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SYNCHROMODAL LOGISTICS NETWORKS

Mariyan Rahnev

KONSTANTIN PLERSLAVSKI UNIVERSITY OF SHUMEN, SHUMEN 9700, 115 UNIVERSITETSKA ST.,

e-mail: marian.rahnev@brc-bg.com

Abstract: *The intermodal freight transportation is being discussed for decades as an alternative to the unimodal automobile transportation. However, it is still not a significant part of the total market of the freight transportation. A new and promising possibility for improvement the efficiency of the freight transportation systems is the synchromodal design of the transportation systems on the inside. A cornerstone for the synchromodality is the integrated view in the design and functioning of the intramodal transportation.*

With the synchromodal transportation we have a flexible and dynamic way of choosing the best transportation. Synchromodality can lead to a modal transition to a slower but more ecological ways of transport without compromising the cost or the quality. A prerequisite for synchromodal transportation is the ability to freely choose which transportation method to use and easily to switch from one method to another.

Key words: *Freight transportation systems, synchromodal freight transport, multimodal transport, transport service scheduling*

Synchromodal transportation in terminal systems

The biggest synergic effect from using the synchromodal transportation in the system of intermodal terminals is achieved by applying the principles of the synchromodality. Many authors who discuss these principles and approaches also use the terms synchromodal transportation, synchromodal logistics, etc.

The main idea of the synchromodality is the complex integration of the freight and transportation flows in order to use the transportation possibilities in the best way and at the same time to decrease the cost and the ecological effects.

The practical application of this concept suggests integrated management of the transportation and the commodity flows, based on the free choice of the type of transportation and the transportation operator for the specific transport, on the possibility to switch the flows between the transportation services in real time, as well as on the transparency of information and the operational cooperation of the transportation and logistics operators.

It is considered that for the first time the term synchromodality in this context was introduced in 2010 by *Strategish Platform Logistiek (SPL*) which represents the interests of the Netherlands' logistics industry.

In an analytical report [SPL, 2010], prepared for the Netherlands' government, the synchromodal transport is defined as a method for organizing the delivery which does not have a default mode. The transportation parameters are defined online according to the market situation. The above-mentioned research studies the synchromodal transportation in the first place, as a potentially effective instrument for increasing the efficiency of the national logistics system.

Currently the concept for synchromodality is in the process of development and formation. The definitions of the term which are used in the written works give an idea for the most important aspects in this concept form the point of view of different researchers:

- synchromodal transportation is "an intermodal transportation with possibility to switch between the types of transportation in real time." [Van Riessen, 2013];

- "synchromodality is making optimal use of all modes of transport and available capacity, at all times, as an integrated transport solution" [Ham, P., 2012];

- synchromodal approach means "constant adaptation of the goods and the transportation networks and infrastructure in such a way that it ensures the best combination of different types of transportation at all times in order to satisfy the transportation needs." [Lucassen I., 2012].

The emergence of the concept of synchromodality is objectively caused and prepared by the consistent development of the theory for intermodal transportation systems and the practice of their application. The gradual development of this process enables us to formulate four of the most specific models for management of the transportation and commodity flows at intermodal transport of goods, shown on fig. 1.

Model 1. Traditional intermodal transportation. The transportation is done step by step by means of different types of transportation (for example railroad and automobile or maritime and railroad) with one or more loading and unloading in the intermodal terminals. The control of the flow in this case suggests:

- choice of operators and/or services of specific parts of the transportation which allows to change the speed and the cost of the transportation. In this case the route remains unchanged;

- accumulation of a certain reserve of TEU with goods at transshipment terminals.

This very simple option of flow control is used for example when substantial quantities consumer goods are sent by sea from the production regions in Southeast Asia towards the consumer markets but the specific destinations for every specific lot are defined when the containers arrive at the terminal at one of the European or American ports. This creates a "virtual" or "mobile" warehouse of products which do not have a specific recipient until a given moment. The maximum delay at the moment of choice of the end destination for the delivery decreases the total logistics costs. (fig. 1, a).

