
The Forecasting of Dangerous Goods Transport by Rail in Poland in Terms of Environmental Security

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Abstract:

Purpose: The research problem discussed in the article concerns the transport of dangerous goods by rail in Poland and its forecasting for the future through the obtained evaluation from the analysis of retrospective data. The purpose of the study was outlined for the adopted research problem. The aim of the study is to forecast the number of dangerous goods transported by rail in Poland for the years 2020-2023.

Project/Methodology/Approach: Theoretical research methods for the analysis of the literature were used in the study which allowed to solve the adopted research problem. The literature on the transport of dangerous goods by rail in Poland was reviewed. The method of comparison was also used which made it possible to rank companies in terms of their participation in the transport of dangerous goods by rail in Poland. The method of the forecasting of dangerous goods transport by rail for the years 2020-2023 was used. The obtained forecasts were analyzed and evaluated through the forecast remainder.

Results: The forecast for the transport of dangerous goods by rail in Poland for 2020 is 26 151 tons, for 2021 it is 27 899 tons, for 2022 it is 28 005 tons and for 2023 it is 28 752 tons. The forecast was considered very good as the mean absolute percentage error (MAPE) of the obtained forecast was 3,50%.

Practical implications: On the basis of the evaluation of historical data through the detection of regularities from the past, such as an increasing trend, a model to forecast for the future can be selected.

Originality: The grouping of primary data allowed for their comparison on categorized bar and line charts to compare them dynamically and, thus, highlight their similarities and differences.

Keywords: Transport, rail transport, goods, dangerous goods, forecasting, environmental security.

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1. Introduction and Literature Review

The research problem undertaken in the study focuses on the issues related to the transport of dangerous goods by rail in Poland and its forecasting for the future. According to Stajniak, transport in the economic sense relates to activities concerning the management of the supply chain and the paid provision of services in the scope of movement, storage, packaging and others (Stajniak *et al.*, 2008; Ioppolo *et al.*, 2016; Ersoy and Tanyeri, 2021). Dangerous goods are the object of the research. In the literature, goods are defined as products intended for sale (Świdarska, 2003). One of the types of goods are the dangerous ones. The analysis of the documents shows that dangerous goods (TN) are materials and items whose transport by rail is prohibited or allowed under strictly defined conditions included in the regulations of international carriage of dangerous goods by rail (PLK, 2021).

In Poland, two types of transportation are mainly used for the transport of dangerous goods, road and rail. The evaluation of information compiled on websites regarding the transport of dangerous goods in Poland shows that shippers more often choose road transport due to greater flexibility and lower costs associated with it (Rynek and Kolejowy, 2021). It is common practice to combine these modes of transport when transporting hazardous materials. A growing trend has been observed in the Polish market in the number of newly built transshipment terminals which allow for many new possibilities in terms of the combination of the dangerous goods transport by road and rail (Kwartalnik and Chemiczny, 2021).

Rail is considered to be the safest type of transport of dangerous goods in Poland. In 2018, 37 incidents were recorded during the transport of hazardous materials by rail in Poland, i.e. six less than in the previous year (Na kolei 100 lat; 2021).

The transport of dangerous goods by rail in Poland is regulated by the following normative documents (Urząd Transportu Kolejowego, 2021):

- [1] The Act of 28 March 2003 on rail transport;
- [2] The Act of 19 August 2011 on the transport of dangerous goods and the regulations on the transport of dangerous goods, such as:
 - RID - regulations for the international carriage of dangerous goods by rail, constituting Appendix C to the Convention on International Carriage by Rail (COTIF);
 - Annex 2 to SMGS - regulations on the transport of dangerous goods to the Agreement on International Rail Freight Communication;
- [3] Others presented in the bibliography as normative acts.

The division of dangerous goods according to RID class is presented in Table 1.

Thirteen groups of dangerous goods marked with classes were analyzed in the study. The regulations on the transport of dangerous goods by rail in Poland

indicated in the study mean that shippers and carriers are subject to many obligations resulting from the risk factors related to the transport of this type of goods. The following factors have the greatest impact on the risk related to the transport of dangerous goods: the quantity and intensity of transport, the technical condition of vehicles and tanks used for transport, partial or complete monitoring of transport, selective compliance or total non-compliance with international regulations on the transport of dangerous substances (TUV Rheinland, 2021).

