THE PREDICTION MODEL OF ELECTROMOTION SPARE PARTS DEMANDS

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Abstract

This paper describes the design of a simple model and its practical application to predict the need for a spare part. Such a proposed model can be a part of the purchase planning of spare parts within the company's logistics system. The described model was designed for a small enterprise performing service and distributing spare parts. That is why the material flow of spare parts is dominant element in terms of logistics costs in this enterprise. Its management is therefore important for cost optimization, customer satisfaction and market sustainability in a competitive environment. The paper, in its introductory part, provides an overview of similar practical solutions within the research of this topic, but many models are designed to be applied in a global market environment and predict the amount of spare parts needed in different industries. However, these models are difficult to use for the needs of this small enterprise, as the main problem lies in the time of a spare part need rather than its quantity. If there is a need for a specific spare part, which costs several hundred or thousands of euros, but the consumption is only a few pieces per year or more than a year, the time prediction of required spare parts is therefore crucial.

Keywords: Spare parts, prediction, model, forecast methods

1. INTRODUCTION

One of the major logistical challenges in many manufacturing but also in non-manufacturing enterprises is the management of spare parts stock of mechatronic equipment. The problem lies in the great stochasticity of the need for spare parts, and therefore setting the optimal level of these stocks requires a scientific approach. In many cases, it is essential to decide whether it is necessary to keep spare parts in a stock at all or when they are needed and to prepare and store them at right time.

Consumption of spare parts is very specific from a statistical point of view. Time series are characterized by a high proportion of zero values, which causes problems in the calculations and inaccuracies in solutions. This paper presents the predictive model that has been designed for a particular service company of power motion units. The proposed model thus points to a possible solution for a spare parts stock management.

This topic is relatively widespread, and many spare part prediction solutions have been worked out in the world. In the paper from Dyntar and Gros [1], there is introduced a system of spare part distribution management using simulation, including a predictive model of inventory management with regard to the cost of stockpiles of spare parts. Compared to forecasting methods, it has acceptable outcomes and reduced the high commitment of funds. However, this model is limited in situations when the total demanded quantity in all simulated periods is extremely high which may cause unbearable time consumption spent on the simulation run. Thus the simulation run has to be substantially accelerated. The simulation itself is also not able to take into account unexpected and rapid demand changes in a way leading to the risk reduction connected with the stock keeping of such item [1].

In the paper from authors Wang J., Pan, Wang L., Wei, there is introduced the prediction model of aerospace spare parts management for the aerospace industry based on the known forecasting methods, the accuracy of the model is evaluated by using so called the grey comprehensive correlation degree [2]. The results show that different situations influence the accuracy of individual methods, but the universality of the solution is missing.

There are many similar works using the ARIMA and ANN methodologies. Despite these sophisticated methods, which are linked to the concept of high reliability and accuracy, error indicators such as MSE (Mean Square Error) and MAPE (Mean Absolute Percentage Error) show relatively high values. It means that the accuracy of the results is still not sufficient to predict events such as the need or consumption of spare parts.

Probably, this has led authors Qian, Shenyang, Zhijie and Chen to create the predictive model of spare parts consumption using Engineering Analysis Methods [3]. This includes methods such as FMEA (Failure Mode Effect Analysis), FTA (Fault Tree Analysis), FMFRA (Failure Mode Frequency Ratio Analysis) and UFRC (Unit Failure Rate Calculation). However, the calculated results of the accuracy of this model are not known. Nevertheless, the predictive model thus constructed may indicate the direction of creating similar models that are no longer fully mathematical - statistical models. The combination of such solutions with the addition of heuristics satisfies the assumptions of the correct foundations of logistic systems [4-7].

