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Research paper

Forecasting Service Parts Demand on Automotive Industry Using Artificial Neural Network (ANN)

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Abstract

Production planning in an industry, required precise decisions to made in order to determine the exact amount of product that will be produced to fulfill the customers demand. Demand forecasting is one of the most important factor in production planning process that able to generate precise production decision. The automotive industry like car manufacturer, always need an accurate demand forecast serve the uncertain demand of their products, especially the service parts product, that in fact always has uncertainty in it's demand and frequently causing the manufacturer company lose their profit due to the backorder and overstock occurrence. Several quantitative forecasting method is used to overcome this problem, one of them is devoted for fluctuate or uncertain demand which is single exponential smoothing. The modification of this method generate croston's method with better performance in forecasting intermittent demand. There is also artificial neural network, a machine learning computation method that could work similarly like human brain that also can forecast a non-linear data. This research is aim to compare the performance of the three forecasting method on an object with fluctuate demand. The data was gained from the demand of seven car's service parts in an automobile manufacturer and processed using the three methods to produce forecasting with the most accurate result. The result of the calculation in this research shows that forecasting with artificial neural networks produce the most accurate forecast for the car's service parts demand, outperform the other two methods.

Keywords: *Artificial Neural Network, Demand Forecasting, Manufacturing, Production Planning, Service Parts*

1. Introduction

Manufacturing industry, especially for automotive sector, has a great amount of production to fulfill the customer's demand. Production planning is one of the most crucial process before an automotive industry making their product. One of the most important activity in production planning is predicting the amount of product produced by the company accurately. Many automotive car manufacturer working on this activity by doing demand forecast during their production planning phase. The accurate demand forecasting will help the car manufacturer to decide the amount of precise product to be produced and prevent the impact of uncertainty in demand such as backorder and overstock that will cause a great amount of cost.

In automotive industry, one of the most challenging product to forecast is service parts. Service parts was claimed to have an intermittent demand due to it's uncertain time of needs. Intermittent demand appear randomly, with several time period showing zero demand [10]. Demand that is intermittent is often also 'lumpy', meaning that there is great variability of nonzero values [12]. Service parts with this characteristics of demand will be harder to forecast since the data has much of variability. Several forecasting methods have been developed to overcome this challenge in an automotive industry. One of the most common method to forecast demand in an automotive industry is single exponential smoothing. This method uses weighted moving average of past data as the basis for a forecast and then keeps a running average of demand and adjusts it for each period in proportion to the difference between the latest actual demand figure and the latest value of the average [9]. Another method to forecast intermittent demand is croston's method. Croston's method was developed as the modification of exponential smoothing method. Croston's method is the most frequently used technique for sporadic demand forecasting [7]. Croston's method has prove it's performance to provides more accurate forecasts of the mean demand per period than exponential smoothing [12]. Beside those two methods, there is Artificial Neural Network (ANN), which is a class of generalized nonlinear nonparametric models inspired by studies of the brain and nerve system [10]. This method is well suited for problems whose solutions require knowledge that is difficult to specify but for which there are enough data or observations [13]. ANN models overcome the limitations of traditional forecasting methods, including misspecification, biased outliers, assumption of linearity and re-estimation [8]. Previous studies in different objects have concluded that artificial neural network outperformed the accuracy of other forecasting methods in terms of forecasting fluctuative of intermittent demand [8, 4, 7].

This research aims to analyze the forecast performance and result of artificial neural network by comparing it with single exponential smoothing (SES) and croston's method in forecasting the demand of automobile service parts. The result of this research is expected to be the base to choose better forecasting method in automobile industry, especially for service parts production.

