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DESIGN OF AGENT-BASED MODEL FOR BARGE CONTAINER TRANSPORT

Summary. The increasing importance of intermodal transport in Europe requires an alternative way of designing new logistics solutions to ensure sustainable development, mobility and, in particular, optimal transport costs. The aim of the paper is to design a model for connecting inland navigation into the European intermodal transport system. The paper presents a proposal for the agent-based simulation of container barge navigation on TEN-T (Trans-European Transport Network) corridor Rhine – Danube. A theoretical basis in the field of network design and simulation is also presented.

PROJEKT MODELU AGENTY DO TRANSPORTU KONTENERÓW NA BARKACH

Streszczenie. Rosnące znaczenie transportu intermodalnego w Europie wymaga nowych opcji alternatywnych rozwiązań logistycznych na rzecz zrównoważonego rozwoju, zrównoważonej mobilności, a w szczególności optymalnych kosztów transportu. Celem artykułu jest opracowanie modelu podłączenia żeglugi śródlądowej do europejskiego systemu transportu intermodalnego. Przedstawiono propozycję symulacji w systemie intermodalnym dla TEN-T trasy Ren – Dunaj. Przedstawiono również podstawy teoretyczne projektowania sieci i symulacji.

1. INTRODUCTION

Nowadays, nearly every product is within reach- from fresh fruits all year around, through affordable electronics, to exotic wines from around the world. Products are designed and created through global supply chains that, through outsourcing, are trying to access the best quality at the lowest possible cost. Intermodal transport is still considered a relatively new form of transport, which was developed from the specifications of the various transport modes [1-3]. Intermodal transport is very closely linked to international trade and globalization. In order to respond to the requirements of trade and international supply chains, ports need to accommodate and handle more and larger ships, and faster hinterland transport modes.

The European transport system will face considerable challenges in the next decade. It will be important to put a great effort to find the necessary funding for the long-term investments into the transport infrastructure, as well as to avert the possible collapse of the road freight transport system. Due to the high proportion of road transport in the freight market, combined transport may be the only option to ensure sustainable development, sustainable mobility and, in particular, optimal transport

costs. This issue is specifically addressed in the 2013 White Paper [1], which proposes a clear intention to transfer 30% of road transport, over long distances (over 300 km), by 2030 to an energy-efficient mode of transport, rail or water transport are options receiving favourable consideration.

Within global political arrangements that have been evolving in recent decades, maritime container transport has created strong connections from the Far East container ports to the Western Europe ports. Over the past decade, the capacity of the container ships sailing to this area has almost tripled the capacity. Notteboom in his work [4] identified 10 key areas in European intermodal transport systems with the biggest traffic flow, which he called multi-port gateway regions. The container ports in the Hamburg-Le Havre range (which includes all ports along the coastline between Le Havre in France and Hamburg in Germany), handle about half of the total European container throughput [4]. This area is represented by three regions: The Rhine-Scheldt Delta, the Helgoland bay, and Seine Estuary.

The Black Sea ports, Constanta in particular, were on the rise in the early 2000s, from nearly no traffic to a European share of 1.7% in 2008. Constanta attracted terminal investments, given its potential to serve as a gateway to Eastern Europe and a transshipment hub for the Black Sea area. The financial crisis abruptly ended this unfolding success story, and Constanta's container throughput fell sharply from 1.38 million TEU (Twenty-foot Equivalent Unit) in 2008 to 594 299 TEU in 2009. In the following years, the port could only present a modest growth to reach 684 059 TEU in 2012. The Bulgarian ports of Varna and Burgas remain small players in the container market. The traffic decline in Black Sea ports is in sharp contrast to the strong growth witnessed by Piraeus and Turkish deep-sea ports near the Sea of Marmara. This development demonstrates that shipping lines, for the time being, prefer a hub-feeder model in the Mediterranean to service the Black Sea area, instead of direct deep-sea calls in the Black Sea [4, 5].