Table 1. Division of dangerous goods according to RID class

RID class	Material
1	Explosives and objects with explosives
2	Gases
3	Flammable liquids
4.1	Flammable solids, self-reactive materials, polymerizing materials and solid desensitized explosives
4.2	Spontaneously combustible
4.3	Substances which, in contact with water, emit flammable gases
5.1	Oxidising agents
5.2	Organic peroxides
6.1	Toxins
6.2	Infectious substances
7	Radioactive material
8	Corrosives
9	Miscellaneous dangerous goods

Source: Own study based on data obtained from the website:

<https://dane.utk.gov.pl/sts/przewozy-towarowe/przewozy-ladunkow-niebe/16771,Przewozy-ladunkow-niebezpiecznych.html#UDZIA%C5%81Y%20W%20RYNKU>; as of 19.05.2021

The analysis of secondary information shows that in Poland, on average, about 20 million tons of dangerous goods are transported by rail (Urząd Transportu Kolejowego, 2021). The largest part of dangerous goods transported by rail in Poland are: 90% crude oil and petroleum products, including gasoline, diesel oil and technical gases, mainly propane-butane and sulfuric acid (Urząd Transportu Kolejowego, 2021). The transport of dangerous goods is important in terms of the maintenance of environmental security. Environmental security concerns threats to sustainable development and the preservation of the human natural environment at the level necessary for the survival and development of humanity (Nurzyńska, 2016). In terms of the issues raised, environmental security is associated with the minimization of the effects of pollution and contamination through correct

planning, preceded by the forecasting of the number of dangerous goods transported by rail in a dynamic terms in Poland.

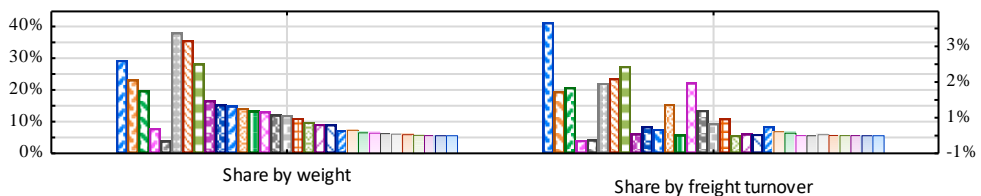
In the study, the forecasting was preceded by an analysis and evaluation of the time series of the total mass of dangerous goods transported by rail in Poland between 2012-2019, in thousands of tons. To analyze and evaluate the considered time series in the article, the methodology presented in the following references was used (Luszniewicz, 2003; Kozicki *et al.*, 2018; Kozicki, 2020; Rabej, 2018; Makridakis, Wheelwright, and Hyndman, 1998; Dittmann, 2016).

The conducted research allows for the detection of regularities, such as an increasing trend. This, in turn, became the premise for the forecasting of the considered data for the future with the use of the Holt's exponential smoothing method (Dittmann *et al.*, 2016). The obtained forecasts were evaluated through the use of forecasting error indices. The research in the study began with an analysis of the participation of carriers in the transport of dangerous goods by rail in Poland in 2019.

2. Analysis of the Number of Dangerous Goods Transported

Figure 1 summarizes the information on the participation of carriers in the transport of dangerous goods by rail in Poland in 2019.

Figure 1. Bar chart of the participation of carriers in the transport of dangerous goods by rail in Poland in 2019 (by weight; by reloading activity) (in percent) (two scales of the Y axis: right and left - detailed description in the legend)



Left Y axis:

Lotos Kolej (L) PKP Cargo(L) OrlenKolTrans (L) Pol-Miedź(L) CTL Logistics (L)

Right Y axis:

DB Cargo Polska (R) PKP LHS (R) Captrain Polska (R) Eurotrans(R) PUK Kolprem(R) Rail Polska (R) Transchem(R) Kolej Bałtycka (R) LTE Polska (R) Olavion (R) Grupa Azoty KOLTAR (R) PCC Intermodal (R) Barter(R) HSL Polska (R) DB Cargo Spedkol (R) CD Cargo Poland (R) Ecco Rail (R) Metrans (R) IRT (R) EP Cargo (R) Freightliner PL (R) ZIK(R) Majkoltrans (R) Silva LS (R) Karpieł (R) Rail Cargo Carrier(R)

