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Original Article

A Probabilistic Modeling of the Demand and Supply for Rotable Aircraft Components (Case Study: Brake Assembly of Boeing 737-800)

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Abstract: Spare parts control is an important factor in every airlines company. The unavailability of the spare parts may affect the airlines operationally, thus a delay and even a cancellation may happen. A common assumption used to calculate spare part requirements is that the demand is stochastic and the supply is constant. But in real operational circumstance, both of those are stochastic. This research develops the spare parts demand and supply model, and the calculation method of service level and safety stock in the bi-variate distribution from a real data of demand and supply of a rotable component. A fit test is conducted to determine the probability density function of the distribution. An analysis is then carried out after implementing the model in a case study. Historical data of brake assembly used in Boeing 737-800 New Generation is used in the case study. The result of this research are a model to determine demand and supply of aircraft spare part components, a method to calculate service level and safety stock for probabilistic model of demand and supply, and the amount of spare parts required for a brake assembly inventory system.

Keywords: probabilistic modeling, spare parts, aircraft components, supply and demand

1. Introduction

There are three classification in aircraft inventory system: rotable component, repairable component, and expandable component. Rotable component is a component which can economically be repaired to its serviceable condition with a very low or even negligible scrap rate [1]. In repairable component, the component's scrap rate is quite considerable that it should be included in spare part calculation, while in expandable component, the scrap rate is 100%, so typical inventory management calculation such as Economic Order Quantity can be applied for expandable component. Rotable components usually are critical components that may cause a delay or cancellation if not available. So, management of rotable component is important.

In one echelon inventory system or in-house supply inventory system, rotable component follows a usage cycle of operation, removal, repair, storage, and back to operation as illustrated in Figure 1. Calculation and management of rotable component aims that in every removal, the probability of components available is equal or more than the service level intended. Thus, procurement of safety stock is necessary to fulfill the service level.

A common assumption used to calculate spare part requirements is that the demand is stochastic and the supply is constant [2]. For rotable component, the calculation of safety stock is

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done by using a calculation called provisioning method. Provisioning method assumes that the demand is following Poisson distribution and calculates the number of safety stock needed for a year. However, provisioning method does not depict demand and supply distribution.

This research models demand and supply distribution of a rotable component in graphical model so that the position and pattern of supply and demand distribution can be illustrated. By understanding the position and pattern of demand and supply, decision making of service level fulfillment can be determined.

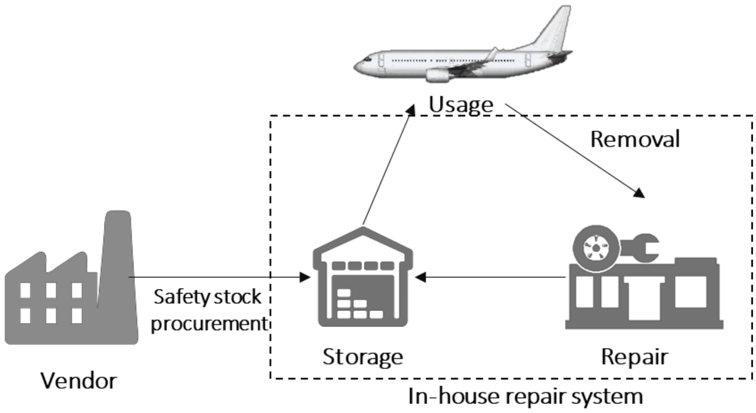

Figure 1. Cycle of a rotable component.

Guide Jr. and Srivastava [3] discussed various types of inventory models for repairable components. Typical problems in inventory model of repairable components is optimization to minimize total inventory cost, and to do that, detailed data of costs such as repair cost, holding cost, procurement cost, and other cost data will be needed. Other than cost, another factor that influence the decision of inventory management is service level. In ideal condition, inventory policy aims to minimize cost as well as maximize service level. However, as the rotable component is a critical component that may have safety consequence for its unavailability, then service level needs to be more considered. To fulfill the service level intended, safety stock need to be procured.

