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Forecast for the Development of the International Freight Transport Market in Poland Until 2030

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This paper includes the forecasts of the volume of transport performance (in tonne-kilometres) of Polish international truck transport up to 2030.

Keywords: Freight transport, Forecasting.

1. INTRODUCTION

Polish international freight transport currently plays a significant role on the European market: domestic international freight transport companies have – hold more than 25% share in the haulage work of the entire international freight transport of the European Union countries. In addition, the production of this transport (tkm) makes up about 60% of the haulage work of the entire Polish freight transport. However, this situation may take an unfavourable turn from the point of view of Polish carriers, given the currently observed activities of some EU institutions and countries, especially Germany and France, which can be seen as a protectionist policy towards domestic international road transport companies. These undertakings, confirmed by the position of the EU Council on the posted workers, are a threat to high competitiveness of, among others, Polish international carriers, which may have adverse effects on Poland in the social and economic aspect.

In connection with the above premises, the Motor Transport Institute developed a variant, expert forecast of the dynamics of haulage work, until 2030, performed by international freight transport companies registered in Poland. The results obtained are presented in this paper. The first part presents the forecast obtained as a result of the analysis of the current dynamics of the haulage work. The result is a combined (weighted) forecast of a series of partial (individual) forecasts obtained using selected models of the time series theory. These results provide a point of reference for the expert forecast determined using the Cross Influence of Events (CIE) method and taking into account the hypotheses formulated by the experts regarding possible future scenarios of the international transport market evolution, see e.g. (Cieślak 2005).

The authors hope that the obtained forecasts for the development of the international freight transport market in Poland will be to some extent helpful in assessing the effects of the development of this market in terms of economic, as well as social, energy and environmental aspects.

2. METHODOLOGICAL NOTES

The presentation of the results will be preceded by mentioning the forecasting models used.

3. FORECASTS BASED ON THE SELECTED TIME SERIES MODELS

There is a huge variety of tools for qualitative and quantitative analysis and time series modelling. These methods were developed in different years, but their common feature is undoubtedly that they are still very popular today as recognized tools for time series modelling and forecasting.

The forecasts made in this paper were created using a series of time series models: *ETS* class models (*Error, Trend, Seasonal*, see e.g.

(Hyndman et al. 2002)), *ARIMA* class models (*AutoRegressive Integrated Moving Average*, e.g. (Box and Jenkins 1976),(Brockwell and Davis 2002),(Hamilton 1994)); non-linear switchover autoregressive models (Self-Exciting Threshold Autoregressive Models, SETAR, e.g. (Tong 1990)) that are a combination of ARIMA models and a switching mechanism depending on the cur-rent and delayed values of the explained variable. The last group of individual forecasts was the result of using models based on neural networks[1]. Each of the mentioned model classes was the source of individual forecasts. Based on them, combined forecasts were determined.

The process of combining forecasts allows to work out a kind of compromise, i.e. compromise expectations regarding the phenomenon or process whose course is the subject of the forecast. Practical experience, but also the results of theoretical considerations, show that forecasts resulting from the use of individual models or procedures (called individual fore-casts), are usually not as accurate as, those constructed based on the larger number of them, mixed (combined) forecasts. It seems that the basic reason for this is the fact that each of the models takes into account, to a differing degree, various aspects of the studied phenomenon, and in a different way takes into account the specific features of its dynamics. Till present (see e.g. reviews (Clemen 1989) and (Wallis 2011)) the process continues which was started by Bates's and Granger's article ((Bates and Granger 1969)) on searching for more and more subtle methods of combining forecasts, that would be characterized not only by the smallest possible error but they would also be more stable and therefore less susceptible to errors in the specification of models generating individual forecasts. Even the simplest method of combining forecasts, which is to determine the usual average of individual forecasts, usually leads to a significant increase in accuracy. Such a procedure often reduces the magnitude of the error to such an extent that it can be smaller than the errors of all individual forecasts[2].

