A Prognostic Model of Diesel Fuel Consumption for Railbuses

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In this article, the model for prediction of diesel fuel consumption by railbuses is presented. In order to create the model, the results of measurements of the average fuel consumption of eight dual mode railbuses of type X (manufactured by the same producer) are used. The usefulness of the indicators method in additive and multiplicative version is assessed. For both models, the percentage share of the trend, seasonality, and irregular (random) components are analysed and the results for the multiplicative version are given.

Keywords: prediction of diesel fuel consumption, indicators method, case study, dual mode railbus.

1. INTRODUCTION

From the economic point of view, the most important operational parameter is diesel fuel consumption by a vehicle per labour unit. This parameter is given by manufacturers in the technical data of vehicles. Thus, a buyer (before a purchase) knows the average fuel consumption of the selected vehicle.

The fuel consumption, given in the technical data, is measured under laboratorial conditions, hence the manufacturer's declared value does not always agree with reality. Actual values of diesel fuel consumption depend on, for example, seasonality, so it is very important to be able to build models of seasonality and make a forecast on the basis of these models. Statistics provides a lot of tools for prediction of diesel fuel consumption taking into account seasonal fluctuations and for verification of the authenticity of obtained results. Among these tools is, for example, the method of seasonal fluctuations. This method is described, among others, in the following works:[1], [2], [3].

The objective of the article is to present and evaluate the usefulness of the used predictive model for diesel fuel consumption by dual mode rail buses. In prediction, the indicators method in both additive and multiplicative version is utilized. In order to verify prognostic properties and the "goodness" of the model, the data of diesel fuel consumption by railbuses are used. Prediction results generated by indicators method in multiplicative form are presented. The model can be a useful tool in an assessment process of the economic effectiveness of railbuses.

2. OBJECT AND RESEARCH PERIOD

The prognostic model of diesel fuel consumption by railbuses during their effective use was made for eight dual mode railbuses of type X (manufactured by the same producer), which are a homogeneous set of objects in terms of construction solutions. The railbuses are owned by the Lower Silesia Marshal's Office, and operated by a regional rail carrier. Because of a signed statement about preservation of data confidentiality, the name of the rail carrier cannot be disclosed and the marks (inventory numbers) of vehicles have to be changed.

The analysed railbuses include the ones which were taken by the analysed company from another railway company, and the new ones which were bought by the Regional Government, and rented to the analysed company. The vehicles were in possession of the analysed company in different times of their life, as illustrated in *Figure 1*.

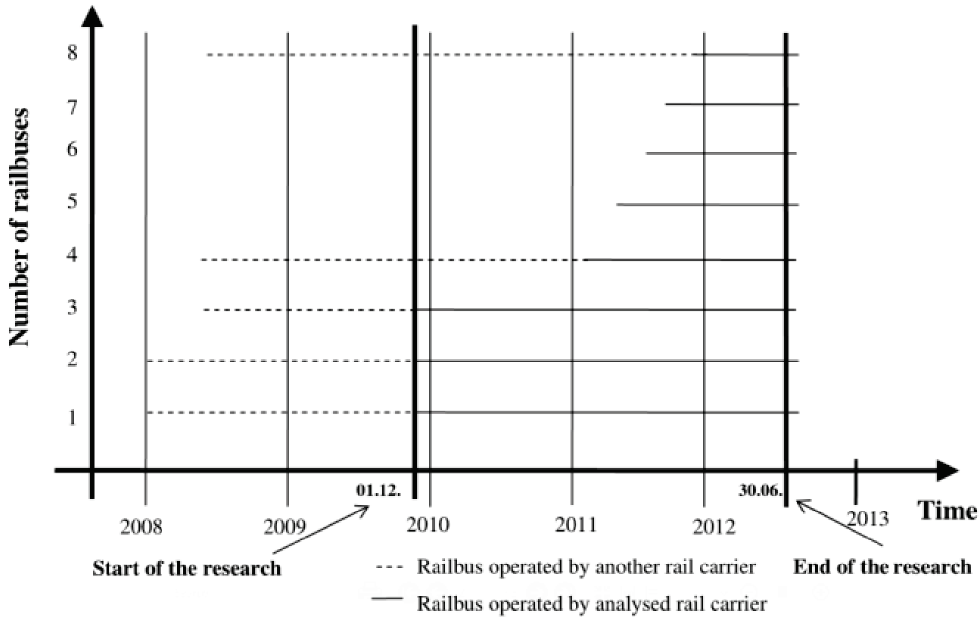

Fig. 1. Time schedule of performed research analysis.

