Co-evolution approach to management by the transport networks’ innovative transformations
Part 1. The basic problems and trends innovative transformations

Iouri Semenov

Abstract

The TEN-T (Trans-European Transport Network) is main an element of economic competitiveness as supports development of the transport services market. At the same time the TEN-T is the important factor of the balanced and sustainable development of the European Union, consolidating its economic and social unity. For success achievement on this way is required of implementation and adaptation of innovative changes in modal networks, vehicles and its systems of service. It is connected by that combined railways/road transport widely used in XX century is currently struggling with high external costs along the main traffic corridors of the TEN-T, including costs of eco-security, environment renewal, congestion consequences and refund of traffic accidents charges. Experience of some EU Member States has shown, that innovative approaches to the organization of inland navigation as an essential element of the transport network could help to solve these problems. For this purpose, first of all, it is required to the interconnected coordination between various vehicles for interoperability of different transport modes and secondly to focus decision-makers attention on effective creation of intermodal chains.

Nomenclature

\( n \) - number the river vessels;
\( t_{ct}, t_{c} \) - time of circular trip & time of pusher and barge coupling;
\( t_{ds}, t_{us} \) - time of downstream trip and time of up-stream trip according;
\( t_p, t_s \) - time of port transshipment and sluicing time according;

\(^1\) Technical University of Szczecin, Faculty of Marine Technology, Piastów Avenue 41, 71-065 Szczecin, jusiem@shiptech.tuniv.szczecin.pl
$B_\eta$ - barriers’ overcoming costs, $\eta = 1/7$

$B_v, B_s$ - breadth of vessel and sluice gate according;

$C_\alpha$ - network compatibility’s maintenance costs, $\alpha = 1/7$;

$L_s, L_v, L_w$ - sluice, vessel and wharf length according;

$M_\mu$ - management costs, $\mu = 1/15$;

$R, R_m$ - trip and maneuvering distance according;

$R_r$ - river bend’s radius;

$TR_\gamma$ - costs of transportation, $\gamma = 1/8$;

$V_{haulage}$ - commercial speed of vessel;

$TH$ - throughput of an inland waterway;

$Z$ – carrying capacity of the transport system.

### 1.1. Introduction

Two scenarios for EU development in the future exist [3]:

– "Do-nothing" scenario, which demand indeed the downsizing of EU intervention;

– “Business-as-usual” scenario foresee the series of actions according challenges facing Europe namely, globalization effects, jobs increase, enlargement of the economical relationship, competitiveness growth, environment protection and social security, and weaknesses elimination in the European transport system. Transport services market plays a key role in the European economy because transportation a various raw material, products and passengers along TEN-T. Let’s create general classification of the transport service market.

**A. Transport Market Relationships:**

1. One Transport Mode Service – not consumers.
2. One Transport Mode Service – one consumer.
3. One Transport Mode Service – multiple consumers.
5. Multiple Transport Mode Service – one consumer.

**B. Form of Transport Mode Service:**

1. Defined by Transport Mode situations.
2. Defined by transportation contract requirements.
3. Defined by consumers’ preferences.

**C. Level of Demand:**

1. Demand exceeds free tonnage.
2. Sometime Demand exceeds free tonnage.
3. Demand doesn’t exceed free tonnage.

**D. Direct:**

1. Mass consumers.
2. Individual consumers.

**E. Goal’s Type:**
i Profit maximization, typical for private (NGA) transport firms.
ii Nonprofit activity, typical for public (GA) transport company.

For this, further we shall discuss one of the most widespread transport market situations which are characterized by the following classification attributes: multimodal transport service, certain of the market situations, periodical demand of the free tonnage, mass consignors and profit maximization. In support to the enlargement of the transport services market, as well as re-enforcing economic, social and environment cohesion, the construction of the TEN-T is a key element in economic competitiveness and 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.

