Optimizing Japanese Domestic Airlines Network by Evolutionary Computation

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Abstract - In recent years, various networks have come to exist in our surroundings. Not only can the internet and airline routes be regarded as networks; protein interactions are also networks. A network is defined as a structure of nodes (points) and links (lines). As described in this paper, an airline network is used as an example of an “economic network design problem.” For the airline network, modeled based on a connection model proposed by Jackson and Wolinsky, a utility function can be defined as the sum of profits obtained from each route. Furthermore, an optimization simulation using the evolutionary computation is presented for a domestic airline in Japan.

Keywords: Airline Network, Simulation, Network Game Theory, Evolutionary Computation

1 Introduction

In recent years, the Japanese aviation industry has been in dire straits, and the failure of Japan Airlines (JAL) has been well publicized. Although JAL has announced abolition of one loss-producing line one after another, All Nippon Airlines (ANA), which had been expected to replace JAL, has shown bad financial health. In such a situation, finding optimal airline networks that maximize profits is extremely important. Because the profits of other routes might also be affected by abolishing a loss-making line, it is necessary to consider transitions in an aviation network. Properly speaking, when abolition of a route is determined, it is desirable to consider not only the influence of the direct flight, but the concomitant increase and decrease of passenger traffic effects on transit passengers. Therefore, this paper defines a profit function that regards the influence on transit passengers explicitly. We seek the optimal airline network that maximizes profits. In modeling of the airline network, connections models of Jackson and Wolinsky (1996) are extended to a model in which profits generate on a link and the utility function of the network is defined.

In the paper “airline network optimization problem,” analyses were conducted for the network to maximize network utility, but finding optimal network theory is difficult when assessing real-world problems. Therefore, we propose a solution using evolutionary computation to resolve “airline network optimization problems.” Furthermore, optimization simulation using evolutionary computation is demonstrated for a domestic airline in Japan. Optimal networks obtained when only the rate of the passenger discount by the transit was changed were found using the proposed algorithm.

The remainder of this paper is organized as follows. Section 2 formulates an “airline network optimization problem.” Section 3 presents a description of a method of an “airline network optimization problem” using an evolutionary computation. Simulation results are presented in Section 4. Finally, we state the important conclusions in Section 5.

2 Airline network

An airline network is modeled in this paper based on Jackson and Wolinsky’s (1996) connections model. In Jackson and Wolinsky (1996), the form that a stable network takes is analyzed under the situation in which formation of the link with a new each node (player)(relation) and an existing link disconnection are selected in the strategy. The network formation game theory proposed by Jackson and Wolinsky (1996) can become a substantial framework when dealings between varieties of economic agents are analyzed. For example, the conclusion distribution of the Free Trade Agreement in an international trade is foreseen, and it is applied to the analysis of the decision of the best airline line network etc. In the following, after first describing the utility function in the connections model, the airline network is modeled.

2.1 Connections model

As described in this paper, an economic network is denoted as a non-directed graph $G = (V, E)$ according to the graph theory. Graph $G$ consists of node set $V$ and link (edge) sets $E$. For example, a node in a graph represents an economic player (individual, group, city, and nation), and the link stands for a transport link, a telecommunication net, an economic regional alliance, etc. A link $e \in E$ is sets of node pairs $e = \{i, j\}$. A link between $i$ and $j$ is simply denoted $ij$. Considering a complete graph that consists of node set $V$, an economic network that consists of nodes (players) is subgraph $G$ of complete graph $K$. The values of $w_{ij}$ is an intrinsic value to obtain node $i$ from node $j$ by a direct link, and $c_{ij}$ is the running cost of link $ij$. The utility function to obtain node $i$ in graph $G$ is defined as shown below.

$$u_i(G) = \sum_{j=||i\neq j}^{||V||} \delta^{(G)}_{ij} w_{ij} - \sum_{j=||j\in G}^{||V||} c_{ij}$$ (1)
$|V|$: number of nodes in $V$
$\delta$: decay rate of the gain
$s_i(G)$: shortest path length in $G$
$w_{ij}$: gain to obtain node $i$ from node $j$ through link $ij$
$c_{ij}$: running cost of link $ij$
Furthermore, $\delta \in [0,1]$ is the decay rate of the gain.
Considering the shortest path length $s_{ij}$ between $ij$, $\delta^{s_i(G)}w_{ij}$ is the gain to obtain node $i$ from node $j$ through the shortest path $s_{ij}$. Only when the link exists directly between $ij$ is the link running cost $c_{ij}$ needed. The graph value (utility of the entire network) is a summation of utilities of all nodes that exist in the network. The graph value is defined by the following equation.

