# Optimization of Spares for Wind Turbine Blade Manufacturing

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## Comments by the Faculty

This paper presents the work carried out by Dheeraj Shetty at a major Indian wind power equipment manufacturing company. The name of the company being referred in the paper has not been mentioned as per the instructions from the company for the purpose of confidentiality. The company under study is one of the world's largest wind turbine manufacturers in terms of cumulative installed capacity.

Well-coordinated and optimised service and maintenance strategies are essential for the success of any manufacturing firm. One of the key strategies that influence the success of the manufacturing firm is related to spare parts. A lot of research has been done regarding the optimization of spare parts, which is evident from the copious amount of literature that is available related to the subject. Although the challenges pertaining to handling and storage of spares parts are not in any way unique for wind turbine blade manufacturing, every organisation's setup, processes, priorities etc., are different and hence every organisation's issues need to be addressed inimitably by diligently using the appropriate theory/model/ framework. The study presented in this paper is an endeavour in solving the issues related to spare parts handling and logistics of a wind turbine blades manufacturing company.

Adopting a case study approach, the work presented in this paper has first identified and categorised all the spares parts. Subsequently with help of the historical data, the pattern of usage of spares has been constructed along with analysis of the inventory based on parameters like frequency of issue, annual consumption, criticality etc. With guidance of the experienced employees of the company and based on the data collected and analysed, Dheeraj Shetty has developed an inventory management system to ensure that the demand for all the critical spares in the plant is met with limited (or no) downtime and at the same time to make sure that the unnecessary costs incurred by holding on to the less important spares are reduced.

The work presented in this paper is well planned and based on many well established management concepts. Although the effectiveness of the inventory management system and other recommendations proposed by Dheeraj could not be fully tested for the want of time and resources, it gives fair account of specific issues related to spares management.

**Mohamed Minhaj**

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## Introduction

### *Company profile*

**ABC-Wind Energy Major** *(name of the company has been disguised to maintain confidentiality)* is an Indian wind power equipment manufacturer. It is one of the world's largest wind turbine manufacturers in terms of cumulative installed capacity. The company's global spread extends across Asia, Australia, Europe, Africa, North and South America. Currently it has over 21,500 MW of wind energy capacity installed in over 30 countries, with a workforce of over 13,000.The Company's core business area is wind turbine manufacturing and it is also a turnkey wind power solutions provider.

It is globally integrated, with production facilities in India, USA, Germany and Portugal catering to key markets. The Group's current annual manufacturing capacity stands at 5,900 MW. The company is currently working on a technology with strong focus on increasing the energy yield of wind turbines at a given rating by improving aerodynamics and applying larger rotors.

## Objective

The main objective of this study was to implement a better inventory management system by ensuring that demand for all the critical spares in the plant is met with limited(or no) downtime and at the same time to make sure that the unnecessary costs incurred by holding on to the less important spares are reduced.

## Methodology

The methodology employed involved the classification of spare parts into different categories based on the corresponding machines which used these spare parts and then development of the inventory control systems for the same. Finally, based on the study conducted a few recommendations for better optimization of spares inventory were suggested.

a. Identification of spare parts

b. Usage pattern analysis

c. Inventory analysis

d. Forecasting of spare parts requirement

e. Development of inventory control systems

f. Recommendations

### *Identification of Spare Parts*

The first and the most critical component of the study is to identify the different spare parts being used in the plant at different stages of operation. Generally, there are several spares being used at different levels of operation in a plant but most of the time companies keep track of only a few of the more prominent (expensive) ones and hence several other spares which could be important for various purposes take backstage. The primary motive behind classification of spare parts is to get an all-round idea on the different set of spares and their corresponding categories (machines), which serves as a platform for further analysis.

In this case the spare parts are majorly classified into 4 categories: Plant and Machinery, Hand Tools, Consumables and Preventive Maintenance. There are over 1500 spares classified under these four categories.

### *Usage Pattern of Spares*

After the classification of spares into different categories the next step followed here is the usage pattern study for these spares. For this purpose the last 4 year's consumption pattern of different spare parts data was collected from the maintenance department and from that data the more frequently consumed spare parts were identified and classified.

