The application of EOQ and lead time crashing cost models in material with limited life time (Case study: CN-235 Aircraft at PT Dirgantara Indonesia)

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Abstract. PT. Dirgantara Indonesia, one of State Owned Enterprises engaging in the aerospace industry, targets to control 30% of world market for light and medium sized aircraft. One type of the aircrafts produced by PT. DI every year is CN-235. Currently, the cost of material procurement reaches 50% of the total cost of production. Material has a variety of characteristics, one of which is having a lifetime. The demand characteristic of the material with expiration for the CN-235 aircraft is deterministic. PT DI does not have any scientific background for its procurement of raw material policy. In addition, there are two methods of transportation used for delivering materials, i.e. by land and air. Each method has different lead time. Inventory policies used in this research are deterministic and probabilistic. Both deterministic and probabilistic single and multi-item inventory policies have order quantity, time to order, reorder point, and lead time as decision variables. The performance indicator for this research is total inventory cost. Inventory policy using the single item EOQ and considering expiration factor inventory results in a reduction in total costs up to 69.58% and multi item results in a decrease in total costs amounted to 71.16%. Inventory policy proposal using the model of a single item by considering expiration factor and lead time crashing cost results in a decrease in total costs amounted to 71.5% and multi item results in a decrease in total costs amounted to 71.62%. Subsequently, wasted expired materials, with the proposed models have been successfully decreased to 95%.

1. Introduction
Industrial development in Indonesia is growing rapidly that listed in the National Industrial Development vision on PP No. 28 on 2008 that Indonesia will become advanced industrial country in 2025. In addition, the industrial development in Indonesia is also characterized by formation of 35 industrial cluster priorities roadmap which transport industry is one of them. Transport industry
includes motor vehicle industry, shipbuilding industry, the aerospace industry and railway industry[1]. The Aerospace industry is one of priority industry that listed on Indonesia Industrial Development. Demand for light and medium size aircraft is estimated at 450-500 units in the decade [2].

PT. Dirgantara Indonesia, one of state-owned enterprises engaging in the aerospace industry, targets to control 30% of world market for light and medium sized aircraft. Business run by PT DI is produce aircraft and aero-structure. One of the aircrafts being produced by PT. DI every year is CN-235. Contribution to the cost of material procurement reaches 50% of the total cost of production.

Materials used for manufacturing CN-235 are divided into two types, i.e. aircraft and non-aircraft. The materials have a variety of characteristics, one of which is a limited life time (expiration). The demand characteristic of the material with expiration for the CN-235 aircraft is deterministic.

PT DI does not have any scientific background for its procurement of raw material policy. The impact of this condition is PT DI has excess material with limited life time that cannot be used and will be discarded. This condition increases the total inventory cost. The amount of material used in PT DI is lower than material that has purchased. Material used in PT DI only reached 50% of the purchase. In addition, there are two methods of transportation used for delivery of goods, which are by land and air. Each method has a different duration, so an evaluation is needed to determine the optimum lead time.

Inventory policies proposed in this research are deterministic and probabilistic for single and multi-item policies. Decision variables considered in this research are order quantity, time to order, reorder point and optimum lead time that will minimize wasted expired material and minimize total inventory cost in PT DI.

Main objective of this research is to determine the appropriate inventory policies for materials with expiration for CN 235 aircraft that minimize the total cost of inventory of those materials at PT DI.

The objects of the research are focused on both non-aircraft and non-metal materials with limited life time for producing CN-235 aircraft. Materials implemented in this research are limited to ten materials that have 6-24 months life time and the data used are the demand projection of materials for year 2014-2018. The assumptions used in this research are holding and expiration costs are defined as the percentage of the price of materials as well as no limitation of storage capacity, supply from the suppliers, and financial support in PT DI.