Maritime container transport impacts transportation flow of inland barge transport, especially on the Rhine. For several years, the Netherlands has the largest share of the transport of containers by inland waterways (more than 5 MM TEU), followed by Belgium (2.8 MMTEU), and Germany (2.40 MM TEU) [6]. Mainly empty containers [6] are transported on the Danube.

The potential for navigation on the Danube is heavily influenced by the economic environment, particularly the situation in the transport market. Over the last 10 years, the development of navigation on the Danube was affected by a series of negative factors that were primarily political. Navigability also explains the absence of a comprehensive, coordinated financial plan for the development of waterways, the introduction of new, advanced transport technologies that prevent the use of existing fleet. [7] Unlike the Rhine and other rivers in Western Europe, container transport on the Danube is still not sufficiently developed for the following reasons:

• Long connection between the major distribution centres on the Danube (Belgrade, Budapest, Bratislava, Vienna, Enns) and cargo port, where containers arrive daily from international maritime routes (e.g. Port of Constanta).
• Navigation and sailing conditions.
• Underdeveloped infrastructure.

This paper focuses on finding the right setting for integrating inland waterway transport into intermodal transport, from seaports to hinterlands. The key task is to identify the elements that contribute to the formation of an intermodal transport network in Europe, with a focus on container transport by inland waterways. A theoretical basis in the field of network design and simulation is also presented. The paper presents the design for the agent-based simulation of container barge navigation on TEN-T corridor Rhine - Danube. The methodology for agent procedure is described by using UML language.

2. FRAMEWORK FOR INTERMODAL INLAND WATER NETWORK DESIGN

The definition of Intermodal Transportation Network (ITN) is derived from the specification of intermodal transport, and means a logistically-linked system using two or more transport modes with a single rate [3]. Fig. 1 presents a framework of the factors that influence the performance of intermodal barge transport. The framework shows the determinants of the main factors, the size of the

vessel and the time variables, as well as their relationship to the performance indicators of intermodal barge transport, from both the barge operators' and shippers' perspectives. This general framework can also be used as a tool to explain and evaluate the relationship among barge network design, the transport market and the performance of intermodal barge transport [2].
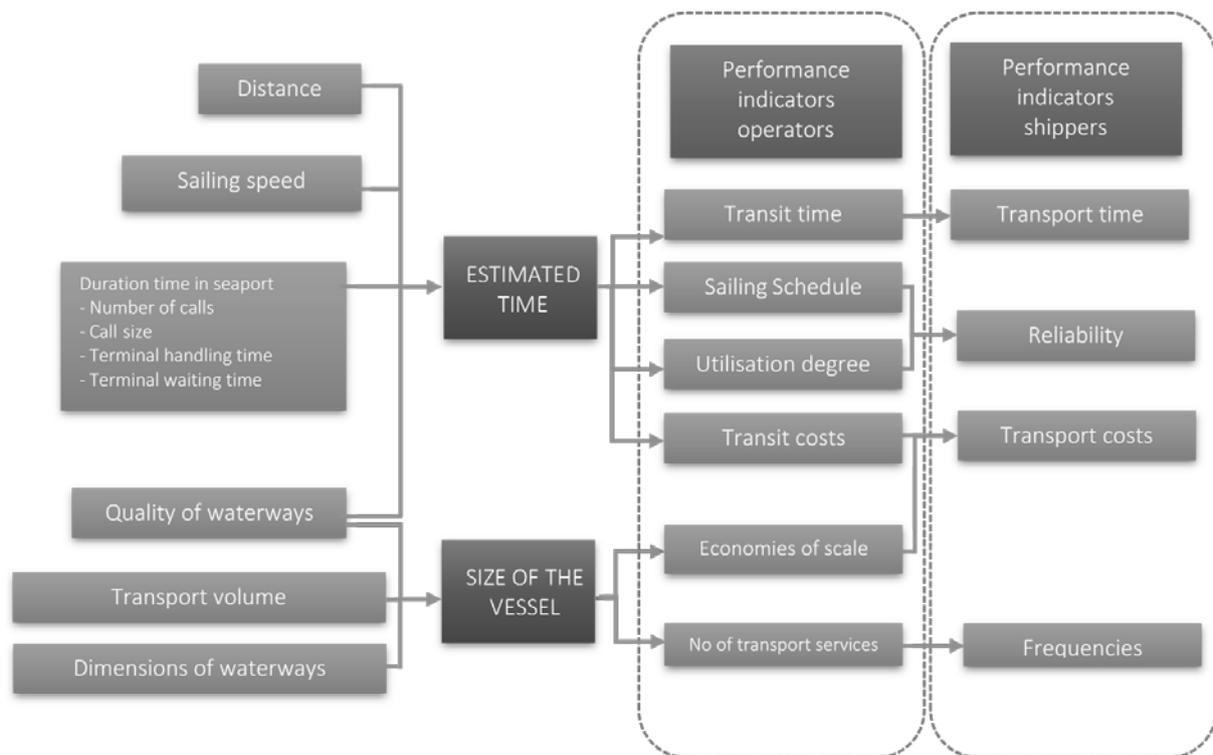