Table 1.1

Sequence of the transport network's management. Source: Author’s research

<table>
<thead>
<tr>
<th>Transportation costs</th>
<th>Handling &amp; storage costs</th>
<th>Barriers’ overcoming costs</th>
<th>Network compatibility’s maintenance costs</th>
<th>Management costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR₁ TR₂ TR₃ TR₄ TR₅ TR₆ TR₇ TR₈</td>
<td>H&amp;S₁ H&amp;S₂ H&amp;S₃ H&amp;S₄</td>
<td>B₁ B₂ B₃ B₄ B₅ B₆ B₇</td>
<td>C₁ C₂ C₃ C₄ C₅</td>
<td>M₁ M₂ M₃ M₄ M₅ M₆ M₇ M₈ M₉ M₁₀ M₁₁ M₁₂ M₁₃ M₁₄ M₁₅</td>
</tr>
</tbody>
</table>

Number of controlled network links / Management methods

<table>
<thead>
<tr>
<th>3 1 3 1 2 2 3 1 1 2 1 3 1 2 1 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRM - TRM - - - TRM - - - TRM - - - TRM</td>
</tr>
<tr>
<td>CP₁ CP₂ CP₃ CP₄</td>
</tr>
</tbody>
</table>

Critical points in the traffic planning

Transport by inland waterways has an important role for creation of the intermodal chains in the freight/passengers TEN-T. Illustration of such chain realizing in transport network is shown in Table 1.1. 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. It is consequence of fact that more than 35,000
kilometers of inland waterways connect hundreds of various nodes, namely, loading terminals, river ports, and logistical centers, located in different European 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 EU. For example, near 130 billion ton-kilometers 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. Transportation chains barriers can be separated on two groups, namely:

a. **Nature barriers** among which distinguish absolute and relative barriers.

![Absolute barriers diagram](image)

**Fig. 1.1.** The absolute barriers. By the example of the intermodal chain. Source: Author’s research

**Absolute nature barriers** (see Fig 1.1). The geographical (usually, continental) specificity that entirely eliminate possibility of freight haulage by traditional land transport. They need to be bypassed or overcome by TEN-T infrastructures. For example, rivers are considered as an absolute barrier for landside transportation chains and can only be overcome by means of tunnels or bridges. Seas are absolute barriers too and could be overcome if first of all, transport networks have such nodes as seaports, and secondly, will be organized waterborne intermodal chains using e.g. fast ferries, containerships, etc. On the other hand, land is an absolute barrier for the waterborne transportation and can be surmount if transport networks have such links as rivers, lakes, navigation canals.

![Relative barriers diagram](image)

**Fig. 1.2.** The relative barriers /constant/. By the example of the railway. Source: Author’s research

**Relative barriers.** The geomorphologic (usually, regional) specificity that can be represented as routes with “constant or periodical bottlenecks” (see Fig. 1.2 & Fig.1.3). Existence of “bottlenecks” fundamentally limits transportation in case of the freight haulage
and the passengers’ mobility. In turn, it is possible to predict, that these “bottlenecks” will limit throughput of the any routes connecting different nodes, namely origin points and destination points. Classic examples of a relative barrier are such narrowness as canyons, mountains, hills. For maritime transportation, usually relative barriers are straits, sandbanks.

![Diagram](image)

Fig. 1.3. The relative barriers /periodical/ By the example of the inland navigation. Source: Author’s research

b. **Economical barriers** among which distinguish micro- and macro-economic barriers.

– **Microeconomic barriers** representing adverse circumstances creating factors negatively influencing financial stability of transport firms. Among these are necessities of the personnel retraining, high transport risk, dumping policy of the firms having leadership in the market and customer’s preferences changes.

– **Macroeconomic barriers** representing adverse circumstances creating factors negatively influencing stability of the transport services market. Among these are adverse market conjunctures, instability of the monetary and financial market, incompatibility of the national transport networks, drastic increase of the fuel cost, the freight flows’ instability and high political risk. For example, cost supporting road infrastructure in Germany formed on level 0, 4-0, 5 mln €/ km/year. Overcoming of the listed barriers essentially increases transport costs (see Table 1.2), and the aspiration to elimination of such barriers demands the large-scale investments into innovative transformations of the transport networks (see Table 1.3).

