

Ecological conditions for the implementation of the european modular systems in road transport

Anna Dzioba^{1*}, *Marietta Markiewicz*², *Jan Gutsche*², *Adam Talaśka*²

¹ Cuiavian University in Wloclawek, Faculty of Social and Technical Sciences, ul. Okrzei 94A, 87-800 Wloclawek, Poland

² Bydgoszcz University of Science and Technology, Faculty of Mechanical Engineering, Al. prof. S. Kaliskiego 7, 85-796 Bydgoszcz, Poland

Abstract. This article focuses on the challenges and problems facing road transport nowadays. The main aspect discussed in the paper is the ecological aspect. As the demand for transport services has been constantly growing for the last 20 years, solving the problem has become a great challenge. In the further part of the study, an attempt was made to indicate solutions applied in the European Union. Another solution is presented in this paper, which is the introduction of European Modular Systems to road transport. Their characteristics were presented and countries in which such solutions are used were indicated. Based on the analysis of studies in the field of the discussed issues, a comparison of fuel consumption and CO₂ and NO_x emissions of standard sets with EMS sets was carried out.

1 Introduction

The road transport sector is one of the fastest growing sectors of economy. With its development, the number of vehicles is increasing, which gives rise to a problem related to the emission of harmful substances into the environment. Pollutant emissions are directly related to fuel consumption per transported weight, the higher the fuel consumption, the higher the CO₂ and NO_x emissions. The processes are one of the causes of greenhouse gas emissions. Observations and forecasts indicate that the increased demand for transport services has and will continue to have an upward trend, which is why it is important to introduce solutions that will make it possible to provide transport services at the same time with minimum pollution of the natural environment. At the same time, the European Commission and other legislative organisations are developing various types of legal acts which stipulate reducing emissions. Manufacturers of heavy goods vehicles, transport companies and other organisations are involved in the processes. One of the solutions proposed in this article is the implementation of extended 25-metre sets, otherwise known as road trains. Many organisations, including the European truck organisation ACEA and the carriers' association IRU appeal to the authorities to introduce this type of solution. According to the organisations mentioned above, as well as on the basis of tests carried out in other countries, it can be concluded that it would be reasonable to implement EMS in road transport.

* Corresponding author: annadzioba1@gmail.com

2 Contemporary challenges and problems in road transport

Road transport is a branch of transport where activities of carriage of goods and passengers by motor vehicles are undertaken and carried out.

The advantages of road transport are:

- a. the possibility of door-to-door delivery,
- b. unlimited possibilities for delivery due to well-developed infrastructure and road network,
- c. fulfilment of orders within a short period of time and at an affordable price.

Road transport can take place in the territory of the country, which kind of transport is called domestic road transport and outside the country and then such transport is called international road transport [1].

The road transport sector is one of the fastest growing sectors of economy. An increasing volume of goods is being transported by this branch of transport, which is supported by the aforementioned advantages. Efficient and fast transport of goods is the basis for the functioning of not only the economy, but also companies. Thanks to fast, efficient and precise cargo transport, production processes are carried out at a high level and consumers have access to a wide range of products. Road transport means are used for transporting heavy goods, oversized goods, sensitive goods, including goods with short shelf life, dangerous goods and others. The execution of this type of transport requires the appropriate adaptation of transport means (with regard to their construction, diagnostic susceptibility, operational parameters, ...), applying relevant legal regulations and possessing appropriately qualified employees for executing the transport [2-19].

The road cargo transport industry is currently at the peak of a growth phase. The demand for transport services is increasing year by year. Transport and forwarding companies are expanding, competing with each other in order to effectively meet their objectives and customers' needs. Road transport dominates in cargo transportation both in Poland and in the European Union. According to Eurostat data, in 2016, road transport accounted for 72% of exports and 45% of imports of goods, and Polish companies carried nearly 270 million tons of cargo, which accounted for 23% of EU road transport cargo [20]. According to forecasts for the next years, the situation will have an upward trend, which means that transport needs will be even higher. With the increase in demand for transport services comes the problem of emissions of harmful substances into the atmosphere, this is all related to greenhouse gas emissions and global warming. One of the main gases is carbon dioxide (CO₂). Apart from many natural and anthropogenic factors, transport, including road transport, is responsible for its emissions. The situation implies that regulations in this area will become more and more stringent, therefore reducing greenhouse gas emissions is and will be one of the most important challenges in the world [21]. It is estimated that up to about 30% of total CO₂ emissions in the European Union come from transport, 72% of which come from road transport [22]. Therefore, the European Union has set a target of reducing transport emissions by 55% by 2030 and achieving climate neutrality by 2050. Achieving the target will not be easy, if only because of the increasing demand for transport. [23,24].