2. THE CASE STUDY DEFINITION

Management of the enterprise, which deals with servicing of specific equipment, distribution and also the procurement of parts, faces the challenge of fast responding to a customer's request. This also requires the management of flow of parts and components (**Figure 1**). This flow is affected by two factors: the length of delivery times and the cost of spare parts. If spare parts orders are sent to a supplier at the moment of need, it extends the time of customer's order releasing. On the other hand, if the parts are ordered on the basis of keeping the stock level or by the PUSH system, the company's funds are bound to a particular spare part stock. In addition, the release time of a spare part is not known in advance (because of irregularity). This is the core of the biggest problem in the concerned company Motor Drive s.r.o. (the name is intentionally altered) that the lead-time of the required spare parts delivery is too long because of the long-time cycle *order to a supplier - delivery from a supplier*. Selected types of spare parts are ordered by the company, as a subsidiary, from the Austrian company Watt Drive GmbH, which produces these parts in its own factory overhead. Due to the time of the parent company's procurement, the process of supplying spare parts is relatively time-consuming. This represents a prolongation of the procurement process for the concerned company [8].

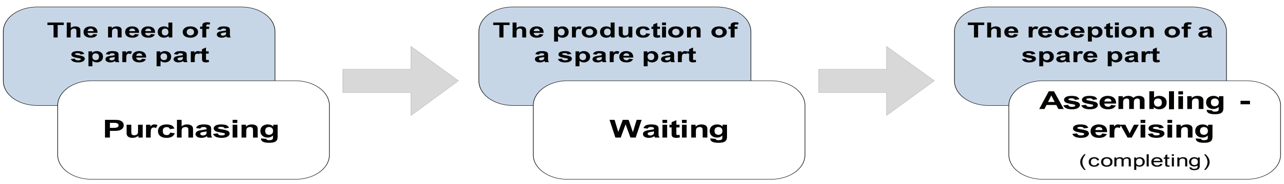


Figure 1 The process of a spare part order releasing [8]

The solution of the aforesaid problem is in the creation of the model for forecasting of selected groups of spare parts needs, and then in use of these results to manage spare part stocks. The result of the forecast is the time of anticipated need for a spare part. By subtracting the time of production of order in the parent company, the concerned company will acquire the time of issuing the order for a spare part. This will enable to shorten the process of spare part order releasing in the concerned company, which would add a value to a customer and increase the competitiveness of the concerned company.

3. CREATION AND DESCRIBTION OF THE FORECAST MODEL

The concerned company Motor Drive s.r.o. mediates spare parts but the company itself consumes many kinds of spare parts. Therefore, it is impossible to provide a comprehensive overview of the prediction of all spare parts needs. In particular, the company needed to apply the proposed model for selected spare parts items that are critical in terms of order, consumption, or price. The basis for the forecast calculation is the data on the need occurrence of particular spare parts from previous years.

The drive units, in which the company services maintenance or repairs, consist of an electric motor and a gearbox. That is why the spare parts consist of two main groups. Further, these parts are classified according to the type groups (e.g. depending on motor power). Finally, there is a selection of two specific spare parts from the two main groups on which the proposed forecasting model will be presented. There are selected spare parts and their consumption in the years 2014-2017 in **Table 1**.

Table 1 Consumption of the selected spare parts in 2014 - 2017 [8]

