Abstract: The study analyses certain particularities of the railway transport system, highlighting advantages compared to other modes of transport. There are investigated the operational efficiency of rolling stock, the power sources in use for railway traction and the adaptability to intermodality. There are presented actual achievements and consistent possibilities for a necessary revival of railway system, with the aim of increasing its attractiveness, leading to efficient and sustainable balance of more environmental friendly transport modes.

Key-Words: sustainability, transport systems, railway, operational efficiency, intermodality

1 Introduction

It is well stated that transport represent a key factor in modern economy, with crucial impact regarding the economic and social development. In fact, a strong and healthy economic growth, jobs creative, can work only based on an efficient transport system, allowing the use of all advantages for internal markets and globalized trade. Nevertheless, the transport industry itself is an important part of the economy. Referring only to EU citizens, transport covers over 5% of total employment and accounts for about 7% of the GDP of the European Union [1, 2, 3].

It is equally true that transport is inevitably associated with environmental degradation, especially in terms of air pollution. At planetary level, it represents an intensive energy consumer that relies overwhelmingly on oil, using about 50% of the total production of petroleum products [2, 3, 4, 5].

Moreover, the motor vehicles emissions have a pronounced local and even regional negative impact, being also inevitable associated to the adverse effects on noise and land use [6]. There are also other major issues, including the accentuated unbalanced development of different modes, both for freight and passenger transport market [4].

Unfortunately, the evolution in time shows an increased imbalance mainly between land transport modes.

A normal concern about such an evolution is determined by the fact that such tendencies do not necessarily reflect a better adaptation of certain modes to the requirements of the global economy and of a sustainable transport.

Another major problem is caused by the congestion of auto and rail routes, the direct effect of the bottlenecks being not only exasperating, but also consequential direct or indirect costs increasing. Moreover, congestion affects not only urban areas, but also the entire European transport network: approx. 7500 km (about 10% of the road network) are daily affected. Also, 16000 km of railway network, representing approx. 20% of the network, are classified as having traffic troubles. A number of 16 major EU airports recorded over 15 minutes delays on more than 30% of the flights. Putting together, these delays result in an additional consumption of $1.9 \times 10^9$ litres of fuel, i.e. approximately 6% of the annual consumption [4].

On the other hand, in the last period, the transport needs patterns have changed in Europe, both because the overall changes of socio-economic and policies fundaments, as well as those arising in the transport system as a whole, the general economic growth, liberalization and privatization having a major influence.

Being increasingly aware of the importance of transport, but also knowing the main weak points, is compulsory to optimize the transport system in order to meet the demands of sustainable development, keeping a fair and balanced correlation with both economic developments as well as to quality and safety requirements of society. In addition, one must put together the necessity to preserve, protect and improve the environmental status and the human health, following a prudent and rational use of the natural resources [1, 2, 4].

As a clear consequence, European transport policy deemed a priority to change the ratio between the
different transport modes with the obvious goal to encourage the most sustainable ones, by rail and by water. As regards land transport, a priority is the revitalization of railway system, strategic sector with a great potential in changing the balance of transport modes, especially for freight. In the same general context, the classical "door to door" request can become a more efficient and environmentally friendly activity by bringing together various types of infrastructures and their related services, while maintaining the benefits of the specific advantages of each transport mode. The flexibility of road, combined with the high capacity of rail and the low costs of water services, when necessary the high speed of air transport, can be efficiently joined in intermodality. Developing an integrated system can also result in a significant decrease of road vehicles use for passengers and freight transport, increasing the use of rail and water transport means, recognized as more energy efficient and environmentally friendly, providing a more sustainable and coherent growth of the transport sector.

Based on the present problems, strategies and policies in transports, the study aims to highlight certain peculiarities of the rail system, focusing on important issues that are of concern for specialists in railway rolling stock in the attempt to increase attractiveness and revitalization of this strategic sector.