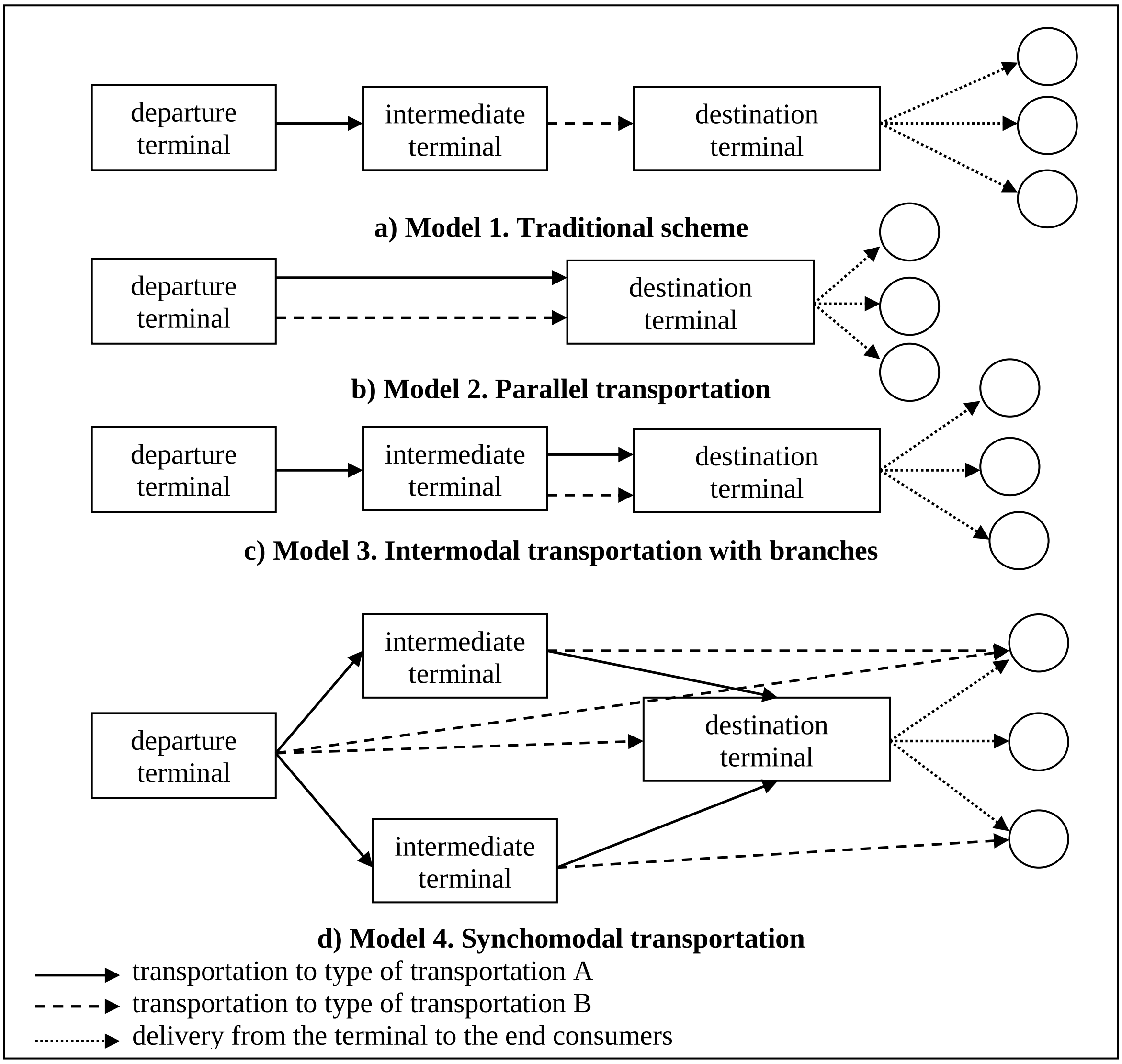

Fig.1. Models of transportation organization in the intermodal transportation system

Model 2. Parallel transportation (scheme b).