The period of research analysis encompasses 31 months of rail carrier performance, from December 2009 to June 2012.

The data about railbuses' operational process performance are taken from their operational books which are prepared by Department of tram maintenance employees.

The operational book is located in each railbus, and is filled by engine drivers, warehousemen, and service engineers. Such document contains information, including the date of refuelling of the railbus, mileage at the time of the refuelling and the number of litres of tanked diesel oil.

3. DESCRIPTION AND RESULTS OF RESEARCH

Based on eight vehicles, the decomposition of time series of unit diesel fuel consumption was performed. Time series was built by averaging the average monthly unit demand for diesel fuel measured in litres of fuel per kilometre (l/km) (*Figure 2)*.

The percentage share of the trend, seasonality, and irregular (random) components for additive and multiplicative models were studied. The results of the analysis are shown in *Figure 3*.

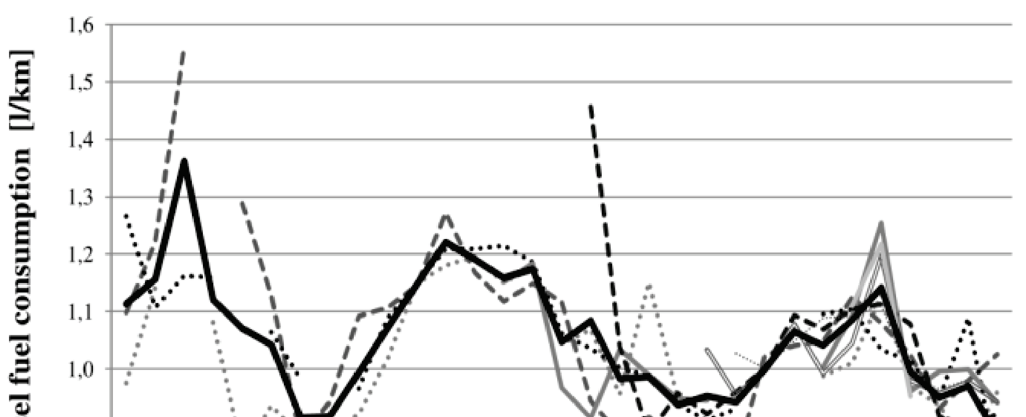

Fig. 2. Data for the analysis of time series of dual mode railbuses and the average calculated from the eight series.

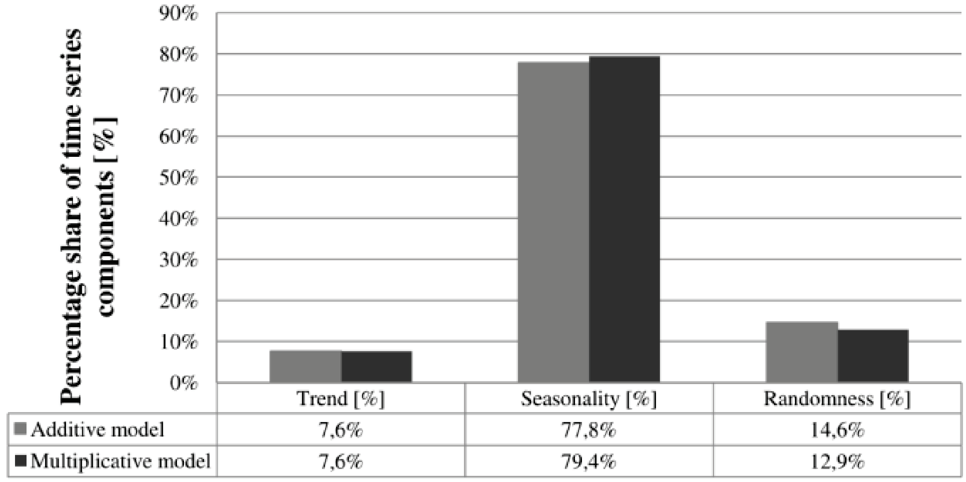

Fig. 3. Comparison of time series structure for average fuel consumption data.

Study findings show that an impact of the trend is small but the seasonality is extremely important. It can also be noticed that there is no difference in presented models in terms of structure - both models have a similar percentage share of randomness. A multiplicative model was selected for further analysis, because the model shows less randomness. Seasonal indicators for the selected model are given in *Figure 4*.