**Table 1.2**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Transport cost / unimodal chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Transport by railways</td>
<td>0.27 ± 0.31</td>
</tr>
<tr>
<td>2 Transport by inland waterways</td>
<td>0.17 ± 0.19</td>
</tr>
<tr>
<td>3 Short Sea Shipping</td>
<td>0.95 ± 1.25</td>
</tr>
<tr>
<td>4 Transport by highways</td>
<td>1.18 ± 1.31</td>
</tr>
<tr>
<td>Pre-and-post haulage</td>
<td>1.25 ± 1.37</td>
</tr>
<tr>
<td>Transhipment (handling, storage, stowage, marking etc.)</td>
<td>60 €/ILU + 70 €/ILU</td>
</tr>
<tr>
<td>Extra transport cost (forwarders, insurance, taxes, etc.)</td>
<td>+ (17% +19%) total cost</td>
</tr>
</tbody>
</table>

Source: Intermodal transport reduction possibilities, RECORDIT, December, 2001
The development history analysis of transport networks has been considered in some papers [16]. Principles of Inland Navigation as element network have been investigated in work Daggett, S. [4]. It is necessary to note paper Bourne, R. in which he performs historical analyses of railways and the hinterland channels using for the intermodal purposes [2].

The problem of inland ports’ attractiveness increase, removing thus crowding, and attendant delays of the large coastal ports, was investigated by MacDonald, M. E., Ness R., Mogelluzzo B. [10], [12], [11]. In paper by Robinson, A.E. is shown that inland ports are a further integrating mechanism within the intermodal chain management [14]. By enhancing multiple alliances, both vertically and horizontally, 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).

### Table 1.3

<table>
<thead>
<tr>
<th>Mode</th>
<th>Investments before 2000 year</th>
<th>Investments during 2000 – 2020 years</th>
<th>Total investments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>billion €  %</td>
<td>billion €  %</td>
<td>billion €  %</td>
</tr>
<tr>
<td>Roads</td>
<td>81 34.99</td>
<td>62 38.04</td>
<td>143 36.25</td>
</tr>
<tr>
<td>High-Speed Trains</td>
<td>72 31.10</td>
<td>57 34.97</td>
<td>129 32.70</td>
</tr>
<tr>
<td>Conventional Railways</td>
<td>22 9.50</td>
<td>23 14.11</td>
<td>45 11.41</td>
</tr>
<tr>
<td>Inland Waterways</td>
<td>14 6.05</td>
<td>11 6.75</td>
<td>25 6.34</td>
</tr>
<tr>
<td>Ports</td>
<td>1.50.64</td>
<td>0.5 0.31</td>
<td>2 0.51</td>
</tr>
<tr>
<td>Airport</td>
<td>24 10.37</td>
<td>4.5 2.76</td>
<td>28.5 7.22</td>
</tr>
<tr>
<td>Inland Navigation Management</td>
<td>9 3.89</td>
<td>5 3.06</td>
<td>14 3.55</td>
</tr>
<tr>
<td>Others</td>
<td>8 3.46</td>
<td>0 0</td>
<td>8 2.02</td>
</tr>
<tr>
<td>Total</td>
<td>231.5 100</td>
<td>163 100</td>
<td>394.5 100</td>
</tr>
</tbody>
</table>

Source: European Intermodal Programs: Planning, Police & Technology. ITRI, Baltimore, MD 21210

The analysis of 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.L. On the basis of the historical data’s analysis author is created the shipper’s preferences checklist, including nodes location, transportation cost, quality service, reliability level, infrastructure accessibility and conjecture on market, level of customs fee, equipment capacity, and environmental issues [13]. Other interesting work is the paper written by Wright, P. H., et al. which is devoted to exploration short and long term transportation planning as well as non-engineering aspects integrated on a multimodal basis [19].

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 Polish commodity producers and carriers in the world transport markets, and also of passengers mobility, at simultaneous reduction of traffic congestion and the environmental impacts’ decrease. One of general ways for achievement of these purposes is development transport networks on the basis of advanced technologies [5]:

- to make better integration of the Member States;
- to create favourable conditions for the development of the intermodal transport;
- to increase of investment funds for the TEN-T quality management;
- to fruitful use of available resources & reduction the transport expenses in goods cost;
- to encourage business to widen use of the transport by inland waterways;
- to format conditions for quality services of the passengers with disabilities;
− to coordinate development of Poland’s transport infrastructure with the purpose of fuller integration with EU logistical systems for wide unobstructed transportation;
− to optimized of transport process with the purpose of transit quality improvement;
− to decrease traffic tariffs by means of the carrying capacity increase;
− to reduction of a overland (trucks, lorries, trains etc.) traffic;
− to create conditions for increase of a service quality (information, safety, accessibility);
− to decrease the transport expenses in final cost of the goods;
− to provide convenient connections into logistical chains intra- EU and outside- EU.