$$u_{net}(G) = \sum_{i=1}^{|V|} u_i(G)$$

$$= \sum_{i=1}^{|V|} \sum_{j=1}^{|V|} \delta^{s_{ij}(G)}w_{ij} - \sum_{i=1}^{|V|} \sum_{j=1}^{|V|} c_{ij}$$

The economic network design problem above can be formulated as follows.

$$\arg \max_{G \subseteq K_{|V|}} u_{net}(G)$$

(2)

### 2.2 Airline network model

There was a problem of lacking concreteness, although the connections model of Jackson and Wolinsky (1996) was able to assume various networks. Therefore, the analytical object is focused on the airline network. In the following, the airline network is modeled based on a connections model. The point in which the airline network model differs greatly from the utility function of connections model is to examine the utility obtained from a link.

In the airline network model, a node and a link respectively signify an airport and a route. The airline route with only the outward or homeward journey is a rare case. Therefore, the airline network is assumed to be a non-directed graph that does not incorporate the direction of the connection of the link. A link $e \in E$ of non-directed graph is a set of node pairs $e = \{i, j\}$ (i, j $\in V$ and $i \neq j$) without the order. A link between $i$ and $j$ is denoted simply as $ij$, and $ji = ij$. Furthermore, $r_{ij}$ is an income of link $ij$; $c_{ij}$ is an operation cost of link $ij$. The profit obtained between links $ij$ in graph $G$ is defined as

$$\pi_{ij}(G) = \begin{cases} 
  r_{ij} - c_{ij} & \text{if } ij \in G \\
  \delta^{s_{ij}(G)-1}r_{ij} & \text{otherwise}
\end{cases}$$

(4)

$|V|$: number of nodes (airport)
$\delta$: decay rate of the profit
$s_i(G)$: shortest path length in $G$
$r_{ij}$: income between $i$ and $j$
$c_{ij}$: operation cost of link $ij$

Also, $\delta \in [0,1]$ is the decay rate of the profit. Considering that the shortest path length $s_{ij}$ between $ij$, $\delta^{s_{ij}(G)-1}r_{ij}$ is the income got from node $i$ by a passenger who goes to node $j$. Only when a direct flight exists between $ij$ is operation cost $c_{ij}$ needed. For these analyses, it is assumed that operation cost $c_{ij}$ is necessary only for the direct flight's existing according to connections model. It is assumed that a flight need not be increased even if the number of passengers increases by an indirect link. Consequently, for aircraft that are not used over capacity, the load factor is at the 60% level also for the main route.

In addition, the income is the product of ticket price $p_{ij}$ and the number of passengers $q_{ij}$. Also, $\delta$ is the product of the decay rate of ticket price $\delta_1$ and the passenger decay rate $\delta_2$. Equation (4), showing the price of the airline ticket and the number of passengers, can be rewritten as the income as follows.

$$\pi_{ij}(G) = \begin{cases} 
  p_{ij}q_{ij} - c_{ij} & \text{if } ij \in G \\
  \delta^{s_{ij}(G)-1}p_{ij} \cdot \delta_2^{s_{ij}(G)-1}q_{ij} & \text{otherwise}
\end{cases}$$

(5)

$\delta_1$: decay rate of ticket price
$\delta_2$: passenger decay rate
$p_{ij}$: ticket price between $i$ and $j$
$q_{ij}$: passengers between $i$ and $j$

Also, $\delta_2 \in [0,1]$ is the decay rate of the ticket price. The fare that a passenger must pay indeed gives a discount if the number of times of connection increases. In addition, $\delta_2 \in [0,1]$ is the passenger decay rate. Whenever the number of connections to the destination increases by $\delta_2$, it is included in the model that the number of passengers decreases.

