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Research paper

Forecasting Military Vehicle Spare Parts Requirement using Neural Networks followed by Application of Tacit Knowledge

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Abstract

Spare parts forecasting can generally be divided into two approaches that are deterministic and stochastic. Deterministic forecasting is often predictable and often comes from production while stochastic forecasting is often adapted in areas of uncertainties. Even though there are many forecasting techniques available nowadays, the accuracy is often questionable as there may be possibilities of errors especially when it involves inconsistent lumpy demands. The aim of this paper is to look into existing theories with the intent proposal of an alternative method in adapting neural networking where demand patterns from the various external sources would be captured and use to provide an improved prediction method. Therefore, adapting this alternative method would increase the accuracy and confidence level compared to the existing forecasting techniques. This research would also include obtaining tacit knowledge in the purchasing process that is often considered after obtaining the forecasted results prior to the purchase of spares.

Keywords: *Forecasting; Neural networks; Stochastic approximation; Tacit knowledge*

1. Introduction

The Malaysian Army has large fleet of vehicles, weapon systems, electronic items and many others that need maintenance. Vehicles and equipment are purchased through various sources either locally produced or overseas. Priority of sourcing would be given to local defence industries but nevertheless it is limited to the capabilities of respective defence industries. Hence, the vehicles and equipment would have to be purchased from overseas either directly or through a local agent and normally there would be separate contracts engaged for the purchase of vehicles and equipment and spare parts.

Whilst vehicles and equipment are being kept, the operational availability of the assets should be of high state of readiness and to achieve this would require close monitoring and collaboration with respective suppliers to ensure smooth flow of spare parts requirement to fulfil the organisational goals. In this aspect there seem to be a different perspective in comparison with logistics and supply chain. While logistic looks into processes like transportation, purchasing, warehousing and distribution, supply chain would be concern over the flow of materials and services from the point of origin right up to the point of consumption.

In the Malaysian army, there are three types of vehicle that are: (1) Armoured vehicles such tanks and Armoured Personnel Carrier. These types of vehicle would normally have at least three separate systems namely automotive, weapon and communications; (2) Soft skin vehicles that are military trucks, land rovers and other land vehicle and; (3) Engineering vehicles such as tipper, bulldozer and bridging vehicles. The vehicles would be under the administrative command of the field units.

The general responsibility for maintaining the armoured and other land vehicles would be under the care of the Royal Electrical and Mechanical Engineers (REME) Corps and the spare parts required would be handled by the Royal Ordnance Corps (ROC). However, specifically for the Engineering vehicles, the maintenance is handled directly by the Royal Engineers Regiment.

Spare parts are needed in order to ensure all vehicles are to be at the highest operational state of readiness. The categories of spares could further be generally classified into: (1) Servicing items that require scheduled maintenances and; (2) Those required for repairs. For scheduled maintenance, forecasting would be deterministic, while for repairable items, forecasting trends may be lumpy and stochastic or increased complexity in provisioning. Forecasting vehicle spare parts would generally fall either into independent (stochastic) or dependent (deterministic) [1][2] .

Forecasting is an initial approach taken prior to the purchase of inventories. The four principles of forecasting: (1) Forecasts are wrong, (2) Forecasts tend to be increasingly inaccurate the further to the future it is estimated. Estimates of requirement five years ahead may not be as accurate as estimates for the current year and basing over historical data would be better, (3) Aggregated forecast for product or service groups tend to be more accurate, and (4) Forecast cannot be a substitute for derived value [1]. Though the first principle highlights the danger of forecasting going wrong, this often leaves no choice but to adapt as there is no other better way or manner or method to address the matter. Many organisations tend to fall back to actual requirement to ensure more accuracy and to minimise any error leading to wastage.

2. Background of Study

2.1 Background of Organisation.

The Malaysian Armed Forces have the vision to be a credible Armed Forces and their main mission **is** to protect the sovereignty of the nation and its integrity towards the national interest as a whole. The Malaysian Army being part of the Malaysian Armed Forces has the role of protecting the security and national sovereignty of the nation in support of the MAF role and also to enhance battle readiness to counter any sort of threat [3]. In order to fulfil these roles, the supply chain for the Malaysian Army capital assets have to be planned well ahead for sustainability, robustness and able to withstand any and all situations.

