Decision Making of Spare Parts Inventory Based on Risk Quantification

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Decision Making of Spare Parts Inventory Based on Risk Quantification

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***Abstract*— Financial losses due to spare part breakdown in plant operation have created an upsetting situation among stakeholders. The failure increase the cost of repair and production downtime. . Obviously, maintenance planner tends to increase the spare part inventory level in order to meet the operational requirement and this in return has increased the inventory cost. The maintenance and inventory function is important in order to ensure the plant operate accordingly. Moreover, it is necessary for the plant maintenance to balance the issue of shortage and excess of inventory in plant maintenance. In view of this situation, the spare parts become a critical matters and it is good starting point to tackle the issues from looking at the perspective of spare parts inventory risk. This paper explain about the development of risk based technique using the shortage and excess situation of spare parts inventory by using the Breakdown Probability Table to quantify the risk for decision making purpose.**

***Keywords*—** *Spare part, Inventory Cost, Spare Part Probability Breakdown*

1. Introduction

Plant maintenance in manufacturing industries is a key driver towards achieving organizational performance. Due to the fierce market competition, it is critical for the organization to be self-competence and manage resources efficiently [1]. Often, maintenance cost is keep on increasing from time to time. According to the recent studies, companies spent average of RM40 million or 12% of the annual budget for the cost of maintenance [2]. In addition, [3] has discovered that manufacturing company spent about 80% from its operation cost to address issue on equipment failures and injury to people. Thus, these issues have drawn response among various industries to look into maintenance management seriously [4]. According to [5], inventory management has the largest impact towards maintenance productivity. Due to improper inventory management, resulting in stunted maintenance process and ultimately led to the issue of company opportunity loss. However, [6] claimed that the most difficult part of the whole process was to select the right technique to address the maintenance issues. By selecting the right technique the maintenance manager would be able to assist the company to increase the plant reliability and reduce the operating cost.

2. Literature Review

Spare parts are known to be related to uncertain demand and that nature of demand pattern required forecasting and stock control in order to achieve the optimum stock level [7]. The intermittent or uncertain demand [8], the large numbers of spare parts [9] and the risk of spare parts obsolescence [8] may cause the spare parts not meeting the supply chain points. Thus, being out of stock when a spare part is needed leads to downtime of capital goods, which is very expensive due to loss of operational continuity. According to [10], the commercial aviation industry has as much as $30 billion worth of spare engines on stock. Similarly, the loss of operational due to spare parts breakdown in this particular area will create a disastrous event to the whole industry. Meanwhile, in the semiconductor industry alone, the loss of production due to breakdown issues estimated at tens of thousands of euros per hour [11]. Hence, the problem of spare parts inventory is critical and the issues in spare parts management need to be solved accordingly. Risk-based approach is one of the technique that is commonly used in order to deal with issues of uncertainties in executing management choices. This approach helps decision makers to formulate a strategic options and decisions to assess various impacts and implications [12]. Specifically, risk perspective in plant maintenance is essential for ensuring asset integrity in a process facility [13]. With the increased mechanization and complexity in process plant, there is a rise in the number of equipment failure scenarios. Failure of equipment incurred downtime and unavailability of the plant, which may prolong with the inadequacy of spare parts. In view of this situation, the Risk Based Maintenance (RBM) is used by the plant maintenance to reduce the risk from the unexpected failure happen in the

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operation premises [14].[15] prioritized and quantified the risk from the risk based maintenance activity. Hence, [16] suggested on the implementation of regular inspection activity for the high risk spare part in order to avoid the potential failure and achieving appropriate risk toleration.[14] used the risk matrix to define the risk and consequences. . Besides that, [17] developed checklist for chemical industry and [18] used the check list for listing the possible risk that is related to plant hazard in operation. Assessing risk is crucial because the decision to maintain equipment can affect cost [15]. Subsequently, spare parts have great influence on all types of maintenance activités and the availability of process plant. For the case of critical equipment this could lead to severe consequences like excessive downtime costs, idle manpower cost and so on. Maintenance often depends on the spare parts availability and, thus, the adequacy of spare parts in stock has a direct impact on the operability of the system. It could easily be achieved by storing an adequate quantity of spares in the inventory. [13] develop a risk-based approach for spare parts demand forecast and spare parts inventory management for effective allocation of limited resources. [19] used optimization technique to determine the best method to predict initial stock requirements and quantify the risk. Meanwhile, [20] used the binary decision in order to quantify the risk.The title of the paper is centred 17.8 mm (0.67") below the top of the page in 24 point font. Right below the title (separated by single line spacing) are the names of the authors. The font size for the authors is 11pt. Author affiliations shall be in 9 pt.

3. Methodology

In this paper, a specific steps were developed to transform the input and formulation into a technique that can generate information for decision making purposes. The elements for each component was identified based on the detail discussion done between the researcher, plant manager and inventory executive after obtaining the appropriate items from the literature. The following figure 1 illustrates the steps required to perform the risk based technique.

