



Development Rate of Maritime Container Ports: A Case of Transatlantic Ports

H. Maučec^{1,3,*}, R. Zelenika², D. Sever^{1,4} and A. Ogorelc^{1,5}

ARTICLE INFO

Article history:

Received 26 February 2013;
in revised form 08 March 2013;
accepted 23 May 2013

Keywords:

Transatlantic container flows; Attraction of maritime container ports; Optimization of container transport; Port engineering.

ABSTRACT

This article aims to determine the development (rate) of maritime container ports in a case involving transatlantic container transport in order to ascertain a model of container flows between container terminals in the United States and container terminals in Western and Northern Europe. The model proposed by the authors is made using the following eight key elements: transport infrastructure and suprastructure, influence of the intelligent information system, economic growth, transport ecology, transport flows, innovations and safety and security and transport energy. The research builds mainly upon empirical data analysis.

© SEECMAR / All rights reserved

1. Introduction

Port and urban specialists often focus on what may appear as processes and actors of distinctly different nature. One example is the large body of research on so-called port systems where neighboring port nodes go through successive development phases marked by varying traffic concentration levels. Geographers have been particularly active in describing the spatial evolution of port systems where load centers and off-shore hubs influence the port hierarchy due to their competitiveness and attractiveness in the transport and logistics chain at sea and on land (Fleming and Hayuth, 1994; Notteboom and Rodrigue, 2005).

The reaction to the financial and economic crisis has shown a new redesign of scenarios taking into account the changes made by maritime companies choosing different ports (González et al., 2010). In this research, containerized traffic evolution in 2008 and 2010 is described, both in big ports and

geographic regions as from the emergent port activity areas. Database used is a sample of the world containership fleet movements that have called in some Chinese port in the years analysed. Calculus methodologies based on Graph Theory are applied to this set of data, able to give information about the global and local importance of a port given. Containerized goods transportation network have been contracted between 2008 and 2010 respect the port throughput, but there's no contraction in the distribution capacity of the main hub ports, which seem to have adopted commercial diversification strategies and foreland expansion. On the other hand, port emergent regions placed in the entrance and exit of Panama Canal will have important business opportunities.

A dramatic boom in the Pearl River Delta (PRD) port system has emerged during the past two decades, from having Hong Kong as the only gateway hub to the coexistence of three world-ranked container ports. PRD port system development to date and identifies the underlying forces driving the port system evolution. In particular, the unique process by which the PRD port system went from one gateway port to two ports and the undergoing regionalization with specialization is examined. The network strategy is stressed in shaping the port system structure. With the advantage of a hinterland regionalization, Shenzhen, among the gateway ports in PRD, has acquired the market share from Hong Kong. Shenzhen and

¹ University of Maribor, SI-2000 Maribor, Slovenia.

² Professor, Department of Theoretical Economics, Ivana Filipovića 4, University of Rijeka, HR-51000 Rijeka, Croatia.

³ Ph.D. candidate, Department of Transportation Engineering, Smetanova 17.

⁴ Professor, Department of Transportation Engineering, Smetanova 17.

⁵ Professor, Department of International Exchange of Goods and Services, Razlagova 14.

* Corresponding Author. Email: hugo.maucec@gmail.com, Tel.+38613200192.

Guangzhou ports move from the hinterland-dominated regionalization to a more balanced regionalization based on an established inland transport network, whereas Hong Kong undergoes a foreland regionalization. If the hinterland connection remains relatively weak, the gateway function of the port in Hong Kong will further decline, but its transshipment role will further dominate (Liu et al., 2013).

The main purpose of this research is to work out an optimal overseas model of container transport based on the pre-determined rate of the United States Atlantic container ports and ports in Western and Northern Europe. In order to elaborate upon such a model, it is first necessary to compare development rate of maritime container ports, and on this basis, to determine attraction of maritime container terminals of the above-mentioned ports. To enable the managers to carry out the important tasks in container transportation on basis of quality and with competence, they have to know the following eight important elements of the container transportation model, which derive from the main areas that are important to container carriers and influence the calculation of the development rate of maritime container ports.

Our research questions are the following:

- 1) 'What is the role of the development rate of maritime container ports?'
- 2) 'How can a new optimal overseas model of containers' (TEU) transport be developed?'

2. Literature review

The commonly used, idealized model on network development as presented by (Taaffe et al, 1963) suggests an increasing level of port concentration as certain hinterland routes develop to a greater extent than others in association with the increased importance of particular urban centres. As a consequence of the competition among seaports, among inland centres and between seaports and inland centres, the geographical system evolves from an initial pattern of scattered, poorly connected ports along the coastline to the sixth and final stage of the Taaffe et al model, whereby a main network consisting of corridors between gateway ports and major urban centres is established. The resulting port concentration can cause degradation of minor ports in the network. Eventually, some smaller ports may even disappear. Recently, (Slack, 1990) added a seventh stage to the model of Taaffe et al, indicating a further concentration of traffic flows on major corridors as a result of the realities of intermodal systems. He states that where a fully developed intermodal system has been accomplished, hereby referring to the extensive intermodal network in the US, all former inland terminals that no longer serve as hubs will be excluded from the network.

The model developed by (Barke, 1986) is quite similar to the Taaffe et al model. In the final stage of his five-phased model, however, he introduces a process of deconcentration. This occurs when large and rapidly growing port areas begin to suffer from excessive congestion, thus encouraging some port activities to leave the urban core for less-congested sub-

urban or peripheral port sites. In a less extreme form this deconcentration phase refers to the infrastructural extension of ports away from the historical core to less-urban port areas. The downstream development of terminal infrastructures in many European ports illustrates this process. In a more extreme form this deconcentration tendency implies an activity shift from major ports to adjacent less-congested (new) ports. Also, in the latter case the deconcentration process described by Barke is limited in space. A more radical spatial deconcentration process can be found in the Hayuth model on the dynamics within container port systems (Hayuth, 1981). This model is a result of empirical research in the US container port sector and is of particular interest in the study on concentration tendencies in the European container port sector.

