Summary: The urgent need for deepening economic and social relations between the EU and Ukraine determines the priority of effective international rail traffic. Creating wagons gauge 1520/1435 mm (the "East-West" wagons) for non-transshipment transporting on different gauge standards with the use of automated transfer gauge system (ATGS) technology demands a wide range of research and feasibility studies for assessment and forecast of transportation markets between Ukraine and EU and introduction into circulation of rolling stock which would operate both on the 1435 mm and 1520 mm tracks. In these studies the positive results of transportation market assessment and pre-feasibility study were obtained that allowed articulate and prove the general requirements to wagons of 1520/1435 mm gauge and recommendations for the formation of the new rolling stock fleet of the "East-West" wagons.

Keywords: combined transport, gauge change, rolling stock

1. INTRODUCTION AND OBJECTIVES

The socio-political situation that emerged, the state of Ukraine's economy in general and rail transport in particular require urgent actions to reformat trade and economic relations with neighboring countries and the reorientation of traffic flows towards the European Union. The urgent need for active deepening of political, economic and social relations between the EU and Ukraine determines the priority of effective international rail traffic. Association Agreement between Ukraine and the European Union in the field of transport leads to the implementation of effective and safe transport, intermodality and interoperability of transport systems and the development of multi-modal transport network linked to trans-European transport network TEN-T.

The known problems remain that require systemic solution when planning actions for the integration of railways of Ukraine into the European transport network and include issues related to the safe and rapid transfer of rolling stock through the junction points of
different tracks standard. Under the Roadmap to support the realization of the Directive on the interoperability of the railway system a key technical issue that remains open is: Will the Ukraine use an automatic change of gauge, taking off the real limit to interoperability, by changing the width of the track on the border with the EU, or remain in the current schemes of reloading cargoes and changing bogies of passenger cars on the border with the EU?

The use of automatic gauge change by means of Automated Transfer Gauge Systems (ATGS) significantly reduces the border-crossing time of rolling stock at junction points of different track standard. Besides improving the time factor, disappear all the inconveniences and drawbacks of existing rearrangement technology. By now, implemented in practice European automatic rolling stock gauge change systems at joints of different gauge width include: Spanish TALGO and BRAVA systems, Bulgarian BT system, Polish SUW2000 and German DB AG / Rafil systems [2].

The solution with variable was carried out 15 years ago by Polish and Ukrainian railways. The ATGS technology based on Polish SUW2000 bogies and track gauge change station was tested and a passenger train between Poland and Ukraine was launched [1]. Another and quite recent example is the passengers train between Turkey and Azerbaijan via Georgia with German DB Rafil type V variable gauge that is reported to be successful.

As any of ATGS technological solutions is rather expensive, considerably exceeding conventional railway rolling stock, the return of investment (ROI) is crucial. Obviously the ROI depends on goods transported and traffic volumes as well as on rail and road transport tariffs, railway infrastructure access charges. In other words, the transportation market, both actual and forecast, should be taken into account to choose the best ATGS technological solution for rail transportation of goods between Ukraine and EU.

2. NEW TRANSPORT MARKETS UKRAINE – EU

Major traffic flows of foreign trade goods between Ukraine and the EU were the subject of analysis that was made on the basis of statistical data for 2012 - 2015 years (Eurostat and Ukrcstat official web-sites). On this basis the following conclusions were drawn:

- freight (goods of foreign economic activity) from Ukraine to the EU (about 48 mln tons) is significantly higher than traffic in the opposite direction, from the EU to Ukraine, which amounted to about 9,6mln tons (5 times smaller);
- trend of significantly higher transportation volumes from Ukraine to the EU than in the opposite direction is likely to continue in the future up to 2025, as it depends on the state of the economy, the structure of production and consumption of goods in Ukraine and the EU;
- when introducing ATGS technology one should focus on the flow of goods from Ukraine to the EU, taking into account the structure and the possible transport of goods in the opposite direction to minimize empty return;
largest volumes of goods between Ukraine and the EU are carried (in descending order) by rail, sea and road transport, and the structure of trade flows in these modes is very different, as illustrated below with classification of Eurostat (Fig. 1-3).