Safety stock is usually calculated as a stock for anticipating the uncertainty in demand. Thus, safety stock calculated by assuming that the demand is stochastic while the supply is constant. To model the probabilistic demand and probabilistic supply, material structure reliability modelling by Rao can be adopted [4]. The model is illustrated in Figure 2, where l is structure load and s is structure strength. The overlapping area between fl(l) and fs(s) represent the unreliability of the structure. Thus, the reliability can be calculated by determining the probability of strength more than load, or can be stated as in Equation (1) below.

$$R = P(S > L) = P(S - L \geq 0) \quad (1)$$

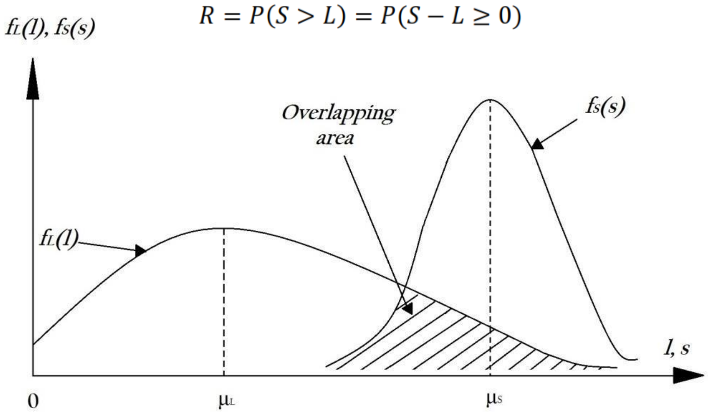

Figure 2. Probability density function for material structure load and strength [4].

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3. Materials and Methods

3.1. Collection of shop report data

Every repair activity is recorded in a report called shop report. The data needed to be obtained from shop report are arrival date dan finish date of a component for a year. Those data is then sorted in a table to help the calculation of repair duration and the number of component arrived and finished in those duration. The repair duration is then called Turn Around Time or TAT.

3.2. Every Calculation of mean TAT

TAT acts as a lead time for in-house supply inventory system. For rotable component, the repair time for each serial number varies. In order to simplify the modeling, mean TAT is used. Mean TAT is calculated by using Equation (2).

$$\overline{TAT} = \frac{1}{n}\sum_i^n TAT_i \quad (2)$$

3.3. Calculation of number of supply and demand per TAT

After determining mean TAT, the number of supply and demand per TAT can be obtained by sorting the data based on date started and date finished. The first period is started in the beginning of the planning horizon T_0 to T_1, with T_1 is T_0 plus mean TAT. The next period is sorted by adding the previous period with TAT as shown in Figure 3 and Equation (3).

$$T_i = T_{i-1} + \overline{TAT} \quad (3)$$

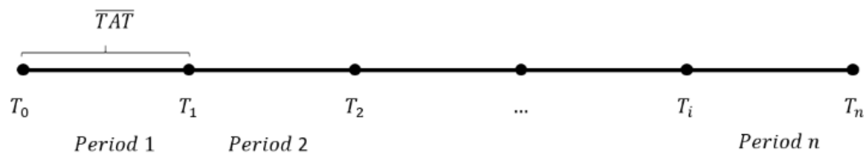

Figure 3. Period for demand and supply calculation

For each period, the number of demands can be obtained by counting the number of components arrived in the period and the number of supplies can be obtained by counting the number of components finished in the period.

3.4. Distribution fit test and parameter estimation of demand and supply distribution

For every TAT period, the number of demand and supply will vary and form certain distribution. In this research, an assumption that demand and supply are normally distributed is used. Therefore, Kolmogorov Smirnov Test is used. The steps of the test are described as follows.

3.4.1. Hypothesis

Hypothesis for Kolmogorov Smirnov test is,
H_0 : no different with normal population
H_1 : there is differences with normal population

3.4.2. Significance level

Significance level is used to compare the value calculated and the value from Kolmogorov Smirnov Statistics Table. Significance level used is 5%.