There is an intimate relationship between national security, as it is broadly defined, and economic and social development; the former requires the fullest and most profitable commitment of national potential in all fields of endeavour, including social, economic, political and military (Ademuni-Odeke, 1984). If without security there can be no development, the reverse is also true. The relationship between the two factors of security and development provides the precise forms and proper perspective for an analysis of the problem of transport in all its intricate and multifold aspects (Black and Black, 1982). Although transportation is vital to every nation, the relative importance of each of several modes of transport may vary from one nation to another. This variance depends on the interplay of a multiplicity of physical and economic factors, such as geographic location; territorial arrangements and topography; extent of navigable inland waterways (Black and Rimmer, 1982), economic and technological advances; size of the domestic market; direction of the main stream of trade; or even entirely subjective factors, such as the national inclination or disposition of its people (Bannister, 1983).

The proposed classification of the European continental container port system into three main port ranges is particularly interesting in view of the assessment of inter-range port competition, i.e. the competition between ports situated in different port ranges. Hence, extensive hinterland networks allowed deeper inland penetration and contributed to the establishment of vast hinterlands shared by the major European ports. These developments encouraged inter-range port competition, especially in the container sector (Notteboom and Winkelmans, 1994).

Recent studies have analysed varying impacts of railway capacity, port efficiency, containers and logistics. Cambridge Systematics, Inc. (2007) assessed current and long-term capacity expansion of US freight railroads and the role of congestion among corridors. Christenson Associates (2008) indicated capacity "tightness" is primarily due to congestion at terminals or other specific network locations. Port efficiency has been examined in several studies (Notteboom, 2006; Heaver, 2006; Talley, 2007; Brooks, 2007; Ramos-Real and Tovar, 2010 and De Borger and De Bruyne, 2011). Ramos-Real and Tovar (2010) examined economics of scale in container shipping and (De Borger and De Bruyne, 2011) examined effects of vertical integration between port activities

and hinterland congestion. Notteboom (2006) evaluated the effect of delays on shipping logistics. Rodriguez-Alvarez et al. (2011) indicated that port terminal costs are impacted by demand uncertainty. O'Kelly and Bryan (1998) developed a model to reflect scale economies that are generated on inter-hub links. Racunica and Wynter (2005) and Rodriguez et al. (2007) used optimization models of hub-and-spoke type networks for rail freight. Fewer studies have analyzed impacts of congestion on spatial and inter-port competition (Maguire et al., 2010; Ilmer, 2010). Crainic and Kim (2007) discussed the interpretation of congestion in the context of network flow models of intermodal transportation. Other studies on container shipping and congestion include (Fan et al., 2009, 2010; Fan and Wilson, 2011).

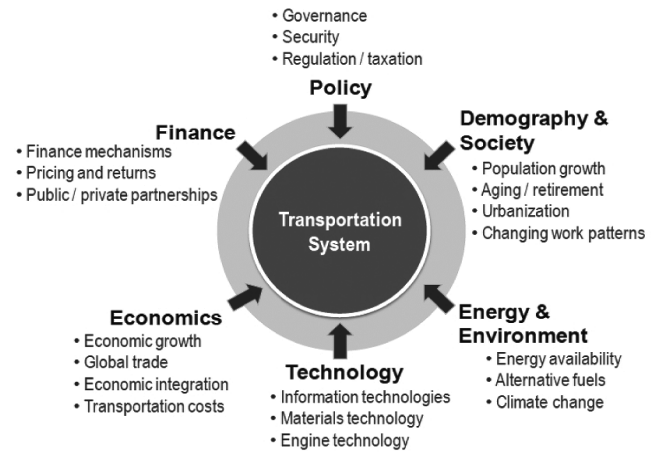
Supply-chain optimization models developed by (Leachman, 2008) and (Jula and Leachman, 2011a,b) used mixed integer programming models to determine the least cost supply chain for an importer of containerized products to US regional distribution centers. The models focused on location decisions and included logistical costs and strategies including inventories, inventory costs, lead time, etc. as well as analyzing risk pooling strategies. Capacity constraints and congestion were not part of the model and some of the shipping channels were pre-determined, though these were suggested as areas for future research.

More recently Leachman and Jula (2011, 2012) analyzed congestion for west coast imports of containers by estimating dwell times for ports and railways and included these in their logistical model for importers' location decision.

As global logistics and supply chain management plays an important role on the products and service flow for sustainable economics, several studies have been conducted to highlight the importance of container route optimization (Lee, 2011) and visualization (Lee et al., 2011) of the results for management decisions. (Luo and Grigalunas, 2003) analyzed import and export container markets in Canada by optimizing container routes and simulating hypothetical ports as alternative entry points. In their research, they applied a minimum cost path algorithm based on a shipper's decision-making process in reallocation of network volume. (Leachman et al., 2005) and (Leachman, 2008) estimated the optimized routes and trips for the import container markets in the U.S. by assigning a "trade partner" through feasible rail and highways.

Obviously, maritime transportation is comprised of maritime ship transportation and the dimension of maritime ports. The areas listed in Figure 1 are main areas whereby to establish the vision of future development of maritime transportation. They will help with the changes involved in overcoming the obstacles; assist with the development of new innovations; and facilitate the establishment of the operational structure at the global and national levels, which shall also contribute to the development of a durable society and a successful transport system. Furthermore, one should also consider how the transport system can change based on momentary transport requirements and political goals that could influence the planned development trends of the maritime transportation industry.

Figure 1: Influence of important areas on the carriers for the future.



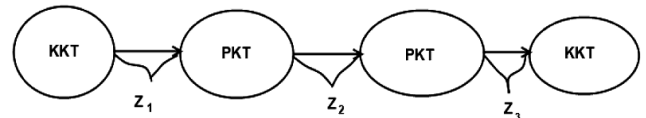
Source: Adapted from (Rodrigue, 2010).

3. Research design

The main objective of this study is to ascertain an optimal overseas model of container transport based on the pre-determined rate of maritime container ports in Eastern states of the United States of America and countries in Western and Northern Europe.

In such, our research elaborates on an optimal overseas model of container (TEU) transport, which can be determined as follows (Figure 2).