As it results from the forecast concerning the demand for road transport, included in the Strategy of Sustainable Transport Development until 2030, the demand for transport services is in the growth phase. The pessimistic and optimistic scenarios of transport development and the range of changes taking place in road transport are presented below. 2015 was used as the base year. The forecast was developed assuming a simple continuation of the current trends [25]. The forecasted volume of road cargo transport demand (carried out by Polish and foreign carriers) is presented in Table 1. The forecasted transport workload is presented in Table 2.

Table 1. Forecasted volume of demand for road cargo transport (carried out by Polish and foreign carriers) (mln of tons) [42].

Year	2015	2020	2025	2030
Million tons – minimum forecast	1 550	1 674	1 733	1 746
Million tons – maximum forecast	1 550	1 715	1 845	1 955

Table 2. Forecasted transport workload for road transport (billion tkm) [42].

Year	2015	2020	2025	2030
Billion tkm – minimum forecast	319	383	405	416
Billion tkm – maximum forecast	51	54	58	60

As can be seen from the above tables, in the period up to 2030 the volume of transport demand and the projected road transport workload will increase compared to 2015.

As a result, transport companies are faced with increasingly stringent regulations to reduce their exhaust emissions. A lot of measures are being taken to comply with the EU requirements. The European Commission (EC) believes that vehicle manufacturers should also become deeply involved in reducing CO₂ emissions by advising customers on emission standards for trucks as well as on stringent emission standards in the future. Much attention is being paid to Euro standards [23]. The European Union imposes standards for acceptable emissions in new vehicles sold, and these standards result from a variety of European Directives. As a result of increasingly strict regulations in this respect, the production costs of new trucks are increasing, as well as the costs incurred by carriers in connection with road tolls [26].

Taking into account the continuous growth of demand for transport services, such actions seem insufficient. Therefore, it is necessary to look for other solutions, which will make it possible to organise transport on a larger scale, at the same time eliminating its negative effects. One of such solutions could be the use of European Modular Systems, which are currently used worldwide [27-31]. Such a solution will allow replacing 3 standard sets of vehicles by two longer sets [29, 32].

3 Characteristics of European Modular Systems

European Modular Systems (EMS in short) can be found under various names: Longer and Heavier Vehicles, Gigaliner, Megatruck, Monstertruck, Eurokombi. These vehicles can also be found under the names road train, megatruck or heavy road vehicle [28-30]. The European Modular System is regulated by the Council Directive 96/53/EC of 25 July 1996 on the maximum authorised dimensions in national and international traffic and the maximum authorised weights in international traffic for certain road vehicles circulating within the Community [29,33,34].

In the above-mentioned Directive, European modular systems are also referred to as the "modular concept". Article 4 of the above-mentioned Directive indicates that Member States may authorise the use of vehicles or combinations of vehicle sets, which are intended for the transport of goods in national traffic, provided that they do not significantly restrict international competition in the transport sector. Vehicles deviating from the values laid down in the Directive may then circulate within the territory concerned [27,29,33,34].

In Appendix I of the Directive, the normative values are specified for [27,28,34]:

- a. maximum allowable vehicle lengths:

- engine vehicle or semi-trailer - 12 m,
 - articulated vehicle - 16,5 m,
 - road train - 18,75 m.
- b. maximum allowable vehicle widths:
- 2,55 m – all vehicles,
 - 2,6 m in the case of freezer trucks.
- c. maximum allowable height of 4 m.
- d. maximum allowable vehicle weight:
- road trains or articulated vehicles - 40 t,
 - articulated vehicles transporting 40 feet long containers - 44 tons.

The European Modular System uses transport vehicles that are currently in use in Europe. The configured vehicle sets are 25,25 m long. The sets can be formed and unformed at will, allowing both normative and non-normative vehicles to be formed from them.