Source: Own study based on data obtained from the website:

<https://dane.utk.gov.pl/sts/przewozy-towarowe/przewozy-ladunkow-niebezpiecznych.html#UDZIA%C5%81Y%20W%20RYNKU>; as of 19.05.2021

The information presented in Figure 1 shows that the largest participation of carriers in the transport of dangerous goods by rail in Poland in 2019, according to the weight of transported goods, is occupied by three companies:

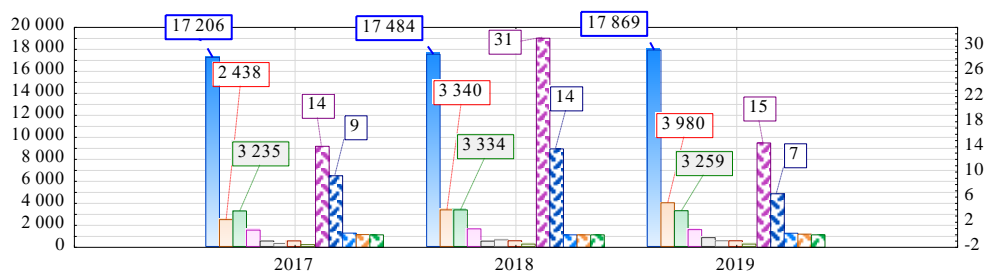
- [1] Lotos Kolej – 29,37%;
- [2] PKP CARGO – 23,27%;
- [3] Orlen KolTrans – 19,81%.

The sum of the shares of the three leaders in the classification according to the weight of transported goods is 72,45%. There are a total of 31 shareholders. The median share is 0,57% while the standard deviation from the arithmetic mean is 7,25%. In the case of the participation of carriers in the transport of dangerous goods by rail in Poland in 2019, according to the criterion of reloading work, three of the same leaders can also be observed with the following values of the share:

- [1] Lotos Kolej – 41,29%;
- [2] Orlen KolTrans – 20,78%;
- [3] PKP CARGO – 19,52%.

The sum of the shares of the three presented leaders according to the reloading work criterion is 81,59%. 31 shareholders were observed in this classification. The median share is 0,18% while the standard deviation from the arithmetic mean is 8,65%. Then, in Figure 2, the values of masses by groups of dangerous goods (described by class codes in the legend) transported by rail through Poland between 2017-2019 are presented.

Figure 2. Bar chart of masses by groups of dangerous goods transported by rail through Poland between 2017-2019 (in thousand tons) (two scales of the Y axis: right and left - detailed description in the legend)



Left Y axis:

3(L) 9(L) 2(L) 8(L) 4.2(L) 5.1(L) 4.1(L) 6.1(L)

Right Y axis:

1(R) 4.3(R) 7(R) 5.2(R) 6.2(R)

Source: Own study based on data obtained from the website:

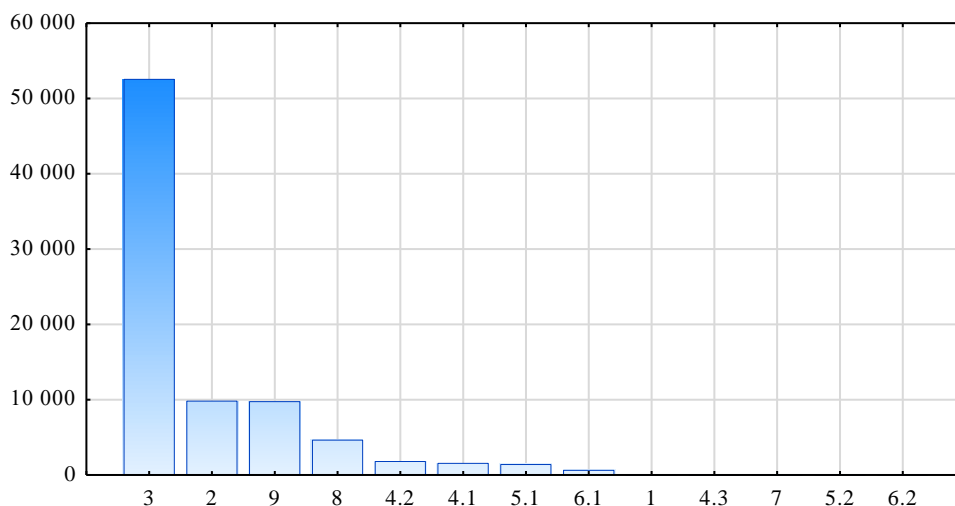
<https://dane.utk.gov.pl/sts/przewozy-towarowe/przewozy-ladunkow-niebezpiecznych.html#UDZIA%C5%81Y%20W%20RYNKU>; as of 19.05.2021