Figure 2: An optimal overseas model of containers' (TEU) transport



$$Z = Z_1 + Z_2 + Z_3 \quad (1)$$

KKT –Continental container terminals

PKT –Maritime container terminals

Z_1 –Container transport optimisation (TEU) on the road, from the continental container terminals of the Eastern states of the United States of the America (KKT/A) to the maritime container terminals in the Eastern states of the United States of the America (PKT/A)

Z_2 –Container transport optimisation (TEU) on the sea, from the maritime container terminals in the Eastern states of the United States of America (PKT/A) to the maritime container terminals in Western and Northern European countries (PKT/E)

Z_3 –Container transport optimisation (TEU) on the road, from the maritime container terminals in Western and Northern European countries (PKT/E) to continental container terminals in Western and Northern European countries (KKT/E)

In the problem of the optimisation of container transportation (TEU), there are m resources with the capacities of U_i units and n users with demands for D_j units. The problem is balanced when the joint capacities of resources are equal to the demands of end users.

Let's denote the number of containers (TEU) that need to be shipped from the resource i to the user j with X_{ij} and transport costs per number of containers (TEU) with C_{ij} , u_j is attraction of maritime container terminals and S_{r_j} is the development rate of maritime container ports.

Mathematical model of the problem:

$$Z = \sum_{j=1}^n \sum_{i=1}^m c_{ij} x_{ij} \rightarrow \min \quad (2)$$

$$Z = \sum_{j=1}^n \sum_{i=1}^m u_j S_{r_j} x_{ij} \rightarrow \min \quad (3)$$

Under conditions:

$$\sum_{j=1}^n x_{ij} = U_i \quad i = 1, \dots, m \quad (4)$$

$$\sum_{i=1}^m x_{ij} = D_j \quad j = 1, \dots, n \quad (5)$$

Subject to:

$$x_{ij} \geq 0 \quad (6)$$

$$\sum_{j=1}^n U_i \leq \sum_{i=1}^m D_j \quad (7)$$

4. Attraction of maritime container ports

To enable the managers to carry out the important tasks in container transportation on basis of quality and with competence, they have to know the following eight important elements of the container transportation model, which derive from the main areas that are important to container carriers and influence the calculation of the development rate of maritime container ports: 1) transport infrastructure and transport suprastructure, 2) influence of the intelligent information system, 3) gross domestic product – economic growth, 4) transport ecology, 5) transport flows, 6) innovations, 7) safety and security and 8) transport energy. Development rate of maritime container ports – S_{r_i} can be defined as follows:

$$S_{r_i} = f_i \sum_{i=1}^n \left(\frac{y_{i,t} - y_{i,t-1}}{y_{i,t}} \right) \quad i = 1, 2, \dots, n \quad (8)$$

$$S_{r_i} = f_1 \times S_{r_{psup}} + f_2 \times S_{r_{iis}} + f_3 \times S_{r_{bdp}} + f_4 \times S_{r_{pek}} + f_5 \times S_{r_{pt}} + f_6 \times S_{r_{ino}} + f_7 \times S_{r_{avar}} + f_8 \times S_{r_{pene}} \quad (9)$$

$$\sum_{i=1}^N f_i = 1 \quad (10)$$

$$f_i = \frac{r_i}{\sum_{i=1}^n r_i} \quad (11)$$

$$u = \frac{C_i}{S_{r_i}} \quad (12)$$

Subject to:

y_i –value status of the element of the container transportation model (transport infrastructure and transport suprastructure, influence of the intelligent information system, gross domestic product-economic growth, transport ecology, transport flows, innovations, safety and security, transport energy)

t –year

f_i –influence portion of certain element per average development rate

r_i –development rate of individual element of the container transportation model

C_i –transportation price

u –attraction of maritime container terminals

Attraction of a port –u: determines which maritime container port generates the majority of transport flows of containers (TEU) shipped from continental container terminals to state maritime container terminals, and which maritime container port in other countries generates the majority of transport flows of containers shipped from state maritime container terminals.

5. Results of the empirical analysis

The development rate of the element i of container transportation (TEU), depending on the element j , is defined as the growth of the estimated state of the i element of container transportation (TEU) Δy_{it} and the value of the estimated j el-

ement of container transportation (TEU) in the period t .¹

Table 1 shows the estimation of elements of the container transportation model (TEU) in 2009, 2015 and their growth up to 2015, including: transport infrastructure and transport suprastructure, the influence of an intelligent information system, gross domestic product – economic growth, transport ecology, transport flows, innovations, safety and security and transport energy.

The values of elements of the container transportation (TEU) (e.g., as an estimated state, parameter, etc.) are denoted with y_{it} and $y_{i,t-1}$, for i transport container element (TEU) in

the period of t and $t-1$. The period t is the year 2015, the period $t-1$ is the year 2009. The growth of the value of estimated state of the i element of the container transportation element (TEU) is, according to (Stojanović, 1988):

$$\Delta y = y_{it} - y_{i,t-1} \quad (13)$$

The development rate of the element i of container transportation (TEU), depending on the element j is defined as the growth of the estimated state of i element of container trans-

Table 1: Estimation of elements of container transportation model.