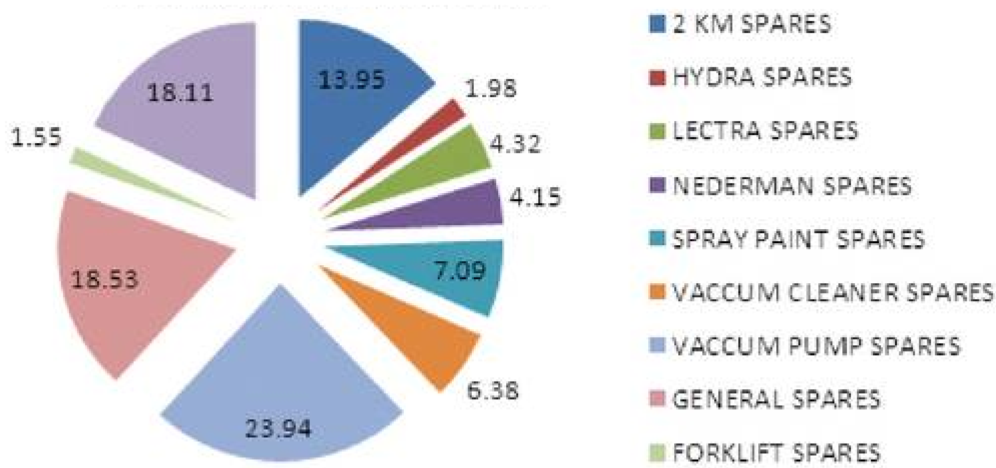



***Figure 1 : Spares Annual Contribution (In %)***

### *Inventory Analysis*

Based on the study conducted by Manuel D. Rossetti (Ph. D., University of Arkansas) and Joffrey Collignon on-***Techniques for Inventory Management***, it can be concluded that for successful spare parts management, it is essential to analyze the spare parts inventory based on various characteristics such as the frequency of issues, the annual consumption value, the criticality, the lead time and the unit price. This is essential as it would not be possible to exercise the same type of control for all items and it may not really be effective. Inventory analysis aids selection of policies for selective control.

**Objectives of Inventory Control**

1. To keep the investment on inventories to the minimum.
2. To minimize idle time by avoiding stock outs and shortages.
3. To avoid carrying cost.

Some of the most prominent inventory analysis techniques used here are as follows.

(1) ABC Analysis

(2) FSN Analysis

(3) SDE Analysis

**ABC analysis:** This technique involves classification of spares based on annual consumption value. A being the most valuable items, B as a set of interclass items and C being the least valuable ones. This method aims to draw manager's attention on **the critical few** (A-items) and not on **the trivial many** (C-items).

Through this categorization, management can **identify inventory hot spots**, and separate them from the rest of the items, especially those that are numerous but not that profitable. (ABC analysis). (Joffrey Collignon, 2012). After the classification pareto chart was used to represent the same.