In this paper, however, we limit ourselves to linear methods of combining forecasts, i.e. procedures in which the forecast is combined with a linear combination of individual forecasts $\hat{Y}_1, \ldots, \hat{Y}_k$:

$$\hat{Y} = \sum_{i=1}^{k} w_i \hat{Y}_i. \tag{1}$$

Moreover, we assume that (1) is an arithmetic mean, so all weights have the same values, $w_i = 1/k$. Thus, when calculating the combined forecast by this method, neither the accuracy of individual forecasts is taken into account; each of the individual forecasts is thus regarded as if it is on a par with the others.

4. METHOD OF CROSS INFLUENCE OF EVENTS

The prepared forecast also uses the method of mutual interaction of the events. It allows the direct construction of a probabilistic model of the studied value and its dynamics, and consequently to determine the forecasts. This method is particularly useful when it is necessary to take into account the possibility of events or processes having an impact on the analysed value, and at the same time for which it is difficult to find counterparts in the past. Expert knowledge, experience and intuition seem to play a role difficult to overestimate in such a situation. Experts were provided with a questionnaire, in which a list of events was specified, mainly of an economic and political nature, which could have a significant impact on the shaping of haulage work of the international freight transport in the coming years. The following events have been identified that have a significant impact on the development of the haulage work in the relevant scope during the forecast period:

1. "Production potential of the Polish economy". This event, further referred to as z_1, means the development of the national economy with the dynamics similar to the one observed in recent years.

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[1] Obviously, the number of possible model classes is much greater. Many premises, based mainly on numerical experience, indicate that considering more models and, consequently, a larger number of individual forecasts, does not significantly improve the quality of forecasts, see (Clemen 1989). This thesis is also confirmed by experiments conducted on the occasion of forecasting the economic situation in transport.

[2] Although there are a number of theoretical results in this matter, the assumptions made there are often too restrictive from the point of view of the practice of forecasting.

2. "Demand for goods in Poland" (z_2) – analogically to z_1 but it applies to the final demand.
3. "Integration and international economic cooperation" (z_3) – at a level no less than the previous one.
4. "Innovativeness of the manufacturing activity affecting the material consumption of production" (z_4) –at a level greater than the previous one.
5. "Competitiveness of the Polish road carriers in the light of the planned EC regulations" (z_5) – at a level no smaller than the current one.
6. "Liberalization of the EU transport services market and its impact on inter-modal competitiveness" (z_6) – at a level greater than the current one.
7. "Costs in the Polish international freight road transport enterprises" (z_7) – at a level greater than the previous one.
8. "Condition of the transport infrastructure in Poland" (z_8) – at a level no smaller than before.
9. "Demand for the services of Polish road hauliers in the Brexit situation" (z_9) – changes in the competitiveness of the transport market caused by this process.

The data obtained from experts included estimated subjectively:

1. Event z_j probabilities, further referred to as Π_j^e ($j = 1, \dots, 9$)
2. Conditional probabilities of z_i provided that z_j: $\Pi_{i|j}^e$
3. Conditional probabilities of z_i provided that z_j does not occur: $\Pi_{i|-j}^e$
4. Annual rates of changes of the forecasted haulage work caused by the occurrence of event z_i: r_{it} ($t = 2017, \dots, 2030$).

The averaged data obtained from experts is included in the Appendix. This data, based on the probabilistic model of the situation under consideration, were used to formulate prognostic predictions. The model was constructed as follows.

Let $Z = \{z_1, \dots, z_9\}$ and mean the aforementioned set of basic events whose occurrence could have an impact on transport production in the road transport. We associate elementary events with subsets of Z; for example $\omega = \{z_1, z_2\}$ corresponds to a scenario in which only basic events z_1 and z_2 occur. The set of elementary events, Ω, consists of all subsets of Z. The family $\mathcal{M}$ of events consists of all subsets of Ω. Each function $\pi: \Omega \to [0,1]$ satisfying the condition $\sum_{\omega \in \Omega} \pi(\omega) = 1$, clearly determines the probability $\Pi: \mathcal{M} \to R$: for any $A \in \mathcal{M}$ we have:

