INLAND WATERWAYS AS THE POWERFUL TOOL FOR THE FURTHER DEVELOPMENT OF INTERMODALITY

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SUMMARY

The intermodality is main an element of economic competitiveness and basic tool for support of the Trans-European Network - Transport (TEN-T) development. This paper offers the analysis of the promising innovative approaches to synthesis of the intermodal traffic systems including inland navigation. Inland waterways are the powerful tool for the further development of intermodality. Waterborne transport is the oldest mode of the cargoes haulage and the passengers’ travels. Now this environment-friendly transport mode gets main importance again, that requires innovative changes in the inland vessels, pushers, barges and its service systems. It is connected by that the combined transport, namely rail/road using along the main traffic corridors of the TEN-T is currently struggling with high external costs, including costs of environment renewal, congestion consequences and refund of traffic accidents charges. Experience of some EU countries has shown, that innovative approaches to the organization of inland navigation as element of integrated transport systems could help to solve these problems including elimination of “bottlenecks” in transport chains. For this purpose, first of all, it is required to the interconnected coordination between various modes for interoperability with inland waterborne transport, & secondly to focus decision-makers attention to creation of cost-effective intermodal chains.

NOMENCLATURE

- $\lambda_{v_j}$: Arrival density of vessels
- $\lambda_{vi}$: Frequency of a vessels arrival in inner port
- $\mu_i$: Intensity of vessels transhipment
- $f$: Number freight flows
- $s_i$: Transshipment of the river vessels at moment $t$
- $s_j$: River vessels on outer anchorages at moment $t$
- $(ch)$: Transport system transition
- $n$: Number the river vessels
- $t(ch_i)$: Time for realization of the some type’s transition
- $t_{ct}$: Time of circular trip
- $t_c$: Time of pusher and barge coupling
- $t_{ds}$: Time of downstream trip
- $t_{us}$: Time of up-stream trip
- $t_p$: Time of port transhipment
- $t_s$: Sluicing time
- $R$: Trip distance
- $R_m$: Maneuvering distance

1. INTRODUCTION

Transport services market plays a key role in the world economy because transportation various raw material, products and passengers along TEN-T. In contributing to enlargement of the transport services market, as well as re-enforcing economic, social & environment cohesion, the construction of the TEN-T is a key element in economic competitiveness & sustainable development Member States of the EU. It forms requirements to increase the interconnection, interoperability and flexibility of national networks as well as the access to them. Transport by inland waterways has an important role for creation of the intermodal chains in the freight/passengers TEN-T. The Commission's White Paper on transport outlines clearly the issues at stake and the decisions that need to be taken to assure the decision that need to be taken to assure the future of sustainable transport in the enlarged EU. One of the major suggestions was the need to shift transport from road to more environmentally friendly modes as rail, shipping and inland navigation [10]. It is consequence of fact that more than 35000 km of inland waterways connects hundreds of various nodes, namely, terminals, ports and logistical centers located in different EU regions. The most of Members States have advanced inland waterways infrastructure. However, the modal share of river transport accounts for 10-12 % of the total transport market in the European Union. For example, near 130 bn tkm of freight were dispatched by inland navigation in 2004. In the hinterland-seaports haulages, a modal share of inland navigation reaches 40-42%, e.g. Antwerp & Rotterdam feeder systems. But the transport throughput’s further growth is limited to some barriers e.g. trafficability etc. The development history analysis of transport networks has been considered in some papers. Principles of inland navigation as element network have been investigated in work Daggett, S. [5]. Historical analyses of railways and the hinterland channels using for the intermodal purposes was performed by Bourne, R. [3]. The problem of inland ports’ attractiveness increase and attendant delays of the coastal ports, was investigated by MacDonald, M., Mogelluzzo, B., Ness R., [14], [15], [17]. In paper by Robinson, A. is shown that inland ports are a further integrating mechanism within the intermodal chain management [19]. By enhancing multiple alliances, inland ports become economic growth nodes. Inland ports facilitate the shortening of the intermodal chain, thereby reducing total transportation costs. Costs are further reduced by making information transparent and avoiding such effects as the ‘bullwhip effect’ (pricing strategy). The analysis of the shipper’s preferences at a
select of the most excellent variants of logistical chains for the consumer’s needs satisfaction has been made by Richardson, H. On the basis of the historical data’s analysis author has created the shipper’s preferences checklist, including nodes location, transportation cost, quality service, reliability level, infrastructure accessibility and conjugate on market, level of customs fee, equipment capacity, and environmental issues [18]. Other work is the paper written by Wright, P., et al. which is devoted to research of transportation planning as well as non-engineering aspects integrated on a multimodal basis [23].

