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A Simplified Forecasting Model for the Estimation of Container Traffic in Seaports at a National Level – the Case of Poland

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ABSTRACT: Comprehensive forecasting of future volumes of container traffic in seaports is important when it comes to port development, including investments, especially in relation to costly transport infrastructure (e.g. new terminals). The aim of this article is to present a specific, simplified model of demand forecasting for container traffic in seaports as well as to give a practical verification of the model in the Polish seaport sector. The model consists of relevant indexes of containerisation (values, dynamics) referring to the macroeconomic characteristics of the country of cargo origin as well as destination-predictor variables (e.g. population, foreign trade, gross domestic product). This method will facilitate the evaluation of three basic segments of the container market: foreign trade services, maritime transit flows and land transit flows. International comparisons of indexes (benchmarking) as well as extrapolations of future changes can support this prediction process. A practical implementation of this research has enabled us to calculate that the total container volume in Poland will be approximately 4.69 – 4.87 million TEU by the year 2023.

1 INTRODUCTION

Issue in the operation and future development of maritime ports, therefore relevant methods for the prediction of container demand (or other types of cargo or passenger traffic) need to be implemented. When it comes to the main elements or types of forecasting procedures, the following issues should be noted:

- differences and relationships between primary demand (requirements of the socio-economic system - trade) and secondary demand (transport flows served by ports),
- different time perspectives of forecasting (from very short to long-term predictions),
- internal structures of container traffic – spatial sources of demand,
- variations in approaches, methods and techniques of forecasting.

Trade flows should be regarded as a key driver of demand and development for container services in seaports. In addition, specifically, intercontinental trade relations affect the field of container technology implementation. As a result, export and import volume is strictly related to the specific production and consumption characteristics of a country. Therefore, GDP is an important factor affecting containerisation activities. A much wider approach could be also used, where the PESTE3 method can be applied (Lappalainen, 2013). Identification of secondary demands requires further actions, - a commonly implemented approach is to use a five step procedure (Jensen, 2014):

[3] A method which considers the influence of Political, Economic, Social, Technological and Environmental issues on the state and future of a phenomenon or organisation.

1 production and attraction (primarily demand identification),
2 distribution (transport flows selection),
3 logistics (location of logistics nodes, e.g. maritime ports),
4 modal split (modal allocation of the flows),
5 assignment (traffic per maritime port).

Regarding the time periods of predictions, the following types of forecasts can be distinguished:
– short (e.g. one-day forecasts/ simulations/ planning (Gokkus, Sinan Yildirim and Akoglu, 2015) (KRILE, MAIOROV and FETISOV, 2018) (Iannone *et al.*, 2016)),
– medium (seasonal analysis based on monthly data (Chen and Chen, 2010) (Peng and Chu, 2009)),
– long-term (Gökkuş, Yildirim and Aydin, 2017) (Rahman, Muridan and Najib, 2015) (Rashed *et al.*, 2018) forecasts.

Implementations of competent methods of forecasting are also related to specific sectors of container traffic, which we can categorise into the following elements:
– foreign trade traffic – international trade to the country where the port is located (intercontinental),
– inland transit traffic – international trade between neighbouring countries served by land-based modes of transport (e.g. railways, road haulage, inland navigation)
– maritime transit traffic (transshipment) – international trade between neighbouring countries served by feeder vessels.

Container flow can be divided into further different levels: separation of import and export traffic (Chou, Chu and Liang, 2008) or full and empty container turnover (Diaz, Talley and Tulpule, 2011).

Finally, different approaches (e.g. Shima & Siegel, Brockwell & Davis, Schultz (Darabi and Suljevic, 2015)), models (e.g. time series, system dynamics, regression, input-output models (Kotcharat, 2016)) and tools/techniques (e.g. generic programing, decomposition approach, SARIMA[4] (Chen and Chen, 2010), input-output models (Kotcharat, 2016), neuron networks (Gosasang, Chandraprakaikul and Kiattisin, 2011) (Gökkuş, Yildirim and Aydin, 2017)) to forecasting can be implemented in the research.

