Systematization of rolling-stock parameters in piggyback systems

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Abstract. The growth of the external trade between countries makes it necessary to modernize the transport system and realize intermodal technologies that provide effective cargo delivery. Analysis of using piggyback transportation abroad and in Russia is done in this article. Parameters system of rolling-stock in piggyback transportation is proposed. Using the proposed system will enable the compatibility assessment of vehicles that are used in shipment organization. And it will help to choose the most appropriate option of shipment using piggyback transportation.

1. Introduction
Freight transportation is the key element of the supply chain, which provides qualitative and effective delivery of raw materials and finished products. Under trading globalization, growth of the foreign trade turnover between European and Asian countries [1], and also increase of export share of Asian countries (PRC, Republic of Korea, India) [2] in total world trade, the task of developing international transport corridors, building-related infrastructures and using inter-modal technologies, that provide servicing for freight flows, becomes very relevant. For the Russian transport system, that claims for promotion freight flows on its own territory, within the project ‘Silk Roads’ [3], solvation of the listed tasks might be reached by the organization of multi- and inter-modal shipping. One variant of such shipping is piggyback transportation [4]. According to the international experience, government plays the key role in their organization, [5, 6] because using piggyback transport related to significant investment in infrastructure development and rolling-stock [7, 8], preparation of the regulatory framework [6]. However, the use of inter-modal technologies makes it possible to increase the efficiency and quality of the carriage delivery [9, 10]. It also decreases the transportation process energy consumption and reduces the negative environmental impact [11, 12], and moreover, it stimulates the development of the ‘green technologies’ [13]. For example, the experience of European countries shows us that using of piggyback transportation provides reducing of annual ecological costs by 200 million euros, and also reduces road maintenance price to 500 million of euros a year [14].
Implementation of piggyback transportation in Russia requires a solution of the objectives set, which are connected with the legislative and regulatory frameworks, organizational, technical and technological aspects of rail and road transport interaction [15-17]. The task of agreement of parameters of road vehicles and railway rolling-stocks, which are used in piggyback transportation, is particularly relevant. It caused by the large share of the freight turnover that is done by the railway (it is more than 46% from the whole freight turnover in a country or 2597 milliards tones per km in 2018 [18]) and a wide assortment of truck tractors, trailers and semi-trailers that are used for cargo
transportation. Parameters systematization of road vehicles and railway rolling-stocks, that is used in piggyback transportation, will enable an effective assessment of the vehicle compatibility, which is used in the organization of freights. It will ensure optimal variants of delivery cargos using the piggyback system.

2. Literary review
In compliance with development strategy of transport [19] European Union, at the 2030 year it is planned to transfer 30% of road freight traffic to rail transport, and at 2050 – 50% [4]. In our time piggyback transportation in Russia organized like pilot project [4, 15, 20]. The authors [15, 21] specify devoted not enough researches on the regular basis for solutions of problems. Scientific works allow allocating the main multi-field and researches:

- synthesis – literary review and practice of realization of piggyback transportation [4, 7, 17, 20-22];
- policy – regulatory questions, the role of the state and international organization in intermodal and multimodal technology [15, 23-25];
- technology – existing intermodal technologies of rolling-stock analyze [20, 26];
- infrastructure – infrastructure, terminals and transport network development [16, 27, 28];
- environment and sustainable development – impact assessment on the environment by piggyback transportation [13, 29];
- economy – assessment on cost on development piggyback transportation, their competitiveness, and investments [9, 14, 30].

Now piggyback rolling-stock parameters are not comprehensively accounted and systemized, even with existing works that are dedicated to increasing effectiveness and quality of piggyback transportation.

3. Piggyback rolling-stock basic parameters explanation
According to [31] piggyback transportation is the transportation, on a certain route, of road trains, automobiles, trailers, semi-trailers and swap body cargo areas in loaded or empty condition. Authors of this article consider piggyback transportation as the complex technical system consisting of a large number of elements which functioning forms quality of transportation process [32]. Key elements of this system is road vehicles, railway rolling-stocks and also intermodal technologies. Variety of technical and operational element characteristics is the significant limitation of the system forming and functioning. It caused by:

- the wide nomenclature of road vehicles and railway rolling-stocks types and models. They have a lot of differences in structural peculiarities, carrying capacity, size, weight, etc.;
- the existing of piggyback systems – Modalohr, CargoBeamer, MegaSwing, CargoSpeed, FlexiWaggon and others. They differ in trans-shipment technologies of road vehicles and formation of piggyback trains, and also the type of terminal equipment [4, 27, 28].

According to that, we can see that the system, which we regard, characterized by the significant amount of piggyback transportation organization varieties. Both for providing logistic service for small and large haulers level, and on level of choosing the piggyback system and formation terminal infrastructure and railway rolling-stock. It determines the need for detail and rationale of, the considered system, parameters.

In unaccompanied piggyback transportation involving the transportation by semi-trailers with subsequent delivery («last mile») to the consignee by the operator's truck tractor, the compatibility of the truck tractor model with the semi-trailer model must be checked. Checking parameters are: full mass of the semi-trailer, load on the coupling device of the towing vehicle, the road train mass, etc. The same check is necessary when transporting trailers onboard vehicles. Transportation of road vehicles inside flatcars needs for compatibility verification of the next parameters: piggyback type and mass, full piggyback weight and flatcars carrying capacity, piggybacks oversize, etc. Piggyback
systems and road vehicles are interrelated by: piggyback type, full piggyback weight and specialized platform carrying capacity, freight car accompaniment, etc.