The analysis of seasonal indicators showed

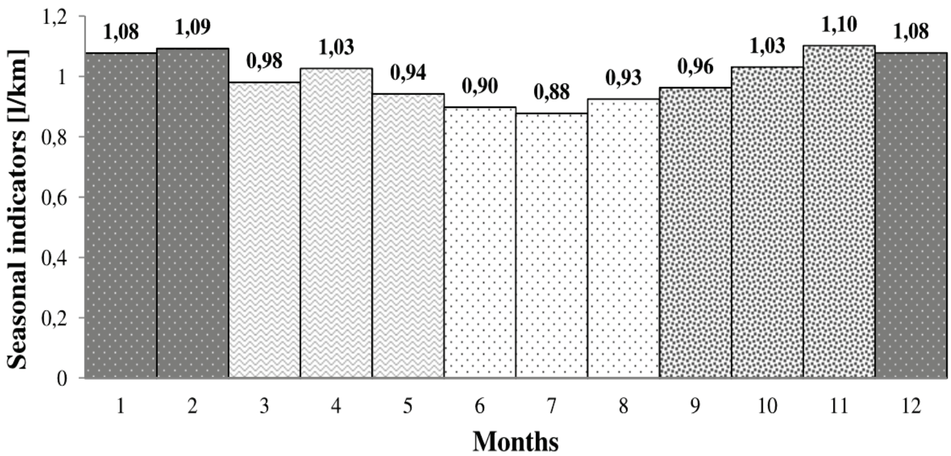

Fig. 4. Seasonal indicators for the multiplicative model.

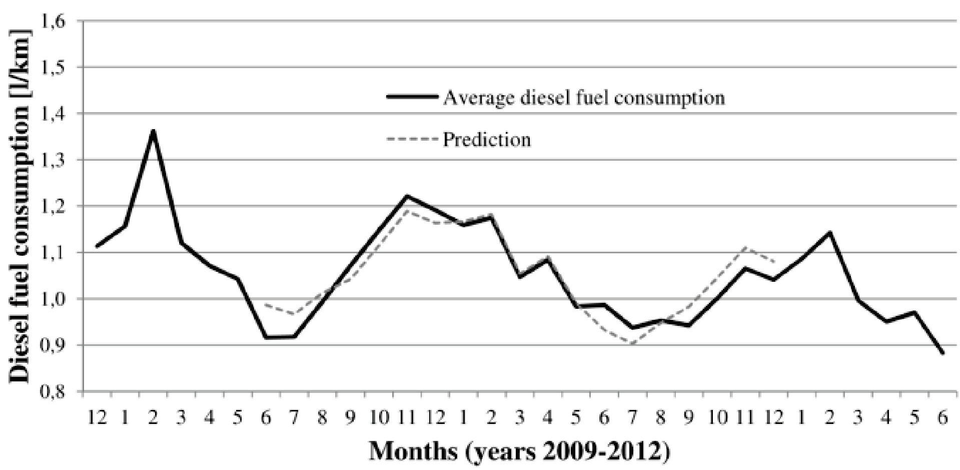

Fig. 5. The graph matching of prognostic model of diesel fuel consumption by railbuses based on seasonal indicators.

higher demand for diesel fuel in the winter months than in the summer ones. On the basis of calculated indicators, a forecast based on the multiplicative model was built.

Level matching of prediction of multiplicative model to the average of measurement data in time series is shown in *Figure 5*. The coefficient of determination R^2, which is 0.8707, which indicates that the level of matching, is relatively high.

Predictions for multiplicative model and adopted mean value (average consumption of diesel fuel by analysed railbuses is equal to1,039 litres per kilometre) are summarized in *Figure 6*.

The big question is whether one can use this model in practice because of a forecast error. A summary of annual relative errors for forecasting model is shown in *Figure 7*. The analysis shows that the mean relative error using the method of seasonal indicators and the multiplicative model is less than 7%, which is quite a good result for industrial predictions.

On the basis of the constructed model, a seasonal component was isolated in order to remove the seasonality from the time series. The result of this operation for the vehicle 1 is presented in *Figure 8*.This operation is intended to find an answer to the question whether a small impact of a trend (about 8%, see *Figure 3*) can be omitted in further analyzes.