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 and negative effects’ decrease is submitted in paper by Kroon, M. et al. [9]. The Transport Policy and quantitative assessment of transport’s impacts on an environment was investigated in work edited by Banister, D. [1].

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 European Union has for some time recognized the great potential that Europe's transport network has for freight and passenger traffic. Intermodal chains are considered rather cheap and efficient, reliable, safe and environmental friendly particularly compared with haulage by trucks.

**Assumption 1.1** Inland shipping is slower than and not as flexible as overland transport, but its advantages are lower expenses and greater payloads. If these advantages will be using in intermodal chains this give to EU economics new impulse for development

### 1.2. The basic problems & trends of innovative transformations

The basic problems of the transport innovative transformation – implanting new solutions to encouragement of the interactions compatibility between the haulage & handling technologies from the one hand, and development of the integrated solutions to industry new issues from the second hand while estimating the impact on sustainable transport development now and in the future. Basic problems of sustainable transport development are [7]:

**Research of new technologies and innovative conceptions for all transport modes.** R & D should be concentrated on advanced haulage and handling technologies, high efficiency of the re-loading equipments and the propulsion systems. The emphasis will be use of alternative (renewable) fuels and the engines distinguishing by low emission.

**Implantation of advanced vehicles and transshipment equipments.** Attention should be concentrated on “transport-specific” advanced pre- and post-haulage technologies, handling and storage means for improving competitiveness through adaptation environmentally friendly vehicles.

**Rebalancing and integrating different transport modes.** Attention should be concentrated on integration of a national railway systems and competitive inland navigation for efficiency increasing of TEN-T as whole.

**Increasing of the transport safety and elimination of traffic congestions.** Research should be concentrated on strategies and technologies to increase TEN-T throughput using waterborne and railway transport, contemporary communication systems, and effective management techniques under condition of environment respect.
Search and investigation different solutions which touch the problems including river transport into intermodal chains have many years. Limitation of resources on development of transport by 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:

- enlargement market of inland navigation, with the purpose, first of all, preservation of traditional cargo-carrying waterways and secondly tracing of new inland waterways routes;
- modernization of inland nodes as river ports and transshipment terminals;
- design of the innovative vessels, e.g. small-draught ships, for short-route consignment delivery for freight/passengers service on the small rivers;
- upgrading of passenger vessels according a comfort conditions;
- unfolding of a riverside infrastructures for service passengers;
- widening of material base of waterborne transport education;
- reconstruction of shipyards and repair yards.

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 super-size pusher-barges systems and novel self-propelled vessels can have the great future. Depending on freight traffics capacity, pusher-barges systems can be using “point-to-point” (linear/shuttle shipping) or “multi-points” (tramp/charter shipping) schemes that are defined by transportation profitability. In the rivers with the limited fairways sizes, expedient pusher-barges 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 forms of servicing. In this situation the 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” as shown in Table 1.4.

Table 1.4

<table>
<thead>
<tr>
<th>Vessel location / activity</th>
<th>Graphic interpretation</th>
<th>Incompatibilities causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>River port / transhipment</td>
<td><img src="%E6%B2%B3%E8%BE%B9%E7%A0%81%E5%A4%B4/%E7%A0%81%E5%A4%B4" alt="" /></td>
<td>The vessel length is more, than the wharf length - ( L_w &lt; L_r )</td>
</tr>
<tr>
<td>Inland waterway / traffic</td>
<td><img src="%E6%B2%B3%E5%BC%AF" alt="" /></td>
<td>The vessel length is more, than the river bend’s radius - ( R_r &lt; L_r )</td>
</tr>
<tr>
<td>Inland waterway / sluicing</td>
<td><img src="%E8%88%B9%E8%BF%87%E6%B0%B4%E9%97%B8" alt="" /></td>
<td>The ship width is more, than the sluice gate - ( B_s &lt; B_r )</td>
</tr>
</tbody>
</table>

Inclusion of transport by inland waterways into intermodal chains demands enhancement of compatibility between different transport modes. One of the main solutions is implantation of the "River information System" as component “Global Intermodal Information System” on permanent updated database [5], including:
– Fairway information (e.g. geographical, hydrological information);
– On-line traffic information (e.g. affecting immediate-navigation decisions in the actual traffic situation and geographical surroundings);
– Planning traffic information (e.g. voyage time-table, lock and port throughput);
– Transport market information (e.g. cargo supply and tonnage demands);
– Navigational database (e.g. tracking and tracing of the vessels routes);
– Supporting information (e.g. current claims and incident reports, information about impossible interconnection and interoperability with other transport modes).