### 2 Particularities of railway transport system

Compared to other motorized transport systems, railways have certain peculiarities, beginning with the very low coefficient of friction between wheel and rail and the fact that the track provides not only support, but also guidance for the vehicles. In context, a defining aspect is the energy consumption and, directly related, the participation in air pollution caused by the railway transport system. According to statistics, in the EU, otherwise similar on planetary level, the transport system is responsible for a very high percentage (approx. 31%) of the total energy consumption. Analysing the transport mode partition, however, one may note that only 2.5% is consumed by rail, while road transport uses over 80% of it (see Fig. 1) in 2005. Six years later, in 2011, the situation is almost similar [3], but it is to notice a 2% increase for transport, while a slight decrease for railways (see Fig. 2). More striking is to analyse the allocations of transport energy relative to final energy consumption. The situation presented in Fig. 3, is relevant for the efficiency of rail sector.
the six gases identified as responsible for the greenhouse effect on a global scale (United Nations Framework Convention on Climate Change - UNFCCC) [7, 8].

From this point of view, in 2005, at EU level, transports are considered responsible for approx. 27% of GHG emissions. Of these, rail contributes to less than 2%, compared to over 70% determined by road sector (see Fig. 5).

As time evolution, it is to observe that regarding the modal split, in five years’ time, the ponder of railway influence has also slightly decreased, unlike the other components of the transport system [3] (see Fig. 6)

At least as relevant remains the disproportion between road and rail if reporting the data above presented to the market segment coverage. For an average of about 64.15 / 9.3 ≈ 7 transport market covered by road in 2011, the total energy consumption is more than 40 times higher than for the rail sector. Almost the same proportions are valid regarding the GHG correspondent emissions. Even just these data are striking both in terms of energy efficiency, as well as in terms of adverse effects on the environment, relative to the amount of carbon dioxide generated by rail operations. In fact, such a conclusion was expected as long as large part of lines in use (53.2% of a total length of 213574 km in EU-27 in 2011 [3]) are electrified and traction vehicles on these sections have no direct contributions to air pollution. It must however to be noted that this advantage is certainly dependent on resources and the way of achieving the primary energy production (hydro, thermal, nuclear or other modes based on wind, solar, geothermal energy etc.).
From this point of view, statistical, for EU, the situation is presented in Fig. 7.

As reference, Fig. 8 presents the share of resources used for power generation in the same year in Romania. It must notice that in conventional electric power plants, fossil fuels do not have to be of high quality. More, stationary regime operation allows a very rigorous control of the combustion process, ensuring efficiency, with a corresponding reduction of pollutants submitted into atmosphere. The electrification of new traffic sections, although constitutes a substantial investment of capital, labour and time, can be done keeping them operational by use of diesel traction until the completion of the work.

The overwhelming majority of non-electric rail traction vehicles engines are equipped with diesel engines that obviously run on diesel. In diesel composition, fractions are heavier than in gasoline, having a lower volatility. Consequently, is reduced the pollution with volatile organic compounds, particularly with regard to 1,3-butadiene. Also, aldehydes are much less present in the exhaust gas of diesel engines. At the same time, the amount of carbon monoxide in combustion gases is usually lower, as diesel engines are generally slower and there is sufficient time for a complete combustion and therefore the complete oxidation, including carbon to carbon dioxide.

Regarding sulphur oxides, fact remains that diesel content is higher than gasoline, but currently permissible limits are very restrictive, so in general, the contribution of rail sector to generate sulphur oxides is quite small.

Still, the general use of diesel engine raise a number of issues, for example related to particulate matter, mainly soot, that usually does not occur in spark ignition engines. In addition, nitrogen oxides are present in a greater amount in the exhaust gas of diesel engines because temperatures can be sufficiently high and, due to the longer duration of the combustion process, there are promoted the dissolution and oxidation of the nitrogen’s chemical bonds present in the fuel mixture.