The modules from which they are formed are listed below [27,30,34]:

- a. truck tractor or lorry (standard),
- b. 13,7 m long articulated trailer (standard),
- c. 7,82 m long trailer (standard),
- d. 2-axle truck (called a bogie) (non-standard),
- e. special 7,82 m long 3-axle articulated trailer with a removable container/body at the front, equipped with a fifth wheel for attaching another articulated trailer (non-standard).

Modular system configurations are illustrated in Figure 1 [27,28,30]:

- a. configuration A - 2/3-axle truck tractor hooked to a 13,6 m long 3-axle articulated trailer, hooked with an 8-centre trailer with a length of up to 7,82 m,
- b. configuration B - 2/3-axle road tractor coupled to a special articulated trailer to be hooked on a standard 13,6 m long articulated trailer
- c. configuration C - 4 axle 8x2/8x4 chassis hooked to a 3 axle trailer,
- d. configuration D - 3-axle chassis 6x2/6x4 hooked by a fork lift truck and a 13,6 m 3-axle articulated trailer,
- e. configuration E - two-axle chassis hooked with two 7,82 m long tandem centre-axle trailers.



Fig.1. Modular system configurations [27].

Of the above concepts, it seems that configuration D with a 3-axle 6x2/6x4 chassis hooked by a fork lift truck and a 13,6 m 3-axle articulated trailer deserves special attention in terms of use. Considering the passage through roundabouts on national roads where the radius of the inner island is 5 m, vehicles in the above configuration are technically suitable [31,36].

4 Functioning of the European Modular Systems in Europe

The 1930s are considered to be the beginning of the use of European Modular Systems in the world. The country where their use began was Australia. In that country, the vehicles were used to transport at longer distances between cities. Other countries in the world where road trains were used were Canada, the United States, Mexico and Argentina. In Europe, modular systems were first used in Sweden. Since 1996, vehicles with a length of 25.25 m and a total weight of 60 tons have been widely used in this country. In the Netherlands, the first tests of road trains began in 1999 and the operation of this type of vehicles in that country was divided into several phases, in which the participation of transport companies gradually increased. In the last third of the test phases, 397 companies joined the tests. Tests have shown that the introduction of longer vehicles in the Netherlands has contributed to a reduction in the number of kilometres travelled and an increase in cargo transport, as well as, very importantly, a reduction in CO₂ emissions from 63 to 56g per ton-kilometre, which represented about an 11% reduction in CO₂, and in NO_x emissions from 0.4 to 0.37g per ton, which involved a 14% reduction [27-31,33,34]. In addition, analyses have shown that there has been an increase in transport efficiency, and the Dutch are also trying to test longer 32 m vehicle sets which, if the tests are successful, they will authorise for use on fixed routes. Finland is another European country that has authorised longer vehicles for use. Analyses confirm that the operation of road trains in this country contributes to a reduction in fuel consumption and therefore a reduction in negative environmental impacts. Finnish legislation from 2019 also allows vehicles longer than 25,25 m, this type of vehicles is used on routes between shopping centres and factories [27].

Denmark, another country that has been running tests to allow EMS vehicles on its roads for years. It currently allows the use of vehicles with a permissible weight of 48 tons. In Denmark, however, work is still underway to modernise the infrastructure and expand car parks to accommodate longer vehicles [27].

In addition, there are many other countries, such as Germany, Norway, Spain, Portugal and Belgium, which allow the use of 25-metre sets. In some of them this is based on a permit, in others, such as Germany it is allowed in some federal states [27].

The following table lists the countries that allow road trains on their territory.

Table 3. Countries permitting the use of road trains [27].

EU Country	Length of set	Admissible total weight of the vehicle
<i>Sweden</i>	25,25 m	64 t
<i>The Netherlands</i>	25,25 m	60 t
<i>Denmark</i>	25,25 m (tests till 2030)	48 t
<i>Finland</i>	34,5 m	76 t
<i>Norway</i>	24 m (25,25 m based on a permit)	60 t
<i>Germany</i>	25,25 m (some roads and some federal states)	40 t
<i>Spain</i>	18,75 (25,25 m based on a permit)	44 t (60 t based on a permit)
<i>Portugal</i>	18,75 (25,25 m based on a permit)	40 t (60 t based on a permit)

<i>Belgium</i>	18,75 (25,25 m based on a permit)	44 t (50 t in Walloon Region)
<i>Czech Republic</i>	18,75 (25,25 m based on a permit)	48 t

According to the study, the use of European Modular Systems is becoming widespread in Europe. European countries make use of derogations from the Directive and allow the operation of longer road sets. The leaders are the Scandinavian countries, which have pioneered EMS in Europe.