Elements of container transport model	Estimated state y_{it}		Growth	Notes
	2009	2015	y_j 2015	
1. Transport infrastructure and transport suprastructure	4.78	4.87	0.09	Total of average value of the following countries USA, Germany, France, the Netherlands, Spain; http://data.worldbank.org/indicator , (accessed 6 December 2009).
2. Influence of intelligent information system	120,500,000,000 \$	122,909,972,931 \$ (value calculated based on the GDP value)	2,409,972,932 \$	Ezell, S. (2010) 'Intelligent Transportation Systems', The Information Technology & Innovation Foundation, January, pp. 10.
3. Gross-domestic product – economic growth	22,258,715,599,486 \$	22,703,889,911,476	445,174,311,990 \$ (2 % growth)	Total average value of the following countries USA, Germany, France, the Netherlands, Spain; Retrieved from http://data.worldbank.org/indicator , (accessed 6 December 2009); http://www.targetmap.com/viewer.aspx?reportId=4284 (accessed 6 December 2009).
4. Transport ecology	21.28	21.07	0.425 (GDP growth by 2 % taken into account)	Transport ecology expressed in an average index value of biodiversity (value 0 – no potential of biodiversity, value 100 (the biggest potential of biodiversity) for following countries USA, Germany, France, the Netherlands, Spain; available at http://data.worldbank.org/indicator/ER.BDV.TOTL.XQ/countries , (accessed 6 December 2009).
5. Transport flows	530,000,000 TEU	590,000,000 TEU	60,000,000 TEU	'Maritime Transportation: Drivers for the Shipping and Port Industries', International Transport Forum, Transport and Innovation: Unleashing the Potential, Paper Commissioned for the Experts "Session on Innovation and the Future of Transport", Paris, January 2010, p. 15 (taken into account is the maturity scenario).
6. Innovations	491,917,614,748 \$ (2.21 % GDP)	501,755,967,043 \$ (2.21 % GDP)	2,459,588,074 \$	Total average value of the following countries USA, Germany, France, the Netherlands, Spain; http://data.worldbank.org/indicator/EG.USE.COMM.KT.OE/countries , (accessed 6 December 2009).
7. Safety and security	1,294,776,520 \$	1,320,672,050 \$	25,895,530 \$ (GDP growth by 2 % taken into account)	http://ec.europa.eu/transport/maritime/studies/doc/2009_04_scanning_containers.pdf , (accessed 6 December 2009).
8. Transport energy	588,271 kt oil	654,868 kt oil	66,597 kt oil	Total average value of the following countries USA, Germany, France, the Netherlands, Spain; Retrieved from http://data.worldbank.org/indicator , (accessed 6 December 2009). - calculated based on the transhipped amount of containers.

Source: Authors.

¹ Stojanović, D. (1988) 'Matematičke metode u ekonomiji, dodatak matrica rasta', seventh revised edition, Contemporary Administration, Belgrade, pp. 351.

portation (TEU) Δy_{it} and the value of the estimated j element of container transportation (TEU) in the period t , or as the case may be:

$$r_{ij} = \frac{\Delta y_{it}}{y_{it}} \quad i, j = 1, 2, \dots, 8. \quad y_{i,t-1} \neq 0 \quad (14)$$

The development rate of a certain element of the container transportation can be expressed in the development matrix:

$$f_i = \begin{bmatrix} r_{11t} & r_{12t} & \dots & \dots & r_{1nt} \\ r_{21t} & r_{22t} & \dots & \dots & r_{2nt} \\ \dots & \dots & \dots & \dots & \dots \\ r_{n1t} & r_{n2t} & \dots & \dots & r_{nnt} \end{bmatrix} \quad t = 1, \dots, T \quad (15)$$

$$\Delta y'_{2015} = \begin{bmatrix} 0.09 \\ 24.0997 \times 10^8 \\ 4451.7431 \times 10^8 \\ 0.425 \\ 0.6 \times 10^8 \\ 24.5958 \times 10^8 \\ 0.2589 \times 10^8 \\ 0.0006 \times 10^8 \end{bmatrix} \quad (16)$$

$$1/y_{2015} = (1/4.87; \quad 1/1229.0997 \times 10^8; \quad 1/227038.8991 \times 10^8; \quad 1/21.07; \quad 1/5.9 \times 10^8; \quad 1/5017.5596 \times 10^8; \quad 1/13.2067 \times 10^8; \quad 1/0.0654 \times 10^8) \quad (17)$$

$$R_{2015} = \begin{bmatrix} 0.02 & 0 & 0 & 0.0043 & 0 & 0 & 0 & 0.000137 \\ 4.9486 \times 10^8 & 0.02 & 0.000106 & 1.1437 \times 10^8 & 4.1 & 0.005 & 1.8 & 0.000036 \\ 914.1156 \times 10^8 & 0.36 & 0.02 & 211.2834 \times 10^8 & 754 & 0.9 & 337 & 0.00679 \times 10^8 \\ 0.09 & 0 & 0 & 0.02 & 0 & 0 & 0 & 0 \\ 0.12396 \times 10^8 & 0.000049 & 0.000002 & 0.0284 \times 10^8 & 0.1 & 0.00012 & 0.045 & 92 \\ 20.2019 \times 10^8 & 0.008 & 0.00043 & 0.4669 \times 10^8 & 17 & 0.02 & 7.4 & 0.00015 \times 10^8 \\ 0.05317 \times 10^8 & 0.000021 & 0.000001 & 0.0123 \times 10^8 & 0.04 & 0.000005 & 0.02 & 39 \\ 0.00013 \times 10^8 & 0 & 0 & 0.00003 \times 10^8 & 0.00011 & 0 & 0.00005 & 0.1 \end{bmatrix} \quad (18)$$

In Table 2, the development rates of individual elements of the container transportation (TEU) between the Eastern states of the United States of America and Western and Northern European countries in the time period of 2009-2015 have been shown.

Subject to which are the elements on the main vertical that denote direct development rates ($i=j$), the others denote indirect development rates of an individual element of the model. The elements in the line i denote the growth of the estimated state in the element i of the container transportation model (TEU) in the function of sustainable development based on the estimated state in other elements of the container transport model (TEU). The elements in column i denote the growth of the value of the estimated state in all elements of the model according to the estimated state of the element i in the period $t = 6$ years.

The highest development rate is present in the transport flows element and the transport energy element in the time period of 2009-2015 with the value of 0.1; following are the transport infrastructure and suprastructure element, influence of the intelligent information system element, the gross domestic product-economic growth element, transport ecology, innovations, and safety and security, with the value of 0.02.

The calculated portions of a certain element of the container transportation model (TEU) per an average development rate of maritime container ports in the Eastern states of the United States of America and in the Western and Northern European countries are shown in Figure 3.