The basic purposes of Poland transport development are creation of favorable conditions for fuller and effective satisfaction of region’s economy needs and the country as a whole in sustainable transport services, expansions intra-EU transportations, competitiveness increase of passengers’ mobility, at simultaneous reduction of traffic congestion and environmental impacts’ decrease. One of the general ways for achievement of these purposes is development transport networks on the basis of the advanced technologies oriented on [6]:
- upgrading of the EU infrastructure;
- creating favourable conditions for the development of the intermodal chains;
- policy improvement of the TEN-T management (information, safety, accessibility);
- fruitful using of available resources & reduction the transport expenses in goods cost.

Special attention in European Transport Policy for 2030 is devoted to problem of transportation impacts on an environment. The review of traditional and innovative approaches to reconciliation of need for haulage increase & negative effects’ decrease is submitted in paper by Kroon, M. et al. [12]. The quantitative assessment of transport’s impacts on an environment was investigated in work edited by Banister, D. [2].

If problems of a congestion and pollution are obvious it is necessary to search for other ways of the freight/passengers transportation guaranteeing higher carrying capacity and environment-friendly, namely, a railway, short-sea shipping, inland navigation. The EU economy has the great potential and transport network is important factor for its growth as today as well tomorrow. Under condition the feasibility of an international legal instrument multimodal transport systems have chances for quick enlargement [16]. Such statement follows from facts that multimodal transport is considered as rather cheap and efficient, reliable, safe and environmental friendly.

2. THE BASIC TRENDS OF TRANSPORT INNOVATIVE TRANSFORMATIONS

The basic problems of transport innovative transformation are an implantation of new conceptions to support of compatibility between haulage technology and loading equipment and increase of research and development (R&D) for implantation of radical innovations into the industry. Its solutions will be giving positive impulses for sustainable transport development as today as tomorrow. The basic problems of sustainable transport development are [6]:

- **Creation of transport innovative conceptions.** R&D should be concentrated on “unit-oriented” novelties for increase of handling equipments efficiency, of the ships’ propulsion systems, alternative (renewable) fuel to growth of vehicles profitability.

- **Implantation of advanced transshipment and stowage technologies.** The attention should be concentrated on “technology-oriented” innovation (pre- and post-haulage, transshipment and stowage) to improve competitiveness of the European transport services.

- **Rebalancing and integrating different transport modes.** Investigation should be concentrated on “compatibility-oriented” modernization of national transport systems as transport by railways, waterways etc. to increase integrality of TEN-T.

- **Increasing of the transport safety and elimination of traffic barriers.** Research should be concentrated on “safety-oriented” traffic organization for TEN-T throughput increase, using contemporary communication systems and effective management techniques under condition of an environment respect.

Search and investigation of different solutions which concern problems, including river transport into intermodal chains, last many years. Limitation of resources on development of transport by an inland waterway demands their concentration on the major directions according the Member State’s national interests. In this connection on the analysis basis of modern experience, dominant importances for inland navigation development are:

- market expansion of inland navigation, with the purpose preservation of traditional cargo-carrying waterways and tracing of new inland waterways routes;
- modernization of inland nodes;
- renovation of passenger vessels according a state-of-art requirements;
- upgrading of riverside infrastructures for passengers’ service improvement;
- widening of methodical base for waterborne transport education.