Currently, researchers are trying to combine different methods and techniques to create hybrid models (Rashed *et al.*, 2018), where a combination of quantitative analysis is implemented alongside expert knowledge (Huang, Qiao and Wang, 2014) (Huang *et al.*, 2015).

Ultimately, issues of balance between sophistication and generalisation in the differing forecasting methods, especially in relation to long-term perspectives, will need to be considered. Sophisticated methodology with highly-enhanced detail may result in a high level of complexity and may be costly for forecasting procedures. However, uncertainties about changes in the port environment (political, economic, social, technological) may cause significant distortions in any estimated volumes. Moreover, detailed analyses, especially of international aspects, may require access to relevant data and information which may not be available, especially on the global scale.

[4] SARIMA - Seasonal Autoregressive Integrated Moving Average Model.

2 METHOD

Simplified model of container traffic forecasting at a national level, proposed by the author consists of several steps (Fig. 1). The first challenge is the collection of relevant data of container traffic, with distribution on the three types of flows being dependant on specific sources of primary demand. Research into changes over time in the basic parameters requires a ten-year period of coherent data.

The identification of relevant predictor variables constitutes the second step in the process. Three parameters: trade volume (tons), GDP (EUR) and population changes are the key parameters used in the research. In the case of trade volume, specific trade relations (intercontinental) need to be specified (especially in relation to EU member states). Therefore, access to a comprehensive data base is required (e.g. Eurostat). Assessment of correlations between container traffic and main predictors have to be tested.

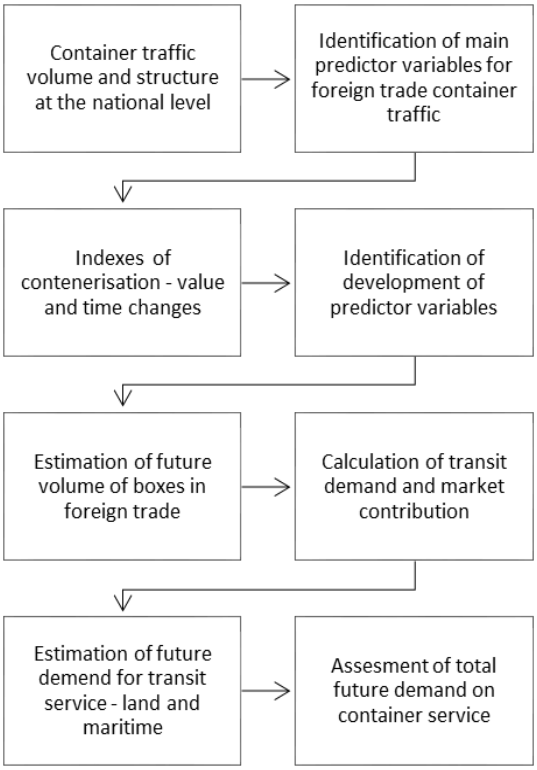

Figure 1. Proposed simplified forecasting procedure for national container traffic
Source: Own elaboration

Calculations of the relevant indexes of containerisation, including container traffic and predictor variables, is the next stage in the research. Levels of implementation of container technology in

the national economy and trade need to be established. However, it should be noted that any assessment of technology utilisation requires comprehensive references (best practices), such as comparisons to other countries (market leaders) or groups of countries (e.g. EU28). Comparisons of the levels and development of index values need to be treated as integral growth factors.

The next step in the research is identification of future changes in predictor variables. International organisations (e.g. IMF, World Bank, OECD, WTO) as well as national statistical offices are the main sources of such information. It should be emphasized that the range of data availability will determine the scope of indexes in any forecast.

By combining forecasts and indexes, an estimation of future volumes of containers could be made. The approximation of certain outcomes necessitates the setting of minimum and maximum scenarios for foreign trade flows in containers.