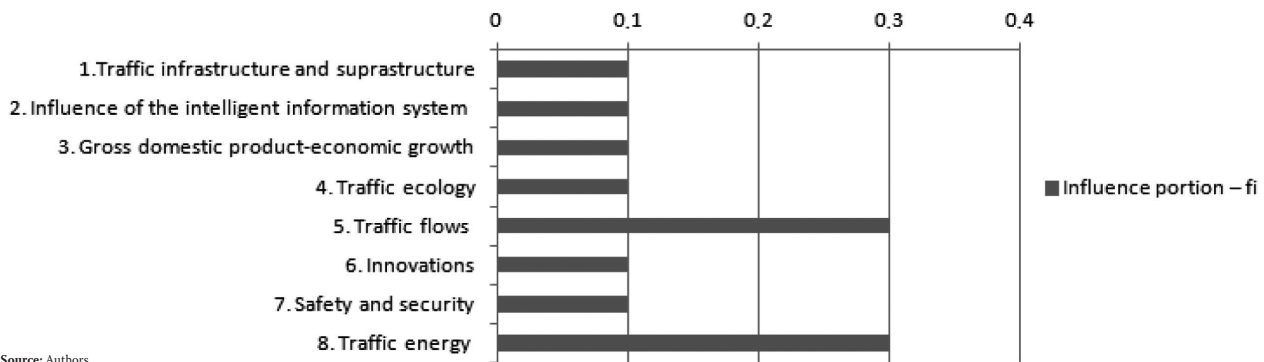
Figure 4 shows that the highest influence on the calculation of an average development rate of individual maritime container ports in the time period of 2009-2015 contains two elements—the transport flows element and the transport energy element—with the value of 0.3; following are the transport infrastructure and the suprastructure element, gross domestic product-economic growth, transport ecology, innovations, safety and security and influence of the intelligent information system, with the value of 0.1.

The data for the calculation of the development rate of maritime container ports in the Eastern states of the United States of America and in Western and Northern European countries are shown in Table 3.

Table 2: The development rate of individual elements.

	1	2	3	4	5	6	7	8
1	0.02	0	0	0.0043	0	0	0	0.000137
2	4.9486x10 ⁸	0.02	0.000106	1.1437x10 ⁸	4.1	0.005	1.8	3.680
3	914.1156x10 ⁸	0.36	0.02	211.2834x10 ⁸	754	0.9	337	0.00679 x10 ⁸
4	0.09	0	0	0.02	0	0	0	0
5	0.12396x10 ⁸	0.00049	0.000002	0.0284x10 ⁸	0.1	0.00012	0.045	92
6	20.2019x10 ⁸	0.008	0.00043	0.4669x10 ⁸	17	0.02	7.4	0.00015 x10 ⁸
7	0.05317x10 ⁸	0.000021	0.000001	0.0123x10 ⁸	0.04	0.000005	0.02	39
8	0.00013x10 ⁸	0	0	0.00003x10 ⁸	0.00011	0	0.00005	0.1

Source: Authors.

Figure 3: Portion of the influence of the element of the container transportation model.

Source: Authors.

Table 3: The data for the calculation of the development rate of maritime container ports.

Maritime ports	f_1	Sr_{pisup}	f_2	Sr_{iis}	f_3	Sr_{bdp}	f_4	Sr_{pek}	f_5	Sr_{pt}	f_6	Sr_{ino}	f_7	Sr_{vavar}	f_8	Sr_{pene}	Sr
Boston ²	0.1	0.1	0.1	0.4	0.1	0.1	0.1	0.3	0.3	-0.004	0.1	0.4	0.1	0.2	0.3	0.8	0.4
New York ³		0.7		0.2		0.2		0.6		-0.0004		0.3		0.02		0.5	0.3
Philadelphia ⁴		0.5		0.2		0.6		0.8		-0.0008		0.5		0.02		0.6	0.4
Baltimore ⁵		0.2		0.1		0.7		0.5		-0.0002		0.5		0.01		0.4	0.3
Norfolk ⁶		0.1		0.1		0.02		0.6		-0.0006		-0.8		0.03		0.7	0.2
Savannah ⁷		0.6		0.7		-0.1		0.7		-0.0004		0.1		0.8		0.4	0.4
Rotterdam ⁸		0.5		0.8		-0.04		0.1		-0.0004		0.2		0.2		0.2	0.2
Bremerhaven ⁹		0.6		0.6		-0.06		0.2		-0.0007		0.1		0.1		0.2	0.2
Hamburg ¹⁰		0.4		0.6		-0.3		0.1		-0.015		0.3		0.2		0.1	0.1
Le Havre ¹¹		0.3		0.9		-0.1		0.8		-0.0004		0.3		0.2		0.2	0.3

Source: Authors.

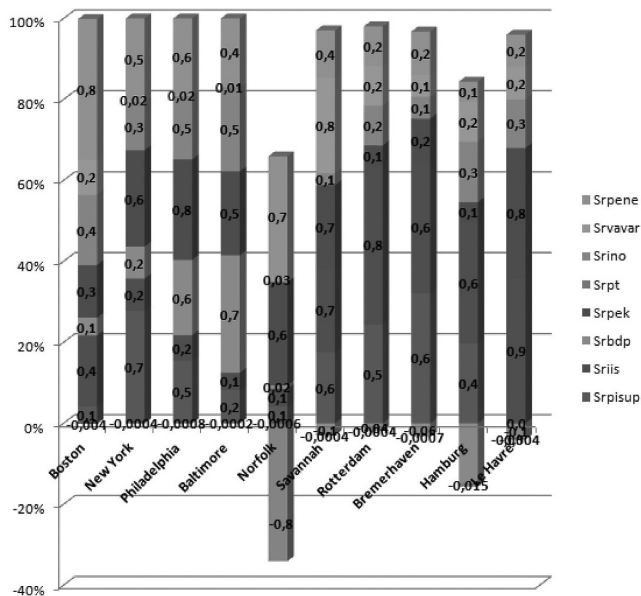
Notes:

