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N. Y. Shramenko, Dr. Sc. (Tech.), Prof.

Kharkiv Petro Vasylenko National Technical University of Agriculture, Kharkiv, Ukraine, e-mail: nshramenko@gmail.com.

EVALUATION OF THE EFFECTIVENESS OF PIGGYBACK TRAFFIC IN THE CONTEXT OF CREATING TRANSPORT AND LOGISTICS CLUSTERS

Н. Ю. Шраменко, д-р техн. наук, проф.

Харківський національний технічний університет сільського господарства імені Петра Василенка, м. Харків, Україна, e-mail: nshramenko@gmail.com.

ОЦІНКА ЕФЕКТИВНОСТІ КОНТРЕЙЛЕРНИХ ПЕРЕВЕЗЕНЬ В УМОВАХ СТВОРЕННЯ ТРАНСПОРТНО-ЛОГІСТИЧНИХ КЛАСТЕРІВ

Purpose. Determination of the scope of effectiveness of piggyback cargo delivery in the international traffic.

Methodology. The scope of efficiency of piggybacked cargo delivery in international traffic is determined using mathematical modeling. Methods of mathematical statistics are used to estimate parameters that are random in character.

Findings. The problems of organizing piggyback transportations in international traffic, having a technical, technological and economic character are revealed. The main trends of the development of piggyback traffic in Ukraine, requiring state support and financing, are identified. It is determined that the law of distribution of service intensity at the Border Inspection Post is exponential, the intensity of service is 1.83 veh/hour; the law of time distribution for loading cars onto platforms is normal, with a mathematical expectation of 0.712 hours and a standard deviation of 0.24 hours. A rational distance of piggyback traffic in international traffic is determined, which corresponds to 307 km and over. Practical recommendations on the rationalization of the technological process of interaction between the road and rail transport with the help of an automated heuristic system, which makes it possible to determine the rational technology for delivery of goods in international traffic, taking into account the minimization of the total time for delivery of goods are offered.

Originality. Dependences of specific costs on transportation distance with the help of which it is possible to determine the rational transport-technological scheme of cargo delivery under given conditions are obtained. The schedule of technological process of functioning of both production and transport, assuming the coordinated technology of work of interconnected enterprises at the organization of piggyback delivery in conditions of transport-logistical cluster functioning is offered. It is proposed to carry out the transfer of information on the movement of a loaded car using a GPS tracker.

Practical value. Dependences of unit costs on the distance of transportation make it possible to quickly estimate the cost of delivering goods in international traffic for alternative transport-technological schemes. The use of an automated heuristic system that allows determining the rational technology of piggyback transport, taking into account the minimization of the total time for delivery of goods, makes it possible to make managerial decisions in the event of an unforeseen situation by making adjustments to the existing technology. The schedule of the technological process of functioning of both production and transport preconditions the possibility of rationalizing the technological process of road and rail transport interaction at the organization of piggyback cargo delivery.

Keywords: *intermodal technology, multimodal system, piggyback transportation, measure of effectiveness, transport and logistics cluster*

Introduction. The location of Ukraine on the continent is such that it is of great importance in particular as a transit state [1]. The development of piggyback transport will ensure the preservation of the ecological balance and the effective use of the road transport complex of the country. A significant role in the development of piggyback service in Ukraine can be caused by tightening the norms of legislation on environmental problems and the condition of motorways in the country, as well as the introduction of a toll road system.

The growth of intermodal transport volumes is natural, since it is associated with the improvement of the structure of production and transportation, where an increasing proportion will be occupied by ready-made container products. In general, Ukraine has all the necessary components to create a competitive system for transporting goods using intermodal technologies. In turn, the development of promising types of transportation along the international transport corridors of Ukraine will be facilitated by the organization of its own technical base [2, 3], the development of transport infrastructure [4, 5] and the implementation of a flexible tariff policy [5].

Mining enterprises, metallurgical and machine-building complexes feature transportation of multi-nomenclature small-batch cargoes of production and technical

purposes [6], periodic regularity of which stipulates the possibility of using piggyback technologies. In turn, piggyback technologies can become the most effective for delivery of finished products of these enterprises, especially export rolled metal products.