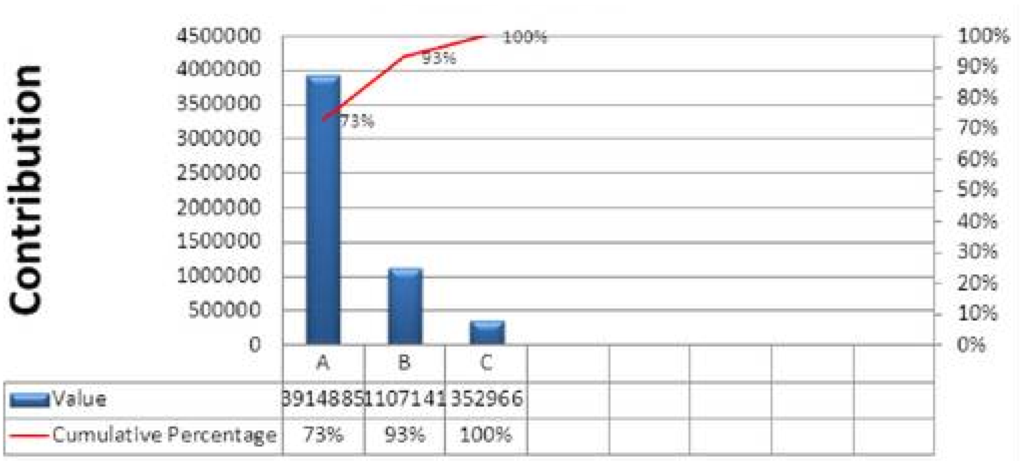



***Figure 2 : FSN Analysis - Classification based on Frequency of usage***

F, S & N stand for Fast moving, Slow moving and Non-moving items. This form of classification identifies the items frequently issued, less frequently issued for use and the items which are not issued for longer periods. Even if a few of them ( Non-moving spares) are disposed off and the locked up capital is made available, it will make available additional working capital to the organization. Action for disposal of such spares should be taken based on the value of each item of spare. (Vaisakh P. S., 2013)

**SDE Analysis: Classification Based on the Lead Time:**

This classification is carried out based on the lead time required to procure the spare part. The classification is as follows:

Scarce (S): Items which are imported and those items which require long lead time.

Difficult (D): Items which require more than a fortnight but less than a month lead time.

Easily available (E): Items which are easily available i.e., less than a fortnights lead time.

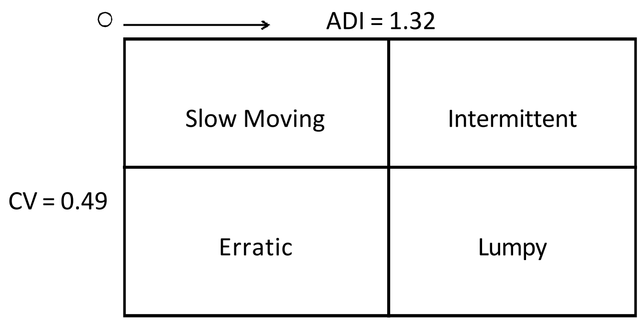
## Forecasting of Spare Parts Demand

Forecasts are vital to every business organization and for every significant management decision. While a forecast is never perfect due to the dynamic nature of the external business environment, It is beneficial for all levels of functional planning, strategic planning, and budgetary planning. Decision makers use forecasts to make important decisions regarding the future direction.

### *Spare Parts Features*

Spare materials have peculiar characteristics that distinguish it from all other materials used in a productive or service system. The demand of the spare parts is in major number of cases intermittent in nature **(an intermittent demand is a demand which takes place with irregular time intervals and has frequent intervals with zero demand.**

For valuation of this double characterization of spare parts demand, **Dr A.A Ghobbar of Delft institute of technology, Netherlands** designed a model which allowed a more detailed characterization of the intermittent standard of spare parts demand. The figure presents the four categories of the spare part demand (patterns) as they are defined by this model.




A A Ghobar Model

ADI- Average inter-demand interval

CV- Coefficient of variation

### *Types of demand*

a) **Slow moving (or smooth):** For spares which show this kind of demand we make use of ***Exponential smoothing technique*** to forecast the demand.

b) **Strictly intermittent:** For spares which show this kind of demand we make use of ***Croston method*** to forecast the demand.

c) **Erratic:** For spares which show this kind of demand we make use of ***weighted moving average (WMA) technique*** to forecast the demand.

d) **Lumpy:** For spares which slow this kind of demand we make use of ***Syntetos-Boylan approximation technique*** to forecast the demand.

## Development of Inventory Control Systems

Efficient management of spare parts inventory is essential to many companies, those manufacturing ones (automotive, food processing, petrochemical industry, etc.) as well as those in the service sector (telecommunications, electricity, water supply, etc.). Spare parts are kept in storage to facilitate execution of maintenance functions in the event of equipment breakdowns.

In the management of spare parts inventory there is a need to answer the following questions:

a) **Keep each spare part in stock or not?**

Generally, a part will be stored if the benefit of current availability is greater than the cost of holding inventories. Comparing the storage costs and the costs related to stock out at the time of the spare needs, gives the answer to this question.

b) **How many to order at once?**

To determine an optimal order quantity, a well-known classical economic order quantity (EOQ) formula can be used.

c) **How many pieces to keep in stock?**

For this decision information is required on the annual demand, ordering costs and holding costs of inventory.

d) **When to release a new order?**

Having too many items on stock can result in high holding costs. On the other hand, having too few items on stock can result in high penalty costs.