The decision of the indicated problems will allow using effectively transport by inland waterway, to lower transport expenses, to improve an ecological situation, to provide safety of traffics, to increase number of workplaces. Inland navigation, using the super-size pusher-barges systems and novel self-propelled vessels can have the great future. Depending on freight traffics capacity, pusher-barge systems can be using “point-to-point” (liner service) or “multi-points” (tramp service) schemes that are defined by transportation profitability. In the rivers with the limited fairways sizes, expedient pusher-barge systems equip an articulate architecture, more effective in comparison with self-propelled ships. The role of inland shipping in the common EU transport system will be defined by competitiveness and innovative
means of servicing. In this situation main goals of EU transport politics are: organization stable and quality service of cargo/passengers flows; improvement of interoperability intra- multimodal systems; free consignors from superfluous transport risk; preparation of conditions for transport networks’ innovative transformations e.g. implantation intermodal cargo-carrying according “Trunk & feeder” scheme, elimination possible “bottlenecks” etc. Intermodal freight transportation planning methodology is presented in paper by Eatough, C. et. al. [7].

Potential of the TEN-T depends from modes compatibility, including transport by inland waterway, railway, airways etc. Rising this potential allows:

- increase of infrastructure nodes attractiveness (should satisfy passengers);
- diversity and serviceability of the transport systems (should satisfy customers);
- reduction of the delivery times & haulage tariffs (should satisfy consignors/consignees);
- profitability of the networks’ innovative transformations (should satisfy investors);
- efficiency of the management techniques (should satisfy decision-makers).

3. TRANSPORT BY INLAND WATERWAYS

3.1. THROUGHPUT VS. MODE

Inland Shipping Networks (ISN) evolution last near 4500 years. Analyses of ISN basic generations since from simplified unilateral network as the first generation (FG-ISN type) shown on Fig. 1. First of all, shall describe specific characteristics of the offered inland FG- network. For this purpose we shall: give historical review, analyze innovative transformations & enumerate key parameters according which management decisions are applied. Becoming and prosperity occurred during the period with 2200 B.C. till XVIII century. It has been connected to the transport potential’s use of rivers and the navigation channels’ laying. One of the first river channels was built in Mesopotamia. About 2200 B.C. Shatt-el-hai Canal linked the Tigris and Euphrates Rivers. Basic innovative decisions of this period were various rafts, the river sailing-ships, and afterwards the paddle–wheel’s steamers. The first model of such steamer was constructed in 1788 by W. Symington [21]. Up to the end of XVIII century the paddle–wheel’s steamers were used only for the purposes of home-trade haulage. In this period the key parameters of management decisions efficiency were expenses minimization and payload maximization. For estimation of vessel capacity satisfactory for the shipowner demands can be using methods of the queuing theory (controlling of the freight’s flows) or methods of the scheduling theory (controlling of the passengers’ flows). Investigate two tasks.

**Task A.** The vessel is used under “point-to-point” mode, i.e. linear (shuttle-type) shipping. Analyze pros and cons of linear navigation. The vessel can be loaded by one cargo kind, usually. The analysis allows suggesting opinion that shuttle-type shipping is profitable if the cargo meets to the vessel’s specification. From the practice, such situations don’t exceed 0.3–0.4 likelihood in the traffics by hinterland channels. Hence, it’s demerit. But under condition of stable freight flows the vessels will be profited, and can be used under the shuttle-type scheme i.e. cargo transportation back and forth over a short stretch between two ports. Hence, it’s advantage. Assess the haulage time for transport by inland waterways using graphical methods (see Fig. 1.).

**Task B.** The vessel is used under “multi-points” mode, i.e. tramp shipping. Analyze pros and cons of tramp service (Fig.2.). Such vessel can be loaded by Freight All Kinds (FAK), e.g. lightweight, heavy freight etc. It’s advantage. But simulation analysis allows suggesting that the tramp shipping has lower functional efficiency, than shuttle-type of shipping under various conditions, e.g. large shipments, lack of demand etc. It’s demerit. Thus, it is possible to assert, that inclusion of inland navigation into logistical chains will allow raising its functional efficiency, under conditions of the stable cargo flows, especially.