Fig. 1. Framework for barge network design
Rys. 1. Ramy do projektowania sieci

Given that intermodal transport and inland waterway transport systems are very complex, and are interconnected with separate units, we had to find a suitable modelling methodology. The most frequently used methods in modelling complex systems are the event-based simulation, agent-based simulation and system dynamics [8]. The agent-based simulation methodology is represented through autonomous agents who are able to solve assigned tasks and communicate with each other on the occurrence of complex problems. Evaluated models can be divided into separate units, but at the same time we can capture their interconnections. This method provides a high degree of decentralization, making the whole system well-sustained. We had established our research on this particular method. Within the research, there were no simulation tools that would allow us to create the model we had in my mind. Therefore, we settled for and ran with the general draft of the agent-based modelling paradigm [9, 10].

3. AGENT-BASED MODEL OF BARGE CONTAINER TRANSPORT ON DANUBE

In the draft of integrating inland waterways into intermodal transport systems, we focused on the use of the Danube for Economies of Scale container barge transport for the port of Constanta. Economies of scale are determined by how many layers of containers we can stack on the barge, size of pusher convoy does not change. Our chosen route starts from the mouth of Danube, where it is

located prime river kilometre and ends in the terminal Linz, with r.km 2131 (2131 kilometers from the river mouth). Figure 2 [11] shows map of the model.
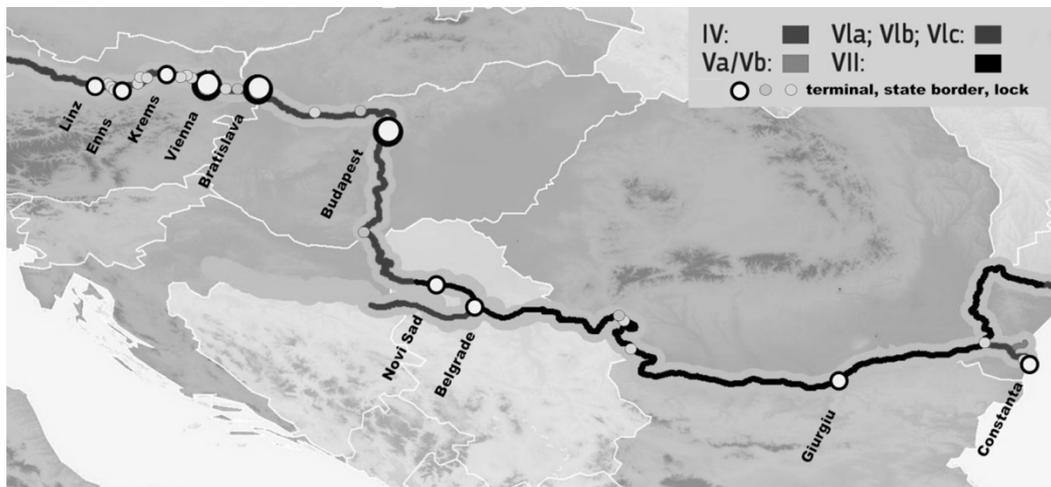