Electromotor power category "90"	Date (MM.YY)	**1.14**	**2.14**	**3.14**	**4.14**	**5.14**	**6.14**	**7.14**	**8.14**	**9.14**	**10.14**	**11.14**	**12.14**	**1.15**	**2.15**	**3.15**	**4.15**	**5.15**	**6.15**	**7.15**	**8.15**	**9.15**	**10.15**	**11.15**	**12.15**
	Shaft (rotor)	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	1	0	0	0	1
	Winding	0	1	0	0	3	1	0	1	3	1	2	0	1	0	3	0	2	1	0	0	3	1	3	1
	Date (MM.YY)	**1.16**	**2.16**	**3.16**	**4.16**	**5.16**	**6.16**	**7.16**	**8.16**	**9.16**	**10.16**	**11.16**	**12.16**	**1.17**	**2.17**	**3.17**	**4.17**	**5.17**	**6.17**	**7.17**	**8.17**	**9.17**	**10.17**	**11.17**	**12.17**
	Shaft (rotor)	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1
	Winding	1	0	4	0	3	1	0	3	0	0	4	2	1	0	3	0	2	2	0	0	0	1	1	0
Gearbox power category "66"	Date (MM.YY)	**1.14**	**2.14**	**3.14**	**4.14**	**5.14**	**6.14**	**7.14**	**8.14**	**9.14**	**10.14**	**11.14**	**12.14**	**1.15**	**2.15**	**3.15**	**4.15**	**5.15**	**6.15**	**7.15**	**8.15**	**9.15**	**10.15**	**11.15**	**12.15**
	Gearwheel	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0
	Shaft	0	1	1	0	0	0	1	0	0	2	1	0	1	1	2	0	0	0	1	1	0	2	2	0
	Date (MM.YY)	**1.16**	**2.16**	**3.16**	**4.16**	**5.16**	**6.16**	**7.16**	**8.16**	**9.16**	**10.16**	**11.16**	**12.16**	**1.17**	**2.17**	**3.17**	**4.17**	**5.17**	**6.17**	**7.17**	**8.17**	**9.17**	**10.17**	**11.17**	**12.17**
	Gearwheel	1	2	1	0	0	1	2	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	1	0
	Shaft	1	1	1	0	2	1	1	1	0	2	1	1	0	1	0	1	1	1	1	1	0	1	0	1

After the transformation of these events for the need of a spare part according to the time elapsed between the two nonzero requirements, new time series will be created (**Table 2**). These are the subject of forecasting, the result of which is the period of assumption of the demand occurrence for a particular spare part (SP).

Table 2 Elapsed time (in months) between two consecutive periods of a SP need

Electromotor power category "90"	Nr. of occurrence	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**		
	Shaft (rotor)	2	3	7	1	3	4	4	1	11	2	4	6	-	-	-		
	Winding	2	3	1	2	1	1	1	2	2	2	1	3	1	1	1		
	Nr. of occurrence	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**		Average quantity per occurrence:
	Shaft (rotor)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Shaft (rotor)	1
	Winding	1	2	2	1	2	3	1	1	2	2	1	4	1	-	-	Winding	2
Gearbox power category "66"	Nr. of occurrence	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**		
	Gearwheel	2	11	2	8	2	1	1	3	1	3	5	3	4	1	-		
	Shaft	2	1	4	3	1	2	1	1	4	1	2	1	2	1	1		
	Nr. of occurrence	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**		Average quantity per occurrence:
	Gearwheel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Gearwheel	1
	Shaft	2	1	1	1	2	1	1	2	2	1	1	1	1	2	2	Shaft	1, recommended: 2

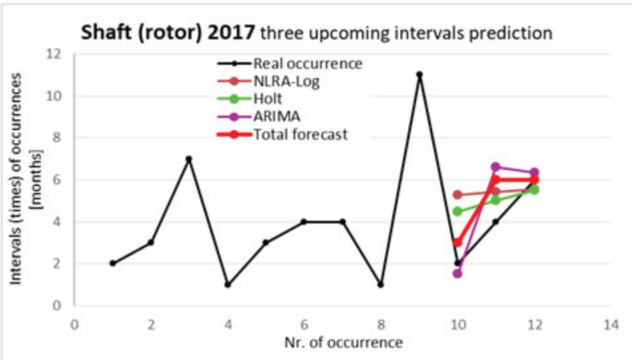
Because the spare parts requirements are stochastic, the choice of forecasting methods will be taken towards the methods that have the character of smoothing of acquired data interval for the occurrence of spare part requirements except ARIMA - this method was chosen according to the general accuracy. For this reason, these forecast methods were chosen: regression analysis, Holt method and ARIMA. The forecast will be carried out in two ways:

