa desplazada y por carga útil.

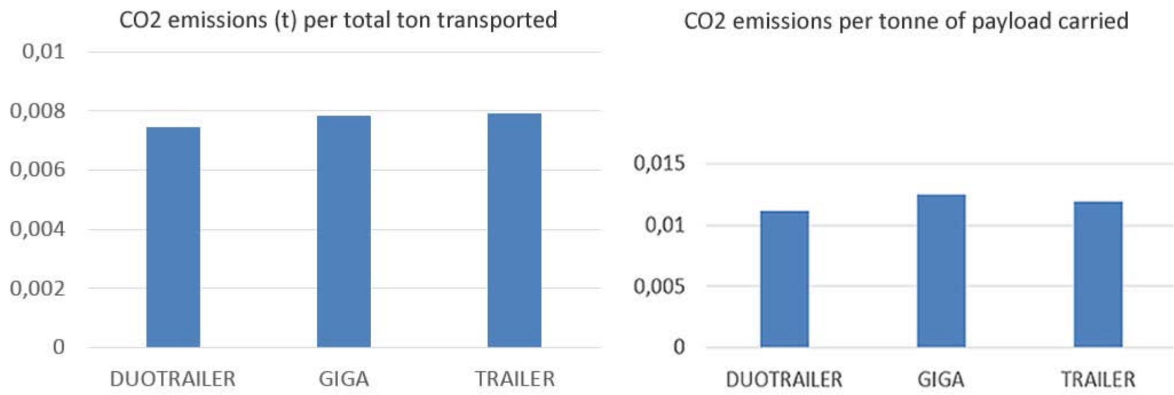


Fig. 6 – CO_2 emissions as a function of the mass displaced by each type of vehicle

5. CONCLUSIONS

In this research, through a set of experimental tests it has been possible to analyze the behavior of EMS vehicles in real road behavior, in this case the Duotrailer vehicles. The data capture and monitoring during the test allows obtaining data from the entire operation and a comparison with other vehicles, both in volume transport and maximum load.

Results are considered positive from the standpoint of the behavior of the vehicle, and the environmental, operational and economic improvement. Other conclusions include:

- The vehicle in terms of dynamics and mechanics behaves properly and its maneuverability is correct in all sections where it has been tested.
- The vehicle has shown safety throughout the test run and no incidents occurred during the tests.

- The vehicle is stable in running behavior and does not show road damage, given its distribution of axle loads.
- The test scenarios performed and their repetition, allows to verify the behavior of the vehicle both in terms of safety, maneuverability and its economic and environmental profitability.

Future research will focus on conducting more tests, in order to assess more possible scenarios, corroborate the results obtained and verify that the vehicle's behavior complies with all safety and effectiveness guarantees in road transport operations.

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REFERENCES

ACEA (2019). High Capacity Transport. Smarter policies for smart transport solutions. Available at: https://www.acea.be/uploads/publications/ACEA_Paper-High_Capacity_Transport.pdf [Accessed: 22 February 2020]

ACEA (s.f.). European Modular System. Available at: https://www.acea.be/industry-topics/tag/category/european-modular-system [Accessed: 7 March 2020]

ITF (2019). High Capacity Transport. Towards Efficient, Safe and Sustainable Road Freight. International Transport Forum Policy Papers, No. 69, OECD Publishing, Paris.

JAGELČÁKA, J.; KIKTOVÁA, M.; FRANČÁKA, M.; MARIENKA, P. (2019). The possibilities of using longer and heavier vehicle combinations in Slovakia. Transportation Research Procedia, Vol. 40, pp. 271–278.

LAHTI, O. (2020). 76 t 34,5 m Trucks in Finland. Disponible en: https://www.traficom.fi/sites/default/files/media/file/76%20t%2034%2C5%20m%20in%20Finland.pdf [Accessed: 22 February 2020]

MOORE, B., REGEHR, J. D. and REMPEL, G. (2014), "Compliance mechanisms for higher productivity vehicles", in. HVTT13: International Symposium on Heavy Vehicle Transport Technology, 13th, 2014, San Luis, Argentina. Available at: https://trid.trb.org/view/1343731 [Accessed: 22 February 2020]

TFK (2007). European Modular System for road freight transport – experiences and possibilities. ISBN 13: 978-91-85665-07-5