2. Literature Review
The model referred in this research covers inventory issue with deterministic demand (EOQ inventory method) by considering expiration factor [4] and using inventory model considering lead time as decision variable for inventory with probabilistic demand [5]. There are four models used in this research. There are deterministic and probabilistic, single and multi-item models. Models used in this research have some differences. Referring to [6], the differences for deterministic and probabilistic models can be seen in Table 1, where the differences for single and multi-item models can be seen in Table 2.

| Table 1. Differences for Deterministic and Probabilistic Model [6] |
|-----------------------|--------------------------|
| **Comparison** | **Deterministic Model** | **Probabilistic Model** |
| Demand | Deterministic | Probabilistic |
| Order Quantity | Constant | Constant |
| Time To Order | Variable | Variable |
| Life time | Constant | Constant |
| Storage Condition | Lost sales | Lost sales |
| Lead time | Constant | Variable |
| Safety stock | No | Yes |
Table 2. Differences for Single and Multi-Item

| Comparison          | Single Item                                      | Multi-Item                                      |
|---------------------|--------------------------------------------------|-------------------------------------------------|
| Time To Order       | Different for every material                     | Same for all material                           |
| Demand              | Dependent                                        | Independent                                     |

Demand characteristic for inventory by using deterministic model is constant [3,4]. Thus, probabilistic model has probabilistic demand during lead time and we assume that the demand follow a normal distribution with mean D and standard deviation S [5].

3. Model Development

Algorithm used in this study classified to four types, i.e. algorithm for deterministic single item model, deterministic multi item model, probabilistic single item model, and probabilistic multi item model. Below are the notations used in this research.

Mathematical Notations

| Notation | Description         | Unit of Measure |
|----------|---------------------|-----------------|
| \(O_T\)  | Total Inventory Cost| $/Year          |
| \(Q_i\)  | Order Quantity      | UOM             |
| \(T_i\)  | Time to Order       | Month           |
| \(r\)    | Reorder Point       | UOM             |
| \(D_i\)  | Demand              | UOM/Year        |
| \(A_i\)  | Cost per Order      | $               |
| \(h_i\)  | Holding Cost/ Material| $/UOM.Year    |
| \(E_i\)  | Expired Cost        | $/UOM           |
| \(P_i\)  | Price               | $/UOM           |
| \(C_{ij}\)| Crashing Cost      | $/Week          |
| \(t_{ij}\)| Life Time          | Month           |
| \(L_{ij}\)| Lead Time         | Week            |
| \(a_{ij}\)| Minimum Lead Time Duration| Week      |
| \(b_{ij}\)| Maximum Lead Time Duration| Week       |
| \(O_{bi}\)| Purchase Cost      | $/Year          |
| \(O_{pi}\)| Order Cost         | $/Year          |
| \(O_{si}\)| Holding Cost       | $/Year          |
| \(O_{ei}\)| Expired Cost       | $/Year          |
| \(O_{ci}\)| Crashing Cost      | $/Year          |
| \(Q_{ei}\)| Expired Material   | UOM             |
| \(SS_{ij}\)| Safety Stock        | UOM             |

Algorithm for determine decision variable:
Decision variables are solved iteratively with number of expired materials (\(Q_e\)) is zero at first.

Algorithm 1 : Deterministic Model For Single Item

Set \(Q_{eo}=0\) and total inventory cost \((O_T)_0=\infty\).

Step 1. Compute order quantity (\(Q\)) using Eq 1.

\[
Q = \sqrt{\frac{2AD+2Q_eED-hQ_e^2}{h}}
\]  

Step 2. Compute expired materials (\(Q_e\)) using Eq 2.

\[
Q_e = Q - t_{1i}xD
\]
Step 3. Compute purchase cost using Eq 3.

\[ O_p = D \times p \]  

(3)

Step 4. Compute order cost using Eq 4.

\[ O_p = \frac{AD}{Q} \]  

(4)

Step 5. Compute holding cost using Eq 5.

\[ O_s = \frac{h(Q^2-Q_e^2)}{2Q} \]  

(5)

Step 6. Compute expired cost using Eq 6.

\[ O_e = Q_e \times E \times \frac{D}{Q} \]  

(6)

Step 7. Compute total inventory cost using Eq 7.

\[ O_T = D \times p + \frac{AD}{Q} + \frac{h(Q^2-Q_e^2)}{2Q} + Q_e \times E \times \frac{D}{Q} \]  

(7)

Algorithm 2: Deterministic Model For Multi Item

Step 1. Compute time to order using Eq 8.

\[ T = \sqrt{\frac{2D\sum_{i=1}^{10} D_i + \sum_{i=1}^{10} 2Q_i E_i D_i - \sum_{i=1}^{10} h_i Q_i^2}{\sum_{i=1}^{10} h_i D_i^2}} \]  

(8)

Step 2. Compute order quantity for each material by Eq 9.