The use of European Modular Systems in Europe and the rest of the world seems to be justified in recent times also because of the ever-increasing volume of transported goods and environment protection.

5 Environmental conditions for the implementation of EMS in road transport

The road transport sector is, as has already been indicated, one of the fastest growing sectors of the economy. However, with its development and the increase in the number of vehicles, there is an increasing problem with emissions of substances harmful to the environment. Reducing emissions is becoming one of the biggest challenges in the world. In road transport, motor vehicles are powered by conventional fuels, and as a result they have a large share of atmospheric emissions of carbon dioxide CO₂ and other pollutants, particularly nitrogen oxides NO_x, and PM particulates. Exhaust emission standards are introduced to establish guidelines for the emission of harmful substances from vehicle engines. The latest and most currently valid standard is Euro VI. The European Union does not give vehicle manufacturers freedom in the case of CO₂ emissions. It imposes limits that every new model must meet. Since 2025, other, more restrictive standards of CO₂ emissions are to come into force [6,8,35].

The European Commission also proposes monitoring and reporting emissions from new heavy-duty vehicles, which will be subject to a certification procedure. Such action, apart from reducing the emission of carbon dioxide and fuel consumption by heavy vehicles, assumes the objective of standardisation and transparent presentation of data for this sector [21].

Taking into account the above-mentioned actions undertaken by the European Commission, the introduction of long 25 or 32 m trucks in road cargo transport seems to be an appropriate solution.

ACEA, the European organisation of truck manufacturers, has spoken out on the new CO₂ emission limits for heavy-duty vehicles and wants to see their extended versions introduced in the EU countries. According to analyses and tests carried out in other countries already experienced in the use of 25 m trucks, it is safe to say that extended vehicles are more efficient and economical than standard vehicles, and this in turn translates into the ecological aspect [37].

The World Association of Transporters IRU also calls for the lengthening of trucks. IRU has also decided to rename long vehicles, which have so far been promoted as 'mega-trucks', to 'eco-trucks'. In this way, the IRU wants to allude to the ecological advantages that come from reducing the amount of transport. As the organisation calculates, 25m eco-trucks will burn up to 35% less fuel than three 16.5m sets carrying the same amount of goods. Such a solution would translate into lower CO₂ emissions [38, 39].

Polish carriers have also been calling for longer vehicle combinations to be allowed on expressways for years. Transporters have demonstrated that such vehicle combinations are safe to use, as demonstrated during a test on the route between Volkswagen factories in Wielkopolska. The transport industry, on the other hand, indicates that allowing longer vehicles will reduce harmful emissions calculated per ton of load [40].

Tests have already been carried out in other countries which have shown that the use of longer trucks will reduce emissions. Below are the results of a test conducted between Gothenburg and Malmö, which involved transporting the same amount of goods with both regular trucks and heavy-duty vehicles [41].

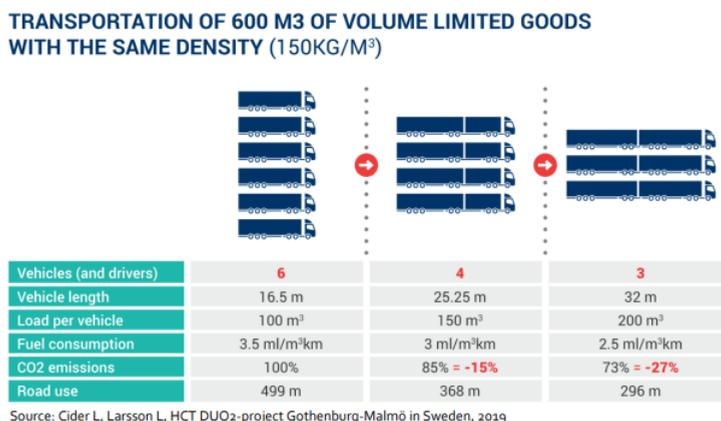


Fig 2. Comparison of selected modes of transport [24].