3.2. THE THROUGHPUT VS. TIME

Describe time’s parameter for the second generation (SG-ISN type) (See Fig 3). For this purpose we shall: give historical review, analyze innovative transformations and enumerate key parameters according which management decisions are applied. Becoming and prosperity occurred...
during the period with XIX till XX century. In this period various canals were constructed for connecting as well the rivers, as oceans.

For example, in 1859 de Lesseps F. begins construction of the Suez Canal, which has been completed in 1869. In August 1914 the Panama Canal was formally opened to traffic of the paddle-wheel’s steamers. In this period innovative achievements were:

− construction of sluices that has allowed to lengthen and to widen of inland waterways;
− development of the pusher-barge systems and screw-propelled vessels, which were narrower than the paddle-wheel’s steamers.

As result, was formed an opportunity for traffic planning, at the same time creating problems with the organization of regular shipping by inland waterways. The efficiency’s key parameters of management decisions were profitability maximization and minimization of the vessels’ downtime. To an estimation of the time-table period under condition of a one-way traffics define time when this route will be occupied servicing other vessels. As regards one-ways mode (moving by unilateral sluicing, see Fig. 4) have lower throughputs than multi-ways (bilateral navigation).

3.3. THROUGHPUT VS. INTERMODAL

Analyze characteristics of the inland network for the third generation (TG-ISN type). This scheme corresponds with the transport by inland waterways as link of intermodal chains.

Intermodalism as new transportation concept has been developed at XIX century. This concept initiated novelties. For example, in the late 1800’s railroad companies offered to carry on flat wagons [22]. However its widespread adoption accounts for the latter half of the XX century. Initiating event was the invention of the container. McLean claimed to have invented the shipping container in the 1930.

The low transport costs, relatively moderate investments into an infrastructure give essential advantage to this mode before others (See Fig 5). Transition to intermodal mode of functioning stimulated a series of new transformations [4], [20]. Among them ports infrastructures modernization for increasing pre- and post- haulages compatibility; shipbuilding of the vessels with restricted –drafts, of the dynamically-supported ships, namely hydrofoil ships (HS), air -cushion vessels.
(ACV), surface-effect ships (SES) and also widespread adoption of GPS, Synchronous Planning Real Time Control Systems (SPARCS) for the intermodal chains communications [1]. The efficiency’s key parameters are:

- economical indexes: value of PBP, NPV etc.;
- functional characteristics: compatibility modes, regularity and safety of traffic, pre- and post -haulages friendly for environment, throughput of the networks;
- customers’ preferences: needs' satisfaction, security of travel, comfort’s level.

4. TRANSPORT NETWORKS MANAGEMENT

4.1. PROBLEMS OF THE INTERMODAL CHAINS MANAGEMENT

Choice of the traffic mode depends from spatial parameters of the TEN-T parts, namely throughput, accessibility, user-friendliness etc. But there are differences between this dependence for separate modes. For example, road-networks and rail- networks can be defined by their paths (by tracks) than by nodes. On the other hand, waterborne-networks and air-networks tend to be defined by their nodes than by their routes. Let's believe, that intermodal chain is controlled if in each its new state can be accepted and implant into practice any decision relatively the cost factor of the freight transport and passengers service quality [9]. Such decisions constitute of CP-sets predetermining transformations’ trajectories of intermodal chains (See Table 1).

Modeling of such trajectories becomes simpler in case of introduction of the following assumptions. But there are differences between this dependence for separate modes. For example, road-networks and rail- networks can be defined by their paths (by tracks) than by nodes. On the other hand, waterborne-networks and air-networks tend to be defined by their nodes than by their routes. Let's believe, that intermodal chain is controlled if in each its new state can be accepted and implant into practice any decision relatively the cost factor of the freight transport and passengers service quality [9]. Such decisions constitute of CP-sets predetermining transformations’ trajectories of intermodal chains (See Table 1). Modeling of such trajectories becomes simpler in case of introduction of the following assumptions.