(2) $$\Pi(A) = \sum_{\omega \in A} \pi(\omega).$$

Occurrence of z_j ($j = 1, \dots, 9$) corresponds to the event $A_j = \{\omega \in \Omega: z_j \in \omega\} \in \mathcal{M}$, while the probabilities

(3) $$\Pi_j^e, \quad \Pi_{i|j}^e, \quad \Pi_{i|-j}^e,$$

determined by the experts are associated with:

(4) $$\Pi(A_j) = \sum_{\omega:\, \omega \ni z_j} \pi(\omega),$$

(5) $$\Pi(A_i|A_j) = \frac{1}{P(A_j)} \cdot \sum_{\omega:\, \omega \ni z_i, \omega \ni z_j} \pi(\omega)$$

and

(6) $$\Pi(A_i|A'_j) = \frac{1}{1-P(A_j)} \cdot \sum_{\omega:\, \omega \ni z_i, \omega \ni z_j} \pi(\omega)$$

respectively.

The volume of international transport haulage work is described by the stochastic process $\{X_t\}$ (where $t \in \{2017, \dots, 2030\}$) defined by experts' estimations of rates r_{it}: in the year t and for scenario $\omega \in \Omega$ the haulage work is equal

(7) $$X_t(\omega) = \prod_{\tau=2017}^{t} \prod_{i=1}^{n} (1 + r_{it}\delta_i(\omega)),$$

where the random variables δ_i are defined as:

$$\delta_i(\omega) = \begin{cases} 1 & z_i \in \omega, \\ 0 & \text{otherwise.} \end{cases}$$

The function π was determined so that the conditional probabilities (4)-(6) were as close as possible to their counterparts in (3). The criterion of the goodness of fit was given by the square loss function, which corresponds to the minimization of the sum of squares of differences between (4)-(6) and averaged data from experts. The probability function π^* which solves this problem determines the determines the point (mean square forecast) forecasts of $\{X_t\}$:

(8) $$E_{\pi^*} X_t = \sum^{\omega \in \Omega} X_i(\omega) \pi^*(\omega)$$

and the confidence intervals (more precisely, the confidence band) of the forecast. The widest band, covering all possible scenarios (and thus the trajectories of the process $\{X_t\}$), we obtain by taking 0- and 1-quantiles of X_t's:

lower bound

$$X_t^d = \min\{X_t(\omega):\ \pi^*(\omega) > 0\} \tag{9}$$

and the upper one:

$$X_t^g = \max\{X_t(\omega):\ \pi^*(\omega) > 0\}. \tag{10}$$

5. RESULTS - FORECASTS OF THE VOLUME OF THE HAULAGE WORK PERFORMED BY THE INTERNATIONAL ROAD TRANSPORT

The forecast based on the analysis of the current dynamics was based on the data of the Central Statistical Office on the volume of haulage work performed by the international road transport. The annual frequency database covered the period up to 2016. The expert's forecast was determined based on the data obtained from experts cooperating with the Motor Transport Institute. The relevant calculations were made using procedures written in an **R** environment.

6. FORECAST BASED ON SELECTED MODELS OF TIME SERIES

The forecast made is a combined forecast of individual results obtained from the models: ETS, NNet (unidirectional neural network with a single hidden layer), ARIMA, models of the Thetam and STL (Seasonal Trend Decomposition with Loess). From each model family, one most promising representative was selected, according to Schwartz's Bayesian information criterion. When determining the combined forecast, the weights that took into account the accuracy of these models (based on the ex post forecasts) were omitted in favour of using the same weights. Certain premises, based mainly on empirical results, see e.g. (Hyndman R.J. 2018), (Elliott G. 2016), show that such a choice often leads to more stable results.

The errors of ex post forecasts confirm that the procedure of combining forecasts improves accuracy: combined forecast is characterized by a smaller error than each of the individual forecasts considered. On the other hand, the inclusion of a larger number of models, and consequently individual forecasts, does not seem to affect the further improvement of forecast quality. This 'saturation effect' confirms well-known observations, see e.g. (Clemen 1989) and (Wallis 2011).