This option is based on the organization of parallel flows of different types of transportation between the departure and destination intermodal terminal. The volume of the deliveries can be quickly redistributed by the operator of intermodal transportation between the branches through which the transportation is performed. The reserve is formed on one or two terminals of the system. This model is called co-modal transportation (comodal transportation).

An example for applying this option is the strategy of some companies which deliver clothing from the countries in Southeast Asia to Europe and a certain part of the production is sent to the consumption regions not traditionally by sea but by air. The duration of the maritime transportation is e 30-32 days and the cost is 180 dollars per ton products. The delivery by air costs 2500 dollars but the time for delivery decreases to 4-5 days. The creation of such a parallel flow allows you to react to the jumps in the demand, as well as losses of goods, caused by maritime deliveries.

Another example for co-modal transportation is provided by *Hewlett-Packard*, one of the leading world producers of electronics. In 2012 the company switches the delivery of some of its products, produced in China and designated for Europe, from the traditional maritime route to railroad route, which passes through China, Kazakhstan, Russia, Belorussia, Poland and Germany. The reason is the considerable decrease of the speed for the maritime delivery which is used by most of the ocean container lines in the period after the crisis in order to reduce expenditures. As a result, the volume of the withdrawn products of Hewlett-Packard became too big and it was difficult to respond to the changes in the demand on the market. The railroad delivery costs the company 25% more than the maritime delivery but the time for transportation decreases from five to three weeks.

The term co-modal transportation has been officially introduced in 2006 by the European Commission in connection with the transportation strategy and it means the use of different types of transportation individually, as well as in combination, in order to achieving the best economic, ecological and social results.

Model 3. Parallel transportation with branches (scheme c).

Unlike the previous option, the parallel flows for delivery are not organized along the whole route but in one of the sections of the delivery chain, while the terminal where the flow branches off is the point of creating the intermediate reserve of products.

This model, for example, is realized by the logistics supplier *Geodis Wilson* which combines services for maritime and air transportation of goods from 14 countries from Southeast Asia to Europe, North and Latin America. The junctions, depending on the direction of transportation, are Dubai (UAE), Los Angeles (USA) or Incheon (South Korea). The delivery to them is made by sea and after that a part of the load volume or the whole volume is transported by air. This service, called *Sea-Air*, is averagely 30-50% faster than the maritime delivery and also that cheaper than air.

To apply models 1 and 2, it is necessary to have parallel services of different types of transportation throughout the whole route of delivery. In addition, the operator of intermodal transport in this model plays a specific role, distributing the freight flows among competing transportation companies.

Model 4. Network intermodal or straight synchromodal transportation (scheme d). Unlike the previous options, the transportation system is not organized by a linear but by a network principle. For it to function, the system needs to have a few intermediate and terminal terminals (distribution centers) and the delivery of goods between them can be done by different types of transportation. At the same time the route of the shipments in the direction end consumers is formed by the operator of intermodal transport online, depending on the demand and the current situation in the transportation system. More specifically, if the individual recipients urgently need to receive a delivery of goods, it is delivered by one of the intermediate terminals directly by road. And vice versa, if the movement of certain deliveries can be slowed down without the harming the consumer, the operator can switch the delivery to railroad or maritime services and thus save from the expenses.

The model of synchromodal transportation is the logical continuation of models 2 and 3. Because it is a lot more complicated from the point of view of management, it is more effective from the point of view of ensuring flexibility and reliability of the deliveries.

If the previous models are used in the intercontinental transportation and refer to the ocean scheme of the synchromodal transportation, the model of the synchromodal transportation is applied in the segment of the combined transportation where transportation networks exist. In the synchromodal system, the intermodal transportation operator receives a possibility to optimally design the transportation network in accordance with the current needs of the client online.