To ensure smooth functioning it is essential to develop a suitable inventory control system by which optimization of spare parts cost is achieved in a systematic way.

## Re-Order Level and Safety Stock

**Reorder level** (or reorder point) is the inventory level at which a company would place a new order. Therefore, the points to be considered while deciding the reorder levels are as follows.

## Recommendations

Streamlining the processes and reducing purchasing, supply and inventory costs is an integral part of increasing profitability. While maintaining appropriate spare parts inventory at the same time it is essential for optimal production. To achieve a balance between these two is paramount. In this document the focus has been on techniques which could actually help in doing it, but there are several other aspects which need to be covered as well for better results.

Here are a few such suggestions which could enhance the effectiveness of the model.

**Spare parts codification:** When a spare part is required to be put into equipment which is under breakdown, it becomes necessary to identify the part for getting the same issued from the store or for purchasing the same from the vendor. While identifying it becomes essential to give the complete description including the size and type of the spare to draw from the stores. It is a cumbersome and time consuming task during every transaction to identify a spare part by its description .

This process can be replaced by **codification.**

For instance, a 10-digit code may signify,

**1st digit** -Imported or indigenous.

**2nd, 3rd & 4th digits** -Machine type, make & model.

**5th, 6th & 7th digits** - Spare-part class.

**8th, 9th & 10th digits** – Size or serial number.

By classifying and codifying all the spare parts, it becomes easy to minimize the duplication of spare parts thereby effecting reduction in the inventory.

## Continuous Review Inventory Module

Implementation of a module in which inventory analysis methods are integrated and continuously monitored will surely help in keeping a better track of critical spares which are tantamount to the organization.

## Forecasting Lumpy Demand

A major problem faced in demand forecasting is forecasting accuracy. The demand of spare part as we have already come across follows an intermittent pattern which is different from the simple continuous demand patterns. In this model has been used Dr. A.A Ghobhar model to determine the type of demand and then accordingly have been approved different forecasting techniques.

Here, implementation of more advanced technique-*Artificial Neural Network models (*Recurrent Neural Network (RNN) and Generalized Regression Neural Network (GRNN) ) could increase the accuracy levels of these forecasts and it is relatively much better than the time series models which if implemented for forecasting lumpy data could help in reduce the error during forecasting by almost 48%.

## Using EOQ model

The safety stock and re-order level determination with respect to service level will help the company in optimizing its inventory levels for sure. But EOQ module along with it will be a good value addition. There are several modified EOQ models available which can be used to handle intermittent demand –" A modified EOQ model" by *Sakon Wongmongkolrit, and Bordin Rassameethes* being one of the most prominent ones which could be employed in future. (Sakon Wongmongkolrit, 2011)

## Reconditioning of Spares

For the spare parts which are very expensive and those which are to be imported, it is essential that the useful life for such spares is extended by appropriate applications of reconditioning and repair techniques. Also, for similar industries establishing of spare parts bank (which the company is interested in) goes a long way in reducing the total inventory holding of the expensive spare parts and also reduces the stock holding cost.

## Conclusion

Spare parts management is one of primary needs for company to win in a tight global competition. Inventory is a significant asset for any organization. Therefore, it should be managed effectively and efficiently to minimize total cost. In any practical situation, spare parts inventory management faces barriers in the form of a tradeoff between minimizing total cost and maximizing service level.

In this project, the reorder point for over 60 critical spare parts was computed using Continuous review model. The results from this research show that the proposed continuous review model results in Lower total cost compared to an existing policy.

Some of the advanced forecasting techniques such as Croston forecasting technique and Syntetos-Boylan method have been used to predict future demands for these spare parts which help in much better inventory control.

The amount of average savings that could be gained by this proposed policy is estimated to be about 6% (minimum) and can go up to as high has 30% in case of machines with very high downtime costs. With a prospective spare bank and more emphasis on preventive maintenance there could be lot of positives that could come along in spares management.

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