Table 1. Haulage work volume forecast in the international transport, 2016 = 100%. The point forecast and the lower and upper bands (95%) of the confidence band.

Year	Point Forecast	Lower Band	Upper Band
2017	105	99	115
2018	112	104	125
2019	118	109	135
2020	125	114	140
2021	131	120	146
2022	136	125	154
2023	141	130	162
2024	146	136	169
2025	151	138	177
2026	155	138	185
2027	160	139	192
2028	165	139	200
2029	169	139	207
2030	174	139	214

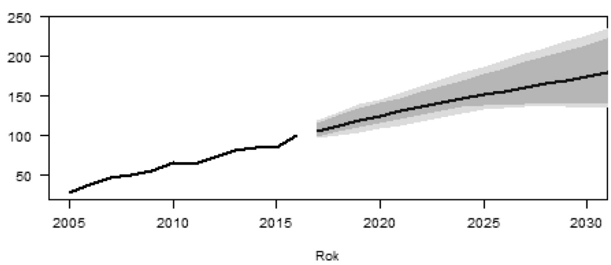

Fig. 1. Haulage work volume forecast for the international transport, 2016 = 100. Averaged (point) forecast and confidence bands corresponding to confidence levels of 0.80 and 0.95 were marked.

The forecast time series is characterized by a upward trend, which is clearly reflected in the forecasts: the average annual growth rate is 4.03%. The expected volume of haulage work in subsequent years increases to about 173.88% of the value from 2016. Detailed results - point forecasts and information on their accuracy - are provided in table 1 and shown in figure 1.

7. FORECAST BASED ON THE METHOD OF CROSS INFLUENCE OF EVENTS

Table 2. Haulage work volume forecast in the international transport, 2016 = 100%. The point forecast and ends of the confidence band calculated using the CIE method.

Year	Point forecast	Lower Band	Upper Band
2017	103	100	106
2018	106	100	112
2019	109	100	118
2020	112	100	124
2021	114	100	129
2022	116	100	134
2023	118	99	139
2024	120	99	143
2025	122	99	146
2026	122	99	148
2027	123	99	150
2028	123	98	151
2029	124	97	153
2030	124	96	156

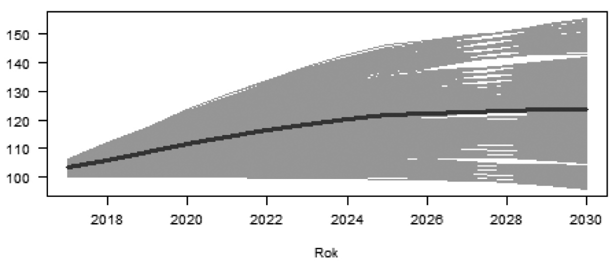

Fig. 2. The volume of haulage work in the international transport for individual scenarios (2016 = 100). The average forecast calculated using the CIE method is marked in blue. Trajectories determine the confidence band for the forecast.

The probability function π^*, best adjusted (with respect to the square loss function) to the expert data, allows to determine the probability of each out of $2^9 = 512$ scenarios. The point forecast is represented by the blue line in Fig. 2. This figure also shows the temporary trajectories of the haulage work for each scenario. The extreme lines mark the edges of the confidence band of the forecast. As in the case of trend analysis, the width of this band, and thus the measure of uncertainty of the forecast, is relatively large. This is a natural effect of significant data discrepancies - above all the expected rates r_{it} of the haulage work - obtained from individual experts. The task of a reliably determining these quantities is a difficult task even if only due to the insufficiently available relevant precedents from the past.

The created forecast tones somewhat the results obtained based on the trend analysis. This is the result of, among the others, the uncertainty of experts about the occurrence of base events $(z_1, \ldots, z_9)$, especially those that signify progress in the liberalization of the freight transport market. This uncertainty translates into a significant reduction in the rate of increase in the volume of haulage work from the baseline 100 in 2016 to 124 in 2030, which gives an average annual rate of change at just over 1.5%. In principle, in contrast to the previous forecast (trend), even a decrease is possible in the considered situation, as evidenced by the negative growth rates corresponding to the bottom edge of the confidence band. Fortunately, such scenarios are very unlikely.