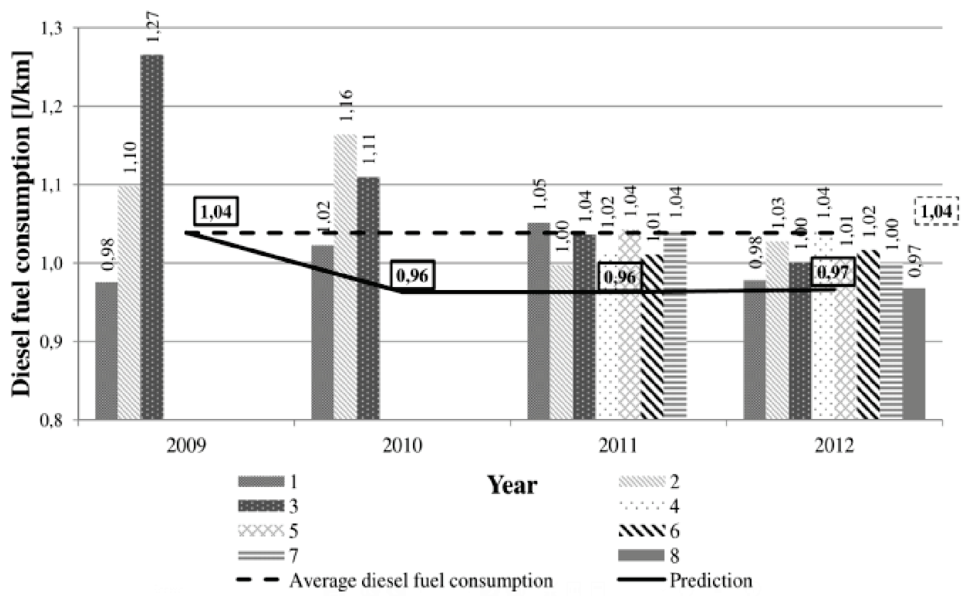

Fig. 6. Statement of average annual consumption of diesel fuel and prediction for multiplicative model.

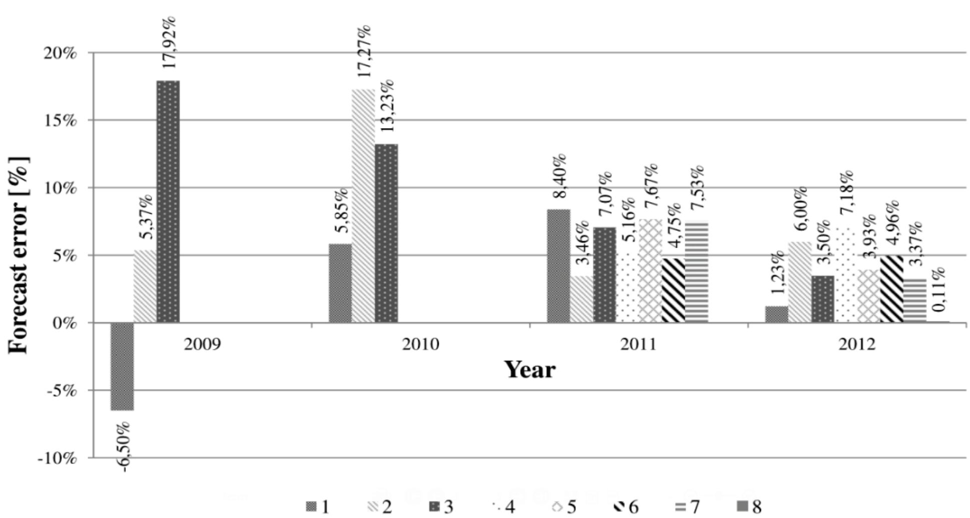

Fig. 7. The forecast error for the multiplicative model.

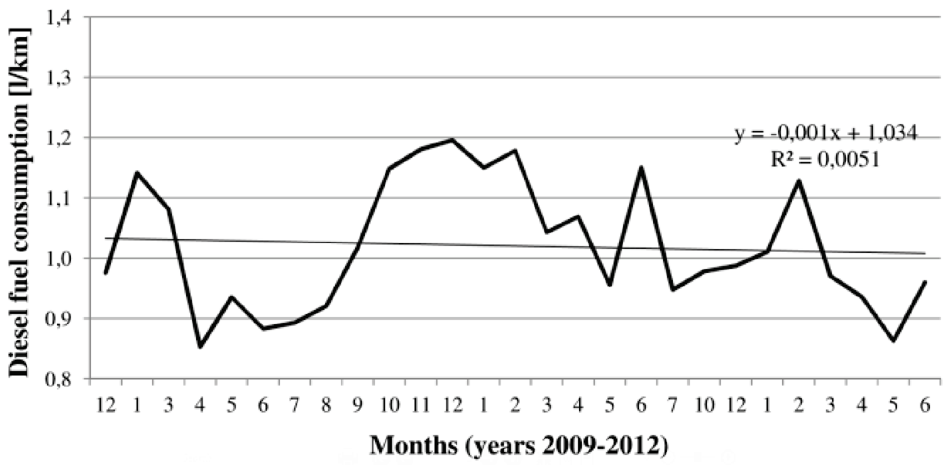

Fig. 8. An example of the series without seasonality for the vehicle 1.