Fig. 1. Transportation from Ukraine to EU by rail

Fig. 2. Transportation from Ukraine to EU by sea

Fig. 3. Transportation from Ukraine to EU by road

Figures 1 – 3 allow to conclude the following.
Railway basically transported in 2014 such loads as: ores; slag; minerals; iron; steel; copper; wood; salts; earth; stone.
Maritime transport basically was carrying loads: cereals and grain industry products; iron; steel; copper; ores; slag; minerals; salts; earth; stone.
Road transport carrying in 2014 basically loads: wood and other products; general cargo; consumer products; iron; steel; copper; cereals and grain industry products.
Most massive cargo at rail transport (ores, slags, minerals) are transported mainly to Slovakia and Poland by track of 1520 mm gauge and therefore do not need to be carried by means of ATGS technology.

Most bulk cargo at maritime transport (cereals and grain industry products) are transported mainly to Spain, Italy, where the sea is the most convenient way, so ATGS technology there is hardly appropriate; but the Netherlands can be considered as a possible direction of transport by rail using ATGS.

In years 2012 - 2014 there have been changes in the volume of cargo transportation of Ukraine in the EU different modes of transport.

### 2.1. RAIL TRANSPORT

Volumes of cargo that can be transported on ATGS technology (all goods except ores, slag, minerals) remained stable for grain (over 0,5 mln tons per year), timber traffic volumes increased (more than 2 mln tons per year), and all other goods transportation decreased.

The most promising goods for transport to the EU, including through technology ATGS, are loads of cereals, as demand for them is stable, and the production of grain in Ukraine is also steadily increasing.

### 2.2. MARITIME TRANSPORT

In 2014, rapidly increased traffic volumes of Ukrainian cereals to Spain, Italy, the Netherlands, indicating the big demand for them in those EU countries.

Slowed down or almost stopped the growth of cargo transportation of "Iron, steel, copper" and "Ores, slag, minerals," which indicates a decrease in the relevant product market in the EU.

Rising grain market and reduce of other markets served by the sea, there is also evidence that the most promising goods for transport from Ukraine to the EU, including through ATGS technology, is grain shipments.

### 2.3. ROAD TRANSPORT

Analysis of the transport of goods from Ukraine to the EU by road which could be switched to rail and carried with the ATGStechnology, shows the following trends and allows to draw such a conclusion.

Reducing transport of most goods, except for timber and grain, is a clear tendency.

The rapid growth of timber traffic and less growth of grain transportation, minor in comparison with other modes of transport and other cargo traffic volumes.
Another conclusion can be drawn that through ATGS technology the market share of piggyback rail transportation of grain and timber can be increased, and also of grain transportation in hopper type wagons.

Review of manufacturing industries, which form the major traffic flows of foreign trade goods between Ukraine and the EU as well as production of various industries, transported by road allows to conclude the following.

Road transport is traditionally seen as a competitor to rail and vice versa. However, they can complement each other in piggyback transport, which expands its possibilities by the use of ATGS technology.

Agricultural products and wood can be transported by rail with the use of this technology and complement schemes of combined (piggyback) traffic. The estimated market evaluation of traffic received based on Eurostat data of year 2014 on transport of goods between Ukraine and the EU by road is average 500 vehicles per day.

3. NEW TECHNOLOGIES OF COMBINED TRANSPORT

An important decision about a significant improvement in terms of combined transport of goods via international transport corridors is the introduction into circulation of rolling stock which would operate both on the 1435 mm and 1520 mm tracks. Creating wagons gauge 1520/1435 mm or, in other words, the "East-West" wagons for non-transshipment transporting goods by rail of different gauge standards with use of ATGS technology will significantly increase the volume of international traffic to facilitate the loading of highways and improve environmental protection.

3.1. GENERAL REQUIREMENTS TO WAGONS OF 1520/1435 MM GAUGE

Freight cars that are designed for transshipment free communication between the railways of 1435 mm gauge and railways of 1520 mm gauge should be constructed in accordance with the requirements of the UIC and OSJD Leaflets in particular with the provisions of OSJD Leaflet 516 and UIC Leaflet 430-4 and Standards railways of 1520 mm gauge. For wagons in empty and laden states should be allowed a maximum speed of at least 120 km/h. Calculated axle load shall be 22.5 ton. Rolling stock construction gauge should be determined by UIC Leaflet 505-1 and OSJD Leaflet 500.