2. Literature Review

Service parts demand can also be said as an intermittent demand with it's lumpiness [12]. Previous study in [12] works on the demand forecasting of the service parts using exponential smoothing

and croston's method with large dataset. It shows that exponential smoothing and croston both are suitable for service parts demand forecast with no significant different on their result. Different service parts research with croston's method, shows that this method is potential for forecasting intermittent demand and has to be modified for it's best performance [11]. Another method that can be used to forecast service parts demand is artificial neural network with it's flexibility on data interpretation [4]. Artificial Neural Network (ANN) method can be used for predicting future situation in linear or non-linear as in the time series dataset, and gave more precision result in predicting the future data [2]. ANN also showed that the network model is able to capture the dynamic non-linear trend and seasonal patterns, as well as the interaction between them [13]. Comparison for artificial neural network method is done in [7] research for forecasting service parts in aviation industry. This study also seperate the data type to be forecasted by the two methods. The research resulted that artificial neural network has better performance in accuracy compared with croston's method. However, artificial neural network performance in forecasting depends on two important criteria which are the network architecture and the training and testing data set.

3. Methods

This research is done by previously collecting historical data from an automobile manufacturing company. Then, seven types of automobile service parts with completely different demand value and pattern were chosen as the research object. Historical data was taken from each of the four service parts demand from January until December 2016 and then divided into 48 periods. The 48 periods of historical demand will be calculated as the input for generating forecast value for 12 upcoming periods with three methods. The first method is single exponential smoothing using Ms. Excel for the calculation. Calculating manually using Ms. Excel require optimum value of alpha (α) which is determined by doing trial and error process within range of 0 until 1. The second method is croston's method which is also calculated by using Ms. Excel. In croston's method formula, there are alpha (α) and beta (β) as the smoothing parameter for the demand forecast which determined by using Ms. excel solver menu. The last method is artificial neural network which is completely different with the other two methods. Artificial neural network is calculated using MATLAB software and the network is built using nntool window in MATLAB. The network used in this research is feed-forward backpropagation network as it stated as the best network types for forecasting with much more efficiency in solving non-linear problems [3]. Historical data value has to be normalized before being put in the MATLAB in order to be calculated with sigmoid bipolar function. The forecast value was generated by 1 hidden neuron layer as its stated as the optimum amount of hidden neuron [5]. Then, each of the service parts demand was trained ten times in order to seek the optimum training amount by looking for it's smallest errors. The best training value then goes to simulation process which would generate the final forecast value for the service parts demand. The parameters that used for the three forecasting methods are explained in table 1.

Table 1: Parameters of The Three Forecasting Methods for Four Service Parts

Service Parts Number	SES	Croston's Method		Artificial Neural Network		
	α	α	β	Hidden Layer	Training	Activation Function
521190M913	0,1	0,1	0,8	1	2	Sigmoid Bipolar (LOGSIG)
521190U920	0,9	0,9	0,1	1	6	Sigmoid Bipolar (LOGSIG)
521590U908	0,7	0,4	0,5	1	10	Sigmoid Bipolar (LOGSIG)
670050K180	0,6	0,2	0,3	1	2	Sigmoid Bipolar (LOGSIG)
521190K951	0,1	0,3	0,2	1	6	Sigmoid Bipolar (LOGSIG)
521190M939	0,1	0,2	0,6	1	8	Sigmoid Bipolar (LOGSIG)
538110K140	0,2	0,3	0,2	1	10	Sigmoid Bipolar (LOGSIG)

After finding forecasting value for the seven types of service parts, the forecast methods must be reviewed for their accuracy by comparing their errors using Mean Squared Error (MSE) and Mean Absolute Percentage Error (MAPE). MSE and MAPE is calculated by finding the difference between the actual value of demand and the forecasted value of the demand. The smaller amount of the MSE and MAPE indicates the more accurate a forecasting method is. This research produce an analysis of those 3 forecasting methods by comparing the results and their performance.