Obviously, the energy efficiency of rail transport is, however, strongly dependent on the capacity-charging rate of railway vehicles and therefore should be considered an increase of the load factor in operation.

In this context, it is important to ensure flexibility and a good adaptability of the rail system to market demands.

An important role has the opening of railway market, the possibilities to allow safe and uninterrupted train operation, providing interoperability, because all these create favourable premises for a rational and energy use adaptation to specific transport demands.

Fortunately, railway is mostly ready in this respect. For example, it is an accentuated tendency in replacing long loco-hauled trains by smaller units with a high degree of modularity and flexibility [9]. The use of multiple units in passenger transport allow coupling in different train compositions and lengths to ensure the required elasticity between the instantaneous transport demands and the provided transport capacity.

Railway is able to sustain intermodal transport, by providing specially designed wagons for transport of containers or palletized freight. The special flat wagons with small wheels that allow loading and transport tractors solve a number of key aspects. One must not neglect the special wagons for transporting cars operated in long-distance night passenger trains.

If we analyse the overall air pollution caused by traction vehicles, an important cause of increase in emissions is the inadequate vehicle maintenance activities, which generally also lead to poor performance and thus to an increase in fuel consumption.

From this point of view, railway technologies and procedures are very clear and strict in respect of testing, maintenance and repairing procedures for traction vehicles, which applies very strictly on a schedule and a well-defined periodicity. These activities contribute to keep the operational characteristics in optimal limits, thereby acting in particular to mitigate the effects of atmospheric pollution by railway transport.

Generally, one must admit that these activities are developed in higher rigor than in the road sector. Objective and subjective reasons stand for it: the traction railway fleet is substantially smaller compared to the automotive one, the activities and
appropriate procedures are carried out in a mere restrained number of units that are authorized in this respect and whose work and quality are more easily verifiable, with clear traceability in this area [5]. It is important to underline the fact that rail transport generates significantly lower external costs than road, first because it is much safer, the number of railway accidents is extremely low and therefore the corresponding costs are much smaller. Just for record, the number of railway passengers killed in accidents involving railway was in 2011 almost 800 times smaller compared to road fatalities (38 vs. 30268) [3]. At the same time, there are avoided major traffic jams that are generating exacerbated local pollution, as well as losses and other economic and social additional costs, including those caused by delays (see Fig. 9).

Nevertheless, in terms of land use, rail is also advantageous. For example, in Fig. 10 is presented a comparison between the passengers transport capacity per meter of infrastructure width for cars, buses and rail vehicles.

The data vigorously points out this aspect. For freight transport, it is a similar situation.

### 3 Operational energy efficiency of railway rolling stock

In the stated context, the energy efficiency of railway transport continues to be a major concern, both in terms of cost and hence potential attractiveness, and in terms of environmental issues. As regards the railway rolling stock, studies in this direction aimed to identify the factors that determine the energy consumption, causes, ponders and possibilities to recover.

On such bases, consistent technical, constructive and operational measures and actions can be synthetized in order to minimize the energy consumption while maintaining and even improving the performances the railway vehicles.

In principle, there were identified four key areas related to energy demand for trains operation (see Fig. 11) [9]:

- the energy required for train motion by the traction forces developed at the wheel/rail contact, which must overcome the resistances and to be able to ensure appropriate accelerations;
- energy losses in the traction equipment, primarily as heat dissipation into the environment, but also determined by the use of auxiliary services necessary in operation;
- the energy used for providing the passenger comfort conditions, e.g. heating, air conditioning, lighting, toilets;
- losses in the assembly of power supply system.

Main parameters major influencing the energy consumed for moving the train are summarized in Fig. 12.