An example for the application of the synchromodal concept is the activity of *Europe Container Terminals (ECT),* one of the biggest European operator of port containers. The company delivers to the European consumers through its three terminals in the port of Rotterdam, where about 100 thousand EUE per week are processed, using means of automobile, railroad and inland water transportation. ECT forms a delivery system which uses regular railroad and river services of different operators for connecting the port terminals of ECT in Rotterdam with intermodal terminals and logistics centers in Germany, Austria, Switzerland, Norway, Spain, Great Britain.

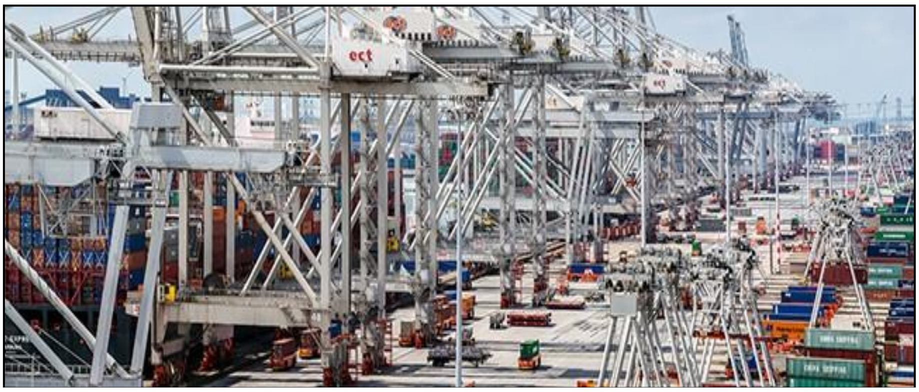

Fig.2. ECT Rotterdam (Europe Container Terminals)
source: https://nl.linkedin.com/company/ect

Fig. 3 shows a fragment of this system in the direction Rotterdam – Tilburg. Both of them are located in the Netherlands at a distance not more than 60 km in a straight line.

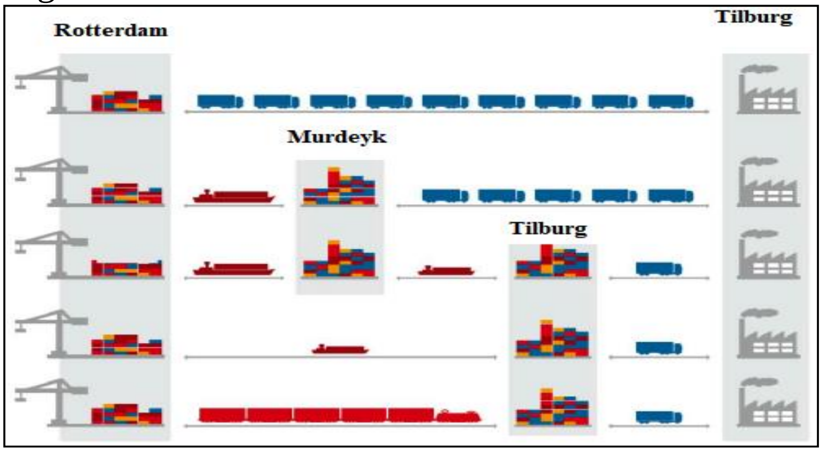

Fig.3. Scheme of the organization of synchromodal transportation in the direction Rotterdam – Tilburg
Source: Lucassen, 2012.

The containers for the consumers in Tilburg can be delivered from port terminals by road, railroad or inland water transportation with the possibility of intermediate storage and unloading and loading of intermodal terminals in Moerdijk and Tilburg. In this case the operator of the intermodal transportation:

- uses the services of one or another type of transportation and terminal operators, depending on the situation on the market for transportation services and the terminals;

- it manages the warehouse supplies in the delivery chains, taking into account the current demand, combining transportation services with different speeds and costs and using intermodal terminals for intermediate storage of goods.