According to UIC/OSJD Code 430-4 wagons equipped with gauge-adjustable wheelsets must pass through the gauge changeover devices with acceptable wear elements of trucks. Individual cars have to ensure passage curve radius of 60 m in both empty and loaded states. Wagons must be suitable for transport on rail ferries. For fixing to ferry cars must have at least four fastening rings on each side. The wagon frame should be provided space for lifting the car when it is loaded or empty. The design of the car should provide its
lifting when empty by the ends of the main pivot beams diagonally. For lifting wagon on the rails, two lifting points must be provided on each headstock front of beam close to the buffer fastening plane.

The conditions for the wagon strength determined depending on the design and operating conditions, and must meet regulatory requirements for railways of 1520 mm gauge and UIC/OSJD Leaflets. Thus the priority has more stringent requirements.

Proof of durability should be taken with calculations and tests. Parts that cannot be unambiguous calculation by known methods should be subjected to the test.

The wagon underframe without permanent deformation must be able to withstand horizontal longitudinal load value of which is determined by OSJD Leaflet 516 and UIC Leaflet 430-4. The bearing structure must be able to withstand without permanent deformation most favourable mode of action vertical load prescribed by technical standards. Thus the frame deflection relative to state of rest should not exceed 3‰ car base.

The provisions of OSJD Leaflet 516 and UIC Leaflet 430-4, concerning the admission to operation relate to the newly built wagons of the "East-West" type. As to conditions of access and operation of freight wagons, which are in retreat from these provisions are built on demands of Leaflets UIC and OSJD for tracks of 1435 mm gauge or only according to the norms of 1520 mm gauge railways, these issues should be decided on the basis of bilateral or multilateral agreements between concerned railway administrations.

3.2. RUNNING GEARS

For wagon bogies recommended axle spring suspension with two-stage characteristic such that static spring deflection on an empty wagon is approximately 35% to 40% that of a loaded wagon. To attenuate vertical and horizontal vibrations, oscillation dampers with force-proportional damping should be used.

The connection between components in the bogie or between bogie and vehicle body may be designed in such a way that the wagon can be lifted together with the bogie.

Brake block arrangement in the bogie must be such that the blocks can be adjusted automatically according to track gauge. This should be ruling out an involuntary displacement of the blocks and ensuring their fixing in extreme positions.

Strength of the bogies must comply with OSJD Leaflet 524, OSJD Leaflet 578 and UIC Leaflet 515-0. Bogies must provide indexes smoothness of motion, which needed to ensure the preservation of cargo.

3.3. RECOMMENDATIONS FOR THE FORMATION OF THE ROLLING STOCK FLEET

To equip with gauge change wheelsets and adapt to the circulation on the railways both gauge of 1435 mm and 1520 mm the intermodal platforms loading of trailer (or swap bodies or containers) are recommended.
For organizations without transshipment traffic in areas of "East-West" by adapting cars to the 1435 mm gauge conditions on the railways of 1520 mm gauge with the following options:

- Production of wagons 1435/1520 mm gauge, according to the requirements attractions OSJD/UIC Leaflet 516 and TSI;
- Adaptation of 1435 mm gauge wagons to working conditions on the railways with track of 1520 mm gauge.

The first option is the most complex and designed for the long term as universal and one that requires a substantial park of "all-terrain" 1435/1520 mm gauge wagons. The second option seems feasible in the short term with the possible purpose – for cargo transportation on certain routes from Ukraine and to Ukraine mainly by trains with the permanent formation of the 1435 mm gauge wagons. Would also be possible to include groups of such wagons in freight trains on track of 1520 mm gauge. The implementation of this option is possible through the purchase of certified wagons of 1435 mm gauge (purchase, lease, creation of compatible fleet of cars etc.).