For any moment transport system structure is defined by:

- states and transition type;
- internal factors e.g. vehicles compatibility and management competence;
- external factors e.g. market situations, consumers preferences etc.

<table>
<thead>
<tr>
<th>TABLE 1 Transport chain. Costs and Critical points</th>
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<tr>
<th>Transportation cost</th>
<th>TC₁</th>
<th>TC₂</th>
<th>TC₃</th>
<th>TC₄</th>
<th>TC₅</th>
<th>TC₆</th>
<th>TC₇</th>
<th>TC₈</th>
</tr>
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<tbody>
<tr>
<td>Handling &amp; storage costs</td>
<td>H&amp;SC₁</td>
<td>H&amp;SC₂</td>
<td>H&amp;SC₃</td>
<td>H&amp;SC₄</td>
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<tr>
<td>Barriers’ overcoming costs</td>
<td>BC₁</td>
<td>BC₂</td>
<td>BC₃</td>
<td>BC₄</td>
<td>BC₅</td>
<td>BC₆</td>
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<tr>
<td>Network compatibility’s maintenance costs</td>
<td>NMC₁</td>
<td>NMC₂</td>
<td>NMC₃</td>
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<td>NMC₅</td>
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<td>MC₁</td>
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<td>MC₅</td>
<td>MC₆</td>
<td>MC₇</td>
<td>MC₈</td>
</tr>
<tr>
<td>Number of controlled network links / Management methods</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
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<tr>
<td>CP - Critical points in the traffic planning tasks</td>
<td>TNC - Transport Network Control</td>
<td>LM - Logistical Management</td>
<td>TRM - Traffic Risk-Management</td>
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Therefore, transformations trajectories of the transport systems can be compared by various indicators. For examples: “before-&-after” vehicles’ transitions, “tolerant -&-intolerant” relatively standing idles, “with-&-without” modern management techniques etc. Management techniques should helps shipping authority to manage every aspect, including decision-making about locks throughput, order of transshipment priorities, traffics services etc. [11]. For that, any transport enterprise has three interconnected purposes of management namely: provide qualitative a service for customers; implement effective financial and innovative policy; increase competitive properties.

Achievement of these goals is possibly thanks to rational planning; the organization and the transportation control (See Table.2).

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<th>Tasks</th>
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<td>Monitoring of network traffic implementing of adaptive control strategies. Introduction of innovative traffic technologies &amp; vehicles</td>
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<td>Links (freeways, transport corridors etc.) management</td>
<td>Monitoring of links conditions identification of flows barriers control of lanes &amp; crossroads using telecommunications system</td>
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<td>Providing cooperative labor / management relationships to increase port productivity integration of the human factor, the equipment efficiency &amp; the infrastructure throughput</td>
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<td>Avoidance of dangers to vehicles and infrastructure controlling access to the transport nodes &amp; links monitoring of vehicles location providing remote monitoring of highway-railway intersections</td>
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<td>Avoidance of dangers to the transport, namely, its use as terrorism instrument and as illegal haulage’s means etc. coming into operation of the emergency transport communications</td>
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- increase competitive properties.

Achievement of these goals is possibly thanks to rational planning; the organization and the transportation control (See Table.2).
On bases [8], [13] it is possible to offer five principles of rational management methods:

1. **The principle of solutions optimality** - essence of this principle consists in achievement of the maximal economical indexes (e.g. NPV etc.) of the intermodal chains under condition of the minimal influence on an environment.

2. **The principle of solutions interoperability** – the essence of this principle consist in necessity of functional coordination of vehicles activities & transshipment facilities which will be used in intermodal chains under condition of acceptable reliability.

3. **Principle of solutions feasibility** – the essence of this principle consists in a guarantee to the customer full compatibility (interoperability) of the different transport modes which will be used in intermodal chains under condition of acceptable transportation tariffs.