\[ Q = D \times T \]  

(9)

Step 3. Compute expired materials (Qe) using Eq 2.

\[ Q_e = \sum_{i=1}^{10} Q_i E_i \times \frac{E_i}{T} \]  

(10)

Step 4. Compute purchase cost using Eq 3.

\[ O_p = A \times T \]  

(11)

Step 5. Compute order cost using Eq 10.

\[ O_p = \frac{A}{T} \]  

(12)

Step 7. Compute expired cost using Eq 12.

\[ O_e = \sum_{i=1}^{10} Q_i E_i \times \frac{E_i}{T} \]  

(13)

Step 8. Compute total inventory cost using Eq 13.

\[ O_T = \sum_{i=1}^{10} D_i \times p_i + \frac{A}{T} + \sum_{i=1}^{10} \frac{h_i ((D_i)^2- Q_e^2)}{2D_i^2} + \sum_{i=1}^{10} Q_i E_i \times \frac{E_i}{T} \]  

(14)

Algorithm 3 : Probabilistic Model For Single Item

Step 1. Compute order quantity (Q) using Eq 14.

\[ Q = \sqrt{\frac{2D(A+R(L)) - hQ_e^2 - 2Z_e S \sqrt{L} \times Q_e + 2Q_eE D}{h}} \]  

(15)
Step 6. Compute expired cost using Eq 6
Step 7. Compute crashing cost using Eq 16.
\[ Oc = c_j(L_j-1 - L_j) + \sum_{k=1}^{i-1} c_k(b_k - a_k) \times \frac{D}{Q} \] 
(16)
Step 8. Compute total inventory cost using Eq 17.
\[ O_T = D \times p + \frac{AD}{Q} + h \times \left( \sum_{i=1}^{i=10} h_i \times s_i + \sum_{i=1}^{i=10} h_i \times d_i + \sum_{i=1}^{i=10} 2h_i \times e_i \right) \times \frac{(Q - Q_e)}{Q} + \frac{Q_e \times E \times \frac{D}{Q} + \left( c_j(L_j-1 - L_j) + \sum_{k=1}^{i=1} c_k(b_k - a_k) \right)}{x} \] 
(17)
Step 9. Compare \( O_{T1} \) and \( O_{T0} \). If \( O_{T1} < O_{T0} \) then go to next iteration (back to step 1) with \( L_1 = L_{\text{max}} - L_0 \). And if \( O_{T1} > O_{T0} \) then \( Q_{\text{ei}}, Q_1, L_0 \) and \( O_{T1} \) as the optimal solutions.

Algorithm 4: Probabilistic Model For Multi Item
Set \( Q_{\text{ei}} = 0 \), lead time = \( L_0 = L_{\text{max}} \), and total inventory cost \( (O_{T0}) \) becomes \( \infty \).
Step 1. Compute time to order using Eq 18.
\[ T = \sqrt{\frac{2(A_1 + R(L)) \sum_{i=1}^{i=10} d_i \times \left( h_i s_i + \sum_{i=1}^{i=10} h_i d_i + \sum_{i=1}^{i=10} 2h_i e_i \right) x \left( \frac{D}{Q} -Q_e \right)}{Q \times T}} \] 
(18)
Step 2. Compute order quantity for each material with Eq 9.
Step 3. Compute expired materials \( (Q_e) \) using Eq 2.
Step 4. Compute purchase cost using Eq 3.
Step 5. Compute order cost using Eq 10.
Step 6. Compute holding cost using Eq 19.
\[ O_s = \sum_{i=1}^{i=10} h_i x \left( \sum_{i=1}^{i=10} h_i \times d_i + \sum_{i=1}^{i=10} d_i \times e_i \right) \times \frac{D}{Q} \] 
(19)
Step 7. Compute expired cost using Eq 12.
Step 8. Compute crashing cost using Eq 20.
\[ Oc = \sum_{i=1}^{i=10} d_i \times \left( c_j(L_j-1 - L_j) + \sum_{k=1}^{i=1} c_k(b_k - a_k) \right) \] 
(20)
Step 9. Compute total inventory cost using Eq 21.
\[ O_T = \sum_{i=1}^{i=10} d_i x p_i + \frac{A}{T} + \sum_{i=1}^{i=10} h_i \times \left( \sum_{i=1}^{i=10} h_i \times d_i + \sum_{i=1}^{i=10} d_i \times e_i \right) \times \frac{D}{Q} \] 
(21)
Step 10. Compare \( O_{T0} \) and \( O_{T1} \). If \( O_{T1} < O_{T0} \) then go to next iteration (back to step 1) with \( L_1 = L_{\text{max}} - L_0 \). If \( O_{T1} > O_{T0} \) then set \( Q_{\text{ei}}, Q_1, L_0 \) and \( O_{T1} \) as the optimal solutions.