Next, operation cost $c_{ij}$ is defined. Actually, $c_{ij}$ is the operation cost of one year for the route between $i$ and $j$, and the cost function is defined by the following equations.

$$c_{ij} = OP_{ij} \cdot FY_{ij}$$

(6)

$OP_{ij}$: cost per flight
$FY_{ij}$: number of annual flights

$$OP_{ij} = W(d_{ij} \cdot FU) + B$$

(7)

$W$: change of the weight by the number of passengers
$d_{ij}$: straight line distance between $i$ and $j$
$FU$: fuel cost per km
$B$: airport landing fee

$$FU = LMX(FP + TAX)/RMX$$

(8)

$LMX$: maximum fuel capacity of the aircraft
$FP$: price per liter of jet fuel
$TAX$: fuel tax per liter
$RMX$: longest cruising range of aircraft

$$W = WE + PF_{ij} \cdot PW$$

(9)

$WE$: operating empty weight of the aircraft
$PF_{ij}$: number of passengers per flight
$PMX$: number of seats of aircraft
PW: weight per passenger

The graph value $\pi_{net}(G)$ (profit of the entire airline network) is the summation of profits of all links in the network. The graph value $\pi_{net}(G)$ is defined by the following equation.

$$\pi_{net}(G) = \sum_{i=1}^{V} \sum_{j=1}^{V} \pi_{ij}(G)$$

$$= \sum_{i=1}^{V} \sum_{j=1}^{V} \delta_{s_{ij}(G)-1} r_{ij} - \sum_{i=1}^{V} \sum_{j=1}^{V} C_{ij}$$

(10)

In equation (4), the profit when the direct link (direct flight) exists between $ij$ differs when the direct link does not exist. However, no problem as $\delta_{s_{ij}(G)-1} r_{ij}$ exists because the shortest path length $s_{ij}(G) = 1$ when a direct flight exists. Equation (10) and equation (2) are the same structures if it is excluded that the exponent of $\delta$ is $s_{ij}(G)-1$. It is understood that the airline network model is a pure application of the connections model.

The airline network optimization problem above can be formulated as follows.

$$\text{arg max}_{G \in \mathcal{K}} \pi_{net}(G)$$

(11)

### 3 Evolutionary computation for “airline network optimization problem”

It is extremely difficult to analyze the network where the utility of the entire network is maximized in non-symmetric node (player) theoretically. One kind of evolutionary computation method, Population-Based Incremental Learning (PBIL) with a local search for the approximate solution method, is applied. Optimization of the network is tried. The basic operation of the improved algorithm is almost identical to that of the usual PBIL, but there is a difference in the update process of the probability vector. The difference point is to do a greedy search based on the selected excellent individual before the probability vector is updated. The former excellent solution is replaced if a better solution is found from the former excellent solution as a result of a greedy search. However, a local search examines the range of Hamming distance 1 as the neighborhood. This proposed algorithm is called G-PBIL. In the following, the schematic diagram of algorithm is presented in Fig. 1, and detailed processing of each Step is described.

Step 1: Initialization of probability vector $\tilde{P}$

The probability vector $\tilde{P} = (p_1, p_2 \ldots, p_{nbit})$ is the probability that each bit of the gene becomes 1. When the search begins, the probability vector is set to all 0.5. $nbit$ is the gene length, which changes according to the scale of the problem. The probability vector in $t$ generation (cycle) is written as $\tilde{P}^t = (p_1^t, p_2^t \ldots, p_{nbit}^t)$.

Step 2: Generate the sample population according to probability vector $\tilde{P}$

Each individual is expressed by the bit string of 0 or 1 that is called a gene, and the probability vector is simply a description of the appearance probability of 1 by the vector.

Step 3: Evaluate the population, and select an excellent individual

The population is evaluated, and an excellent individual with the best fitness in the population is selected. The selected excellent individual is the notation
A term called fitness is used because the right and wrong of an objective function values change with a minimization problem or maximum problem. For a minimization problem, it is considered that a smaller objective function value has higher fitness. Conversely, for a maximization problem, a greater objective function value indicates higher fitness.

Step 4: Greedy search based on a selected excellent individual.

First, the population that changes the gene of \( M' \) by only one bit is generated. Next, fitness of the population that newly generates it is calculated, and the individual with the best fitness among former \( M' \) and newly generated populations is new \( M' \). Greedy search is stopped if former \( M' \) has best fitness. Otherwise, greedy search is tried again based on new \( M' \). However, when trying greedy search again, changing a bit that has already changed from \( M' \) from the first received from PBIL is forbidden. This rule limits the frequency of a greedy search. Even if it is the maximum, the frequency of a greedy search under this rule is gene length. The reason to adopt such a rule is that it is thought that the frequency of a greedy search becomes every high if the bit is changed unrestrictedly.