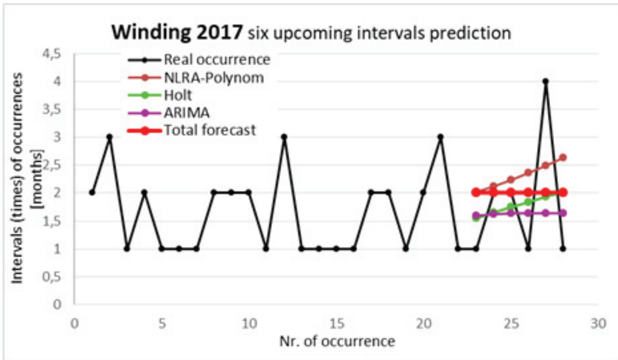
1. From the 2014-2016 data and forecast for 2017 and then the MAPE accuracy indicator and the correlation coefficient will be calculated.
2. From the 2014-2017 data and forecast for 2018. Because the actual values from year 2018 are not known, the MAPE accuracy indicator or the correlation coefficient will be calculated from years 2014-2017.

3.1. Forecast 2017

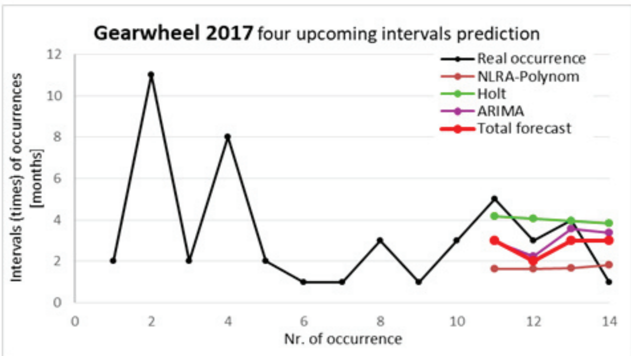
There was also calculated Total forecast from the three aforementioned forecast methods by weighted average (WA). There were used weights according to the MAPE indicator in indirect form. For example: the ARIMA method has the highest accuracy (the lowest MAPE), it means the higher weights at WA calculations. The weights were calculated proportionally and the sum is equal to 1. The forecast results are in the following diagrams and table (**Figure 2** and **Table 3**).

Electromotor power category "90"





Gearbox power category "66"



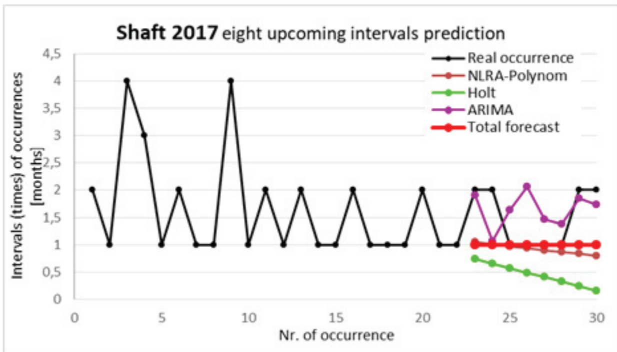


Figure 2 Diagrams of spare parts occurrence forecast of year 2017

The total forecast is rounded to integral numbers. If the predicted occurrence was earlier than real demand, a spare part remains on stock and the next predicted period is ignored until the real demand occurs. If the predicted period was later than real demand, order for a spare part is sent immediately and forecast may be corrected.

Table 3 MAPE indicator of accuracy

Model (method)	Spare p.	MAPE	Spare p.	MAPE	Spare p.	MAPE	Spare p.	MAPE
Nonlinear regression	Shaft (rotor)	89.85 %	Windings	49.78 %	Gearwheel	88.65 %	Shaft	40.79 %
Holt	Shaft (rotor)	72.79 %	Windings	47.60 %	Gearwheel	136.65 %	Shaft	57.45 %
ARIMA	Shaft (rotor)	38.69 %	Windings	34.11 %	Gearwheel	67.34 %	Shaft	42.80 %
Total forecast	Shaft (rotor)	53.70 %	Windings	45.68 %	Gearwheel	75.92 %	Shaft	40.80 %

3.2. Forecast 2018

The rule for total forecast calculation was the same as in the previous case. The forecast results are in the following diagrams and table (**Figure 3** and **Table 4**).