The analysis showed that the effective functioning of the system for synchromodal transportation demands fulfilling of a number of requirements which include:

- big volume of traffic. Examples of an organization of synchromodal systems refer to the most massive European intermodal transportation flow of containers which are shipped to the continental consumers from the ports of the Netherlands and Belgium;
- transfer of the right to the operator of an intermodal transportation to operatively manage the flow of goods through the chain of deliveries. By means of setting schedules, volumes, deadlines, expenditure limits and delivery reliability, the client (the basic company on the delivery chain) gives the operator to choose the transportation route, the type of transportation and the operators which actually take part in the transportation;
- the presence of a developed network of intermodal terminals in direction of the delivery of goods;
- the possibility to store for a short-term storage of intermodal transportation units in the terminals, which in turn ensures a reserve of warehouse areas and reasonable prices for the respective services;
- the existence of enough number of services from the different types of transportation, ensuring communication among the intermodal terminals. In addition to creating enough alternatives for choice of route, transportation and a specific service, a big number of services decreases the delays in the waiting of the terminals;
- the possibility to freely switch the traffic between the types of transportation and online reservation of transportation possibilities for using the services of different types of transportation;
- precise adherence to the announced schedules of regular transportation with different types of transportation;
- transparency of the information and the existence of a uniform information platform for operational management of the transportation chains;
- the readiness of all the participants in the delivery process for a flexible operational cooperation;
- the existence of a system for defining fares, which would ensure fair distribution of the expenses and profit among the participants in the transportation process.

The effects from the usage of the synchromodal concept are felt on the delivery chain, as well as on the subjects of the transportation system.

If we speak about the consumers' interests, then its application ensures decrease of the warehouse supplies and the expenses for delivery of goods, and also it allows us to quickly react to the fluctuations in the demand by fastening or slowing down of the delivery of already sent goods which are in the terminals or are travelling.

In the transportation system the synchromodal management enables us to switch the freight flows from its busiest elements of the network and transportation services where there is an excess of bandwidth or load capacity.

An additional factor is the possibility to switch the load to the most environmentally friendly types of transportation – railroad and internal waterways.

The quantity evaluation of the efficiency of the synchromodal transportation system, as well as its parameterization, meet substantial difficulties due to the fact that the configuration of each such specific transportation system is individual and the efficiency indicators depend greatly on the algorithm for making decisions, which was chosen by the operator of the intermodal transportation.

Choice of parameters of the synchromodal system which uses serial-parallel transport flows.

Fig. 4 shows a scheme for calculating the described volume.