Figure 2 shows that in nine out of thirteen analyzed explanatory variables in 2018, compared to 2017, an upward trend was observed. Similar dynamics was also noticed in nine explanatory variables in 2019 compared to 2017.

The above evaluation indicates the existence of a growing trend because among the observed explanatory variables, which show an increase, there are those with the highest recorded values assigned in Figure 2 to the left axis scale Y. The largest number of dangerous goods transported by rail in Poland between 2017- 2019 is the third group of classification according to the RID: flammable and liquid materials (2019 - 17 869 tons). Alternately, the second and third place between 2017-2019 are occupied by the groups of dangerous goods in the form of: gases (2019 – 2 980 thousand tons) and various hazardous materials and objects (2019 – 3 259 thousand tons).

Then, for illustrative purposes, the ranking of the sum of masses by groups of dangerous goods transported by rail in Poland in total for the period 2017-2019 in thousand tons was outlined.

Figure 3. Bar chart of ranking of the sum of masses by groups of dangerous goods transported by rail in Poland in total for 2017-2019 (in thousand toes) (two scales of the Y axis: right and left - detailed description in the legend)



Source: Own study based on data obtained from the website: <https://dane.utk.gov.pl/sts/przewozy-towarowe/przewozy-ladunkow-niebe/16771,Przewozy-ladunkow-niebezpiecznych.html#UDZIA%C5%81Y%20W%20RYNKU>; as of 19.05.2021

The ranking of the number of goods by weight in respective RID classes transported in Poland in total by rail for 2017-2019 is as follows (from the highest to the lowest value in thousand tons):

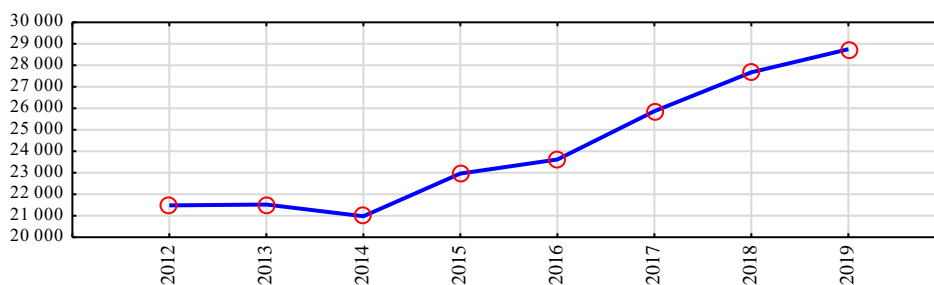
1. 3 – 52559,14; 2. 2 – 9827,41; 3. 9 – 9757,44; 4. 8 – 4646,05; 5. 4,2 – 1810,3; 6. 4,1 – 1570,5; 7. 5,1 – 1410,6; 8. 6,1 – 20,37; 9. 1 – 60; 10. 4,3 – 29,63; 11. 7 – 0,53; 12. 5,2 – 0,163; 13. 6,2 – 0.

The next stage of the research was an attempt to forecast the total weight of dangerous goods transported by rail across Poland for the period 2020-2021.

3. The Forecasting of the Number of Transported Dangerous Goods

The research began with the outline of the total weight of dangerous goods transported by rail across Poland between 2012-2019 in Figure 4 (in thousand tons).