2.2 Logistics Role.

The supply chain for the Malaysian Army is handled by the logistics organisation namely the Royal Service Corps, the Royal Ordnance Corps and the Royal Electrical and Mechanical Engineers Corps together with the civilian counterpart at the Ministry of Defence Headquarters mainly the Procurement Division. In order to be able to provide efficient and effective logistics support and in fulfilling the roles, planning and developing a sustainable supply chain model are necessary. Logistic management has always been a challenge especially when it is handled by different organisations and all this need thorough coordination and cooperation so as to solve any arising issues. However in maintaining capital assets, the role of the Royal Ordnance Corps is to source and supply required spares needed for maintenance by the Royal Electrical and Mechanical Engineer Corps. The Headquarters Army Logistics Command is the main formational headquarters that is responsible for the overall coordination of the Logistics support. Headquarters Army Logistic Command consists of the Service Corps Group, Royal Ordnance Group and the Royal Electrical and Mechanical Engineer Group. These Groups are to help with the coordination of all logistics requirement and direct respective logistic units.

2.3 Sustainable Supply Chain.

It is important to plan ahead in modelling the supply chain to be resilient with continuous updating and able to adapt all types of situation and overcome all sorts of risks of the global supply chain. The Army has the responsibility to carry out missions to ensure continuous sovereignty and to fulfil this role, it has to carefully plan, strategically align policies, appreciate all potential risks and ensure sustainable logistics support for all the troops. To enable these tasks, there arises the necessity to establish a sustainable supply chain for the Malaysian Army as a whole.

2.4 Logistics and Supply Chain.

In order for the Army to sustain its roles and task, a crucial area that needs continuous sustainment would be the Logistics together with the supply chain. Capital assets require continuous maintenance and herein raise the importance of establishing a robust supply chain model that would be able to sustain in different possible scenarios. The importance of planning ahead the organisational supply chain as a strategic differentiator in establishing competitive advantage and examples of market leaders refining their supply chain and adding value and exploring ways to venture into boundaries for further enhancement and performance.

2.5 Supply Chain Risks.

One of the crucial areas of the supply chain is risks. Common risks in the supply chain known as the bullwhip effect of which the slight variances from demand increases from downstream to the upstream of the supply chain [1]. This effect indeed may cause supply chain disruption if not address appropriately. The supply chain also poses other unexpected risks such as the 2011 Japanese earthquake that caused temporal operational shutdowns of manufacturing plants causing disruption to the global supply chain [4]. Numerous risks exist in the supply chain that may cause disruption and it takes careful planning to establish a resilient and sustainable supply chain model.

2.6 Contemporary Concepts.

Coupling with contemporary concepts such as lean management, just-in-time, vendor managed logistics and third party logistics, there is a growing need to look into the areas involving planning and establishing strategies in form of contingencies so as to establish continuous flow of goods and services that addresses all sorts of disruptions that may occur in the future. Lean is popular as it introduces the ability for an organisation implementing the principles to manage efficiently in a cost saving manner [5]. However, lean is quite difficult to implement in the situations where demands are uncertain and long lead time to obtain spares especially when they are from overseas and therefore they require the organisations to keep some buffer stocks to cater for uncertainties.

3. Forecasting Function, Methods and Issues

3.1 Forecasting Function.

Forecasting is a process that looks into many aspects rather than depending on calculations based on models. Figure 1 illustrates the extended needs of the forecasting functions. So upon obtaining forecasting results, there should be further consideration on other factors such as financial constraints, possibility of supply chain being disrupted, environment, changing market demand and many other factors.

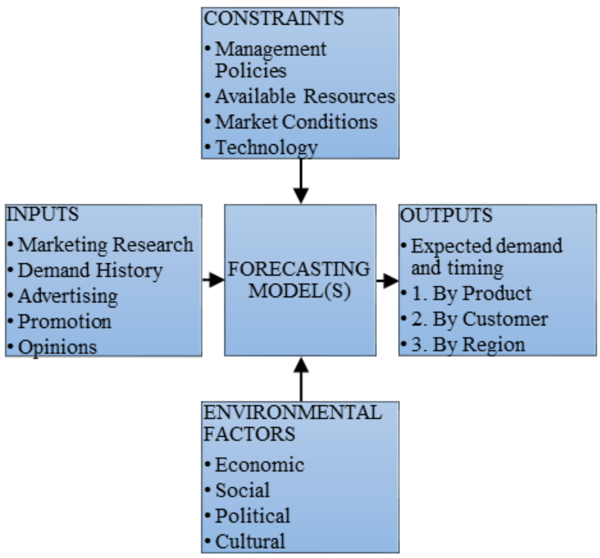

Figure 1: Forecasting Function [6]

3.2 Forecasting Methods.

Most forecasting models require historical data to generate the forecast results. Forecasting methods can be divided into qualitative and quantitative. Summary of methods is shown in Figure 2.

Qualitative method comprises of techniques for time series analysis and causal relationship adapting linear regression methods. Meanwhile quantitative methods includes market research, Delphi method and sales force planning [1].

3.2.1 Naïve Forecasting.

This method uses previous demand value as a basis to perform forecasting for the existing period.