4. **Principle of solutions authenticity** – the essence of this principle consists in necessity of functional management under condition that decisions are supported by the verified information.

5. **Principle of solutions competitiveness** – the essence of this principle consists in necessity to consideration ofdisablehigh-risk investments supposing radical changes in the transport system. Conditions of this state are (1):

   \[ \sum_{i} s_{i} = 0, \sum_{j} s_{j} = 0. \]

The absolute open states have two special cases:

**The first relatively open state** when there are no vessels and infrastructure elements modernization of inland waterways. Conditions of this state are (2):

\[ \sum_{i} s_{i} \neq 0, \sum_{j} s_{j} = 0. \]

**The second relatively open state** when there are no vessels or infrastructure elements modernization the port’s elements of an infrastructure. Conditions of these states are (3):

\[ \sum_{i} s_{i} = 0, \sum_{j} s_{j} \neq 0. \]

4.2. (b) The absolute closed states

**The absolute closed state is situation**, when all of the mooring places into inner port, and also the places at the outer anchorages, are occupied. Author for such transport systems has been introducing concept of Opened Transport System (OTS). One of the possible reasons can be infrastructure elements modernization of inland waterways. Conditions of these states are (4):

\[ \sum_{i} s_{i} = S_{i}, \sum_{j} s_{j} = S_{j}. \]

The absolute closed states have two special cases:

**The first relatively closed state** when all of the inner mooring places into inner port, and also the places at the outer anchorages, are occupied. Author for such transport systems has been introducing concept of Closed Transport System (CTS). The possible reasons can be:

- lack of modernization efforts directed on increase of the inner port’s throughput;
- navigation errors as consequence of the infrastructure deficient.

Such states are typical for situations when port’s authority has the funds debit. As result can be disincentive to the innovative development of the transport system by inland waterways. Conditions of these states are (5):
\[ \sum_{i} s_i = S_j, \quad \sum_{j} s_j < S_j \]

These restriction rules stable modes of the transport systems under stagnation condition.

**The second relatively closed state** when all of the mooring places are free, but are occupied places at the outer anchorages. Conditions of this state are (6):
\[ \sum_{i} s_i < S_i, \quad \sum_{j} s_j = S_j \]

These restriction rules describe unstable modes of the transport systems under stagnation condition.

### 4.2. (c) Intermediate states

Intermediate states are all states between absolute closed and absolute opened inner port situations.

#### 4.3. TRANSITIONS OF THE INLAND NAVIGATION SYSTEM AS A LINK INTERMODAL CHAINS

Transport system transitions from one state in another can be caused by:
- Peculiarities of the transport infrastructure (number of locks & rafts, river bend’s radius, breadth of sluice gate etc.).
- Schemes of the traffic organization (“point-to-point” modes, “multi-point” modes etc.).
- Strategies of the transport system management.

Set of possible transitions at the predetermined managing decisions characterize an evolution trajectory of the transport system efficiency. In this connection, realization of each managing procedure leads to change of transport system state, and, hence, and modification of trajectories efficiency. As result, the pack of trajectories formed can be treated as the dynamic model of an estimation of management efficiency. Notwithstanding the fact that theoretically possible large number of \((ch)\)-transitions, all of them can be grouping to one of five variants.

**The first type’s transition.** Realizing under condition that expectation of the transshipment is very short, i.e. on final phase of the voyage \((s_i\text{-}conditions)\) a vessel can change its state into loading/unloading state \((s_j\text{-}conditions)\) without standing idle. Execution is according “Free in-Free Out” principle. The logic form of transition (7):
\[ s_i \Rightarrow ch_k \Rightarrow s_j (t = 0) \Rightarrow ch_{k+1} \Rightarrow s_i, ch_k \equiv ch_{k+1} \]

The likelihood form of transition (8):
\[ P_{vi} = \lambda_{vi} \times t(ch_k), \quad \text{under } \sum_{i} s_i < S_i, \sum_{j} s_j = 0 \]