Figure 4. Line chart of the total weight of dangerous goods transported by rail through Poland between 2012-2019 (in thousand tons)



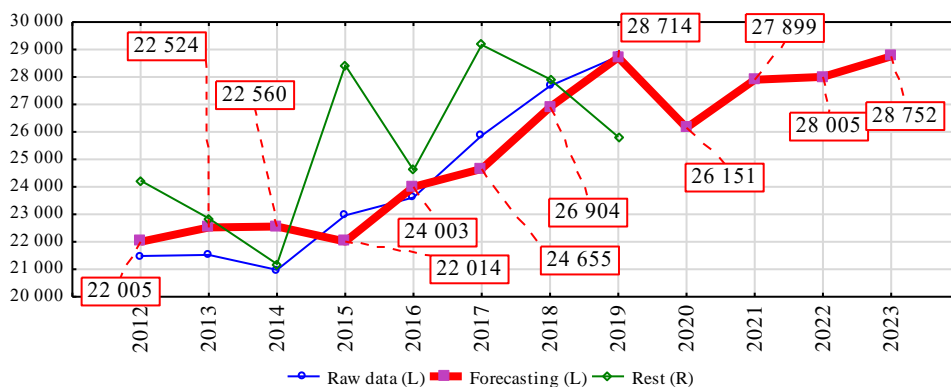
Source: Own study based on data obtained from the website: <https://dane.utk.gov.pl/sts/przewozy-towarowe/przewozy-ladunkow-niebezpiecznych.html#UDZIA%C5%81Y%20W%20RYNKU>; as of 19.05.2021

The observation of the primary data outlined in Figure 4 allows for the conclusion that there is a clear growing trend. This became a direct premise to use the Holt – Winters' exponential smoothing method to forecast primary data. The results are outlined in Figure 5.

The forecasting presented in Figure 5 shows that the predicted values are well matched to the observed ones. The obtained forecast for the years 2020-2023 indicates the continuation of the growing trend.

The forecast for the transport of dangerous goods by rail in Poland for 2020 is 26 151 tons, for 2021 it is 27 899 tons, for 2022 it is 28 005 tons and for 2023 it is 28 752 tons. The last stage of the research is the analysis and evaluation of forecasting errors (Table 2).

Figure 5. Forecast of the total weight of dangerous goods transported by rail through Poland for 2020-2023 (in thousand tons)



Source: Own study based on data obtained from the website: <https://dane.utk.gov.pl/sts/przewozy-towarowe/przewozy-ladunkow-niebezpiecznych.html#UDZIA%C5%81Y%20W%20RYNKU>; as of 19.05.2021

Table 2. Analysis of forecast errors

Index	Result
Mean percentage error	-0,56
Mean absolute percentage error	3,50

Source: Own study based on data obtained from the website: <https://dane.utk.gov.pl/sts/przewozy-towarowe/przewozy-ladunkow-niebezpiecznych.html#UDZIA%C5%81Y%20W%20RYNKU>; as of 19.05.2021

The mean absolute percentage error (MAPE) of the obtained forecast was 3,50% while the mean percentage error was -0,56%. The analysis of forecasting errors shows that the obtained forecast is very good.

4. Summary and Conclusions

The largest participation in the transport of dangerous goods by rail in Poland in 2019, according to the criterion of weight and reloading work, is occupied by three companies out of the thirty-one considered, Lotos Kolej; PKP CARGO and Orlen KolTrans.

The third group of RID classifications, flammable and liquid materials (2019 - 17 869 thousand tons) constitutes the largest number of dangerous goods transported by rail in Poland between 2017-2019. In the period 2017-2019, the following

groups of dangerous goods occupy the second and third place alternately, gases (2019 – 2 980 tons) and various hazardous materials and objects (2019 – 3 259 tons).

The evaluation of the time series analysis of the number of dangerous goods transported by rail across Poland in thousand tons shows that in the period from 2014 to 2019 a strong upward trend is visible. In 2014, 20 977 tons of dangerous goods were transported and in 2019 an increase to 28 750 was observed. The increase from 2014 to 2019 was by 7 773 tons.

The obtained evaluation became the premise for the selection of the method for the forecasting of the considered historical data for the future – Holt's exponential smoothing. The forecast for the transport of dangerous goods by rail in Poland for 2020 is 26 151 tons, for 2021 it is 27 899 tons, for 2022 it is 28 005 tons and for 2023 it is 28 752 tons. The forecast was considered very good as the mean absolute percentage error (MAPE) of the obtained forecast was 3,50%.

Rail transport of dangerous goods in Poland requires correct planning with the use of forecasting methods in order to determine the number of transported goods and to secure the expenditure necessary to ensure environmental security as well as effective management of the entire process in terms of dynamics.

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