Real-time information is not only required by shippers to optimize their inventory-in-motion management, but also by transport operators and service providers to increase their planning capacity and enhance their services. This should allow operators and service providers to and provide transport users with better intermodal chain management. The problems using river ships into multimodal chains has been investigated in several papers.

Intermodal Freight Transportation Planning Methodology is presented in paper by Eatough, C.J., Birch, S.C. and Demetsky, M. J. [6]. The methodology consists of six steps: (1) investigate the freight/passengers flows, (2) identify problems, (3) establish performance measures, (4) collect data and define conditions for specific transportation problems, (5) develop and evaluate improvement alternatives transport technologies, and (6) select and implement improvements into multimodal system.

Role of technological innovations in sustainable mobility development have been investigated in book by Geerlings, H. [8]. In this book is analyzed the relationship between transport and the environment and also is shown the role of technology and the meaning of the concept of sustainable development for the transport services market.

Assumption 1.2. A fully integrated national transport networks is a prerequisite for a real freedom of goods and people movement. An interconnected and interoperable network allows, through a better use of transport, to enhance trade and the competitiveness of the European economy as a whole. The potential of the TEN-T depends from:
– rational transportation modes combination, incl. transport by waterway, railway etc.
– increase of infrastructure nodes attractiveness (should satisfy passengers);
– diversity of the transport services types should satisfy customers);
– reduction of the delivery time & haulage tariffs (should satisfy consignors);
– enlargement of the networks’ innovative transformations (should satisfy investors);
– implantation of the management techniques smart (should satisfy decision-makers).
Let’s research organization principles of the inland transport process.

1.3. The characteristic of inland transport process

General purpose ISN is cargoes and passengers transportation. Every transport network consists from two group’s elements, namely:

**ISN links**, as:
– Rivers, inland canals and lakes’ waterways;
– Fairways for freight/passengers service under hauling from a PoO to a PoD;

**ISN nodes**, as:
– Rivers and coastal ports (including full infrastructure - wharfs, cranes, warehouses etc.) are intended for a cargo taking from consignors;
- Hinterland terminals are means for cargo taking from overland vehicles;
- The locks are intended for letting vessels movement through the canal’s barriers;
- The sluices are means for letting vessels movement through the river’s barriers.

1.3.1. A short-route transportation. The unilateral throughput

ISN evolution last near 4500 years. Let’s analyses of ISN basic generations since from simplified unilateral network as first generation (1G-type) shown on Fig1.4. First of all, shall describe specific characteristics of the offered inland network 1G. For this purpose we shall: give historical review, analyze innovative transformations and enumerate key parameters according to which management decisions are applied. Becoming and prosperity occurred during the historical period with 2200 B.C. till XVIII century. It has been connected to the transport potential’s use of river arteries 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 connected with construction of rafts, the river sailing-ships, and afterwards the steamers with paddle-wheels.

The first working model of such steamer was constructed in 1788 by William Symington. The steamer had 25 feet long, of 7 feet beam, and made 5 miles an hour. The first regular paddle-wheel steamer “Clermont” has been constructed in 1807. Hull of this vessel had 133 feet long, 18 feet wide and 9 feet deep. It traveled on the East River, New York. [17].
Up to the end of XVIII century the steamers with paddle-wheels were used only for the purposes of home-trade haulage. During this period the key parameters of management decisions efficiency were minimization of the transport cost and maximization of the cargo-carrying capacity. The last key parameter we shall consider more in detail. For estimation of vessel cargo capacity satisfactory for the ship-owner demands (NT-netto tonnage & DWT-deadweight tonnage) can be using methods of the queuing theory (when we have controlling of the freight’s flows) or methods of the scheduling theory (when we have controlling of the passengers’ flows). Let’s investigate two tasks.