4. Numerical Example
In this section will conduct numerical example to illustrate the procedure of model. The case is using one type of material, i.e. preservation oil.
Setting parameter
\[ D = 36,000 \text{ ml/year} ; \] 
\[ h = 0.1 \text{ /UOM - year} ; \] 
\[ P = 0.5 \text{ /UOM} ; \] 
\[ A = 2,257.5 ; \] 
\[ l = 9 \text{ month} ; \] 
\[ E = 0.50127 / \text{UOM} ; \] 
\[ t_1 = 12 \text{ month} ; \] 
\[ C_k = 0.01 \text{ /week} \]
Calculations
Algorithm 1
For \( Q_{\text{ei}} = 0 \) and total inventory cost \( (O_{T0}) \) \( \infty \). Compute \( Q \) using Eq. 1 \( Q = 40,136.25 \text{ ml} \)
Compute \( Q_e \) using Eq. 2 \( Q_e = 4316 \text{ ml} \)
Compute purchase cost using Eq. 3 \( O_p = 18,000 \)
Compute order cost using Eq. 4 \( O_p = 2,015.8 \)
Compute holding cost using Eq. 5 \( O_s = 1,992.7 \)
Compute expired cost using Eq. 6 \( O_e = 1,931.97 \)
Compute total inventory cost using Eq. 7 \( O_{T1} = 23,940.49 \)
For $Q_{e0}=4316$, Compute $Q$ using Eq. 1 $Q = 56,354.48$ ml
Compute $Q_e$ using Eq. 2 $Q_e = 20,254.68$ ml
Compute purchase cost using Eq. 3 $O_p = 18,000$
Compute order cost using Eq. 4 $O_p = 1,444.68$
Compute holding cost using Eq. 5 $O_s = 2,448.091$
Compute expired cost using Eq. 6 $O_e = 6,497.38$
Compute total inventory cost using Eq. 7 $O_T = 28,390.16$

$O_T > O_{T1}$. Optimum solution is iteration 1 with $Q = 40,136.25$ ml and $T = 13$ month.

Algorithm 2
For $Q_{e0}=0$ and total inventory cost $(O_T) \to \infty$. Compute $T$ using Eq. 8 $T = 0.887$ year
Compute $Q$ using Eq. 9 $Q = 31,934.96$ ml.
Compute $Q_e$ using Eq. 2 $Q_e = 0$ ml
Compute purchase cost using Eq. 3 $O_p = 18,000$
Compute order cost using Eq. 10 $O_p = 2,545$
Compute holding cost using Eq. 11 $O_s = 1,596.7$
Compute expired cost using Eq. 12 $O_e = 0$
Compute total inventory cost material preservation oil using Eq. 13 $O_T = 22,141.607$
Compute total inventory cost for all material $O_T = 461,157.89$

$O_T > O_{T1}$. Optimum solution is iteration 1 with $Q = 31,934.96$ ml and $T = 0.887$ year (10 month).

Algorithm 3
For $Q_{e0}=0$ and lead time $= L_0$. $L_0 = 36$ week. Compute $Q$ using Eq. 14 $Q = 40,316.24$ ml
Compute $Q_e$ using Eq. 2 $Q_e = 4316.25$ ml
Compute purchase cost using Eq. 3 $O_p = 18,000$
Compute order cost using Eq. 4 $O_p = 2,005.81$
Compute holding cost using Eq. 5 $O_s = 2,005.83$
Compute expired cost using Eq. 6 $O_e = 1,931.997$
Compute crashing cost using Eq. 6 $O_e = 0$
Compute total inventory cost using Eq. 17 $O_T = 23,953.64$