From their analysis, it can be concluded that:

- velocity and mass have a major influence, while number and frequency of stops seriously affect the energy both consumed for start-up, acceleration and dissipated during the braking process;
- the main resistances are essentially affected by the air drag (generally dependent on the square of speed, length and weight of the train, the shape and the size of the end of the train etc.) and by mechanical friction in the vehicle-track system and vehicle itself (axle boxes etc.);
- in the case of freight trains, that run with relatively small velocities, mechanical friction resistances are determinant. Is needed to specify that for freight uncovered wagons, it was attested that the main specific resistances are sometimes much higher for empty uncovered vehicles than when loaded. In these cases, the shape, dimensions and position of the load become more and more important in direct accordance to the increase of running speed for freight trains;
- in the case of high speed passenger trains, aerodynamic drag become predominant, the main resistances becoming proportionally insignificant influenced by mechanical friction;
- energy consumption for accelerating and running on ramps are generally not dissipate, but the train mass accumulates as kinetic or potential energy that can be recovered in a sufficiently large proportion through regenerative braking for vehicles equipped with electric traction motors. As regards the high-speed trains, aerodynamic resistances, having a major influence, are dependent

Fig. 11. Energy flow diagram for a train.

Fig. 12. Main factors influencing the train operation energy.
on the exterior geometry of the train. Surfaces roughness and positioning, the shape and construction of all exterior elements contribute accordingly. Studies in this area highlight the role and contribution of different parts of the train in the assembly of resistances [9].

In context, the track profile has also major influences by size and length of grades and curves, but these cannot be redefined unless the construction of new lines.

Regarding the traction system, it is obvious that conversion and transmission of power, either obtained from the catenary or by fuel combustion on the vehicle, into mechanical energy to the wheelsets, involves inevitable losses.

In the case of passenger trains, about 20% of total energy consumption is used for ensuring the comfort requirements, meaning air conditioning, ventilation, lighting etc.

Based on such studies, it is possible to establish energy efficiency strategies in designing, construction and operation of rail vehicles. A basic summary of these is presented in the following [9]:

- coaches weight reduction may be achieved using lighter equipment and materials (aluminium, carbon fibre), but most effective way would be a rethinking of the whole train, using multiple units due to their advantages, some of them previously highlighted. This results in additional space that can be used for the sitting places, increasing either the number, or the comfort of passengers. The use of bogies on which abuts two consecutive vehicles reduces the number of axles on the train length and therefore its mass and diminishes the resistances, especially in high-speed domain. Also, increases the train stability. Another way to reduce weight/place is an optimal use of space, a method already in use for double-deckers;

- decrease of main running resistances, especially in high-speed domain, can be achieved by several methods: shielding the bogies and even the underside of the chassis with an appropriate shape exterior cover; an aerodynamic shape, the front and end tails having an unexpected importance, in particular in very short trains; avoiding sudden shape changes of the outer surface of the vehicle by optimizing the design of windows, doors and intercommunication areas etc.. As for freight wagons, as it was previous stated, that are recommended in operation especially those covered or even platform with mobile cover, which also have a correspondingly lower tare;

- regenerative electric braking and coast driving strategies, adapted for maximum use of kinetic and potential energy of the train. The known railway operational particularities permit to elaborate computer-conducted advanced driver assistant systems that help train drivers operate their trains in a smooth and energy-efficient manner. Such systems offer on-board advice and comes with back-office applications with sophisticated analysis functionality, e.g. [10];

- development of hybrid railway vehicles capable to store the electric energy recovered during braking and use it in tractive regime.

4 Power sources for railway traction

Currently one can say that the rail transport system is based almost entirely on electric and diesel vehicles. Although there were trends for reducing railway diesel fleet, it will continue to have a significant role as long as electrification is not economically reasonable in many situations. Thus, the dedicated power sources used on-board by railway traction vehicles are compression ignition engines, operating in both four as well as two-strokes, each with the known advantages and disadvantages [11].

In general, one seems to be preferred four-stroke diesel engines, with no reasoned technical position for one of these types of engines; the adoption is more a question of choice [11, 12]. However, two-stroke power engines are advantageous in quite stable regimes. In variable ones, their adaptation is harder, with a lower efficiency and higher fuel consumption. That is why these are mostly used on locomotives for hauling freight trains on long sections with relatively constant or slowly varying supplementary resistances and for quite low running speeds.