**Task A.** Vessel using under “point-to-point” mode i.e. linear (shuttle) shipping. At that this vessel is loading by one type of a cargo. The analysis allows suggesting next opinion: the vessel’s rational use probably only in case of the designed cargo’s transportation. From the practice, such situations don’t exceed 0.3–0.4 likelihood in the traffics using hinterland channels (inland waterways navigation). In this case condition of river vessels profitability requires stable freight flows, and can be used under the shuttle-type transportation scheme. Let’s assess the haulage time for this transport scheme using graphical & analytical methods.

![Graphical method for the estimations of a haulages time by river vessels. The “point-to-point” mode ISN. Source: Author’s research](image1)

First of all, use graphical methods for the estimations of a haulages time by vessels (see Fig.1.5) and haulages time by pusher-barge system (see Fig. 1.6).

![Graphical method for the estimations of a haulages time by pusher-barge system. The “point-to-point” mode ISN. Source: Author’s research](image2)

**Task B.** Vessel using under “multi-points” mode i.e. tramp shipping. At that this vessel is loading by two types of a cargo. Suppose we have demands to loading, namely light freight
and heavy freight. The analysis allows suggesting next opinion: the linear shipping has the lower functional efficiency, than tramp shipping under next conditions, namely small partial shipments or short consignment delivery. Thus there is a basis to assert, that inclusion of inland navigation in intermodal networks will allow raising its functional efficiency, especially in conditions of unstable cargo flows (see Fig.1.7).

![Fig.1.7. Graphical method for the estimations of a haulages time by river vessels. The “multi-points” mode ISN. Source: Author’s research](image)

**Estimation of the unilateral throughput.** Throughput of inland navigation under short-route transportation is defined by overall dimensions of waterway and river vessels’ characteristics, their carrying capacity and commercial speed if the following conditions hold:

\[
h_r > T + \Delta T
\]  
(1.1)

Where:

- \(h_r\) - limit of navigable waterway depth;
- \(T\) - loaded vessel draft;
- \(\Delta T\) - limit of under keel clearance.

Then inland waterway throughput for short-route transportation is defined:

\[
TH_{st} = DWT \times V_{haulage} \times n
\]  
(1.2)

Where:

- \(n\) - number of the vessels used under unilateral mode (depends on fleet’s quantitative composition).

In this statement, vessel speed is function of the current’s speed on given interval of the waterway and is defined:

\[
V_{haulage} = V \pm \Delta V
\]  
(1.3)

Where:

- \(V\) - vessel’s designed speed;
- \(\Delta V\) - speed-down (against current) or speed-up (with current) of vessel movement.
**Assumption 1.3.** Practice of using multi-points inland navigation allows asserting that its throughput is great enough and must be defined only in unusual cases, e.g. for definition of a vessels congestions causes, traffic jams etc.

1.3.2. A long-route transportation. The bilateral throughput

Let’s shall be describing characteristics of the inland network of the second generation (2G- type) which are shown on Fig1.8.

![Diagram of the second generation ISN for cargo transportation by long-term mode. Source: Author’s research](image)

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 historical period with XIX till XX century. This period is differ construction of the lengthy and wide canals, which connecting not only the rivers, but also oceans. For example, in 1859 year Ferdinand de Lesseps begins construction of the Suez Canal which has been completed in 1869 year. On Aug. 1914 the Panama Canal is formally opened to traffic paddle–wheel steamer. Innovative achievements of this period were:

- construction of sluices that has allowed to lengthen and to widen of inland waterways;
- development of the pusher-barge systems;
- shipbuilding of the monohull vessels with the screws having smaller hull width, than the
paddle–wheel steamers.

Fig. 1.9. Graphical method for the estimations of a haulages time by long-route mode. Source: Author’s research

As result, was formed an opportunity for traffic planning, at the same time creating problems with the organization of regular shipping by inland waterways into ISN-2G. The efficiency’s key parameters of management decisions during this period were maximization of transportation profitability 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 this has lower throughputs than multi-ways mode. It’s evidential statement. The vessels passing through sluices in ISN-2G can be moving by unilateral sluicing (using one-way route; shown Fig. 1.9.) The unilateral passing of the vessels (incl. sluicing time; see Fig.1.10) in comparison with bilateral passing of the vessels (incl. sluicing time; represented in Fig. 1.11) essentially reduces throughput of the waterway system. Inland waterway throughput for long-route transportation is defined:

$$TH_L = DWT \times \frac{R}{t_{ct}} \times n_{opt}$$

(1.4)

Where:

$$t_{ct} = t_{as}^{k+1} + t_{ds}^{k+1} + \sum_{k} t_{s} ;$$

$k$ - sluicing number for vessel during one trip.