Step 5: Update probability vector

The probability vector is updated using excellent individual \( M' \) improved by a greedy search.

\[
p_i^{t+1} = (1.0 - LR) p_i^t + LR \cdot m_i^t
\]

(12)

\( LR \) stands for the learning rate. When \( LR \) is large, the search will converge rapidly to the generation's excellent individual. To evade the initial convergence, \( LR \) should be set to a small value. However, because a generation number required for search increases when the value of \( LR \) is small, setting it to an extremely small value hinders the search.

Step 6: Mutation

Mutation occurs at a constant mutation probability, and the value of each element of the probability vector updated with Step 5 is changed further according to the following equation.

\[
p_i^{t+1} \leftarrow (1.0 - MR) p_i^{t+1} + rand \cdot MR
\]

(13)

\( MR \) is a degree of the change by the mutation. The probability vector changes greatly by \( MR \) large. \( rand \in \{0,1\} \) is a uniform random number.

Step 7: Repetition of Step 2 – Step 6

The processing of Step 2 – Step 6 is repeated until the termination condition is satisfied. It is defined as the first generation to repeat the processing of Step 2 – Step 6 once in PBIL. The termination condition of processing when the set number of generations is passed or the convergence of the search is admitted by the convergence criterion is usually adopted as a termination condition.

When this algorithm is adapted to the “network optimization problem” for which a design variable takes the discrete value of 0–1, it is necessary that a gene correspond to a graph as presented in Fig. 2. Denoting a graph by an adjacent matrix, and also making an adjacent matrix correspond to a genotype can express a graph with a gene. The adjacent matrix \( A \) of a graph \( G \) (airline network) is the matrix of \( |V| \times |V| \), where \( a_{ij} \) represents element of row \( i \) and column \( j \) of matrix \( A \). It is assumed that \( a_{ij} = 1 \) when the link (edge) exists directly between vertices \( i \) and \( j \). It is also assumed that \( a_{ij} = 0 \).

\[
a_{ij} = \begin{cases} 1 & \text{if } ij \in G \\ 0 & \text{otherwise} \end{cases}
\]

(14)

When G-PBIL is adapted to the “network optimization problem” in which a design variable takes the discrete value of 0–1, the gene length is set as \( nbit = |V|(|V| - 1)/2 \). In Step 3 of an algorithm, as presented in Fig. 2, a gene is changed to a graph, and the graph value is computed using equation (10). Making a computed graph value into the goodness of fit of a gene is synonymous with optimizing a graph to optimize a gene.

4 Simulation analysis of the optimal airline network

Here, the proposed algorithm is used and simulated. The simulation is targeted to 19 airports of Japan with domestic routes serving 1.5 million passengers or more annually. Figure 4 shows the existing network among the 19 airports.

4.1 Data

To conduct a simulation, some data are necessary: the ticket price \( p_{ij} \), number of potential passengers \( q_{ij} \), and straight line distance \( d_{ij} \) between \( i \) and \( j \). First, we consider the ticket price \( p_{ij} \) between \( i \) and \( j \). If between \( i \) and \( j \) is an existing route, \( p_{ij} \) examines the price of the airline ticket. However, the price cannot be examined about the route that does not exist. Then, the airline ticket price of the non-existent route is estimated by
the following regression by making the distance \( d_{ij} \) into an explanatory variable.

\[
p = \alpha + \beta d
\]  
(15)

A single regression analysis that uses a straight line distance based on Google Map was done with the price of the airline tickets of All Nippon Airways (ANA). A significant result was obtained statistically by \( \alpha = 15562.75 \) and \( \beta = 21.21 \) with correlation coefficient 0.89 and a coefficient of determination 0.80.