In a medium-term perspective, is to expect an increased pressure on diesel traction, both because of European emissions standards tightening for diesel engines as well as the use of alternative or renewable fuel, which has already led to an extremely dynamic development in diesel technology.

In this respect, of great significance in terms of fuel economy is the use of direct injection diesel engines that improves energy efficiency by 15 ... 20%. This resulted mainly from improvements of the injector (with multiple orifices and two stages of injection), the use of higher injection pressures (as a result of improvements to the injection pumps and the use of electronic control) and common rail technology developments [9].

Another particularly pressing problem is framing in accepted norms of pollution that become ever
Generally, gas turbines operate with maximum efficiency at maximum power; at low speeds, the increased fuel consumption affects economic aspects. At the same time, respond less properly to load variations, so their use is justified especially at high rpm and constant power.

The use of gas turbines in railway traction has undergone significant growth in `50-`60s and culminated with the TGV 001, trainset equipped with electric transmission that reached the world speed record of 318 km/h in December 1972. Further development was done, however, as known, with electric units.

An achievement of the end of 2000, railcar Jetrain is intended for a maximum speed of 250 km/h. The end vehicles are engined, being equipped each with two gas turbines, hydraulic transmission and a diesel electric generator group to supply auxiliary services. It is to note that the latter is used for providing the necessary power at low speed operation. There is an operating electronic controlled system, which allows the use of four turbines in the start-up and acceleration to operational speed. Then, depending on the resistances, one or both turbines are removed from the circuit and, for low running speed or during stoppage, only the diesel-electric generator is used [15].

Independent power sources for railway traction are also the fuel cells, based on two electrodes separated by an electrolyte, connected to an external circuit [11]. The fuel cell is supplied from a hydrogen tank and an external air intake, while the exhaust gas of the oxidation reaction between hydrogen and oxygen consists of water vapour. About 60% of the generated energy comes to be converted into electricity without generating noise or vibration.

The main problems are due to the high cost of both the cell as well as pure hydrogen, associated with storage difficulties [15], basically in the form of compressed, liquefied or chemical storage using materials such as nano-carbon, metal hydrides organometallic compounds, fullerenes etc. [16].

Another major problem is to ensure an appropriate cooling. The temperature of the fuel cell must be relatively low, imposing the use of radiators with a much larger thermic transfer surface than in the case of diesel engines. However, at present, fuel cells seem to become the most promising long-term method to replace diesel traction.

5 Railway and intermodal transport
Intermodality is the characteristic of a transport system that requires the use of at least two transport modes in providing "door to door". This refers for
both freight and passengers. In the public acceptation of the term, is used the notion of "integrated" with respect to passenger transport, while the term "intermodal" is used mainly when it comes to freight.

A particular case of intermodal freight transport is the combined transport, in which cargo units (trucks, trailers, with or without tractor, mobile boxes or containers) are moved, where appropriate, on the road, during the initial and/or end. The rest of the transport is performed by rail or on a waterway (inland, sea route) exceeding 100 km in a straight line.

Road-railway combined transport was initiated mainly to achieve a continuous "door to door" transport into a coherent chain of transport. Usually, according to whether the loading unit is or not accompanied by the tractor driver on the rail section interposed, the combined transport is considered to be accompanied (RO-LA) or unaccompanied (containers, swap bodies, semi-trailers).

The RO-LA designation, widely used in Europe, comes from the German "Rollende Landstrasse", meaning literally rolling road (RR). RO-LA is that intermediate area of combined transport characterised by the fact that the whole road vehicle (tractor and trailer), is displaced with specially destined wagons on the railroad.

The carriage of heavy road vehicles on the platform of railway vehicles arose from the need for road decongestion, to expedite customs crossings and, more recently, to abidance by noise and chemical pollution restrains. Road vehicles with high axle loads degrade quickly the roads, causing major infrastructure spending. In addition, environmental problems caused by internal combustion engines are reduced to a minimum, especially when using electric railway traction.