To implement the second option requires a number of works. First of all, the need to determine the types and number of required cars of 1435 mm gauge that meet specific needs in transportation of goods on specified routes. Based on the weighted norms of trains on the Ukrainian railways and the countries of Central and Western Europe, we have established the number of cars on the train routes.

For cars brake equipment necessary to carry out specific types of adaptation in order to ensure compatibility with brake control systems of locomotives on tracks of 1520 mm gauge. It is also necessary to prepare a number of the transitional wagons on border stations.

To install the conditions of running safety of trains with 1435 mm gauge wagons or groups of those wagons on railways of 1520 mm track gauge should be conducted under dynamic calculations using the methods of mathematical modelling. According to the results of computer simulation programs and methods will need to develop and conduct test trips with measurements of dynamic processes in the experimental train.

A necessary step for the organization of work without reloading traffic is drawing up guidelines for station workers, observers of cars and locomotive drivers on specified routes of trains with Western-type wagons or groups of such wagons. On the route of trains involved, line workers should receive appropriate training regarding service features of the new types of cars. In addition, there should necessary spare parts for braking systems and coupling devices be provided for the routes.

After the commissioning of trains for transport of goods without reloading, the defined areas of "East-West" should organize constant surveillance operation on modernized bogies, brake and traction equipment devices.

### 3.4. PROCEDURAL ISSUES ACCEPTANCE OF WAGONS

Currently, there are no specific procedures for admission to the operation of rolling stock designed for use on the railways of 1520 mm and 1435 mm [3]. Therefore the matter of admission to the operation of wagons in international traffic is determined by bilateral or
multilateral agreements between railway administrations as traffic participants. The following are the basic requirements for the procedural provisions of the admission tasks.

Cars for international transport before being approved for operation must undergo comprehensive tests – stationary, strength, running, brake and train sets. These tests are necessary to determine the degree of car conforming to technical requirements on the criteria of traffic safety, durability, reliability and functionality.

Before the series of required testing wagons with bogies equipped with variable gauge wheelsets on a railway of 1520 mm track gauge belongs to validate calculations and modelling of dynamics and strength for the purpose accordance to the obligatory norms.

For admitting to the model tests it is necessary also to conduct verification of accordance of making of bogies with variable gauge wheelsets technical requirements and designer document, and also to the requirements, to certain in the proper normative documents for the freight cars of 1520 mm track gauge. Also need to check for quality certificates, approvals, attestations, acceptance of conclusions for each element and material.

4. CONCLUSION

Based on the economic situation and the economic forecast of Ukraine for 5 - 10 years, as well as the trends in some commodity markets in the EU, we can conclude that the introduction of technology ATGS in rail and combined (piggyback) traffic from Ukraine to the EU may involve the most promising loads as follows:

- grain and oilseed cargo in hopper type wagons of European standard (especially exports from Ukraine to Italy);
- mineral, chemical or nitrogen fertilizers, also in hopper type wagons of European standard with uniform design as for grain wagons (primarily exports from Ukraine to Italy);
- refractory clay, kaolin and other kaolin clays exported to Italy, which may be carried in the gondola type wagons;
- grain and oilseeds, all other goods in 20 feet containers (40 feet container use in terms of Ukraine is still problematic);
- piggyback and trucks on pocket type platforms (for stimulation of traffic appropriate legal regulation of combined transport in Ukraine is required).

Continued widespread use transshipment of technology this is a trend associated with the loss of cargo, damage to rolling stock, and in case of dangerous goods it is also a threat to environmental problems and operational safety. Therefore, there is time for development and introduction of advanced technologies based on the use of transport technology without transshipment. Thanks to scientific and technical elaborations in the last fifteen years, Ukrainian railways have unique among the 1520 mm gauge railways development and experience in technical and technological support without transshipment traffic.

Previous studies of technical and technological provision of international rail connections determined that the use of automated systems transition joints of gauge
1520/1435 mm are attractive because substantially reduces crossing the borders with EU countries and eliminates the need for storage on removable bogies on points of carriages replacement or arrange for transshipment. However, on the way to the practical use of a system of automated transition junction points of different standard tracks need to implement a set of measures to ensure the safe operation of the running gears with the gauge change wheelsets.

References