4. Results and Discussion

Forecast calculation resulted differently for the four types of service parts as the difference from the demand data pattern. From the four service parts demand forecasted with the three methods and compared with the actual demand data, it can be seen that each method has their own character. Each service parts also has different demand pattern which makes the service parts forecasting activity in the real industry is hard to conduct. The figures below, shows the forecast result and the actual demand data as the comparison in graphical form. Single exponential method generate a forecast result that formed a slightly different pattern without much of fluctuation. Croston's method forecast demand result data pattern without much difference from single exponential smoothing (SES) but with some better response on increase and decrease demand. Meanwhile, artificial neural network (ANN) produce a better result for the demand forecasting.

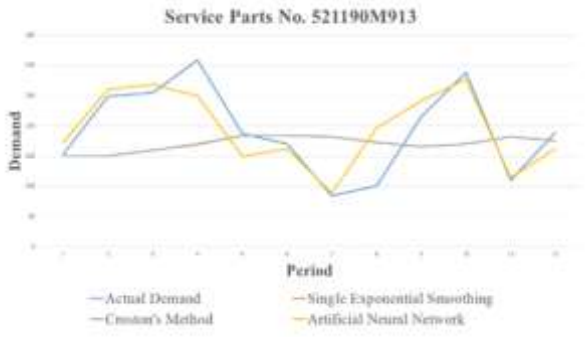

Figure 1: Forecasting Result with ANN, SES, and Croston's Method for Service Parts No. 521190M913.

From figure 1, it can be seen that artificial neural network form a data pattern with almost identical form as the actual demand. In service parts number 521190M913, SES and croston's method formed a similar pattern with almost linear form that is very different with ANN result that formed much variation of the data and resembles the form of the actual demand data. This result shows that ANN can response better in terms of dealing with fluctuate demand forecasting.

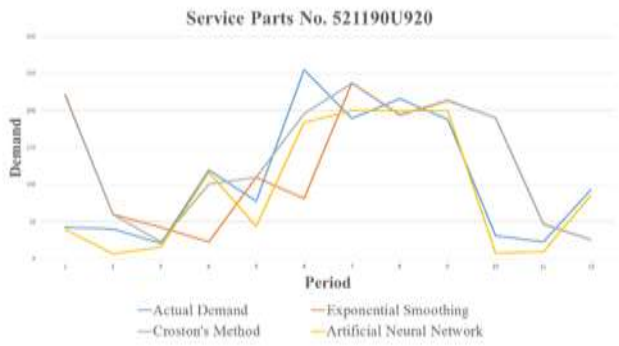

Figure 2: Forecasting Result with ANN, SES, and Croston's Method for Service Parts No. 521190U920.

Service parts number 521190U920 in figure 2, has more various form of data. ANN can keep up almost precisely with the ups and downs of the actual demand and generating a typical data form with the actual demand data with the righ timing. Meanwhile, SES and croston's method forecasting, can also generate a non-linear data that trying to keep up with the actual demand but with late response on the increase and decrease of the data since it's very depending on the previous data.

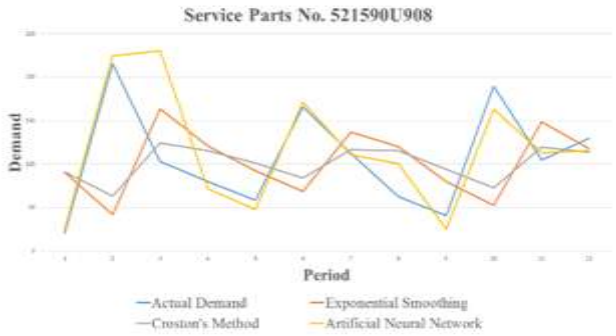

Figure 3: Forecasting Result with ANN, SES, and Croston's Method for Service Parts No. 521590U908.

In figure 3, service parts number 521590U908 demand forecasting using SES and croston's method formed similar forecasting data but cannot predict precisely the time when the data increase or decrease and resulting late response in the forecast. Meanwhile, ANN gives better result compared to two other method as it can predict the actual demand precisely and produce better response time on the increase and decrease of the demand. ANN can predict the upcoming high demand quite precisely for example in period 2, 6, and 10.