$t_{as}$, $t_{ds}$ - periods of the cargo transportation (against current) and downwards (with current).

In statement (1.4) by the basic management problem of inland shipping is definition of the vessels’ optimum. To decision may be offered next optimization model:

$$Z(TH_L) \Rightarrow \text{max}$$

(1.5)

Under the boundary conditions: $n > 0$; $0 < L_w < L_v$; $0 < B_s < B_v$; $T \leq h_r - \Delta T$; $R_c < L_v$. 

Fig. 1.10. Unilateral passing of the vessels through sluices. Source: Author’s research

Fig. 1.11. Bilateral passing of the vessels (pusher- barges systems) through sluices in comparison with unilateral passing. Source: Author’s research

The optimization model analysis is showed, that feasible region of its solutions must be determined by equality:

\[ t_s = t_p + t_{us}(t_{ds}) \]  \hspace{1cm} (1.6)

To calculation of the river-ship's operational speed. Source: Author’s research

Table 1.5

<table>
<thead>
<tr>
<th>Analytical approach</th>
<th>Graphical approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{haulage} = V_{empty} - \frac{T_{haulage} - T_{empty}}{T_{loaded} - T_{empty}} (V_{empty} - V_{loaded}) )</td>
<td>Depends on the ship’s hydrodynamic characteristics</td>
</tr>
</tbody>
</table>

From the condition (1.6) follows, that we have two key problems at management of long-term transportation are:
- co-evolution of next elements of inland shipping: fleet, river-ports & sluices;
- definition of river vessels’ rational speed on the separate interval waterway.
Thus it is necessary to take into account, which a vessel speed depends on its load. The simplified account method of this fact is offered in Table 1.5.

But for vessels speed management, there is some more capability for increase of carrying capacity of the transport systems operating by long-route mode.

1. Transfer from unilateral schemes to bilateral operation schemes (see Fig.1.12). This approach to base on next technique:
   - to each route must be forming the parallel route;
   - throughput estimation can be put in the practice according parameters "the circle’s shipping route period" and “the time-table period”

![Fig.1.12. Bilateral mode for the pusher-barges operation. Source: Author’s research](image)

2. The departure vessels (or pusher-barges) according group operation mode. This approach represents Fig.1.13.

![Fig. 1.13. Pass of the pusher-barges group. Source: Author’s research](image)

**Assumption 1.4.** Efficient of the long-route transportation is dependent from operational speed of the vessel (pusher- barges system), distances between ports and transshipment time at the each port. Traffic simulation allows asserting that use long-term mode have great throughput and can be used as solution in ISN-3G differing high level of congestions, traffic jams etc. In this connection it is recommended:
– to use bilateral regime for the vessels (pusher- barges systems) operation;
– increase of throughput due to the group pass of the vessels (pusher-barges systems).

1.3.3. The intermodal transportation. Estimation of the throughput

Let’s describe characteristics of the inland network of the third generation which show on Fig.1.14.

![Diagram of the third generation ISN to cargo haulage](image)

Fig.1.14. The third generation ISN to cargo haulage. Source: Author’s research
a – objective model of the ISN-3G; b - functional model of the ISN-3G.
A – The innovations surface of land transport.
B – The co-evolution surface of land & river transport innovations.
C – The co-evolution surface of river transport innovations & lock novelties.
D – The co-evolution surface of port technologies, maritime & river transport innovations.
E – The innovations surface of maritime transport.

This scheme characterizes river transport as element of intermodal chains. The concept intermodal chain has been developed at the end of XIX century. In the late 1800’s railroad
companies offered to carry on flatcar wagons loaded with produce for other place [18]. However its widespread adoption accounts for the latter half of the XX centuries when cargoes containerization became the dominating factor of the transport services market’s innovative development. Initiating event was the invention of the container. Malcolm 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. Transition on intermodal mode of functioning stimulated a series of innovative transformations [15]. Among them ports infrastructures modernization with the purpose increases their compatibility for the pre-post haulages; shipbuilding dynamically-supported ships, namely hydrofoil vessels, air-cushion vessels, hard sidewall surface-effect vessels, small waterline area twin-hull vessels and also widespread adoption of systems GPS, Galileo, SPARCS (Synchronous Planning Real Time Control Systems) etc. for the mobile communications in system “river vessels – inshore management”.