The designation of the origin and destination points of cargo flows, located on the foreign hinterland of seaports is required for the next step of the procedure. The collection of comprehensive and coherent data (predictor variables) from neighbouring countries, as well as the proper assignment of relevant indexes of containerisation is necessary. At this stage, a simplified approach, based on the size of populations has proven to be the most suitable. This means, however, that the results obtained should be treated as general. This is because a relatively stable number of citizens does not necessarily create similar changes in the primary demand for container traffic, so only improvements in other indexes as such could change the forecasting of volumes.

The collected results also need to be adjusted by including data concerning any particular countries involved in the service of transit traffic. In these cases, historical changes of shares need to be also included in the analysis and extrapolated for subsequent periods.

Finally, the total demand for container services in ports, at the country level, is estimated. These proposed methods could be implemented for long-term forecasting, however the scope of any predictions will be necessarily restricted by availability or unavailability of data.

3 RESULTS

Initial steps in the process of implementation and verification of the above described model of forecasting is the identification and distribution of container traffic in Polish maritime ports. Market divisions between foreign trade, maritime and land transit flows is presented in Table 1.

Table 1. Structure of container traffic in Polish maritime ports between 2008-2018 [thou. TEU]

	Polish foreign trade	Maritime transit	Land transit	Total
2008	854.9	1.4	3	859.3
2009	670.5	0.4	0.6	671.6
2010	823.0	226.8	0.5	1,050.3
2011	1,117.9	239	0.3	1,357.2
2012	1,250.3	405.9	0.7	1,656.9
2013	1,223.9	745.1	0.4	1,969.5
2014	1,457.0	681.8	0.8	2,139.6
2015	1,408.4	455.1	0.3	1,863.8
2016	1,447.5	583.9	1	2,032.4
2017	1,705.2	678.5	1.1	2,384.8
2018e	2,026.6	806.4	1.3	2,834.3

Source: Own elaboration [18]

3.1 *Foreign trade container traffic*

Significant facilitators of container flows (predictor variables) are both the economic activity of a country (and its neighbours) and volume of trade. Gross domestic product constitutes the first element. In relation to trade flows, additional assumptions referring to the spatial pattern of cargo flows should be made.

Intercontinental trade is the main area of implementation of containerisation, thus the total volume of trade, should include cross-ocean flows (the research includes: Vietnam, United States, Taiwan, Singapore, New Zeeland, Mexico, South Korea, Japan, India, Indonesia, Hong-Kong, China, Chile, Canada, Brazil, Argentina, Australia). These kinds of flows drive maritime transport with specific effects on container traffic – TRADE (cont.).

Table 2. Macroeconomic characteristics of Poland (2008-2017)

	GDP [billion EUR]	GDP per capita [EUR]	Foreign trade–total [m tons]	Foreign trade-container [m tons]
2008	366.2	9,607	196.3	9.64
2009	317.1	8,315	173.0	8.55
2010	361.8	9,515	199.9	9.43
2011	380.2	9,990	213.0	9.93
2012	389.4	10,230	211.3	9.77
2013	394.7	10,371	218.2	11.32
2014	411.2	10,815	232.6	11.78
2015	430.3	11,321	241.8	11.99
2016	426.5	11,235	250.1	13.31
2017	467.2	12,303	261.9	15.96

Source: Own elaboration based on Eurostat database

High levels of correlations between the container turnover in Polish ports and the development of the country's main macroeconomic parameters (GDP value and foreign trade turnover) were revealed. The Pearson correlation coefficient for elaborated parameters reached (2008-2017):

- 0,9640 for GDP,
- 0.9638 for GDP *per capita*,
- 0,9372 for foreign trade (intercontinental).

It could be stated, that any future changes in macroeconomic conditions will constitute the basic driver for further growth of maritime container traffic.

The level of utilisation of container technology is the second factor introduced into our research. Three basic indexes of containerisation were defined in this field:

1 TEU/TRADE (cont.),
2 TEU/GDP and additionally
3 TEU/POPULATION.

TEU/population parameters are useful when conducting research into transit traffic, where access to comprehensive macroeconomic data could be difficult. An assumption of convergence in the European dimension was adopted, so the average value of the indexes of containerisation for the EU28 was taken as a reference point (benchmark) – Table 2. Thanks to this, the problem of structural diversity in container flows (trade-transit) in different countries was eliminated.