For $Q_{e0}=0$ and lead time $= L_1$. $L_1 = 24$ week. Compute $Q$ using Eq. 14 $Q = 40,317.32$ ml
Compute $Q_e$ using Eq. 2 $Q_e = 4317.32$ ml
Compute purchase cost using Eq. 3 $O_p = 18,000$
Compute order cost using Eq. 4 $O_p = 2,015.75$
Compute holding cost using Eq. 5 $O_s = 2,003.46$
Compute expired cost using Eq. 6 $O_e = 1,932.42$
Compute crashing cost using Eq. 6 $O_e = 0.107$
Compute total inventory cost using Eq. 17 $O_T = 23,951.75$

For $Q_{e0}=0$ and lead time $= L_2$. $L_2 = 18$ week. Compute $Q$ using Eq. 14 $Q = 40,370.86$ ml
Compute $Q_e$ using Eq. 2 $Q_e = 4370.86$ ml
Compute purchase cost using Eq. 3 $O_p = 18,000$
Compute order cost using Eq. 4 $O_p = 2,013.08$
Compute holding cost using Eq. 5 $O_s = 2,004.15$
Compute expired cost using Eq. 6 $O_e = 1,953.79$
Compute crashing cost using Eq. 6 $O_e = 5.45$
Compute total inventory cost using Eq. 17 $O_T = 23,976.48$

For $Q_{e0}=0$ and lead time $= L_3$. $L_3 = 12$ week. Compute $Q$ using Eq. 14 $Q = 40,376.21$ ml
Compute $Q_e$ using Eq. 2 $Q_e = 4376.21$ ml
Compute purchase cost using Eq. 3 $O_p = 18,000$
Compute order cost using Eq. 4 $O_p = \$ 2,012.81$
Compute holding cost using Eq. 15 $O_s = \$ 2,002.66$
Compute expired cost using Eq. 6 $O_e = \$ 1,955.92$
Compute crashing cost using Eq. 16 $O_e = \$ 5,991$
Compute total inventory cost using Eq. 17 $O_T = 23,977.39$

Iteration with lowest total inventory cost is iteration 2. So, optimum inventory policy is $Q = 40,317.32$ ml, $T = 13$ month with lead time for 24 week.

Algorithm 4
For $Q_{e0}=0$ and total inventory cost ($O_{T0}$) $\in$, lead time = $L_0$. $L_0 = 24$ week. Compute $T$ using Eq. 18 $T = 0.887$ year.

Compute $Q$ using Eq. 9 $Q= 31,934.96$ ml
Compute $Qe$ using Eq. 2 $Qe = 0$ ml
Compute purchase cost using Eq. 3 $O_b = \$ 18,000$
Compute order cost using Eq. 10 $O_p = \$ 2,554.85$
Compute holding cost using Eq. 19 $O_s = \$ 1,644.75$
Compute expired cost using Eq. 12 $O_e = \$ 0$
Compute crashing cost using Eq. 20 $O_e = \$ 0$
Compute total inventory cost for preservation oil using Eq. 21 $O_{T1} = 22,189.61$

Compute total inventory cost for all materials $O_T = \$ 461,250.2$

For $Q_{e0}=0$, lead time = $L_1$. $L_1 = 20$ week. Compute $T$ using Eq. 18 $T = 0.8873$ year.

Compute $Q$ using Eq. 9 $Q= 31,945.56$ ml
Compute $Qe$ using Eq. 2 $Qe = 0$ ml
Compute purchase cost using Eq. 3 $O_b = \$ 18,000$
Compute order cost using Eq. 10 $O_p = \$ 2,554.015$
Compute holding cost using Eq. 19 $O_s = \$ 1,641.105$
Compute expired cost using Eq. 12 $O_e = \$ 0$
Compute crashing cost using Eq. 20 $O_e = \$ 0$
Compute total inventory cost for preservation oil using Eq. 21 $O_{T2} = 22,185.457$

Compute total inventory cost for all materials $O_T = \$ 461,227.65$

For $Q_{e0}=0$, lead time = $L_2$. $L_2 = 16$ week. Compute $T$ using Eq. 18 $T = 0.8879$ year.