The efficiency’s key parameters of management decisions are:

- **economic parameters**: value of PBP, NVP etc., profitability, level of external costs.
- **functional parameters**: compatibility various modes, regularity and safety of transportation, environmental friendly, networks throughput and their reliability.
- **customers’ parameters**: needs' satisfaction, security of the traveling, comfort’s level.

### Assumption 1.5
The competitiveness, vessels tonnage, terminals productivity and waterways throughput, possible environmental impacts, traffic safety and external costs have to be taken into account to compare transport schemes used. The decisive criteria for the selection of the effectiveness means of transportation are minimal transportation risk, maximal operating speed, maximal carrying ability under minimal services price The economic analysis shows, that river-vessels have profitableness if they are included into transport networks according “Trunk & feeder” scheme. For this, further increase of river navigation’s efficiency depends from feeder transport throughput which requires wide implantation of new solutions, e.g. MTS (Multi-Trailer System) as Long or Short Train; conveyor-belt system that can eliminate up to 120,000 truck trips per year. This problem is investigated in the II-part of the paper.

### 1.4. Final remarks

1. New aspects in transport market relationships (globalization, liberalization, commercialization, competition and deregulation), the emergence of new global actors, changes in consignors’ tastes (values and preferences) and principles of novelties diffusion, must be considered.
2. At present, the implantation of intermodal transport conception is the most important goal of EU on the transport services market. Nevertheless, not more than 10-12% of all exchanged cargo flows in European regions are practically transported by intermodal scheme.
3. The circumstances defining the shifting possibility are:
   - the transport expenses for two modes used by consignor (e.g. inland navigation and railroad) must be less than the land transport cost;
   - time needed for cargoes transport has to be satisfactory for the consignors;
   - the infrastructure of inland waterway system has to permit regular and safe navigation.
   - land networks and inland waterways has to be integrated in the logistic chains.
4. Key to understanding these trends are principle - *increasing returns investment scale*. According to Brian Arthur (1998) these accrue owing to the next facts:
− up-front costs: to create a new technology requires a large investment; to reuse this investment for a new application is likely to be advantageous over starting afresh with a innovative technology;
− network effects: necessary condition for the added profit from high technology are compatible one with another;
− users effects: once users have invested in the training necessary to handle one high-tech technology, new technology which only require minor upgrades to that training have a large advantage over those which require fundamental retraining.

Reference


Acknowledgment

This work was supported by the State Committee for Scientific Research, Poland – BW/2005.


Współ-ewolucyjne podejście do zarządzania zmianami innowacyjnymi w sieciach transportowych. Cześć I. Podstawowe problemy i trendy zmian innowacyjnych

Streszczenie

TEN-T jest jednym z głównych elementów wspierających rozwój rynku usług transportowych, zapewniając konkurencyjność ekonomiki UE. Jednocześnie TEN-T jest istotnym czynnikiem zrównoważonego i stałego rozwoju Unii Europejskiej, umacnia jej jedność ekonomiczną oraz socjalną. Dla pełnego wykorzystania potencjału TEN-T konieczne jest wdrożenie oraz rozpowszechnienie rozwiązań innowacyjnych w rozmaitych systemach transportowych. Konieczność ta jest związana z tym, że kombinowany transport kolejowo – drogowy, który nadal pozostaje najwięcej wykorzystywanym w przewozach głównymi korytarzami transportowymi, w czasach dzisiejszych zmaga się z dużymi kosztami zewnętrznymi, w tym kosztami związanymi z ochroną środowiska, jego renowacją, kosztami kongestii oraz kosztami powypadkowymi. Doświadczenie niektórych krajów – członków UE pokazuje, że wykorzystanie innowacyjnych podejść przy organizacji żeglugi śródlądowej jako istotnego elementu sieci transportowej mogą w znacznym stopniu wpłynąć na skuteczne rozwiązanie tych problemów. Dlatego, po pierwsze, trzeba będzie podjąć działania w kierunku polepszenia koordynacji pomiędzy różnymi gałęziami transportu w celu osiągnięcia jakościowego współdziałania rozmaitych sposobów przewozu, a po drugie, skierować uwagę decydentów na efektywne kreowanie intermodalnych łańcuchów transportowych.