Table 3. Containerisation measures (benchmarks) for Poland and EU28 (2008-2017)

	TEU/TRADE (cont.) [TEU/1000 tons]		TEU/GDP [TEU/ thou. EUR]		TEU/ POPULATION [TEU/person]	
	Poland	EU28	Poland	UE28	Poland	UE28
2008	88.69	123.26	0.0023	0.0061	0.022	0.159
2009	78.41	135.41	0.0021	0.0055	0.018	0.134
2010	87.31	135.41	0.0023	0.0059	0.022	0.150
2011	112.57	137.28	0.0029	0.0061	0.029	0.161
2012	127.94	142.48	0.0032	0.0061	0.033	0.164
2013	108.16	142.27	0.0031	0.0062	0.032	0.166
2014	123.65	148.33	0.0035	0.0063	0.038	0.176
2015	117.47	145.63	0.0033	0.0060	0.037	0.174
2016	108.79	147.56	0.0034	0.0062	0.038	0.180
2017	106.87	144.95	0.0037	0.0062	0.045	0.186

Source: Own elaboration

Statistics reveal discrepancies between the level of the value of indexes calculated for the Polish and European (EU28 [5]) container sectors. In addition, differences in growth trends of the indexes value is also clear (Figure 1). It can therefore be concluded that the level of technology use in Poland is still lower than in the EU, however an increasing tempo of growth will lead to their convergence.

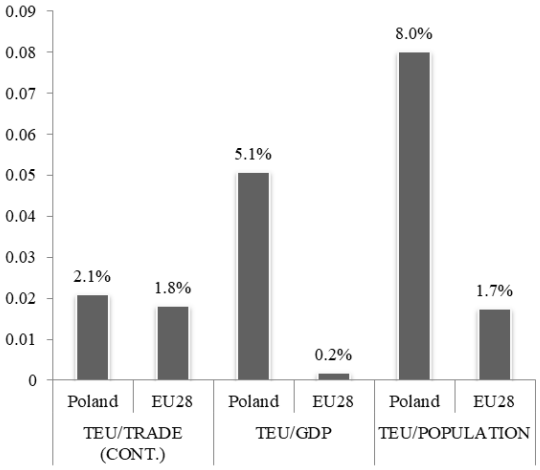

Figure 2. Compound Annual Growth Rate (CAGR[6]) of the value of containerisation measures in years 2008-2017 for Poland and the EU28
Source: Own elaboration

Value of particular indexes (2008-2017) shows that they should unified by the year 2032 (TEU/GDP indicator). Thus, a further improvement in the utilisation of container technology in Poland should be expected. As a result, the future growth of container traffic in maritime ports of Poland should exceed the average European level during the next 20 years.

Taking into consideration predicted increases in growth of Polish trade (*World Economic Outlook Database, October 2018*, 2018), GDP development (*World Economic Outlook Database, October 2018*, 2018) , changes of population (*Population projection at national level (2015-2080)*, 2019) as well as changes over time in the values of indexes, calculations of future container traffic can be made in the field of foreign trade, in Polish ports (Figure 2).