- 2 – http://www.epa.gov/region1/topics/air/sips/ne_sip_summaries.html#me; <http://www.massport.com/port-of-boston/Pages/Default.aspx> (accessed 7 September 2009).
- 3 – http://www.epa.gov/region1/topics/air/sips/ne_sip_summaries.html#me; <http://www.panynj.gov/port/terminal-improvements.html>, <http://www.panynj.gov/about/pdf/CAS-FINAL.pdf> (accessed 7 September 2009).
- 4 – <http://www.philaport.com/> (accessed 7 September 2009).
- 5 – [\[ing/2012/EconomicImpact.pdf\]\(http://www.mpa.maryland.gov/_media/client/planning/2012/EconomicImpact.pdf\), <http://www.mpasafepassage.org/mpanews/2010/2010GreenPort.pdf> \(accessed 7 September 2009\).](http://www.mpa.maryland.gov/_media/client/plann-</p>
</div>
<div data-bbox=)

- 6 – <http://www.nscorp.com/nscorphtml/pdf/foundation-report-2009.pdf> (accessed 7 September 2009).
- 7 – <http://www.philaport.com/news/archives.htm> (accessed 7 September 2009).
- 8 – <http://www.portofrotterdam.com/en/Port-authority/finance/annual-report/Documents/> (accessed 7 September 2009).

- 9 – <http://www.bremenports.de/en/location/media-centre/downloads> (accessed 7 September 2009).
- 10 – <http://www.hamburg-port-authority.de/en/> (accessed 11 September 2009).
- 11 – <http://knoema.com/tbocwag#France>, <http://www.havre-port.fr/images/brochures/flashinfoport2000avril2010.pdf>; <http://www.norwaypost.no/index.php/business/money-and-finance/27710>; <http://www.greenport.com/news101/vessel-build-and-maintenance/initiatives/constant-air-quality-monitoring-at-le-havre> (accessed 11 September 2010).

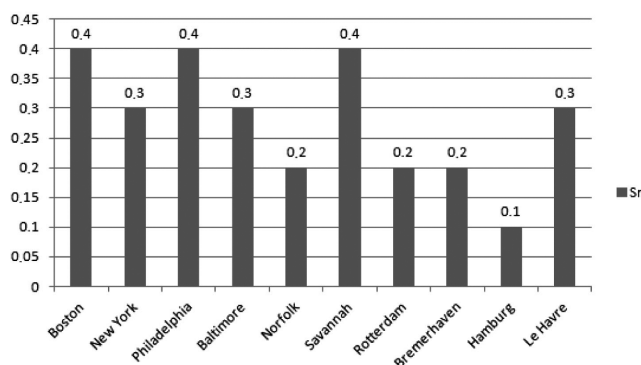
Figure 4: The shown data influence the development rate of the individual elements.



Source: Authors.

The development rate of the maritime container ports in the Eastern states of the United States of America and in Western and Northern European countries is shown in Figure 5.

Figure 5: The development rate of the maritime container ports.



Source: Authors.

The maritime container ports with the highest value of development rate in 2009 were the Philadelphia, Boston and Savannah ports, with the value of 0.4. Following are the maritime

container ports of New York, Le Havre and Baltimore, with the value of 0.3; the maritime container ports of Norfolk, Rotterdam and Bremerhaven, with the value of 0.2; and the maritime container port of Hamburg, with the value of 0.1.

Table 4: Average development rate of maritime container ports.

Country	Average development rate of maritime container ports – $Sr_i(2009)$
Netherlands	0.2
Germany	0.2
USA	0.3
France	0.3

Source: Authors.

It is clear from Table 4 that maritime container ports in the USA and France have a higher development rate than maritime container ports in the Netherlands and Germany.

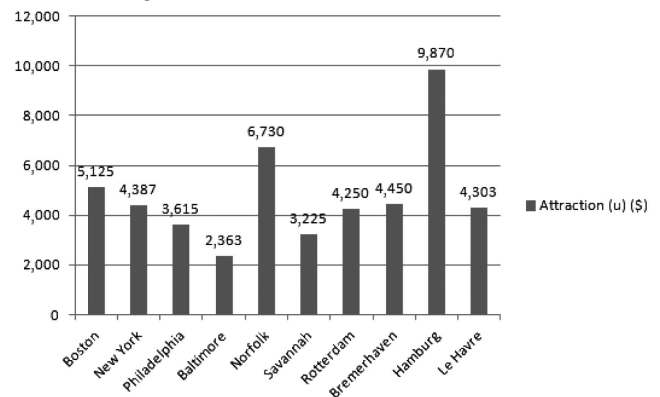
The calculated attraction (u) of the maritime container terminals in the Eastern states of the United States of America (PKT/A) and in the maritime container terminals in Western and Northern European countries (PKT/E) in 2009 is shown in Table 5.

Table 5: Attraction - (u) of maritime container terminals.

Maritime container terminal	C_i (\$)	Sr_i	Attraction (u) (\$)
Boston	2,050	0.4	5,125
New York	1,316	0.3	4,387
Philadelphia	1,446	0.4	3,615
Baltimore	709	0.3	2,363
Norfolk	1,346	0.2	6,730
Savannah	1,290	0.4	3,225
Rotterdam	850	0.2	4,250
Bremerhaven	890	0.2	4,450
Hamburg	987	0.1	9,870
Le Havre	1,291	0.3	4,303

Source: Authors.

Figure 6: Attraction of maritime container terminal.



Source: Authors.

The most attractive (u) for users is the maritime container terminal Baltimore, followed by the maritime container terminals Savannah, Philadelphia, Rotterdam, Le Havre, New York, Bremerhaven, Boston, Norfolk and Hamburg. The aver-

age prices for container transportation C_i are shown in Table 5. (K Line America Inc., 2009a, 2009b).

6. Conclusions

The research results, as specified above, have revealed that elements of the proposed model of container transport have a considerable impact on the sustainable and economic development of maritime container ports in the Eastern states of the United States of America and Western and Northern European countries with decreasing operation costs in the original hub port.