The main problems connected with RO-LA combined transport are related to the compliance with: the rolling stock gauge, ensuring appropriate transport capacity, traffic safety under conditions of relatively high speeds (100 ... 120 km/h), equipment for terminals (special strengthened ramps, electric networks, air compressed sources etc.).

A major task of rolling stock manufacturers is to provide appropriate vehicles and equipment for intermodal transport, in order to increase the attractiveness in area and to be able to take a flow as high as freight as well as passengers.

In addition to compliance with the railway specific requirements, rules and regulations, one must be also targeted the harmonization of conditions for loading and haulage, in terms of maximum allowable weight per axle or per meter, maximum length and gauge conditions.

A series of specialized intermodal transport wagons are described below.

There are two types of special wagons suited for the conveyance of road vehicles in combined transport: fixed-recess wagons and bogie wagons with a low loading surface along their full length.

The recess wagons have two bogies with two axles and are provided with a lowered part of the platform, suited for semi-trailers and swap bodies that can be grab-lifted, as well as for large containers when appropriate [17].

As an example of first vehicle category, currently used in operation is the Sdgkkms type. It is equipped with 760 mm maximum wheel diameter and a height of loading surface above rail level of 650 mm in recess zone and 850 mm in the area of the bogies.

The bogie wagons with a low loading surface along their full length are destined for conveyance of road tractor and semi-trailer combinations and road trains (tractors and trailers). These wagons are designed for horizontal loading and unloading over end-loading platforms, with the headstocks open.

The main constructive features are essentially determined by the condition of framing the wagon, with the entire load, in upper vertical rolling stock gauge. The use of “small diameter wheels” (335 ... 410 mm) solves the problem of a very low platform relative to rail level over the whole length of the underframe. Still, raises several issues: special construction of the wheelset, of the braking system, particular requirements regarding the axle boxes etc. Moreover, the loading/unloading conditions imposed particular requirements for the coupling apparatus and buffers regarding their low position, unlike to standard vehicles.

Under these conditions, the maximum height of the loading surface above the rail level could be lowered up to 454 mm above the hatches in the area of the bogies and 414 mm elsewhere.

Destined for combined traffic, there are also seven types of special wagons suitable for conveying large containers or swap bodies. These must incorporate folding away or retractable devices to secure large containers and swap bodies against the effect of side winds.

An interesting and particularly solution adapted for low intensity and poor equipped terminals for combined road-rail traffic is represented by the wagons specially destined for conveyance of horizontally-transferred roller-units.
The flat-type wagon has three pivoting frames adapted to roller units for horizontal handling [17]. These have two side-bearers, one or several front-end grab handling fittings and one or two pairs of wheels at the rear. They may be loaded on special lorries and conveyed by road. It is not necessary to use special devices for the horizontal transfer lorry/wagon and vice versa. The roller unit is slid onto the swivel frame once the frame has been swung out to receive it. When the roller unit has been placed on the pivoting frame, the frame is realigned on the wagon centre-line and locked into position [17, 18].

Regarding the integrated passenger road-rail integrated system, it is to mention the special wagon for cars. It is adapted for the long distance night passenger trains, designed for corresponding running speed.

6 Conclusion

The railway system has considerable revival potential to become an increasingly attractive option on a land transport market that is disturbed by major imbalances, determined by the exacerbated, but not necessarily sustainable development of road transport. Railways certainly have a crucial role in a sustainable, safer and greener evolution of the transport system. Constant concerns and achievements connected to continuous increasing the performance, velocities of railway vehicles, along with higher hauled tonnages while reducing energy consumption and pollution, the use of alternative fuels and the development of intermodal specialized freight and passenger rolling stock are solid arguments that stand for it.

References:

[10] LEADER Driver Assistant, Knorr-Bremse Group