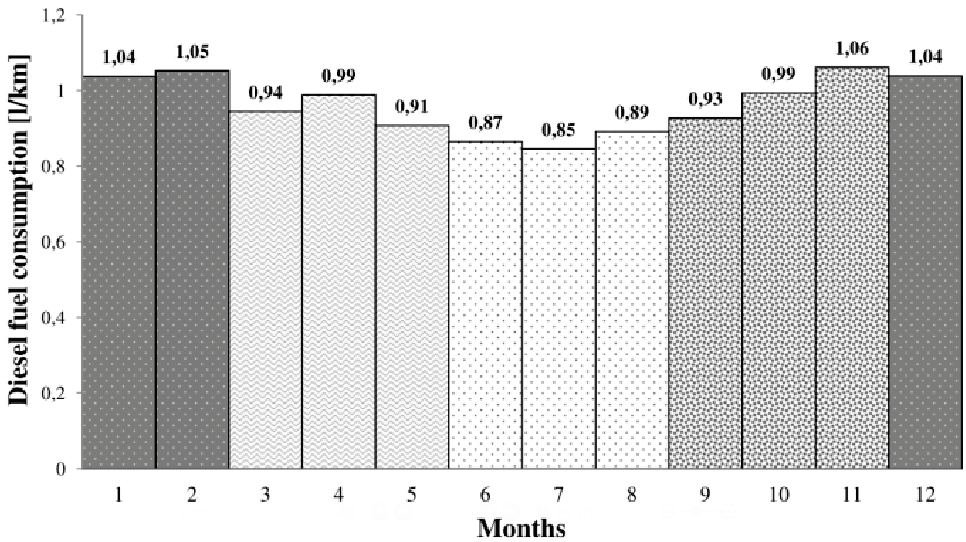

Fig. 9. The annual fuel consumption for particular months.

Performing a regression analysis for the so-built series, one can determine statistical significance of the trend. The results of this analysis are presented in *Table 1*. The trend was determined by an analytical method – to the analysis a linear model in the form of y = ax+b was assumed.

A verification of the statistical significance of the parameter a for each model shows that it is not statistically significant (p>0,05). It follows that during building of prediction, one can omit the trend forecast and replace it with the average calculated from historical data.

The analysis allows to accept for cost analysis, various values of fuel demand for particular months. This difference is due to an impact of weather conditions on a vehicle - as one might have expected the demand in the winter months is higher than in the summer ones (*Figure 9*).

Table 1. The linear regression analysis for the series without seasonality.

Number of railbuses	*Parameter*	*Coefficient*	*Standard error*	*Value-p*
1	a	-0,00096	0,00269	**0,72430**
	b	1,03396	0,04303	0,00000
2	a	-0,00855	0,00297	**0,07802**
	b	1,19853	0,05107	0,00000
3	a	-0,00776	0,00229	**0,23308**
	b	1,17274	0,03668	0,00000
4	a	-0,00474	0,00608	**0,44927**
	b	1,06346	0,05528	0,00000
5	a	-0,01082	0,00836	**0,21797**
	b	1,11452	0,07598	0,00000
6	a	-0,00429	0,00724	**0,56793**
	b	1,03974	0,04913	0,00000
7	a	-0,01404	0,00708	**0,08256**
	b	1,09361	0,04391	0,00000
8	a	-0,18305	0,07711	**0,14090**
	b	1,42475	0,21117	0,02127

4. SUMMARY

The proposed analysis or calculation of seasonal indicators, and performing the prediction of demand for unit fuel consumption by railbuses can be useful to build a general model for fuel demand. The analyses showed that the impact of the length of exploitation on fuel consumption can be neglected because the impact of the trend is small and statistically irrelevant. To calculate the demand for units fuel consumption for each month, the average unit fuel consumption should be corrected with the appropriate seasonal indicator.

There is no need to use seasonal indicators to calculate the annual demand. In this case, multiplying the number of kilometres by the mean value calculated in the analysis is sufficient enough. The constructed method can be used not only to evaluate the effectiveness of railbuses, but also for all kinds of comparisons e.g. to compare ways of economic driving between drivers or to compare the impact of weather conditions on operating costs in different cities.

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