Fig. 2. Map of the Model
Rys. 2. Mapa modelu

In the system, agents are arranged according to Fig. 3. Each agent represents a partial system for which it is responsible. The following agents are identified and modelled in the system: navigation, state border, lock. Agent of Inland Waterway and Port Agent represent water transport in the model; Operator Agent and Agent Terminal represent the intermodal part. Agents can independently implement simple assigned tasks, and communicate with each other on complex problems. Communication within the proprietary agent-based architecture is via messaging. These types of messages are specified under use of specific simulation architecture, respectively. The authors of architecture must define themselves. The simulation architecture we will consider only basic types of message, which have character of notice (notice of certain facts such as "Location of the Barge"), request (a request to carry out certain activities, for example "Request for Water Level", response (a response to a request, for example Water level).

As a demonstration of how communication between agents will run, we use a sequence diagram at Loading in the port, and a sequence diagram for Navigation. Fig. 4 represents Agent' communication at Navigation, followed by communication at Loading (Fig. 5). In this case, we assume the initial condition that the pusher convoy is empty in a port.

At the beginning of sailing, Navigation Agent requests "Request for the Water Level" from Agent of Inland Waterway for the transit section between the two ports. The Agent of Inland Waterway can then generate the Water Level for the selected section and the information is sends back. Subsequently, it will conduct a virtual sailing along the selected route across nodes. These nodes are represented by Agent of the State border and Lock Agent. Agents will receive a request for Time spent in the node or passing through the node; also generate time spent in the node, and such information will be sent to Navigation Agent. Information on passage through each node will also be sent to the Operator Agent, who will have an overview of where the vessel is located and transit time between nodes. After the sailing, Navigation Agent gathers the generated information between the nodes and calculates total transit time between ports. Such information will be sent to the Operator Agent. Information about arrival to the port will be sent to the Port Agent.
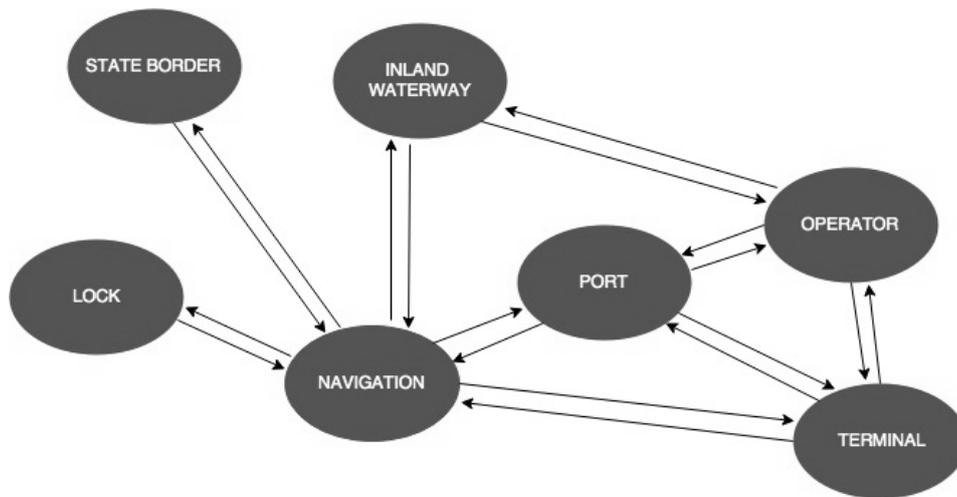
Fig. 3. Arrangement and communication of Agents in the system
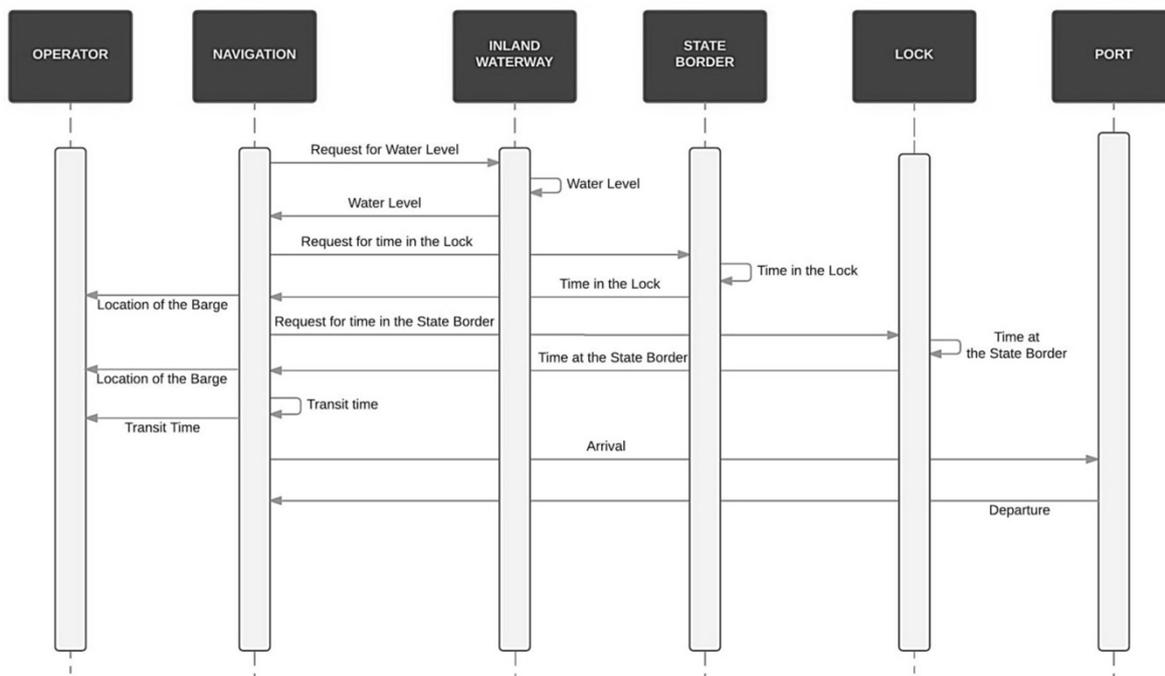Rys. 3. Rozmieszczenie i komunikacja agent w systemie