3.2.2 Moving Average.

Moving averages uses a series of recent historical data in the forecasting technique as shown below:

$$F_{t+1} = \frac{D_t + D_{t-1} + D_{t-2} + \dots + D_{t-n+1}}{n} \quad (1)$$

Where

$F_{t+1} = Forecast\ for\ period\ t+1$

$D_t = Actual\ demand\ in\ the\ period\ t$

$n = Total\ number\ of\ period\ in\ the\ average$

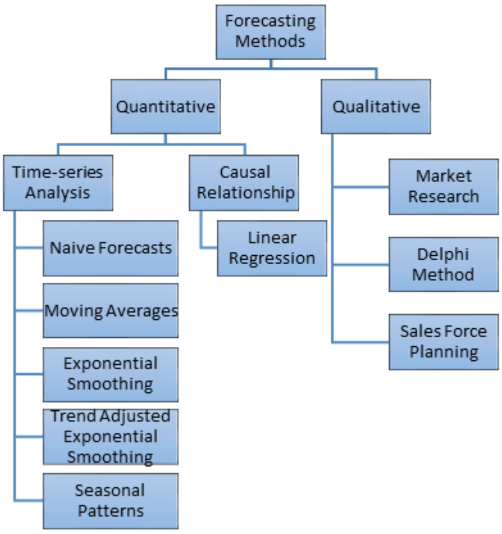

Figure 2: Forecasting Methods [1]

3.2.3 Weighted Moving Average.

This method provides weightage values in the time series data and total weightage value amounts to 1.

$$F_{t+1} = 0.6D_t + 0.25D_{t-1} + 0.15D_{t-2} \quad (2)$$

Where

$F_{t+1} = Forecast\ for\ period\ t+1$

$D_t = Actual\ demand\ in\ the\ period\ t$

3.2.4 Exponential Smoothing.

This forecasting method is based on previous forecast with a percentage varying between previous forecast and the actual. The alpha is a constant used in this formula.

$$F_{t+1} = \alpha D_t + (1 - \alpha) F_t \quad (3)$$

Where

F_{t+1} = Forecast for the period t + 1

α = Smoothing parameter for the average (value between 0 and 1)

D_t = Actual demand for the period t

F_t = Forecast for the period t (previous forecast)

3.2.5 Trend adjusted exponential smoothing.

This technique includes the trend component in the exponential forecast.

$$A_t = \alpha D_t + (1 - \alpha)(A_{t-1} + T_{t-1}) \quad (4)$$
$$T_t = \beta(A_t - A_{t-1}) + (1 - \beta) T_{t-1}$$
$$F_{t+n} = A_t + nT_t$$

Where

A_t = Exponential smoothed average for the series in period t

T_t = Exponentially smoothed average of the trend in period t

α = Smoothing parameter for the average (value between 0 and 1)

β = Smoothing parameter for the average (value between 0 and 1)

D_t = Demand in period t

F_{t+1} = Forecast in period t for demand in period t + 1

n = Number of periods in the future that the forecast is for

3.2.6 Multiplicative Seasonal Index.

This technique takes seasonal factors into consideration and are multiplied based on the average demand estimates to generate a seasonal forecast.

3.2.7 Seasonal Index.

Here the average demand percentage for a particular season is considered.

3.2.8 Linear Regression.

This is a type of qualitative forecasting adapting the causal methods. This technique uses statistics to express forecast variable of which is a linear function of variables.

$$Y = a + bX \quad (5)$$

Where

Y = Dependent variable or forecast

X = Independent variable

a = U-intercept of the line

b = Slope of the line

3.2.9. Qualitative Forecasting.

Qualitative forecasting includes three popular methods which are market research, Delphi method and sales force planning. Market research is a systematic way to measure the interests of consumers on products or services by gathering data through surveys. The Delphi method uses a number of people who are experts forming teams aimed to develop consensus in the forecasting. Sales force planning involves gathering information in the form of opinion from the sales teams and leaders of a particular product or group of products.

3.3. Errors in Forecasting.

Regardless of forecasting models adapted, there is a high possibility of errors. Model selection itself may produce error. Though same historical data is inserted, models may produce results that differ. Therefore it is necessary to further evaluate the results as to minimise forecast errors. Forecast error is seen as the differences between the forecasted results and the actual demand. The methods of measuring errors could be further extended in producing the cumulative sum, mean square error, standard deviation and mean absolute deviation. An example of a simple method to measure forecast errors is as shown below:

$$E_t = D_t - F_t \tag{6}$$

Where

$E_t = forecast\ error\ for\ period\ t$

$D_t = actual\ demand\ for\ period\ t$

$F_t = forecast\ for\ the\ period\ t$

3.4 Inventory Carrying Cost.

The military as an organisation would have desired goals to have the vehicles at high operational availability. To ensure this desire is fulfilled, it is necessary to hold some amount of buffer stocks to avoid stock out resulting the overall rate of vehicle mobility. This decision would further escalate the cost to maintain the inventory [4]. Manpower and space would be needed here and this would be the example of inventory carrying cost that is associated to the decision to hold buffer stocks.