The maritime container ports in the USA and France had a higher development rate than maritime container ports in the Netherlands and Germany in 2009. The highest value of the development rate in 2009 was received by the maritime container ports of Philadelphia, Boston and Savannah, with the value of 0.4. Following are the maritime container ports of New York, Le Havre and Baltimore, with the value of 0.3; the maritime container ports of Norfolk, Rotterdam and Bremerhaven, with the value of 0.2; and the maritime container ports of Hamburg, with the value of 0.1. The maritime container terminal considered most attractive for users is the Baltimore terminal, followed by the maritime container terminals of Savannah, Philadelphia, Rotterdam, Le Havre, New York, Bremerhaven, Boston, Norfolk and Hamburg.

More significantly, with the proposed optimal model of containers' (TEU) transport between the Eastern countries of the United States of America and Western and Northern European countries, it is possible to lower the total average price of container transportation (TEU) to some extent.

Given that the development rate of container ports along the sea may be limited by the geographical conditions, there is a considerable incentive to start new terminals.

References

- Ademuni-Odeke (1984): *Protectionism and the Future of International Shipping*. Dordrecht: Martinus Nijhoff Publishers.
- Bannister, D. (1983): Transport needs in rural areas – a review and proposal. *Transport Reviews* 3 (1), 35–48.
- Barke, M. (1986): *Transport and Trade*. Edinburgh: Oliver & Boyd.
- Benelux Shipping Statistics (1994): *Benelux Economic Union*, Brussels.
- Black, J. A. and Rimmer, P. J. (1982): Japanese highway planning: a Western Interpretation. *Transportation* 11 (1), 20–49.
- Black W. C. and Black T.A. (1982): Deriving areas for mass transit systems. *Trans. Res. News* 16A (3), 185–198.
- Brooks, M. (2007): Issues in measuring port devolution program performance: a managerial perspective. In: Brooks, M. and Culliname, K. Eds. *Devolution, Port Governance and Port Performance*. London: Elsevier.
- Cambridge Systematics, Inc. (2007): National rail freight infrastructure capacity and investment study, Final Report [online]. Available from: http://www.camsys.com/pubs/AAR_RRCapacityStudy.pdf [Accessed 10th May 2012].
- Christenson Associates (2008): A study of competition in the US freight railroad industry and analysis of proposals that might enhance competition [online]. Available from: <http://www.stb.dot.gov> [Accessed 10th May 2012].
- Crainic, T. and Kim, K. (2007): Intermodal transportation. In: Barnhart, D. and Laporte, G. Eds. *Handbook in OR & MS*. Atlanta: Elsevier.
- De Borger, B. and De Bruyne, D. (2011): Port activities, hinterland congestion and optimal government policies: the role of vertical integration in logistics operation. *Journal of Transport Economics and Policy* 45 (2), 247–275.
- EPA United States Environmental Protection Agency (2009): New England SIP Plan Summaries [online]. Available from: http://www.epa.gov/region1/topics/air/sips/ne_sip_summaries.html#me [Accessed 7th September 2009].
- Ezell, S. (2010): *Intelligent Transportation Systems*. Washington: The Information Technology & Innovation Foundation.
- Fan, L.; Wilson, W. and Tolliver, D. (2009): Logistical rivalries and port competition for container flows to US markets: impacts of changes in Canada's logistics system and expansion of the Panama canal. *Marine Economics and Logistics* 11 (4), 327–357.
- Fan, L.; Wilson, W. and Tolliver, D. (2010): Optimal network flows for containerized imports to the United States. *Transportation Research Part E* 46, 735–749.
- Fan, L. and Wilson, W.W. (2011): Impacts of congestion and stochastic variables on the network for US container imports. *Journal of Transport Economics and Policy*, 4–7.
- Fleming, D.K. and Hayuth, Y. (1994): Spatial characteristics of transportation hubs: centrality and intermediacy. *Journal of Transport Geography* 2 (1), 3–18.
- Green Port (2010): Constant air-quality monitoring at Le Havre [online]. Available from: <http://www.greenport.com/news101/vessel-build-and-maintenance/initiatives/constant-air-quality-monitoring-at-le-havre> [Accessed 11th September 2010].
- Hamburg Port Authority (2009): Hamburg Port Authority [online]. Available from: <http://www.hamburg-port-authority.de/en/>, [Accessed 11th September 2009].
- Hayuth, Y. (1981): Containerisation and the load centre concept. *Economic Geography* 57, 160–176.
- Heaver, T. (2006): The evolution and challenges of port economics. In: Brooks, M. and Culliname, K. Eds. *Devolution, Port Governance and Port Performance*. London: Elsevier.
- Jula, P. and Leachman, R.C. (2011a): A supply-chain optimization model of the allocation of containerized imports from Asia to the United States. *Transportation Research Part E* 47, 609–622.
- Jula, P. and Leachman, R.C. (2011b): Long and short-run supply-chain optimization models for the allocation and congestion management of containerized imports from Asia to the United States. *Transportation Research Part E* 47, 593–608.
- K Line America, Inc. (2009a): TASCO EUROPE / SINA EB INLAND TARIFF (Tariff #154) [online]. Available from: <http://www.kline.com/KAMInland-Tariffs/Inland-Tariffs-154-Transatlantic-SINA-Europe-Mediterranean-Eastbound-East-Coast-Ports.pdf> [Accessed 11th September 2009].
- K Line America INC. (2009b): Transatlantic Eastbound Cargo Surcharges [online]. Available from: <http://www.kline.com/KAMSurcharges/Surcharges-TransAtlantic-Eastbound.asp> [Accessed 11th September 2009].
- Knoema (2009): GDP by Country 1980–2013 [online]. Available from: <http://knoema.com/tbocwag#France>, [Accessed 11th September 2009].
- Kuby, M. and Reid, N. (1992): Technological change and the concentration of the U.S. General Cargo Port System: 1970–1988. *Economic Geography* 68, 272–289.
- Laxe, G. F.; Seoane M.J.F. and Montes C. P. (2012): Maritime degree, centrality and vulnerability: port hierarchies and emerging areas in containerized transport (2008–2010). *Journal of Transport Geography* 24, 33–44.
- Le Havre Port (2010): Le Havre Port [online]. Available from: <http://www.havre-port.fr/images/brochures/flashinfoport2000avril2010>, [Accessed 1st February 2010].
- Leachman, R. C. (2008): Port and modal allocation of waterborne containerized import from Asia to the United States. *Transportation Research* 44(2), 313–331.
- Leachman, R. C. and Jula, P. (2011): Congestion analysis of waterborne, containerized imports from Asia to the United States. *Transportation Research Part E* 47, 992–1004.
- Leachman, R. C. and Jula, P. (2012): Estimating flow times for containerized imports from Asia to the United States through the Western rail network. *Transportation Research Part E* 48, 296–309.
- Leachman, R. C.; Prince T. and Brown T. R. (2005): *Port and Modal Elasticity Study*. California, USA: Southern California Association of Governments.
- Lee, E. (2011): *Spatiotemporal Simulation Model for Global Containerized Freight in North America*. North Dakota, USA: North Dakota State University.
- Lee, E.; Oduor P. and Farahmand K. (2011): Heuristic path-enumeration approach for container trip generation and assignment. *Journal of Transportation Research Forum* 50(3), 7–21.
- Liu, L.; Wang K. Y. and Yip T. L. (2013): Development of a container port system in Pearl River Delta: path to multi-gateway ports. *Journal of Transport Geography* 28, 30–38.
- Luo, M. and Grigalunas T. A. (2003): A spatial-economic multimodal transportation simulation model for US coastal container ports. *Maritime Economics & Logistics* 5(2), 158–178.
- Maguire, A.; Ivey, S.; Lipinski, M. and Golias, M. (2010): Reliving congestion