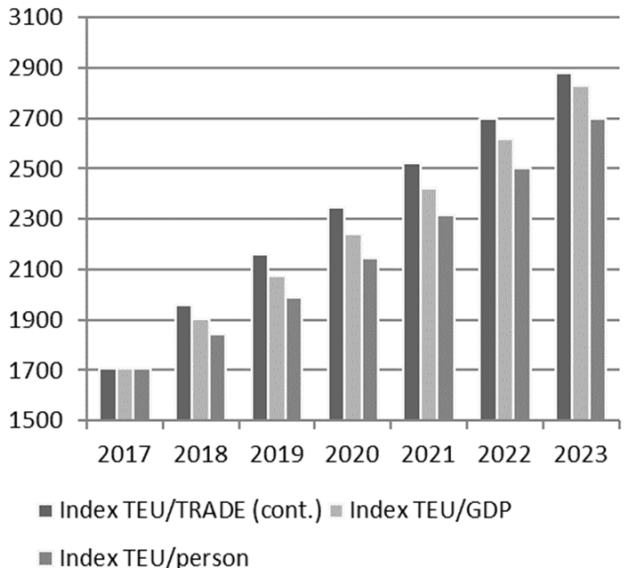

Figure 3. Container traffic forecast for Polish maritime ports (Polish foreign trade flows) up to 2023 [thou. TEU].
Source: Own elaboration

[5] European Union consists of 28 countries

[6] CAGR - Compound Annual Growth Rate

These collected results (maximum and minimum values) can only be considered marginal scenarios in the prediction of future changes in container traffic. Taking this into account, however, the volume of foreign trade containers should reach the level of 2.699 million TEU to 2.879 million TEU by 2023.

3.2 *Transit container traffic*

One of the indexes of containerisation also implemented into this research focuses on current and future demands in transit traffic, both land and maritime. As regards Polish seaports, the following countries could be regarded as potential centres of demand growth:

- maritime transit: Russia, Finland, Sweden, Latvia, Lithuania, Estonia,
- land transit: Czech Republic, Slovakia, Hungary, Belarus, Ukraine.

Because of limited access to comprehensive and coherent data about trade and economic developments in non-EU countries, estimations were based on population factors. Assuming that the non-EU neighbouring countries achieve a level of containerisation already specified for Poland (0,045), and EU member states are characterised by the average European level of the index (0,186), the demand for particular types of transit traffic can be theoretically estimated.

As regards the demand for maritime transit, the total demand can be calculated as 10,461 thou. TEU (data for year 2017), with a strong contribution of that from Russia (6,451 thou. TEU).

The total demand from land transit potentially served by Polish container ports can be estimated to be about 7,120 thou. TEU (with a share of 67.3% from EU countries).

These values are fully theoretical, because in the case of individual countries the current levels of implementation of container technology is so different. Such a phenomenon can be observed in non-EU countries: Russia, Ukraine, Belarus. It can, however, be expected that technological structures will change, and higher volumes of containers will flow through the seaports in the future. On the other hand, parts of the analysed countries have no access to the sea, so foreign trade in those places is served only by foreign ports. In these cases, theoretical volumes of demand were estimated.

Calculations of the contribution of regional transit traffic to Polish maritime ports was the next step in the forecasting process. Currently, the share could be calculated to be 6,54% and 0,02% for maritime and land transit respectively. The share of Polish ports has been growing by 13.02% and 19.54% annually respectively (CAGR) in the period 2011-2017, therefore further improvements in the market position of Polish ports can be assumed. This means looking at the year 2023, the shares of 13.64% and 0.04% could be implemented into our calculations. As a result, the transit traffic served in Polish ports could reach 1.993 thou. TEU by 2023.

3.3 *Total demand*

Summing up, the total forecasted traffic of containers in the ports of Poland would reach levels from 4.692 thou. TEU up to 4.872 thou. TEU by 2023. Obviously, numerous factors, both internal (sector) and external (economy & trade) will have a direct influence on the final results. However, these estimated values could be treated as a starting point to more detailed analysis of future growth.

4 CONCLUSIONS

The above presented methodology towards the development of container demand forecasting should be regarded as relatively simple but useful. Dividing container flows into three key parts, helps facilitate the application of different methods into the prediction exercise. Future changes of predictor variables (trade, GDP) as well as the development of indexes of containerisation, constitute elementary drivers in the further growth of container traffic. This method, in addition to quantitative analysis, also requires an expert opinion, because the choice of extrapolation techniques or implementation of specific factors, require logical verification and sectorial knowledge. The best confirmation of the usefulness of this method have been the preliminary results for 2018 (2.834 m TEU), which are coherent with the results obtained in our calculation (2.653 - 2.770 m TEU).

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