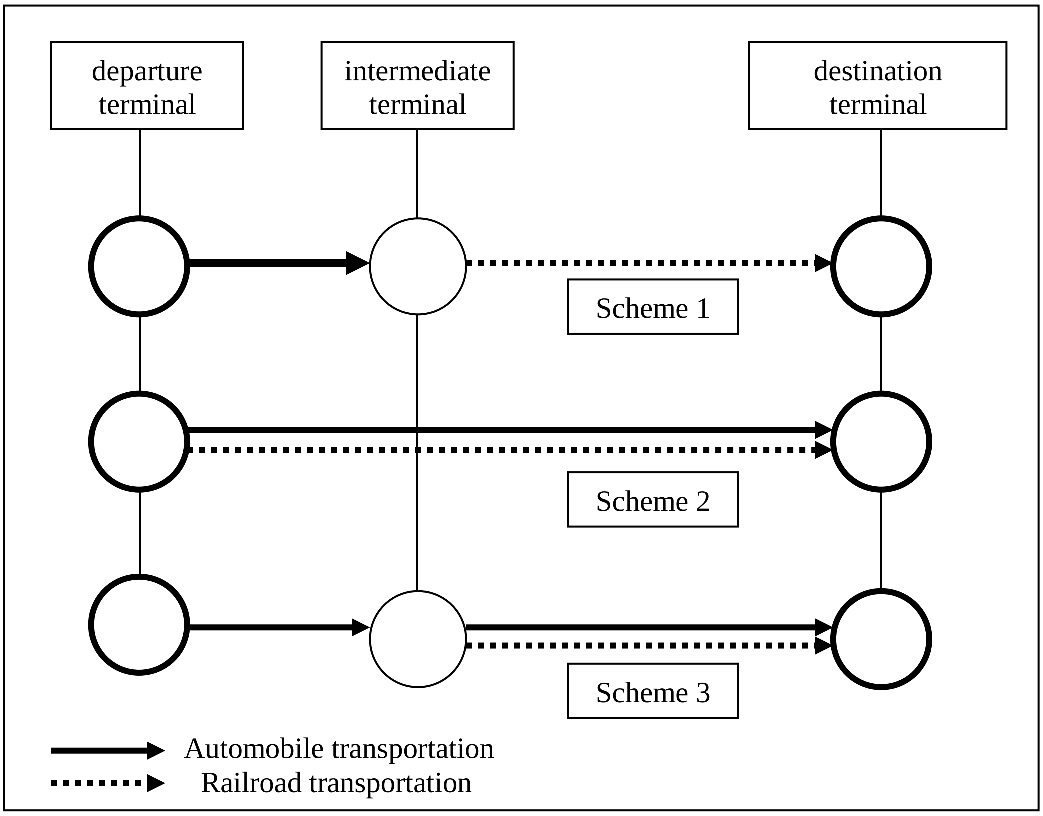

Fig. 4. Design of schemes for synchromodal transportation

Scheme 1 corresponds to the traditional consecutive combined transportation by two types of transportation. The scheme for parallel transportation (scheme 2) suggests the organization of parallel flows by different types of transportation between the departure and destination intermodal terminal.

The consecutive-parallel scheme (scheme for parallel transportation with branches – scheme 3) provides the presence of an intermediate intermodal terminal where the type of transportation for the follow-on shipping is defined in an operational mode. In this case the terminal where the branching of the flow is performed can serve as a point for creating an intermediate reserve of products in the supply chain.

The usage of consecutive and consecutive-parallel schemes of intermodal transportation allows not only to create conditions for better utilization of the load capacities of the different types of transportation but also to decrease the logistics expenses due to the flexible operational switching of the commodity flows between the different types of transportation.

The issue of defining the parameters of the intermodal transport in relation to scheme 2, which is a general one, has been studied. The following assumptions have been made:

- the object of transportation is a set of homogenous products, transported in intermodal transportation units;
- the transportation is done in the following way: the section between the departure to the intermediate terminal is road transportation and the section from the intermediate to the destination terminal is by automobile or railroad transportation;
- the carrying capacity and the transportation abilities of the system are unlimited;
- the necessity of automobile transport is satisfied immediately;
- the railroad transportation is done by intermodal block-trains at specific intervals of time;
- the start and end points are the departure and destination terminals, i.e. delivery-transportation are not studied;
- operations of unloading and loading are not studied;
- the system parameters are the *time* for delivery and the *cost* of delivery;
- the parameters of the system are evaluated in comparison with the direct automobile transportation (such a comparison is a practical criterion for the competitiveness of the intramodal transportation);
- the distances for the automobile and railroad transportation between the same points are considered equal;
- the velocity of the automobile or railroad transportation is the same at every point from the route;

- the expenses for transportation from every type are proportional of the distance.

In the described scheme the operator of the intermodal transportation solves the problem with the quick choice of the way of transportation in the section between the intermediate and the destination terminal. In general, the cargo on this section is shipped by means of parallel flows and the road flow with these suggestions is uninterrupted, while the flow of the railroad delivery is discrete with waiting time which is defined by the frequency of the intermodal block-trains, which are travelling on this section. At the same time the operator of intermodal transportation looks for such a proportion of the volumes of the automobile and railroad transportation (between the speed and cost of delivery) that is the best at the moment from the customer's point of view.

Finding the total expenses of transporting the lot:

(1) $$S = S_1 + S_2$$

where:

S – the total expenses for transportation;

S_1 – the expenses for transportation from the departure to the intermediate terminal;

S_2 – the expenses for transportation from the intermediate to the destination terminal;

(2) $$S_1 = S_a * l$$

where:

S_a – the price of the automobile transportation per unit distance;

l – the distance between the departure to the intermediate terminal.