Analysis of the recent research. Throughout the world, piggyback transportations are considered as a natural process of overcoming competitive relations between the road and rail transport and transition to cooperation relations [7].

Piggyback traffic, as a rule, is focused on international traffic and due to a number of advantages is in demand with freight forwarding and operator companies.

Piggyback routes of Europe include [8]:

1. Wergel (Austria) – Trendo (Italy) – 240 km.
2. Wergel (Austria) – Brenner (Austria) – 95 km.
3. Salzburg (Austria) – Triest (Italy) – 430 km.
4. Salzburg (Austria) – Villah (Austria) – 190 km.
5. Wels (Austria) – Ssegen (Hungary) – 640 km.
6. Wels (Austria) – Maribor (Slovenia) – 320 km.
7. Lyon (France) – Turin (Italy) – 175 km.
8. Bale (Croatia) – Lugano (Switzerland) – 290 km.
9. Freiburg (Germany) – Novara (Italy) – 430 km.

Within the conditions of formation of joint ventures [9] and the development of transport and logistics clusters [10], which are created in countries with a significant transit potential and a developed industrial complex, the urgency of applying piggyback routes both in international and in domestic traffic is growing. This is due to the possibility of organizing the coordinated work of all the participants of piggyback delivery, including the enterprises of transport and logistics infrastructure and logistics service consumers, which will ensure the competitive advantages of respective regions.

The researcher in work [11] emphasized the expediency of using contrailers in both international and domestic traffic. At the same time, it was noted that the evaluation of their effectiveness was not given sufficient attention.

The organization of piggyback transportations is possible on the basis of a developed network of terminal complexes, the technology of functioning of which must be formed on the basis of a logistics approach [12, 13]. In turn, with the coordinated work of all participants of complex production and transportation systems, a synergetic effect is achieved [14].

Thus, it is advisable to create new routes for piggyback trains after commercializing their effectiveness, provided that there is complete information on the structure of the freight flow on a particular route and market segment of the service. At the same time, a logistical approach to the organization of piggyback transportation, using the results of scientific research, is necessary.

Objectives of the article. The purpose of the publication is to determine the scope of effectiveness of piggyback cargo delivery in the international traffic.

Objectives of the study are to analyze the existing problems of organizing piggyback service in the international traffic, to determine the rational distance for piggyback traffic, and to develop practical recommendations.

Methods. The scope of efficiency of piggybacked cargo delivery in the international traffic is determined using mathematical modeling. Methods of mathematical statistics are used to estimate parameters which are random in character.

Explanation of scientific results. The prerequisites for the development of piggyback traffic are the following: seasonal restrictions on the movement of large-capacity vehicles; limitation of the driver's continuous driving time; requirements as for the safety of goods transportation.

As a result of the analysis of practical experience of using piggyback transportation in the international traffic, existing problems of technical, technological and economic nature are highlighted, among which are the following:

- presence of disproportions in the foreign trade of goods, when the predominantly finished goods are imported, and the commodities are exported, so that the goods with different transport characteristics are presented for transportation;
- noncoincidence of the volumes of freight flows in the export and import traffic, which does not allow ensuring a full backload of the rolling stock, and therefore characterizes the inefficient use of the rolling stock;
- low degree of utilization of the load-carrying capacity of railway platform-forms, as they do not transport only cargo, but also road-trains or semi-trailers. This leads to an increase in the cost of transportation;
- the need for a large fleet of specialized railroad platforms to transport laden lorry trains and semi-trailers;
- lack of a developed network of transport and logistics centers in Ukraine within the framework of international transport corridors;
- lack of a representative network of national transport, logistics and forwarding companies outside Ukraine to ensure a high degree of coherence of actions of all the participants of the delivery process and their interest protection;
- lack of the legislative basis and the system of environmental protection from the harmful effects of various modes of transport, which casts doubt on the commercial feasibility of piggyback transportation;
- a significant complexity of developing cross-cutting tariff schemes and the formation of tariff rates for transportation of transit and export-import goods by trailers, connected primarily with different legislative and regulatory frameworks of different states, as well as with different approaches to the formation of tariffs for road and rail transport;
- a limited number of trailing piggy trains, while the need for these transport services exists in many regional centers of the country, not only in the international traffic, but also in the domestic one.