3.5 Managing Suppliers.

Another way to manage is to pass the responsibility to the suppliers to hold the stocks but this could only be done to the local manufacturers provided they are willing to assist. Toyota for example is very particular in choosing their suppliers and appears to be a lengthy and careful process as they believe in long terms relationship which are mutually beneficial. They also perform contingency planning to ensure any case of supply disruption could be overcome in a short duration [7].

3.6 Forecasting for New Vehicle.

New vehicle purchases may have problems in forecasting spare part requirements as it lacks historical data. As vehicles are new, the reliability of vehicles would be high and requirements may be in the form of servicing items. Among methods to address this issue are: (1) Obtain data from market/supplier; (2) Estimate based on similar vehicles; and (3) Set exponential smoothing constant to 0.5 or higher at the initial stage if this method is being used [8].

3.7 Collaborative Forecasting.

Collaborative forecasting requires data from multiple sources. The goal for this technique is to reduce forecast errors and is suitable for complex processes. However in order to succeed, it may require sharing of data from multiple parties, great coordination among departments, compromising as well understanding between multiple parties [8]. Hence this would be an identified area to be further research.

4. Neural Networks and Tacit Knowledge

This proposal involves adapting the neural networks technique to substantiate the forecasting results in collaborative forecasting. The field of neural network was found to have evolved over the years. Neural network involve pattern recognition leading to better prediction for decision making [9]. As forecasting result from the selected model produces results that are error prone, adapting neural networks is an improved approach to increase decision making confidence level through graphic comparison of result from multiple sources.

This approach however, requires collaborative forecasting. Data from multiple sources such as supplier, other organisations, market survey and other methods would be obtained through electronic means involving the data abstraction. Subsequently, based on the data obtained from various sources would be graphically presented for comparison purposes. There would be some processing parameters formed in order to adjust the graphical image according to the requirement comparison.

The study would involve developing the methods to obtain data externally, processing and transforming to graphs and comparing with the forecast requirement to supplement decision making. This method would be helpful to overcome the worrying errors that may raise from the forecasting results. To date, very little literature relating forecasting adapting the neural networking approach could be found.

The neural networking process in determining the demand requirement would be further taught in depth and here tacit knowledge would usually be applied. Forecasting results include from neural networking would be refined into and factors such as economic and financial situation, threat perceptions and politics are examples of situation that may have an immediate impact on the decision of purchase.

Upon completion of forecasting and neural network analysis, the final process recommended is to perform an analysis based on political, economic, social, technical, environment and legal (PESTEL) framework. An extended requirement also include the application of tacit knowledge as part of this analysis process. Here would require a study on how to apply tacit knowledge based on experienced expertise particularly purchasing managers from the industries into the process. The overall processes involve is shown in Figure 3.

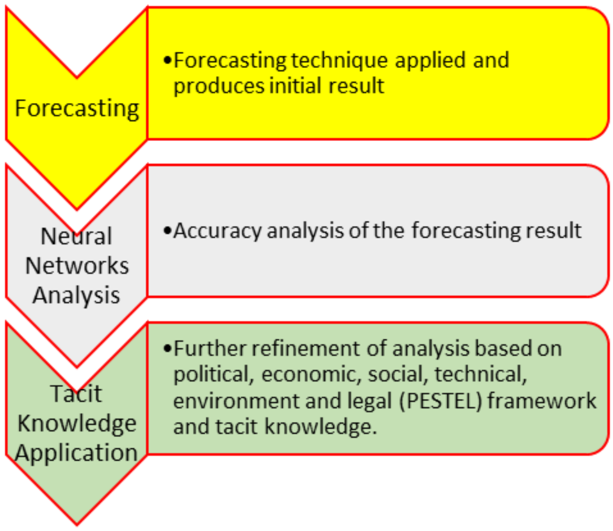

Figure 3: Proposed Forecasting Process

6. Conclusions and Future Works

In summary based on the forecasting functions, forecasting models appear to be supplementing the quantity to buy in purchasing decision making processes. This proposal involves the secondary stage upon obtaining the forecasted result based on the selected model to make graphical comparison through the neural networking techniques from other approaches. Other future work seen in forecasting would be to develop decision making model based on the tacit knowledge usually adapted by purchasing managers based on their experiences to counter check forecasting result prior to decision making on the quantity to buy.

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