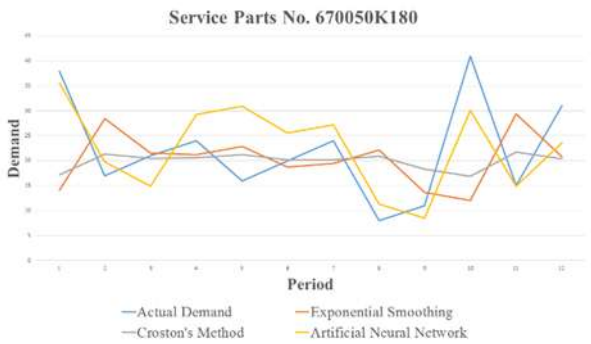

Figure 4: Forecasting Result with ANN, SES, and Croston's Method for Service Parts No. 670050K180.

In figure 4, Service parts number 670050K180 has one high demand increasing in period 10 which can be predicted accurately by ANN. SES and croston's method result differently and still have late response on the ups and downs of the demand. However, croston's method seen to produce more linear data form than SES method which can also reducing the error value of it's difference with the actual demand value. The result for the comparison of the three methods in four different types of service parts shows that Artificial neural network has shown better forecasting performance as it can predict precisely the time when the demand rises or decreases.

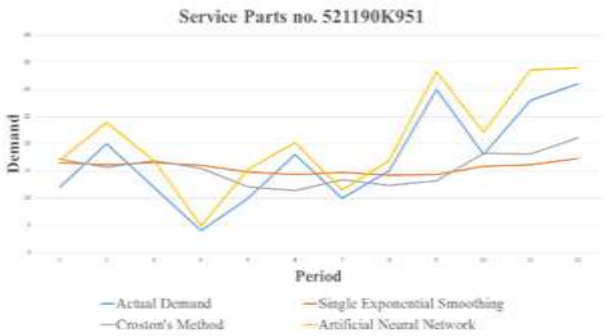

Figure 5: Forecasting Result with ANN, SES, and Croston's Method for Service Parts No. 521190K951.

In figure 5, it can be seen that service parts number 521190K951 has a fluctuate demand with several increase and decrease of it's demand value which clearly can be seen from the graph. ANN can predict the increase and decrease of the demand with high precision on it's period and it's value. ANN perform very well to generate identical fluctuate demand forecasting pattern with the actual demand. Meanwhile, SES and croston's method, did not perform very well on this service parts. They both generate an almost linear result without significant movement on it's data pattern. This resulted in less accurate demand forecasting result of single exponential smoothing and croston's method compared to artificial neural network.

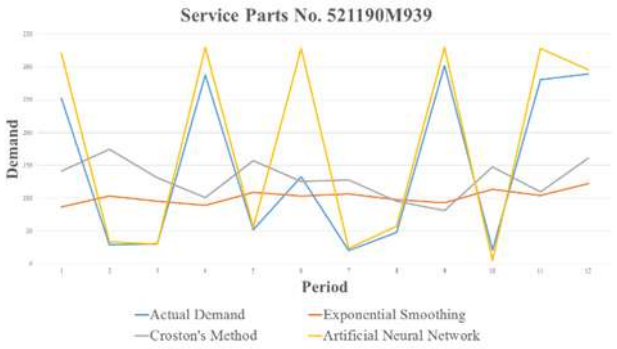

Figure 6: Forecasting Result with ANN, SES, and Croston's Method for Service Parts No. 521190M939.

Figure 6 shows the forecasting result for service parts number 521190M939. The actual demand of the service parts, shows several fluctuation for twelve periods with high value of increase and decrease demand. ANN forecasting, shows that the method can always keep up with the pattern of actual demand, making the method generate high accuracy of forecasting value. SES and croston's method seems struggle to generate high fluctuate forecasting data like ANN and result data pattern that tend to form linear pattern. However, croston's method can form better fluctuate data but with late response compared to SES.