(3) $$S_2 = S_a * L * (1 - w) + S_{ж} * L * w$$

where:

L – the distance between the intermediate and the destination terminal;

$S_{ж} *$ - the price of the railroad transportation per unit distance;

w – the portion of the traffic volume between the intermediate and the destination terminal, done by railroad transportation.

Then the total expenses for transportation of the lot in the intermodal transportation system are defined by the equation:

(4) $$S = S_a * l + S_a * L * (1 - w) + S_{ж} * L * w$$

The cost of the alternative version of transportation – direct road delivery from the departure to the destination terminal is:

(5) $$S_{дир} = S_a * (L + l)$$

Then the relative expenses for the transportation in the intermodal transportation system are defined by the equation:

(6) $$S' = \frac{S_a}{S_{дир}} = \frac{l}{L+l} = \frac{L*(1-w)}{L+l} = \frac{S_{ж}*L*w}{S_a*(L+l)}$$

A parameter m is introduced which defines the position of the intermediate terminal on the route:

(7) $$m = \frac{l}{L+l}$$

The value of the relative expenses for transportation is:

(8) $$S' = 1 + mw\left(\frac{S_{ж}}{S_a} - 1\right)$$

The relative time for transportation is also defined. The average time for transportation in the intermodal system is:

(9) $$T = T_1 + T_2$$

where:

T – the average time for transportation in the intermodal system;

T_1 – time for transportation between the departure and the intermediate terminal;

T_2 – is the time for transportation between the intermediate and destination terminal.

(10) $$T_1 = \frac{l}{V_a}$$

Where V_a is the speed of the automobile transportation.

(11) $$T_2 = \frac{l}{V_a}(1 - w) + w\left(\frac{L}{V_{ж}} + \frac{E}{2}\right)$$

where:

$V_{ж}$ – the speed of the railroad transportation;

E – interval of service, defined by the set schedule of the intermodal block-trains. The value of E/2 defines the average waiting time for railroad transportation.

Considering formulas (9,10,11) and after transformations, the average time for transportation in the intermodal system is defined by the equation:

(12) $$T = \frac{L+l}{V_a} + w\left(\frac{L}{V_{ж}} - \frac{l}{V_a} + \frac{E}{2}\right)$$

Defining the relative transportation time happens when we transfer T to the value $\frac{L+l}{V_a}$, which corresponds to the time of direct road delivery from the departure point to the destination point:

(13) $$T' = 1 + \frac{wV_a}{(L+l)}\left(\frac{L}{V_{ж}} - \frac{l}{V_a} + \frac{E}{2}\right)$$

The formula can be written as:

(14) $$T' = 1 + \frac{w}{T_a}\left(R + \frac{E}{2}\right)$$

where:

T_a – the time of direct road delivery from the departure point to the destination point;

R – the difference in the time between the railroad ana automobile transportation (excluding the waiting time) between the intermediate and destination terminal;

Formula (14) simplifies the interpretation and application of the calculated relation because the time for transportation is practically more transparent and controllable activity in comparison with the speed of travel.

An example for applying the calculated relations in the system with the following parameters is presented in Table 1. The results from the calculations are presented in the diagram in fig. 5.

Table 1

Initial data for calculation of the parameters of the synchromodal transportation

Parameter	Symbol in the formulas	Received value
Share of the shipped volume between the intermediate and destination transport, performed by railroad transportation	w	Varies from 0 to 1
Parameter of the position of the intermediate terminal on the route	m	0,3
The ratio between the expenses for railroad and automobile transportation	$S_ж/S_a$	0,6
Time for direct automobile delivery from the departure point to the destination point, days	T_a	4
Difference in the time of the railroad and automobile transportation between the intermediate and destination terminal, days	R	0.5
Service interval, defined by the set schedule of the intermodal block-trains, days	E	Varies from 7 (for one departure per week) to 2.3 (3 departures per week)