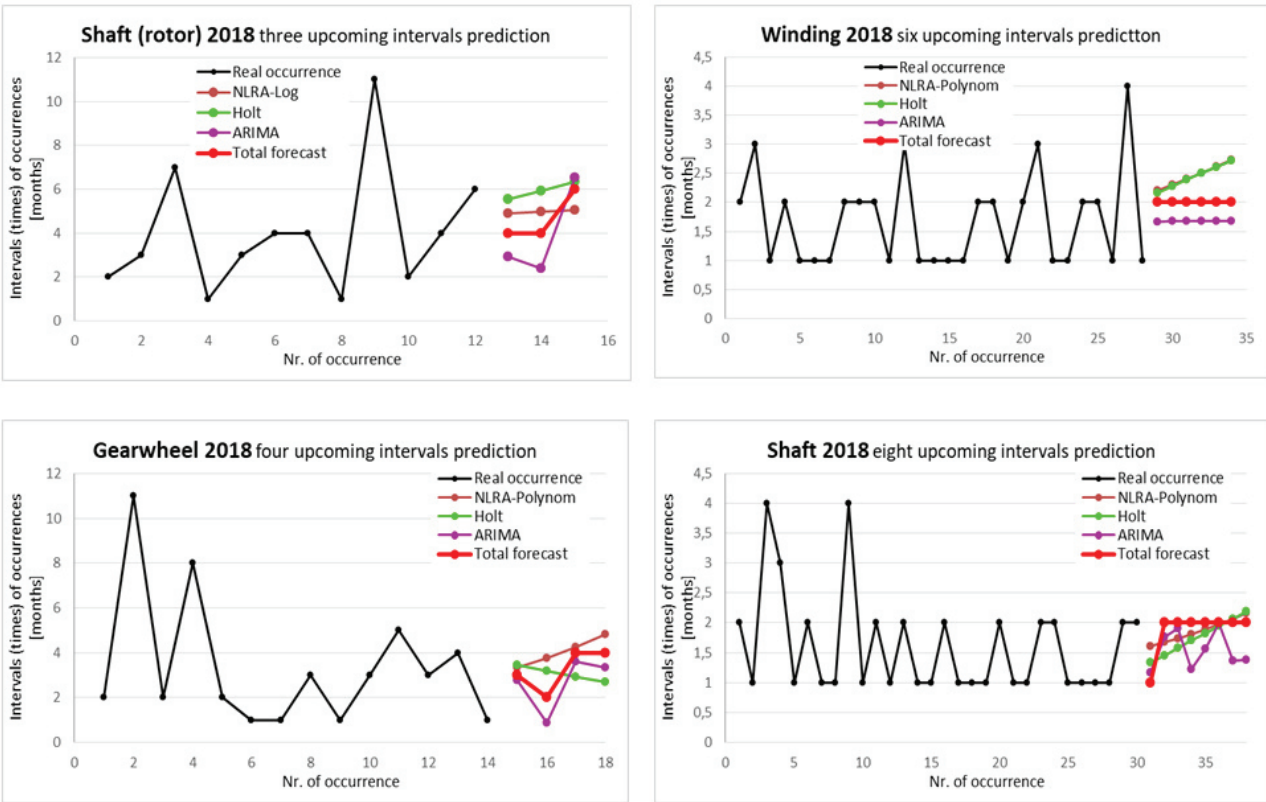


Figure 3 Diagrams of spare parts occurrence forecast of year 2018

The same rule of stock management was applied for the year 2018. In case of predicted occurrence, determined quantity, from the **Table 2**, was ordered to satisfy customer demand.