8. VARIANT FORECAST OF THE HAULAGE WORK OF THE POLISH INTERNATIONAL FREIGHT TRANSPORT BY THE 2030

In addition to the forecast discussed above, the variant forecasts were created, assuming the possibility of only some of the scenarios occurring from among all $|\Omega| = 2^9$ previously taken into account. The results for three possible variants of the development of the transport market and its environment are presented below. They were conventionally defined as a base, moderate and progressive variant. These are predictions based on the assumption of the occurrence of the selected event $A\in \cal M$. The point forecast and its confidence intervals are in this case determined by the conditional (with respect to the event A). The point forecast and its confidence intervals are in this case determined by the conditional distributions of the process (X_t).

Three basic variants, conventionally called basic, moderate and progressive, were distinguished.

The **baseline variant** corresponds to those scenarios where z_4, z_5, z_6, z_7, z_8 do not occur, so we have a conditional forecast with respect to the event $A = \{\omega : \omega \subset \{z_1, z_2, z_3, z_9\}\}$. Taking into account definitions of the excluded events, this variant could be conventionally defined as a continuation of the current economic policy (in particular transport policy). This variant may be regarded as maintaining or even slightly intensifying market regulations, among others also in respect to international freight transport. The political tools applied affecting transport may have an impact on limiting its competitiveness, which may lead to a reduction in the growth rate of haulage work.

The **moderate development variant** corresponds to an event $A = \{\omega\colon\ z_1 \in \omega, z_2 \in \omega\}$ i.e. a family of all supersets of $\{z_1, z_2\}$. In contrast to the previous variant acting of the factors stimulating liberalization, competitiveness and innovativeness in the economy, and in the transport market in particular is currently regarded as possible - although not necessary.

The **progressive variant** corresponds to the event $A = Z$, which means that all described phenomena and processes, beneficial from the point of view of transport, occur. This variant can be called the variant ensuring liberalization of the transport market.

The forecasts and their confidence intervals determined for these variants are shown in Fig. 3.

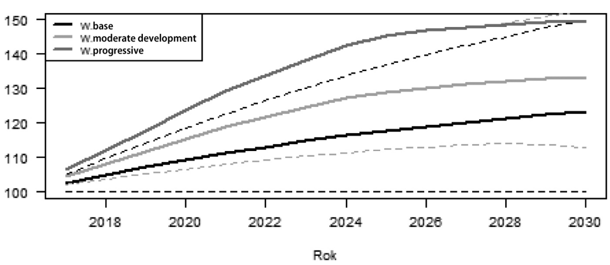

Fig. 3. Variant forecasts of the international transport haulage work. Continuous lines correspond to averaged (point) forecasts, dotted lines define the boundaries of the confidence bands. The year 2016 = 100.

The average forecast is a growing function of time in all considered variants. More specifically, haulage work of the Polish international freight transport, forecasted according to the adopted methodology, fluctuates in 2030 from 225.9 billion tkm in the base variant, through 242.9 billion tkm in the moderate development option, to 274.3 billion tkm in the progressive variant. Compared to the relevant haulage work performed in 2016, the increase in haulage work performed would be approximately 123%, 132% and 149% respectively, which gives an average annual growth rate of approximately 1.5, 2.1 and 2.9 percentage points, respectively.

9. SUMMARY

In the long-term - several years - experts were not willing to share the optimism of the last few years. The optimism visible in the rapid increase in the volume of transport production in the international freight transport and, as a consequence, translating into significant dynamics of the forecasts themselves (Fig. 1). Correction - in minus - in the expert forecast confirms in some way concerns about the possibility of events occurring, that are unfavourable from the point of view of domestic carriers, which they will have to face in the future.

10. APPENDIX. AVERAGED DATA OBTAINED FROM THE EXPERTS

Tables 3 and 4 contain the averaged values of probabilities $\Pi^e_{i|j}$ and $\Pi^e_{i|-j}$ respectively. The averaged probabilities of z_1, …, z_9 are included in Table 5. The last table (6) contains averaged values of experts' annual rates of the changes in the volume of haulage work resulting from individual events (r_{it}).