**The second type’s transition.** Realizing under condition that all quays are occupied, i.e. completion phase of the voyage \((s_i\text{-}conditions)\) turn into waiting phase \((s_j\text{-}conditions)\). This transition is possible, if any part of the outer anchorages is free. Execution is according “Liner In - Free Out” principle. The logic form of transition (9):
\[ s_i \Rightarrow ch_k \Rightarrow s_j (t \neq 0). \]

The likelihood form of transition (10):
\[ P_{vj} = \lambda_{vj} \times t(ch_k), \quad \text{at } \sum_{i} s_i = S_i, \sum_{j} s_j < S_j. \]

**The third type’s transition.** Realizing under condition that transshipment is terminated and a ship expect the departure, i.e. a vessel from transshipment \((s_i\text{-}conditions)\) transform into waiting mode of trip \((s_j\text{-}conditions)\). Execution is “Liner In -Liner Out” principle. The logic form of transition (11):
\[ s_i \Rightarrow ch_{k-1} \Rightarrow s_v. \]

The likelihood form of transition (12):
\[ P_{tv} = \mu_{t} \times t(ch_{k-1}), \quad \text{at } \sum_{i} s_i = S_i - 1, \sum_{j} s_j = 0. \]

**The fourth type’s transition.** Implementing under condition that transshipment is terminated but exist queue and its forced waiting port arrival, i.e.:
- transshipment is terminated \((s_i\text{-}conditions)\);
- ship transform into waiting mode of trip \((s_v\text{-}conditions)\);
- number of busy quays decreased on one.

Execution is “Free In - Liner Out” principle. The logic form of transition (13):
\[ \begin{bmatrix} s_i \Rightarrow ch_{k-1} \Rightarrow s_v \\ s_j \Rightarrow ch_{k+1} \Rightarrow s_i \end{bmatrix} \]

The likelihood form of transition (14):
\[ \begin{bmatrix} P_{iv} = \mu_{i} \times t(ch_{k-1}) \\ P_{ji} = \lambda_{j} \times t(ch_{k+1}) \end{bmatrix}, \quad \text{under } \begin{bmatrix} \sum_{i} s_i = S_i - 1 \\ \sum_{j} s_j = S_j - 1 \end{bmatrix} \]

**The fifth type’s transition.** Realizing under condition that inner port is absolute closed port i.e.:
- all quays are occupied;
- all outer anchorages are busy too.

In this situation a vessel must be waiting when anchorages will be free or continue voyage.

#### 4.4. STRATEGIES OF PORT TRANSSHIPMENT MANAGEMENT

The sets of decision-making regulation which further we shall designate as Decision-Making Procedures (DMP-packet) must correspond to all possible transitions of transport by inland waterways. For successful creating of the transport system structure, everyone DMP must keep up conformity to the following principle: ‘**Profitability and safety of the passengers/freight transportation under any regular conditions**’. The offered principle is answered three basic forms of the DMP-packets.
4.4. (a) DMP as creation tool of the flexible timetables

Such procedures’ packets backed up by priority-service discipline (e.g., a method LIFO when last in queue vehicle is the first to be service) or by random order. Can be using if were planned exclusive service of the arrived vessels. Its have three versions:

- Alternating priorities with queue-classes. Provides mooring of the arrived ship at the outer anchorage. Corresponds to the second type’s transition under the condition: number of outer anchorages is equal to number of the arriving vessels.
- Dynamic priorities without service interruption. Provides mooring of the arrived ship at inner port. Corresponds to the fourth type’s transition under the conditions: one vessel finished its transshipment, but number of uncharged quays is lesser than number of the ships expecting transshipment at outer anchorages.
- Preferential priorities with service interruption. Provides instantaneous unloading of the arrived ships e.g. vessels carrying dangerous goods, by-passing queues at outer anchorages. Corresponds to the first type’s transition.

Comment 1. General requirement for all priorities is unambiguity of this DMP-packet connected to necessity of unconditional observance of management rules by inner port.