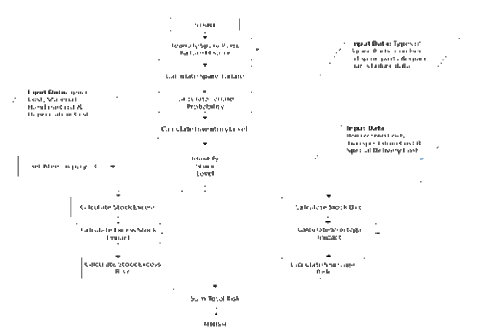

Figure 1. Risk-Based Technique Development Steps

The process includes identifying spare parts failure history, analysing spare part failure and stock level, calculating stock excess, calculating stock out, determining the probability of excess stock and stock out, calculating excess of stock impact and shortage impact and developing risk based calculation. [19, 20] underlined some important elements such as determining the spare parts breakdown and quantifying the inventory consequences in order to calculate the spare parts risk.

3.1 Derivation of Spare Parts Breakdown Probability

The breakdown probability table is referring to the probability of all possible breakdown for every spare part. In order to achieve this, the probability of breakdown for each spare part will be calculated by dividing the possible breakdown with the number of observation.

The probability of *(i, j)* is given by:

$$Pr\ (i,j) = \frac{\sum i\_for\_j}{\sum k} \qquad (1)$$

Where:

i = breakdown

j = spare part

k = observation

3.2 Development of Spare Parts Impact Table

This section will discuss the development of Shortage Impact (SI) due to spare parts unavailability in process operation. Some of these spare parts are essential to the operation in a manufacturing plant and other spare parts do not have such a severe impact on the process. By considering the worst case event, the formulation of shortage impact is depicted as below:

$$SI_{sp} = \sum_{0}^{n} SP \ x \ (PFL + TR + Price) \quad (2)$$

Where:

SI_{sp} = Shortage Impact for Total Plant Breakdown

PFL = Plant Financial Loss

TR = Transportation Cost

SP = Number of spare part

Subsequently the value of PFL is referring to the production loss in daily operation. Thus, the value of PFL is formulated as below:

$$PFL = PQ \ x \ Pr_{NH} \quad (3)$$

Where:

PQ = Quantity production per daily

Pr_{NH} = Ammonia (NH_3) Price

On the other hand, the Excess Stock Impact of spare parts happened when the spare parts were underutilized by the operation. According to [21], holding cost is formed in four components which are the stock unit, reorder, holding and shortage costs. [22] and [23] have same thoughts in terms of the holding cost components such as space rental, storage facilities, material handling, insurance, pilferage, breakage, obsolescence, depreciation, taxes and opportunity cost of capital. The formulation of the excess stock impact was showed in calculation below:

$$ESI_{sp} = (SC + MH + DV) \ x \ SP \quad (4)$$

Where:

ESI_{sp} = Excess Stock Impact

SC = Space cost

MH = material handling

DV = depreciation value

SP = number of spare parts

The risk-based spare parts inventory technique proposed in this study is based on the concept corresponding to the probability of breakdown and impact value. Hence, the risk associated with the value of spare parts shortage and excess in inventory. Both notified components have potential impact on the operational of the plant. The formulation of the quantified risk is developed by multiplying the probability spare parts breakdown table with the value of spare parts shortage impact table and excess impact table. Below is the formulation of the quantified risk:

$$R_{SO} = Pr_{SO} \ x \ I_{SI} \quad (5)$$

$$R_{ES} = Pr_{ES} \ x \ I_{ESI} \quad (6)$$

Where:

R_{SO}, R_{ES} = Spare Part risk for shortage and excess spare parts

Pr_{SO}, Pr_{ES} = Probability table for shortage and excess spare parts

I_{SI}, I_{ESI} = Impact Table for shortage and excess spare parts

Based on the above table the value of RSO and RES will be added in order to obtain the total risk.

Table 1. Total Risk Table (RM)

Spare Part	R_{SO}	R_{ES}	**Total Risk**
A	576,680.00	68,120.00	644,800.00
B	145,070.00	133,088.00	278,158.00
C	0	245,184.00	245,184.00
D	1,458,200.00	28,704.00	1,486,904.00
E	295,540.00	89,768.00	385,308.00
F	2,026,780.00	7,818.00	2,034,598.00
G	1,893,710.00	18,636.00	1,912,346.00

In this study, by completing all the risk quantification steps it indicated that every combination of spare parts inventory will have its own risk value for shortage and excess of spare part.

3.0 Conclusion

The main aim of this study is to develop risk based technique that includes the quantification of spare part shortage and excess. The risk based technique quantify the excess and shortage values and offers a useful tool in assessing the impact of risk which quantified total risk in monetary unit. Later the inventory planner can decide the quantity level of spare parts that required by the maintenance based on the risk options. The concepts of incorporating risk in forecasting of stock for inventory management. To date, less study has been performed on the risk based technique in order to determine the stock level based on financial risk. The developed technique has showed on how the risk is quantified based on the spare parts breakdown event, probability of breakdown and impact consequences. It also provides additional insights on the relationships between inventory forecasting and risk practices in plant operation environment. In further, it can assist decision makers particularly inventory and maintenance managers to decide spare parts requirement effectively.

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