As can be seen from the data above, transporting the same amount of goods in 4 longer 25 m vehicles emits 15% less CO₂ than by 6 standard 16.5 m sets. The project also tested 32 m lorries, which, as the test result shows, emit 27% less CO₂ than the standard sets. This is directly related to fuel consumption per weight carried. A reduction in fuel consumption therefore leads directly to a reduction in CO₂ and NO_x.

6 Comparative analysis of selected means of transport

Taking into account the above considerations regarding fuel consumption and emissions, a comparison between two sets of cars was made to obtain the following data:

- fuel consumption (km),
- CO₂ emissions (g/t),
- NO_x emissions (g/t).

Based on the analysis of the data obtained, a comparison was made between six standard sets on the same route and four EMS sets.

For the purpose of these analyses, a 1699 km route from the Port of Stockholm in Sweden to the Port of Rijeka in Croatia was selected. The route is located between the ports of the Baltic Sea and the Adriatic Sea, which is in line with the implementation of the infrastructure projects of the Three Seas Fund and the operation of longer vehicles in the area [34].

Table 4. Output data (with maximum load of the vehicle)

	Number of pallets	Loading capacity (t)	Fuel consumption (l/100km)
Standard set – 16,5 m	34	40	31
EMS – 25,25 m	52	60	40

Two different sets of vehicles were adopted for the tests:

- Standard set – 16,5 m long,
- EMS – 25,25 m long.

Next, the fuel consumption results for the route from the Port of Stockholm in Sweden to the Port of Rijeka in Croatia, as well as CO₂ and NO_x emissions were presented in the table.

When calculating the emissions, it was assumed that the CO₂ combustion (63 g/t) compared to the standard set would decrease by 15%, while NO_x (0.4 g/t) would decrease by 18%.

Table 5. Fuel consumption and CO₂ and NO_x emissions results for the route from the Port of Stockholm in Sweden to the Port of Rijeka in Croatia.

	Fuel consumption (km)	CO ₂ emissions (g/t)	NO _x emissions(g/t)
Standard set – 16,5 m	566,69	2 520	16
EMS – 25,25 m	679,6	3 213	19,68

Table 6 . Comparison of 6 standard sets with 4 EMS sets

	Fuel consumption (l/km)	CO ₂ emissions (g/t)	NO _x emissions (g/t)	Number of pallets
Standard set – 16, 5 m	3 400,14	15 120	96	204
EMS – 25,25 m	2 718,4	12 852	78,72	208

Summing up the above analyses, it can be clearly stated that while transporting the same number of pallets on the same route, the EMS fuel consumption is 681.74 l/km lower than in the case of standard sets. CO₂ emissions are 2,268 g/t lower, while NO_x emissions are 17.28 g/t lower than for the standard set.

7 Summary

All over the world, the transport industry is facing the challenges and problems of reducing CO₂ and NO_x emissions to the environment. Given the current global situation, it is clear that this is a complex and difficult process. At the same time, it should be emphasised that this process must be set in motion in order to eliminate the negative effects of transport on the environment. It can be done by introducing various solutions and one of them is the implementation of European Modular Systems, which is proposed in this article. The benefit of implementing these types of vehicles is that they are more efficient and productive than standard trucks. EMS can consolidate loads from smaller vehicles, using less fuel and therefore producing fewer emissions per unit of load carried..

Longer vehicles, already referred to by some as eco-trucks, are a response to the ever-increasing needs of the transport and logistics industry, in view of the forecasts of rapid growth in the amount of freight being carried in the coming years. Road trains are already on the roads in many countries of the European Union, and tests carried out in these countries show that this makes economic and ecological sense.

Both the ACEA, which brings together transporters from all over the world, and the IRU, an organisation for vehicle manufacturers, are calling for new regulations concerning the length and weight of heavy goods vehicles and for longer vehicles to be put into general use..

In conclusion, it should also be mentioned that the introduction of this type of vehicle into service will allow for:

- savings for transport companies linked to a reduction in fuel consumption,
- increased competitiveness of companies,
- development of transport,
- reducing transport costs, providing more efficient logistics solutions.

All the above-mentioned solutions go hand in hand with benefits for the environment, both in terms of reducing emissions and in terms of safety and better use of road infrastructure. Another problem that has not yet been addressed in road transport is the current and expected shortage of drivers. The implementation of longer vehicles will allow freight to be consolidated in fewer vehicles, thus offering a technical solution to the shortage of drivers.

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