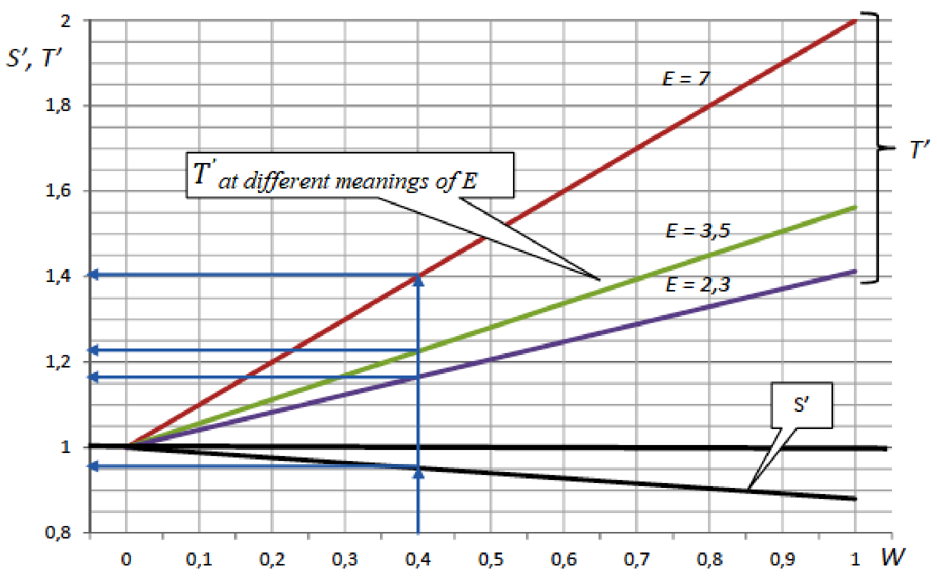

Fig. 5. Example for defining the parameters of the synchromodal transportation

The diagram shows that: if the proportion of the railroad transportation from the intermediate to destination terminal is 0,4, at the given characteristics of the system, the decrease of the expenses for transportation in comparison with the direct automobile version is 10%. At the same time the time for delivery is increased: at a rate 3 times per week railroad transportation, it is 16% more, when the travel is 2 times per week – the increase of time is 22% and if the travel is only once per week, the time is 40% more than the direct automobile delivery.

The described model can be modified if a number of additional factors are considered, more specifically:

- the expenses for railroad transportation (plus the related expenses of the customer) in connection with the frequency of the departures;
- the expenses of terminal processing;
- precision in keeping the announced delivery time (precision in keeping the schedules). The study of this parameter requires the introduction of probabilistic characteristics in the model.

The model for parameterization of the synchromodal transportation allows to calculate the expenses and the speed of delivery in the serial-parallel synchromodal transportation system with intermediate terminal and thus to evaluate the competitiveness of the synchromodal system in relation to alternative transportation possibilities.

References:

[1]. Behdani, B., Fan, Y., Wiegmans, B., Zuidwijk, R., Multimodal

[2]. schedule design for synchromodal freight transport systems, European Journal of Transport and Infrastructure Research, 424-444, 2016.

[3]. Behdani, B., Fan, Y. Wiegmans, B., Zuidwijk, R., Multimodal Schedule Design for Synchromodal Freight Transport Systems, 2014.

[4]. Den, H., Synchromodal transport-efficient en duurzaam via

[5]. Netwerkregie, Buck Consultants International, 2011.

[6]. Burgh, M., Synchromodal transport for the horticulture industry, Rotterdam, Erasmus University, 2012.

[7]. Gorris, T., Groen, T., Hofman, W., Janssen, R., Van Meijeren, Oonk, J., Implementatieroadmap Synchromodaliteit, Connekt & Dinalog commissioned by the Ministry of Infrastructure and Environment, 2011.

[8]. https://transportal.bg

[9]. https://trans.info/ru/sinhromodalnost-rezko-sokrashhaet-transportnyie-rashodyi-chto-eto-takoe-i-kak-eto-rabotaet-119588

[10]. https://www.ect.nl/en