- at intermodal marine container terminals: review of tactical/operational strategies. *Paper presented at 51th Annual Transportation Research Forum*, 11-13 March, Arlington, Virginia, USA.
- Maryland Port Administration (2011): *The Economics Impact of the port of Baltimore 2010* [online]. Available from: http://www.mpa.maryland.gov/_media/client/planning/2012/EconomicImpact.pdf [Accessed 7th September 2009].
- Massport (2009): Massport [online]. Available from: <http://www.massport.com/port-of-boston/Pages/Default.aspx> [Accessed 7th September 2009].
- Norfolk Southern Contributions (2009): Norfolk Southern Contributions 2009 Annual Report [online]. Available from: <http://www.nscorp.com/nscorphtml/pdf/foundation-report-2009.pdf> [Accessed 7th September 2009].
- Notteboom, T. (2006): The time factor in liner shipping services. *Maritime Economics & Logistics* 8, 19-39.
- Notteboom, T. and Rodrigue, J.P. (2005): Port regionalization: towards a new phase in port development. *Maritime Policy and Management* 32 (3), 297-313.
- Notteboom, T. and Winkelmann, W. (1994): Ports as nodal points in a global transport system. *Conference EMIP '94*, Rotterdam.
- O'Kelly, M.E. and Bryan, D.L. (1998): Hub location with flow economies of scale. *Transportation Research Part B* 32 (8), 605-616.
- Philadelphia Regional Port Authority (2009a). Philadelphia Regional Port Authority [online]. Available from: <http://www.philaport.com/> [Accessed 7th September 2009].
- Philadelphia Regional Port Authority (2009b): PRPA: News Archives [online]. Available from: <http://www.philaport.com/news/archives.htm> [Accessed 7th September 2009].
- Port of Baltimore (2009): GreenPort of Baltimore. Available from: <http://www.mpasafepassage.org/mpanews/2010/2010GreenPort.pdf> [Accessed 7th September 2009].
- Port of New York and New Jersey (2009): Terminal Improvements [online]. Available from: <http://www.panynj.gov/port/terminal-improvements.html> [Accessed 7th September 2009].
- Port of Rotterdam (2009): Annual Report [online]. Available from: <http://www.portofrotterdam.com/en/Port-authority/finance/annual-report/Documents/> [Accessed 7th September 2009].
- Racunica, I. and Wynter, L. (2005): Optimal location of intermodal freight hubs. *Transportation Research Part B* 39, 453-477.
- Ramos-Real, F.J. and Tovar, B. (2010): Productivity change and economics of scale in container port terminals: a cost function approach. *Journal of Transport Economics and Policy* 44 (2), 231-246.
- Rodrigue, J. P. (2010): Maritime Transportation: Drivers for the Shipping and Port Industries, International transport forum. *Transport and Innovation: Unleashing the Potential, Paper Commissioned for the Experts "Session on Innovation and the Future of Transport"*, January, 2, Paris.
- Rodriguez, V.; Alvarez, M.J. and Barcos, L. (2007): Hub location under capacity constraints. *Transportation Research Part E* 43, 485-505.
- Slack, B. (1990): Intermodal transportation in North America and the development of inland load centres. *Professional Geographer* 42, 72-83.
- Stojanović, D. (1988); *Matematičke metode u ekonomiji, dodatak matrica rasta*. Belgrade: Contemporary Administration.
- Taaffe, E. J.; Merrill, R. L. and Gould, P. R. (1963): Transport expansion in underdeveloped countries: a comparative analysis. *Geographical Review* 53, 503-529.
- Talley, W. (2007): Port performance: an economics perspective. In: Brooks, M. and Culliname, K. Eds. *Devolution, Port Governance and Port Performance*. London: Elsevier.
- The European Commission (200): *The impact of 100% scanning of U.S.-bound containers on maritime transport* [online]. Available from: http://ec.europa.eu/transport/maritime/studies/doc/2009_04_scanning_containers.pdf [Accessed 6th December 2009].
- The Norway Post (2010): Odfjell Terminals awarded Le Havre Port project bid [online]. Available from: <http://www.norwaypost.no/index.php/business/money-and-finance/27710> [Accessed 1st February 2010].
- The Port Authority of NY & NJ (2009): *A Clean Air Strategy for The Port of New York & New Jersey* [online]. Available from: <http://www.panynj.gov/about/pdf/CAS-FINAL.pdf> [Accessed 7th September 2009].
- The World Bank (2009): The World Bank [online]. Available from: <http://data.worldbank.org/> [Accessed 7th September 2009].
- Via Bremen (2009): Media Centre. Downloads [online]. Available from: <http://www.bremenports.de/en/location/media-centre/downloads> [Accessed 7th September 2009].