Next, passenger \( q_{ij} \) travelling between \( i \) and \( j \) is considered. Data existing for passengers between existing routes can be determined using data of the Ministry of Land, Infrastructure, Transport, and Tourism. Passenger \( q_{ij} \) of the non-existent route is estimated using the gravity model used well in aeronautical demand forecasting. A passenger can be estimated using the following formula and turns into the correlation coefficient 0.806 by \( a = 0 \) and \( b = 2.631 \times 10^5 \). However, only routes of not less than 300 km of distance can be estimated, and passenger \( q_{ij} \) for routes less than 300 km are set to zero.

\[
q_{ij} = b \frac{\text{pop}_i \cdot \text{pop}_j}{d_{ij}^a}
\]  
(16)

**pop** : quota population of each airport

Data used as explanatory variables are the quota population of each arrival-and-departure airport and the distance in a straight line \( d_{ij} \) between airports. Because the quota population of each airport is needed here, we presume that the following methods are used. In this paper, a Voronoi diagram is drawn by setting each airport to the generatrix (node): the population of each area residing with a nearby airport is used most. The quota population (Table 1) of each airport was calculated by the figure of the area divisions and population data are given by Asahi Shimbun Publications. Data of the existing route are obtained using data provided by the Ministry of Land, Infrastructure, Transport and Tourism. Data estimated using the gravity model are used only for the non-existent route.

Each datum used for a cost function is set to a jet fuel value rank \( FP = 50 \) yen/liter, an aviation fuel tax \( TAX=26 \) yen/liter, the landing fee \( B = 400,000 \) yen, and weight per passenger \( PW = 100 \) kg.

### 4.2 Optimization simulation

We simulate the case of one kind of aircraft. Data of the aircraft are computed from the average value of the main aircraft (Table 2). The determined optimal network by the simulation is presented in Fig. 3 – Fig. 6.

When the fare discount rate \((1 - \delta_1)\) and the passenger decrease rate \((1 - \delta_2)\) become small, the optimum network is clarified as centralized on Tokyo International Airport (Haneda). The fare discount rate \((1 - \delta_1)\) and the traveler decrease rate \((1 - \delta_2)\) become small as \( \delta = \delta_1 \delta_2 \) becomes large. That relation corresponds to the previous work clearly to make the network excessively concentrated by growing of \( \delta \). The change to Fig. 4 from Fig. 3 occurs when the passenger decrease rate \((1 - \delta_2)\) becomes small. This change shows that the direct flight from the main island of Japan to Naha Airport is decreasing by two routes. The change to Fig. 5 from Fig. 3 changes when the passenger decrease rate \((1 - \delta_1)\) becomes small. This change shows that the direct flights from the main island of Japan to Naha Airport are decreasing by four routes, and that numerous direct flights between the airports in the main island of Japan are also decreasing. Furthermore, the change to Fig. 6 from Fig. 3 occurs when both the fare discount rate \((1 - \delta_1)\) and the passenger decrease rate \((1 - \delta_2)\) become small. This change shows that the direct flights from the main island of Japan to Naha Airport are decreasing by four routes, and that numerous direct flights between the airports in the main island of Japan are also decreasing. Furthermore, the change to Fig. 6 from Fig. 3 occurs when both the fare discount rate \((1 - \delta_1)\) and the passenger decrease rate \((1 - \delta_2)\) become small. This change shows that the direct flights from the main island of Japan to Naha Airport are decreasing by four routes, and that numerous direct flights between the airports in the main island of Japan are also decreasing. Furthermore, the change to Fig. 6 from Fig. 3 occurs when both the fare discount rate \((1 - \delta_1)\) and the passenger decrease rate \((1 - \delta_2)\) become small. This change shows that the direct flights from the main island of Japan to Naha Airport are decreasing by four routes, and that numerous direct flights between the airports in the main island of Japan are also decreasing. Furthermore, the change to Fig. 6 from Fig. 3 occurs when both the fare discount rate \((1 - \delta_1)\) and the passenger decrease rate \((1 - \delta_2)\) become small. This change shows that the direct flights from the main island of Japan to Naha Airport are decreasing by four routes, and that numerous direct flights between the airports in the main island of Japan are also decreasing.