The mutual influence of parameters is complicated by their significant number. Road vehicles and railway rolling-stocks technical characteristics consist of about 15 parameters. In the detailed description of piggyback systems allocate up to twenty parameters. Considered system structure with basic parameters is shown on Figure 1.

![Figure 1. Scheme of the interrelation of the main parameters of the rolling-stock of piggyback systems.](image)

4. Determination of rolling-stock parameters of piggyback cargo delivery systems

Information technologies provide systematization structuring, storing and on time updating the significant amount of piggyback system parameters. It uses for checking the road vehicles parameters compatibility with railway rolling-stocks, with piggyback systems, and for carrying fees assessment. It is proposed to use a data base that is developed by authors of this article, as a solution to this task [33].

Presented data base is the analysis result of the domestic and foreign scientific works, regulatory and legal documentation, and official sites of manufacturers (road vehicles, railway rolling-stocks and piggyback technologies). It perform the following functions:

- getting parameters and schemes information of road vehicles, railway rolling-stocks and piggyback technologies with the assessment of their compatibility in the organization of piggyback transportation;
- selection of piggyback cargo delivery systems as well as improvement of existing and modernization of new piggyback transportations;
- getting information about tariff rate and freight charge using piggyback systems.

The data base (Figure 2) contains the following objects: interrelated data tables, forms for updating data, view information requests, reports.

Data tables contain parameters values of system elements. Road vehicles are characterized in two tables by single vehicles, truck tractors, trailers and semi-trailers. Data in a table enables to know if the truck tractors compatible with semi-trailers and if single vehicles compatible with trailers. Two tables are connected with previous tables and contain parameters information of railway rolling-stocks. It enables to evaluate flatcars compatibility with road vehicles models and types. The following two tables provide a calculation of the freight charge of different types of road vehicles (when loaded or empty) for a given distance. This makes it possible to compare piggyback transportation with alternative methods of cargo delivery. Parameters of operating piggyback systems reflect technical and technological characteristic. They are shown in the appropriate table, that is connected with the road vehicles table. The table of data on the parameters of the rolling-stock of piggyback systems in the form of an ERD-diagram is shown in Figure 2.

Data base has forms of information actualizing. They serve to clarify the system elements’ parameter values, and to add them if new road vehicles, railway rolling-stocks or piggyback
technologies has been developed. And also there’s a form for moderation of current piggyback transportation tariff rates amount. Forms provide automatic integration of input values.

**Truck tractor (single vehicle):** A1 – truck tractor/single vehicle model; A2 – general view scheme; A3 – country of manufacture; A4 – piggyback type; A5 – overall dimensions: length/width/height; A6 – nominal carrying capacity; A7 – curb weight/full weight; A8 – load on the coupling device; A9 – volume of the bodywork; A10 – maximal speed; A11 – oversize degree; A12 – tariff class. **Semi-trailer (trailer, swap body):** B1 – semi-trailer/trailer/swap body model; B2 – general view scheme; B3 – country of manufacture; B4 – piggyback type; B5 – overall dimensions: length/width/height; B6 – volume of the bodywork; B7 – nominal carrying capacity; B8 – curb weight/full weight; B9 – type and size of swap body; B10 – loaded/empty piggyback state; B11 – oversize degree; B12 – tariff class. **Railway rolling-stock:** C1 – flatcar model; C2 – general view scheme; C3 – country of manufacture; C4 – piggyback type; C5 – flatcar type; C6 – carrying capacity; C7 – tare weight; C8 – axle load when piggyback transportation; C9 – length along the axes/frame; C10 – flatcar base; C11 – floor level height of rails top; C12 – overall floor dimensions: length/width; C13 – constructional speed; C14 – piggybacks oversize; C15 – thruster fixators quantity: wheels/piggybacks; C16 – freight car accompaniment; C17 – side loading capability; C18 – power connect ability; C19 – tariff class. **Piggyback system:** D1 – system name; D2 – platform and terminal scheme; D3 – country of manufacture; D4 – piggyback type; D5 – flatcar type; D6 – carrying capacity; D7 – tare weight; D8 – axle load when piggyback transportation; D9 – flatcar base; D10 – floor level height of rails top; D11 – overall floor dimensions: length/width; D12 – constructional speed; D13 – piggybacks oversize; D14 – specialized terminal having; D15 – terminal type; D16 – front wagon positioning; D17 – parallell loading and unloading availability; D18 – need of staff for cargo transhipment; D19 – freight car accompaniment.

**Figure 2.** ERD diagram of the data base piggyback transportation.

Using interface elements of data base we can get an opportunity to check for compatibility of road trains, side vehicles, trailers, semi-trailers and swap body models with flatcars models. Also, we can know if semi-trailer and trailer models are compatible with truck tractors and side vehicles. Elements of the interface can also give us freight charge calculation results using the tariff scheme and basic coefficients. The whole information is presented in a report form. It’s done for the convenience of results output for printing.

**5. Conclusion**

Thus, this paper presents a new understanding of piggyback transportation as a complex technical system consisting of interrelated elements, the functioning of which provides the transport process.
Road vehicles, railway rolling-stocks and intermodal technologies, are considered as elements of this system. Element's parameters are explained and shown mutual influence on each other. The key element is the assessment compatibility requirement of road vehicles and railway rolling-stocks that is used in piggyback transportation. Systematization of piggyback rolling-stock parameters is reflected in the developed database. It can be used by road vehicles and railway rolling-stock manufacturers, transport-expeditionary companies and logistics service providers for planning and organizing intermodal freights.

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