Fig. 4. Agents' communication at Navigation
Rys. 4. Komunikacja agent w nawigacji

Now, we can move to the Agents communication at Loading (Fig. 5). The convoy comes into the port that is represented by the Port Agent. The Port Agent (as a coordinator) assigned the position of a convoy in the port (to carry out transhipment), it means that it will choose a handling equipment (reloading mechanism) that will operate the vessel and initiate the Loading. Agent Terminal represents in this case the container handling equipment owned by the company. Loading of vessels will be carried out according to cargo plan. Cargo plan is generated by Operator Agent from actual water level during the next session and sequential generation of draught, possible deadweight of barges, number of barges, and random containers, which will be added to Cargo Plan and despatched to Agent Terminal. Agent Terminal, on the basis of a Cargo Plan, will generate total loading time and start

loading. After completion of this session, Port Agent will initiate departure on receipt of job completion signal from Agent Terminal.
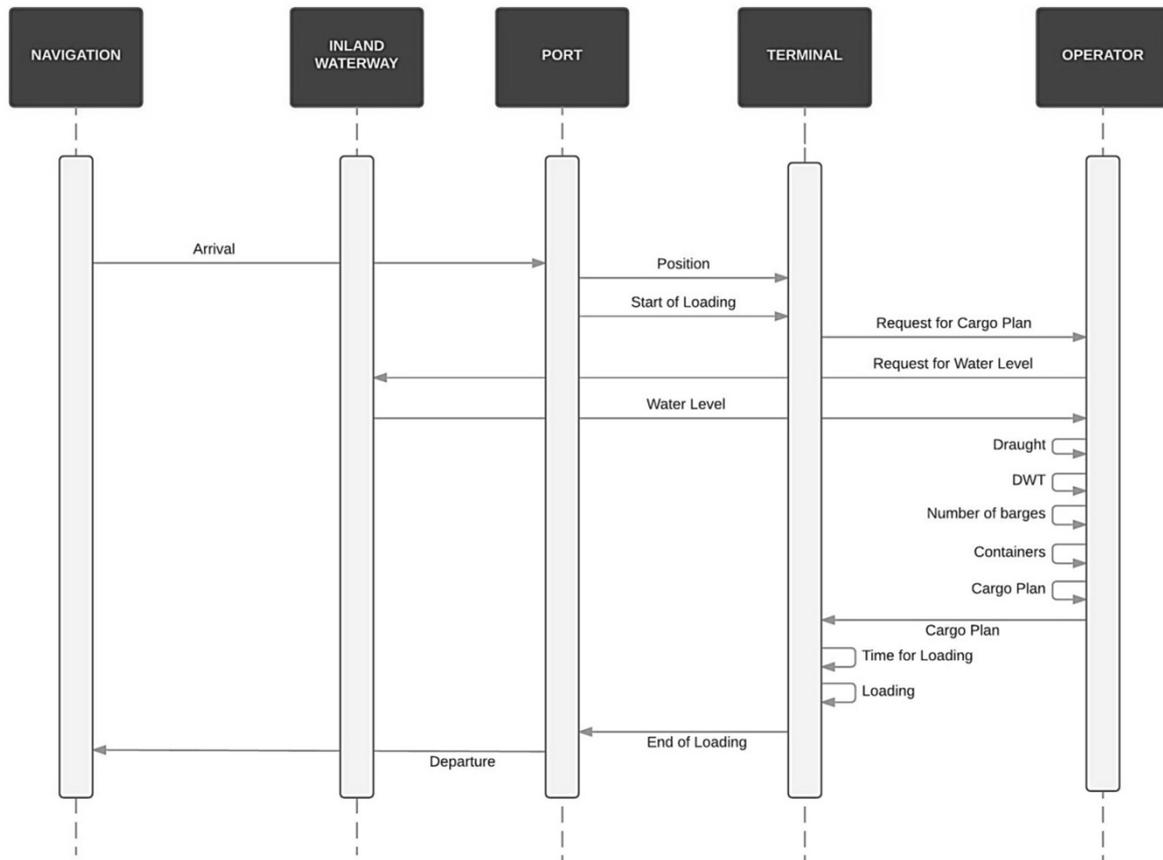

Fig. 5. Agents' communication at Loading
Rys. 5. Komunikacja agentów w załadunku

The situation could likewise be described, when laden convoy from previous session comes to port. Initially, Agent Terminal will unload the convoy according to the instructions from the previous session, and send request for Cargo Plan for the next session. The arrangement of the agents in the system and their mutual communication will be based on the use of a particular type of agent-oriented architecture within the actual simulation. After selecting the most suitable type of architecture, or simulating it, we will be able to modify above-mentioned communication of agents.

4. CONCLUSION

The paper was based on current needs that represent alternative logistics solution in creating new transport chains in Europe transport system. The complexity of the inland waterway transport system is difficult to explain to professionals from other transport branches. Theoretical approaches to this system, without taking account of everyday reality, are almost impossible. Unstable water levels on the Danube waterway are currently the most critical bottleneck, in terms of waterway infrastructure, with which we will have to reckon with when integrating water transport to the intermodal transport system in Europe. An agent-based model was presented which is based on TEN-T corridor using the Danube River. The presented approach can be used on other inland waterways worldwide. Within our knowledge, this is the first approach to create a model of inland barge container transport, using agent-based simulation on the Danube. Given the scope and aim of the work, it was not possible to examine

all aspects of the problem. This area will be the subject of further research and the data in presented simulation will be used. By modelling waterway with current hydro-meteorological characteristics, we will be able to obtain accurate simulation results for real life operation.

Acknowledgement

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