Elimination of these obstacles necessitates the support and financing of piggyback traffic on behalf of the state. At the same time, it is possible to single out the tasks that are of paramount importance:

- the need for substantial investment in the equipment of infrastructure facilities for accumulation, storage and carrying out the loading operations with road trains and semi-trailers at railway stations;
- the need to establish a fleet of specialized wagons and the modernization of railway platforms that allow, if

necessary, transporting either a conventional container or semi-trailers and road trains in order to ensure their efficient operation and simultaneously meet the requirements imposed on the railways with both 1520 mm gauge and 1435 mm gauge;

- large capital investments are needed for the construction of a network of terminal complexes for servicing the piggybackers and equipping the railway stations with special devices for loading and unloading semi-trailers and road trains;

- it is necessary to develop the infrastructure of the transport network along the routes of piggyback trains for the possibility to provide high rates of delivery of transit freight traffic (at the level of passenger train speed) with traffic safety. At the same time, special attention should be given to the development and introduction of technical means for accelerated wagon transition of division points of gauge joints of various widths.

The existing problems in the organization of piggyback traffic necessitate the determination of their effectiveness under the prevailing conditions. It is advisable to compare the piggyback delivery with delivery by road in direct traffic. The efficiency criterion for determining the scope of piggyback transportation in the international traffic is the unit cost of delivery.

Thus, the proposed efficiency criterion for delivery of goods by road transport according to the direct option is as follows

$$R_{avt} = (R1 + R2 + R3 + R4 + R5)/q_c \to min, \qquad (1)$$

where $R1$ stands for costs for transportation of goods by road transport according to the direct option, UAH; $R2$ stands for costs associated with the waiting time of vehicles while passing the state border of Ukraine, UAH; $R3$ is the cost of capital investment into the rolling stock and fixed equipment of vehicles, which accounts for 1 km, UAH; $R4$ stands for costs associated with environmental pollution, UAH; $R5$ stands for costs associated with the exclusion of cargo from the turnover, UAH; q_c is mass of consignment, t.

The proposed efficiency criterion for delivery of cargo by piggybackers includes the following

$$R_{pig} = (P1 + P2 + P3 + P4 + P5 + P6 + P7)/q_c \to min, \quad (2)$$

where $P1$ is the cost of transporting goods by vehicles to the railway station; $P2$ is the cost of accumulating road trains at the railway station and the waiting time for loading onto platforms, UAH; $P3$ stands for costs for loading and unloading of road trains at departure and destination stations, UAH; $P4$ stands for costs for piggyback transportation, UAH; $P5$ is costs associated with the waiting time of vehicles while passing the state border of Ukraine, UAH; $P6$ is the cost of capital investments, which account for 1 km of run, UAH; $P7$ stands for costs associated with the exclusion of the cargo mass from the turnover, UAH.

The method proposed in work [15] for determining the rational distance of a piggyback carriage with allowance for the criteria (1, 2) assumes the presence of technological parameters in mathematical models that are random variables. To evaluate these parameters, statistical data are processed and the laws of distribution of random variables are defined:

- the time of loading vehicles onto platforms is distributed according to the normal distribution law

$$f(x) = \frac{1}{0.24 \cdot \sqrt{2\pi}} \cdot e^{-(x-0.712)^2/2 \cdot 0.24^2};$$

- the intensity of car servicing at the Border Inspection Post is distributed according to the exponential law

$$f(x) = 1.83 \cdot e^{-1.83}.$$

The initial data for the models described in work [15] were obtained on the basis of a trucking enterprise in Kharkiv, as well as on the basis of normative documentation. As a result of simulation, the dependencies of specific costs for delivery of goods on the distance of transportation (Fig. 1) are obtained, according to which the behavior of the functions is observed.

When comparing the options for delivering goods by road using the direct option and piggybackers, the equality of the resulted costs – 619.7 UAH/t – is reached at a distance of 307 km (Fig. 1). Thus, the rational distance of piggyback traffic in the international traffic for accepted in the study initial data is 307 km or more.

To create a coordinated technology for the operation of interrelated enterprises in the organization of piggyback deliveries in conditions of the transport and logistics cluster functioning, the schedule of the technological process of piggyback cargo delivery is proposed (Fig. 2).