Table 4 MAPE indicator of accuracy

Model (method)	Spare p.	MAPE	Spare p.	MAPE	Spare p.	MAPE	Spare p.	MAPE
Nonlinear regression	Shaft (rotor)	79.32 %	Windings	45.89 %	Gearwheel	97.26 %	Shaft	43.06 %
Holt	Shaft (rotor)	72.89 %	Windings	48.10 %	Gearwheel	136.79 %	Shaft	47.46 %
ARIMA	Shaft (rotor)	34.47 %	Windings	40.12 %	Gearwheel	77.67 %	Shaft	38.59 %
Total forecast	Shaft (rotor)	40.82 %	Windings	44.44 %	Gearwheel	96.30 %	Shaft	41.84 %

4. CONCLUSION

Although the MAPE error indicators are relatively high at first sight, it is necessary to emphasise the fact that the consumption of the spare part in the company's conditions is almost random, which reflects the randomness of the failures of many devices operating in different operations under different conditions. Therefore, it is almost impossible to find any dependencies linked to past demand for spare parts in the obtained data. If it is possible to map the situation at individual devices at individual customers who need to replace a particular part from time to time, this randomness of the demand could be reduced, by supposing that the regular weariness of the certain part occurs. However, the evidence of spare parts demands for a particular customer to a specific machine needs to be established, but the company does not have this record. Despite the mentioned randomness of demand for spare parts, ARIMA showed the most accurate results from the demand forecast, of selected spare parts in both groups, in average. It has been suggested that the results of this method are considered with high priority for the company.

According to the latest information, this model has brought shorter order release times of spare parts up to 37 %, which the company considers to be a success. However, the concerned company did not bring any information about the amount of financial savings of that model.

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REFERENCES

[1] DYNTAR, Jakub, GROS, Ivan. Spare Parts Distribution System Management. *Transport & Logistics the International Journal*. 2013. vol 13, no. 26, pp.1-9.

[2] WANG, Jun, PAN, Xing, WANG Ligeng, WEI Wei. Method of Spare Parts Prediction Models Evaluation Based on Grey Comprehensive Correlation Degree and Association Rules Mining: A Case Study in Aviation. *Mathematical Problems in Engineering.* [online]. 2018. vol. 2018, pp.1-10 [viewed 2018-08-24]. Available from: DOI: 10.1155/2018/2643405

[3] QIAN, Zhu, SHENYANG, Liu, ZHIJIE, Huang and CHEN, Zhu. Prediction Model of Spare Parts Consumption Based on Engineering Analysis Method. In *GCMM 2016, 13th Global Congress on Manufacturing and Management*, Zhengzhou: Procedia Engineering, 174 (2017), pp. 711 - 716

[4] MALINDŽÁK, Dušan., TAKALA, Josu. *Projecting of logistics systems: Theory and practice*. Expres Publicit, s.r.o., 2005. p. 221.

[5] ROSOVA, Andrea. The system of indicators of distribution logistics, transport logistics and material flow as a tool of controlling in logistics enterprise. *Acta Montanistica Slovaca*. 2010. vol. 15, no. 1, pp. 67-72.

[6] ROSOVA, Andrea. Logistics cots of enterprise, In: *Acta Montanistica Slovaca,* 2007. vol. 12, no. 2, pp. 121-127.

[7] HART, Martin, RAŠNER, Jaroslav, LUKOSZOVÁ, Xenie. Demand Forecasting Significance for Contemporary Process Management of Logistics Systems. In *2nd Carpathian Logistics Congress.* Jeseník: TANGER, 2014, pp. 199-205.

[8] FUTEJ, Martin. *Design of the Prediction Model of Inventory Levels for Malfunction Parts of Electric Drive Units*. Diploma thesis. Technical university of Košice, 2018, p. 62.