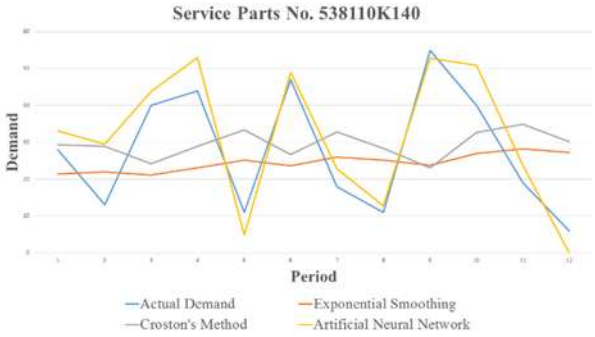

Figure 7: Forecasting Result with ANN, SES, and Croston's Method for Service Parts No. 538110K140.

In figure 7, service parts number 538110K140 has a fluctuate demand data with high increase and decrease data value. ANN perform well to forecast the demand by forming similar pattern with the actual demand and also can predict the data movement precisely. Croston's method generate forecasting result with linear form with small increase and decrease of data value but perform better than SES to generate similar data pattern with the actual demand data.

Table 2: Forecast Error Result Summary

Service Parts Number	Single Exponential Smoothing		Croston's Method		Artificial Neural Network	
	MSE	MAPE	MSE	MAPE	MSE	MAPE
521190M913	6256,66	38%	6253,51	38%	1371,87	17%
521190U920	4071,03	53%	2386,16	49%	717,92	29%
521590U908	6446,80	81%	4854,47	75%	1604,69	26%
670050K180	178,15	51%	122,32	43%	44,51	27%
521190K951	70,04	56%	62,18	52%	12,92	22%
521190M939	9710,20	136%	11733,71	177%	11557,30	63%
538110K140	301,17	86%	339,35	104%	53,66	36%

Another quantitative evaluation on forecasting result can be done with error evaluation using MSE and MAPE. Table 2 shows the value of each forecasting method error in seven types of service parts. Artificial neural network's error both in MSE and MAPE has the smallest value among the three methods which indicate that artificial neural network has the best performance in forecasting service parts with the most accurate result. Croston's method has the second best forecasting performance, outperform single exponential smoothing. However, the difference between croston's and single exponential smoothing result is not much difference from artificial neural network. Croston's method produce better forecasting result than single exponential smoothing without significant differences. ANN gives the most accurate result and the best forecasting performance with smallest value of error since the method can response to sudden increase and decrease of demand value.

After finding forecasting value for the seven types of service parts, the forecast methods must be reviewed for their accuracy by comparing their errors using Mean Squared Error (MSE) and Mean Absolute Percentage Error (MAPE). MSE and MAPE is calculated by finding the difference between the actual value of demand and the forecasted value of the demand. The smaller amount of the MSE and MAPE indicates the more accurate a forecasting method is. This research produce an analysis of those 3 forecasting methods by comparing the results and their performance

5. Conclusion

Service parts demand has been hard to forecast due to it's uncertainty, yet it's not impossible to find the best method to solve this problem. Using three forecasting methods, the service parts demand can be predicted, resulting different types of performance. The comparison analysis has shown that artificial neural network generate the most accurate forecast compared to single exponential smoothing method and croston's method by calculating demand of seven different types of service parts. ANN also gives better timing in response the increase and decrease of the fluctuate and intermittent service parts demand. The result comes from the analysis of forecast error of the three forecasting method and also the result value compared to the actual demand value of each method in each service parts. However, these result do not directly make ANN as the best method to be used in real industry. The trade-off from it's good performance and it's accuracy is the variability of it's parameter that will resulted in different value and the complexity of it's calculation. Single exponential smoothing and croston's method has less complexity and easier to calculate, yet as the result from this study show that these two methods generate less accurate forecast result compared to artificial neural network method.

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