The technological process is closely interconnected with the informational one, therefore it is proposed to carry out the transfer of information on the movement of a loaded vehicle using a GPS tracker simultaneously to the workstation of the terminal operator (railway station) and to the dispatcher's AWM that forms a freight train with specialized platforms for piggyback transportation. This determines the mutual consistency of actions between the delivery participants and the synchronization of technological operations.

The formation of technology for piggyback traffic is proposed to be performed with the help of an automated

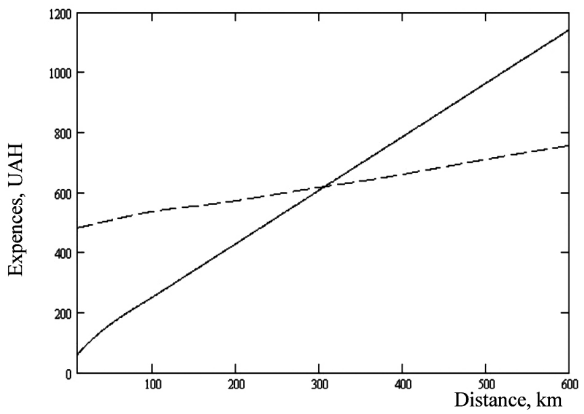

Fig. 1. Dependence of unit costs for delivery of goods on the distance of transportation:
—— – Delivery by road; - - - – Piggyback delivery

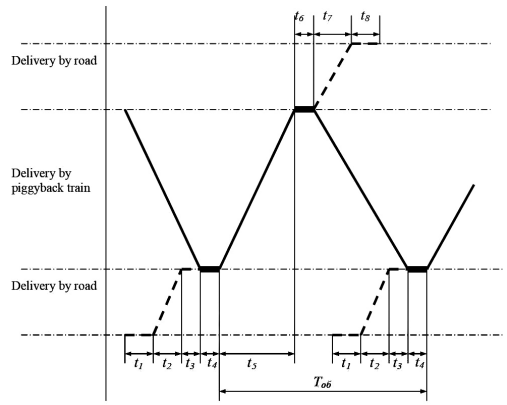

Fig. 2. The schedule of the technological process of piggyback delivery of goods:
t_1 – car loading from the supplier; t_2 – the trip of the car to the station of piggyback-train formation; t_3 – the waiting time of the car to be loaded onto the platform; t_4 – formation of a piggyback train; t_5 – the trip of the piggyback-train; t_6 – unloading of the piggyback train; t_7 – the trip of the car from the arrival station to the consumer; t_8 – unloading of the car at the consumer's premises; t_{turn} – the time of turnover of a piggyback train; ---- – Delivery by road, —— – Delivery by rail, ▬ – Embarkation of vehicles onto the platform

heuristic system, which, depending on the initial parameters, namely a complex of technological and cost indicators and a system of limitations, makes it possible to determine the rational technology of piggyback transportation, taking into account the minimization of the total time for delivery of goods; to receive information on the whereabouts of a loaded car at a particular time; it ensures the consistency of actions of the delivery process participants and the synchronization of technological operations in the course of delivery and gives an opportunity to make managerial decisions in the event of an unforeseen situation by making adjustments to the existing technology.

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Мета. Визначення сфери ефективності контрейлерної доставки вантажів у міжнародному сполученні при заданих умовах.

Методика. Сфера ефективності контрейлерної доставки вантажів у міжнародному сполученні визначена за допомогою математичного моделювання. Для оцінки параметрів, що мають випадковий характер, застосовані методи математичної статистики.

Результати. Виявлені проблеми організації контрейлерних перевезень у міжнародному сполученні, що мають технічний, технологічний і економічний характер. Виділені основні напрями розвитку контр-

ейлерних перевезень в Україні, що потребують державної підтримки й фінансування. Визначено, що закон розподілу інтенсивності обслуговування на пункті пропуску через державний кордон – експонентний, інтенсивність обслуговування становить 1,83 авт./год; закон розподілу часу навантаження автомобілів на платформи – нормальний, при цьому математичне очікування – 0,712 год і середньоквадратичне відхилення – 0,24 год. Визначена раціональна дальність контрейлерних перевезень у міжнародному сполученні, що становить 307 км і більше. Запропоновані практичні рекомендації щодо раціоналізації технологічного процесу взаємодії автомобільного й залізничного транспорту за допомогою автоматизованої евристичної системи, що дозволяє визначити раціональну технологію доставки вантажів у міжнародному сполученні з урахуванням мінімізації загального часу доставки вантажів.