3.4.3. Kolmogorov-Smirnov test

Kolmogorov Smirnov test is started by calculating absolute difference between normal cumulative distribution function and empirical cumulative distribution function. The result is then compared to value in Kolmogorov Smirnov Table. If the calculated value is less than the value in table, H_0 is accepted.

3.5. Service level and safety stock calculation

Service level and safety stock calculation follows adjusted material structure reliability calculation by Rao [4]. The flow diagram is shown in Figure 4.

4. Results and Discussions

Case study is conducted by modeling the demand and supply of brake assembly component used in Boeing 737-800. By following the steps described above, demand and supply of brake assembly in one year is shown in Table 1 with mean TAT is 19 days. Kolmogorov Smirnov test shown that both demand and supply are normally distributed. Probability distribution of demand and supply is shown in Figure 5. Existing service level is calculated by equation provided in Figure 4. And expected service level is 95%.

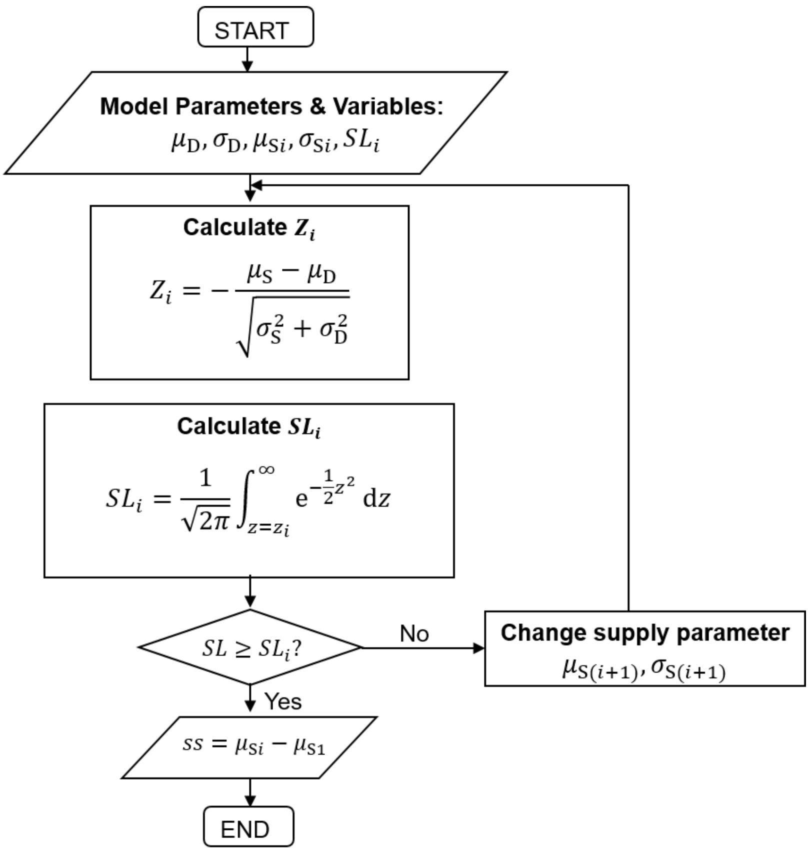

Figure 4. Period for demand and supply calculation.

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Table 1. Demand and supply calculation.

Period		Demand (unit)	Supply (unit)
01-Jan	20-Jan	13	-
21-Jan	09-Feb	10	7
10-Feb	01-Mar	7	13
02-Mar	21-Mar	15	10
22-Mar	10-Apr	16	14
11-Apr	30-Apr	13	16
01-May	20-May	14	14
21-May	09-Jun	12	10
10-Jun	29-Jun	16	13
30-Jun	19-Jul	13	13
20-Jul	08-Aug	19	15
09-Aug	28-Aug	19	14
29-Aug	17-Sep	19	15
18-Sep	07-Oct	8	16
08-Oct	27-Oct	22	19
28-Oct	16-Nov	13	11
17-Nov	06-Dec	26	21
07-Dec	26-Dec	6	24
27-Dec	15-Jan	-	9