Table 3. The averaged conditional probabilities of the events given by experts.

	z1	z2	z3	z4	z5	z6	z7	z8	z9
z1	1.00	0.60	0.60	0.49	0.28	0.32	0.32	0.41	0.29
z2	0.57	1.00	0.53	0.28	0.27	0.31	0.19	0.18	0.30
z3	0.44	0.43	1.00	0.48	0.41	0.48	0.32	0.42	0.32
z4	0.37	0.32	0.52	1.00	0.27	0.32	0.34	0.16	0.09
z5	0.38	0.46	0.56	0.24	1.00	0.68	0.64	0.36	0.39
z6	0.34	0.34	0.50	0.20	0.52	1.00	0.27	0.16	0.30
z7	0.42	0.36	0.49	0.39	0.62	0.62	1.00	0.46	0.33
z8	0.46	0.36	0.46	0.16	0.21	0.24	0.21	1.00	0.13
z9	0.40	0.33	0.40	0.20	0.59	0.63	0.66	0.28	1.00

Table 4. The averaged conditional probabilities of the events given by experts. Continued

	z1	z2	z3	z4	z5	z6	z7	z8	z9
z1	0.00	0.49	0.53	0.66	0.69	0.63	0.65	0.56	0.67
z2	0.66	0.00	0.63	0.78	0.73	0.67	0.67	0.64	0.66
z3	0.61	0.53	0.00	0.46	0.68	0.59	0.49	0.35	0.67
z4	0.49	0.66	0.41	0.00	0.67	0.66	0.70	0.55	0.66
z5	0.55	0.64	0.60	0.61	0.00	0.59	0.59	0.56	0.80
z6	0.49	0.48	0.58	0.68	0.74	0.00	0.67	0.52	0.58
z7	0.56	0.49	0.72	0.76	0.68	0.62	0.00	0.45	0.64
z8	0.59	0.68	0.66	0.68	0.70	0.58	0.71	0.00	0.67
z9	0.56	0.50	0.57	0.52	0.58	0.60	0.69	0.47	0.00

Table 5. The averaged probabilities of the events given by experts.

z1	z2	z3	z4	z5	z6	z7	z8	z9
0.64	0.68	0.49	0.48	0.7	0.57	0.68	0.8	0.68

Table 6. The Averaged expected annual rates of changes in the volume of haulage work caused by possible occurrence of individual events (%).

	z1	z2	z3	z4	z5	z6	z7	z8	z9
2017	1.64	1.86	1.21	0.04	0.39	0.16	0.62	-0.04	0.19
2018	1.55	1.77	1.02	0.04	0.09	0.22	0.46	0.09	-0.03
2019	1.62	1.50	0.88	0.25	-0.03	0.21	0.50	0.23	-0.12
2020	1.57	1.64	0.72	0.23	0.15	0.12	0.30	0.32	-0.12
2021	1.46	1.35	0.62	0.25	0.13	0.05	0.19	0.36	-0.06
2022	1.29	1.01	0.66	0.08	0.12	0.09	0.08	0.34	-0.26
2023	1.20	1.02	0.78	-0.03	0.21	-0.03	0.00	0.41	-0.18
2024	1.12	0.90	0.71	-0.04	0.11	-0.06	0.01	0.37	-0.09
2025	0.86	0.80	0.60	-0.16	-0.14	-0.08	-0.13	0.31	-0.10
2026	0.90	0.72	0.47	-0.22	-0.43	-0.23	-0.23	0.28	-0.27
2027	0.87	0.68	0.42	-0.28	-0.35	-0.18	-0.34	0.21	-0.27
2028	0.89	0.53	0.30	-0.28	-0.36	-0.15	-0.35	0.21	-0.23
2029	0.87	0.63	0.37	-0.16	-0.57	-0.34	-0.25	0.10	-0.24
2030	0.59	0.45	0.43	-0.15	-0.60	-0.26	-0.26	0.20	-0.38

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