Наукова новизна. Отримані залежності питомих витрат від відстані перевезення, за допомогою яких можна визначити раціональну транспортно-технологічну схему доставки вантажів при заданих умовах. Запропоновано графік технологічного процесу функціонування виробництва й транспорту, що передбачає скоординовану технологію роботи взаємопов'язаних підприємств при організації контрейлерної доставки в умовах функціонування транспортно-логістичного кластера. Пропонується здійснювати передачу інформації щодо переміщення завантаженого автомобіля за допомогою GPS-трекера.

Практична значимість. Залежності питомих витрат від відстані перевезення дозволяють оперативно оцінити витрати на доставку вантажів у міжнародному сполученні для альтернативних транспортно-технологічних схем. Застосування автоматизованої евристичної системи, що дозволяє визначити раціональну технологію контрейлерних перевезень з урахуванням мінімізації загального часу доставки вантажів, дає можливість прийняття управлінських рішень при виникненні непередбаченої ситуації шляхом внесення коректівів до існуючої технології. Графік технологічного процесу функціонування виробництва й транспорту обумовлює можливість раціоналізації технологічного процесу взаємодії автомобільного та залізничного транспорту при організації контрейлерної доставки вантажів.

Ключові слова: *інтермодальна технологія, мультимодальна система, контрейлерне перевезення, критерій ефективності, транспортно-логістичний кластер*

Цель. Определение сферы эффективности контрейлерной доставки грузов в международном сообщении при заданных условиях.

Методика. Сфера эффективности контрейлерной доставки грузов в международном сообщении определена с помощью математического моделирования. Для оценки параметров, имеющих случайный характер, применены методы математической статистики.

Результаты. Выявлены проблемы организации контрейлерных перевозок в международном сообщении, имеющие технический, технологический и экономический характер. Выделены основные направления развития контрейлерных перевозок в Украине, требующие государственной поддержки и финансирования. Определено, что закон распределения интенсивности обслуживания на пункте пропуска через государственную границу – экспонентный, интенсивность обслуживания составляет 1,83 авт./ч; закон распределения времени погрузки автомобилей на платформы – нормальный, при этом математическое ожидание – 0,712 ч и среднеквадратическое отклонение – 0,24 ч. Определена рациональная дальность контрейлерных перевозок в международном сообщении, которая соответствует 307 км и более. Предложены практические рекомендации по рационализации технологического процесса взаимодействия автомобильного и железнодорожного транспорта с помощью автоматизированной эвристической системы, которая позволяет определить рациональную технологию доставки грузов в международном сообщении с учетом минимизации общего времени доставки грузов.

Научная новизна. Получены зависимости удельных затрат от расстояния перевозки, с помощью которых можно определить рациональную транспортно-технологическую схему доставки грузов при заданных условиях. Предложен график технологического процесса функционирования производства и транспорта, предполагающий скоординированную технологию работы взаимосвязанных предприятий при организации контрейлерной доставки в условиях функционирования транспортно-логистического кластера. Предлагается осуществлять передачу информации о перемещении загруженного автомобиля с помощью GPS-трекера.

Практическая значимость. Зависимости удельных затрат от расстояния перевозки позволяют оперативно оценить затраты на доставку грузов в международном сообщении для альтернативных транспортно-технологических схем. Применение автоматизированной эвристической системы, которая позволяет определить рациональную технологию контрейлерных перевозок с учетом минимизации общего времени доставки грузов, дает возможность принятия управленческих решений при возникновении непредусмотренной ситуации путем внесения коррективов в существующую технологию. График технологического процесса функционирования производства и транспорта обуславливает возможность рационализации технологического процесса взаимодействия автомобильного и железнодорожного транспорта при организации контрейлерной доставки грузов.

Ключевые слова: *интермодальная технология, мультимодальная система, контрейлерная перевозка, критерий эффективности, транспортно-логистический кластер*

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