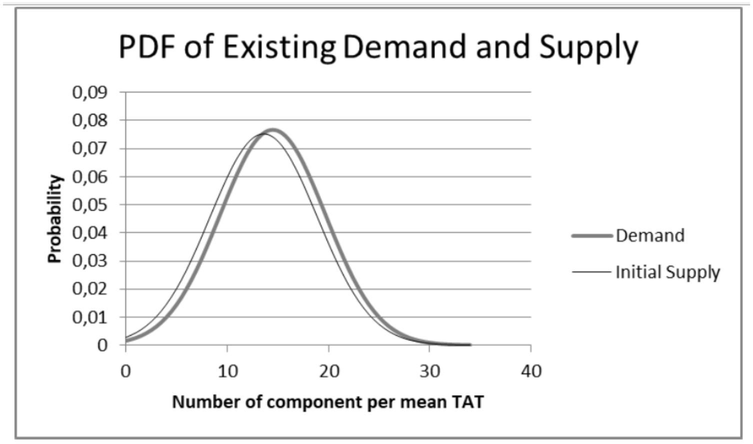

Figure 5. Probability distribution function of the existing system.

From Figure 5, it can be estimated that the service level is below 50%. By the equation provided in Figure 4, it can be calculated that the existing service level is 45,22%. To obtain 95% service level, the supply's pdf needs to be shifted to the right so that the probability of supply to be more than demand will increase. To do that, parameter of supply can be changed as follow:

1. shifting mean supply to the right by adding safety stock;
2. decreasing standard deviation by reduce repair activity variance; and
3. combining both shifting mean supply and decreasing standard deviation.

The first option is illustrated in Figure 6. The shifting of the mean supply is done by adding safety stock. Using equation in Figure 4, it is calculated that the safety stock needed for 95% service level is 14. The second option cannot be implemented because the initial supply and demand probability distribution function almost coincide, so there is no lower standard deviation to get 95% service level than the initial standard deviation. The third option is presented in Table 2. By decreasing the standard deviation and adding safety stock, there will be some combination possible. The decision should be made by also considering company's policy for the best option [4].

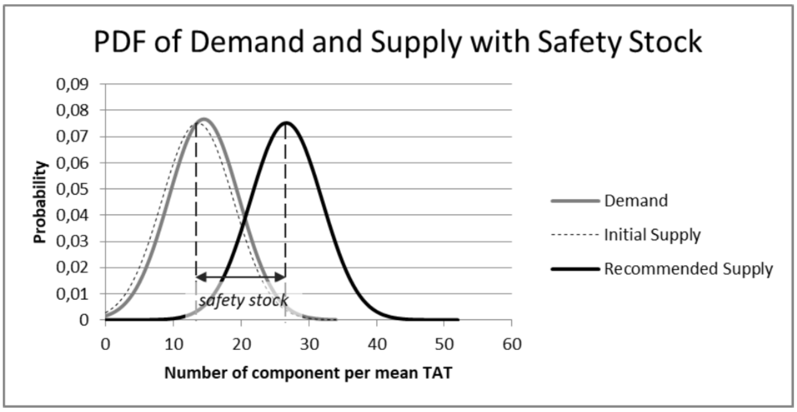

Figure 6. Probability distribution function shifting by adding safety stock.

Table 2. Shifting mean supply and decreasing standard deviation.

Standard deviation supply	Mean supply	Safety stock
1	23,22	10
2	23,67	11
3	24,38	11
4	25,30	12
5	26,37	13

5. Conclusions

Demand and supply for in-house supply inventory system for rotable and repairable components are stochastic and can be modeled probabilistically. By assuming that the demand and supply are normally distributed, then the parameters needed for calculating service level and safety stock are mean demand, standard deviation of the demand, existing mean supply, existing standard deviation of supply, and the desired service level. Service level is achieved by varying supply parameters. For practice purpose, the shifting of the mean supply can be done by adding safety stock, while the shifting in standard deviation can be done by doing activities that can reduce reparation variance, such as addition of repair facilities

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