Compute $Q$ using Eq. 9 $Q= 31,966.75$ ml
Compute $Qe$ using Eq. 2 $Qe = 0$ ml
Compute purchase cost using Eq. 3 $O_b = \$ 18,000$
Compute order cost using Eq. 10 $O_p = \$ 2,542.32$
Compute holding cost using Eq. 19 $O_s = \$ 1,598.33$
Compute expired cost using Eq. 12 $O_e = \$ 0$
Compute crashing cost using Eq. 20 $O_e = \$ 0.6757$
Compute total inventory cost for preservation oil using Eq. 21 $O_{T3} = 22,141.342$

Compute total inventory cost for all materials $O_T = \$ 460,938$

For $Q_{e0}=0$, lead time = $L_3$. $L_3 = 15$ week. Compute $T$ using Eq. 18 $T = 0.882$ year.

Compute $Q$ using Eq. 9 $Q= 31,977.34$ ml
Compute $Qe$ using Eq. 2 $Qe = 0$ ml
Compute purchase cost using Eq. 3 $O_b = \$ 18,000$
Compute order cost using Eq. 10 $O_p = \$ 2,541.487$
Compute holding cost using Eq. 19 $O_s = \$ 1,598.86$
Compute expired cost using Eq. 12 $O_e = \$ 0$
Compute crashing cost using Eq. 20 $O_e = \$ 0.9006$
Compute total inventory cost for preservation oil using Eq. 21 $O_{T4} = 22,141.25$

Compute total inventory cost for all materials $O_T = \$ 460,955.34$
Iteration with lowest total inventory cost is iteration 3. So, optimum inventory policy is Q = 31,966.75 ml, T = 10 month with lead time for 16 week.

Total inventory cost by using multi item deterministic model is cheaper than single item deterministic model. The time to order in multi item model is more often than single item model; therefore it has higher order cost and lower holding cost than single item model. Total inventory cost for all materials cheaper by using multi item model. Based on the concept of multi-item inventory policy, PT DI is advised to order material from same supplier at the same time in order to decrease the ordering cost and subsequently reduce the total inventory cost.

According to this condition, PT DI is advised to order more often rather than store more materials since it causes wasted expired materials that will be discarded.

A performance comparison for existing method at PT DI and proposed model in this research is done to ensure that there is an improvement and the proposed models can solve the problem at PT DI. In general, the proposed models have cheaper total inventory cost than the existing. The problem addressed in this research is the excess of material. Comparison of total inventory cost existing and proposed deterministic single item and multi item can be seen in Figure 1.

![Figure 1 Comparison of Total Inventory Cost (Existing versus Proposed) for Deterministic Single Item and Multi-Item](image)

As can be seen from the chart, expired cost has decreased until zero for each material. It means that expired material has decreased too. Wasted expired materials, with the proposed model, have been successfully decreased to 95%. So, it can be concluded that by using deterministic models single and multi-item, the problem in PT DI can be solved.

The other model used in this research is probabilistic where demand during lead time is probabilistic. This model used to determine the optimum lead time in order to minimize total inventory cost.
Lead time crashing cost model requires an additional cost named crashing cost; this cost will compared with holding cost. The lead time that has crashed to smaller lead time will decrease the safety sock so can decrease the holding cost.

Sensitivity analysis is done for all parameters. Demand and holding cost are parameters that are sensitive for both deterministic and probabilistic single item models while demand is the parameter that is sensitive for both deterministic and probabilistic multi item model.

5. Conclusion

The deterministic model used in this research is EOQ for single item and multi-item considering expiration factor. The probabilistic model used in this research is probabilistic single and multi-item models with lead time as a decision variable.

The proposed inventory policies using the EOQ single item and considering expiration factor results in a reduction in total costs up to 69.58% and the policy using multi item results in a decrease in total costs amounted to 71.16%.

The proposed inventory policy using the model of a single item by considering expiration and lead time crashing cost in probabilistic condition results in a decrease in the total costs amounted to 71.5% and the policy using multi item concept results in a decrease in total costs amounted to 71.62%. Wasted expired materials, with the proposed model, have been successfully decreased to 95%, so it means that order materials are based on the requirements of material usage.

Demand and holding cost are parameters that are sensitive for both deterministic and probabilistic single item models while demand is the parameter that is sensitive for deterministic and probabilistic multi item model.

Some constrains are not accounted in this research. Therefore, further research can be done by knowing the real component lead time and crashing cost and develops the information systems.

The limitation of this research is that the proposed models are suitable only for material with limited life time for manufacture CN-235 aircraft. Nevertheless, proposed models can be implemented for system that use material with limited life time and has deterministic demand characteristic. In the future, we will consider the component commonality using degree of commonality concept to be integrated in the model.

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