Comment 2. Active schedule when arrival of any vessel and departure of any vessel require permissions. May be limits by area compulsory for pilotage, by forbidden zones for anchoring

4.4. (b) DMP as creation tool of the interconnected timetables

Such procedures’ packets backed up by interoperability-principle. Assumes that:

- managers have aspiration to synergy effects (the simultaneous joint action of elements which, together, have greater total effect than the sum of elements effects).
- the part of moorings and parking places can accept the vehicles of various type and size.

Interoperability can be determined as effective interactions of two (or more) modes. This relate to freight transport as well as passengers’ transport. In relation to transport by inland waterways, interoperability is the ability to functional compatibility with feeder transport systems (road and railway transport) to provide efficient freight/passengers’ flows across national borders and eliminate technical, bureaucratic, economical etc. barriers. Analyzing DMP backed up by intermodality-principle and has three versions. If we want to achieve:

- DMP-packet is orientated on achievement technical interoperability i.e. those different transport systems (by railways, by waterways etc.) use compatible vehicles under condition eliminating (or reducing) technical barriers.
- DMP-packet is orientated on achievement technological interoperability, i.e. those different transport systems (by railways, by waterways etc.) able to co-operate and exploit analogous technologies for offer compatible services for users.

Corresponds to first type’s transition of the under condition that some quays intended for the services of intermodal chains. Such MPD-packet is potentially capable to increase the competitiveness of intermodal freight/passengers flows by harmonizing ILU moving and by enlarging throughput of the transport by road, railways and inland waterways.

4.4. (c) DMP as creation tool of the fixed timetables

Three types of the fixed timetable are:

- passive schedule when arrival of any vessel and departure of any vessel is expected in advance. It can be restricted to limits of port only.
- semi-passive schedule when only arrival of any vessel requires permission and vice versa. It can be used, when anyone a vessel should load a dangerous cargo.

Usually using such DMP-packets provide for support:

- The organizing arrival of vessels. More often than not, assumes the arrival times distributed according to a Poisson rule while the transshipments times are corresponding to exponential rule. Moreover, proposes what vessels can arrive singly, as well as together.
- The organizing behaviour of vessels. Typically assumes that vessels may be patient and willing to wait (in the roadsteads). But supposes that separately vessels may be impatient and leave the port after a while.
- The organizing service of vessels. As a rule assumes that the service times are independent of the arrival times and identically distributed. For example, the service times can be deterministic or exponentially distributed. At the same time can be assumes that service times are dependent from the queue length.
- The service discipline. Vessels can be served one by one or in group. DMP-packet should have possibilities for support of vessels services in chronological order, i.e. step-by-step.

5. CONCLUSION

1. New aspects of market relationships (globalization, liberalization, commercialization, competition and deregulation), the emergence of new global actors, changes in consignors’ tastes (values and preferences) should be taken into account at investigation of the preferable strategies of haulages (according fixed, flexible and interconnected timetables), which are planned to use.

2. In conception of the balanced world (transport services market with linear effects) the future transport demand can be forecast in terms of structurally stable relationships between such factors as growth rates, implantation sequence of the new transport technologies based on experts’ assessment of their potential relative to competitors, suppliers and other business-partners.
3. In conception of an interconnected world (transport services market with synergy effects) the structural stability of transport markets should be valued under conditions of an almost chaotic actors-actions when implantation of the new technologies may lead firstly, to radical changes in the market demand and secondly, to significant structural and functional transformations of the transport chains. A fully integrated transport network is a prerequisite for a real freedom of movement of goods and people. A modern, interconnected and interoperable the East-West network should allow enhancing trade and the competitiveness of the European economy as a whole.

4. Enlargement of the intermodal haulages is one of the important goals of EU economic growth. Implantation into this conception such new links as transport by the East-European waterways will allow to increase TEN-T throughput by 12-15% of all cargo flows in EU.

6. ACKNOWLEDGEMENT

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