### Table I

Allocated populations of 19 airports (Unit: 10,000 people)

<table>
<thead>
<tr>
<th>Airport name</th>
<th>Airport code</th>
<th>pop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Haneda</td>
<td>HND</td>
<td>3302.30</td>
</tr>
<tr>
<td>2. New Chitose</td>
<td>CTS</td>
<td>46.73</td>
</tr>
<tr>
<td>3. Osaka</td>
<td>ITM</td>
<td>1422.54</td>
</tr>
<tr>
<td>4. Fukuoka</td>
<td>FUK</td>
<td>312.09</td>
</tr>
<tr>
<td>5. Naha</td>
<td>OKA</td>
<td>134.70</td>
</tr>
<tr>
<td>6. Chubu</td>
<td>NGO</td>
<td>980.25</td>
</tr>
<tr>
<td>7. Kagoshima</td>
<td>KOJ</td>
<td>213.79</td>
</tr>
<tr>
<td>8. Kansai</td>
<td>KIX</td>
<td>188.20</td>
</tr>
<tr>
<td>9. Kumamoto</td>
<td>KMI</td>
<td>184.38</td>
</tr>
<tr>
<td>10. Miyazaki</td>
<td>KMI</td>
<td>66.07</td>
</tr>
<tr>
<td>11. Hiroshima</td>
<td>HIJ</td>
<td>225.93</td>
</tr>
<tr>
<td>12. Sendai</td>
<td>SDJ</td>
<td>220.16</td>
</tr>
<tr>
<td>13. Kobe</td>
<td>UKB</td>
<td>337.01</td>
</tr>
<tr>
<td>14. Matsuyama</td>
<td>MYJ</td>
<td>122.93</td>
</tr>
<tr>
<td>15. Nagasaki</td>
<td>NGS</td>
<td>147.90</td>
</tr>
<tr>
<td>16. Komatsu</td>
<td>KMQ</td>
<td>98.09</td>
</tr>
</tbody>
</table>
island of Japan. However, in this experiment, the passengers of a non-existent route are estimated using the population around an airport, and it cannot be considered that Ishigaki Island is a tourist resort. The route between Haneda Airport and Ishigaki Airport is known for a seat-occupancy rate being high, and probably, it is not realistic to abolish the route. Regarding this point, the seat-occupancy rate is included in a cost function, and improvement with a different seat-occupancy rate for every route can be considered.

5 Conclusion and Future work

As described in this paper, an airline network is modeled based on Jackson and Wolinsky’s (1996) connections model. Moreover, the optimal network in an existing airline network is found using the airline network model. Results of simulations show that because a realistic network identified, the possibility exists that a connections model can be used as a framework for airline network analysis. Although Jackson reported that the connections model can be applied as a framework of various network analyses, few examples have been presented in which a connections model is actually
applied to actual network analysis. This paper has contributed a research example using a connections model. The G-PBIL algorithm that extended PBIL was used for optimization of an airline network. In the simulation, a network that is more efficient than the existing network can be found. When the fare discount rate and the traveler decrease rate were small, the optimum network was shown to centralize to Tokyo International Airport (Haneda).

Future works will expand the simulated range. With the G-PBIL algorithm, although improvement in search performance was sought using a local search together to PBIL, the time which search takes has also increased. The search time by local search increases as the network scale becomes large, and it becomes difficult to perform a simulation. Therefore, it is necessary to consider the proper balance of the evolutionary computation and the local search in G-PBIL. Moreover, although this simulation of only a domestic flight was performed, the international role of Haneda Airport can be clarified by adding main airports of the world. As a subject for other future work, analysis of the optimal airline network when an airport is closed or built is also possible by application of estimation of passengers using a Voronoi diagram and gravity model.

### Table II

<table>
<thead>
<tr>
<th>Aircraft data</th>
<th>Boeing 747-400D</th>
<th>Boeing 777-300</th>
<th>Boeing 777-200</th>
<th>Average</th>
<th>Used data</th>
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</thead>
<tbody>
<tr>
<td>Number of seats 2 class</td>
<td>524</td>
<td>451</td>
<td>400</td>
<td>458.33</td>
<td>450</td>
</tr>
<tr>
<td>Maximum fuel capacity (Unit: liter)</td>
<td>216840</td>
<td>171160</td>
<td>117335</td>
<td>168445.00</td>
<td>150000</td>
</tr>
<tr>
<td>Longest cruising range (Unit: km)</td>
<td>13450</td>
<td>11135</td>
<td>9696</td>
<td>11427.00</td>
<td>10000</td>
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<tr>
<td>Operating empty weight (Unit: kg)</td>
<td>181000</td>
<td>160000</td>
<td>138000</td>
<td>159666.67</td>
<td>150000</td>
</tr>
</tbody>
</table>

(Source: Japan Aircraft Development Corp.)

6 References


