Design Simulation Program of Runway Capacity Using Genetic Algorithm at Soekarno-Hatta

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Abstract

The purposes of this research are to calculate the capacity of runway with runway capacity simulation software using Genetic Algorithm, and to analyze the efforts which have more profound effect. To enhance the runway capacity, some strategies are researched, such as reduction of separation to meet criteria set by FAA's rule, addition of the exit taxiway, addition of the runway according to master plan of Soekarno-Hatta Airport and changing the runway utilization strategies. Out of the four strategies, the most efficient solution is changing the runway utilization strategies and reduction in separation. However, the addition of runway has the highest capacity increase.

Keywords: genetic algorithm, simulation, runway capacity.

1. Introduction

The capacity of an airport is very important to understand, in relation to aviation safety. If the number of aircraft operating at an airport exceeds capacity, the course will cause overload on the system of Air Traffic Management (ATM). For example on the controller, which will experience work overload and fatigue occurs, so that opportunities occur violations will increase that could endanger the safety of flight operations. Another thing related to airport capacity is the quality of service. If the number of aircraft operating greater than capacity Airport, the quality of services provided will decrease. As such there will be delays execution of flight operations, which would be detrimental to consumers.

Airport capacity is a need known to be associated also with an Airport system planning. If demand exceeds the capacity of flight operations continually Airport certainly necessary to improve airport facilities for the capacity to accommodate the request.However, if demand exceeds the capacity of flight operations at the Airport, only certain times, it can be done for instance limiting the number of operations at peak hours. Along with the emergence of new airlines with cheap fares which resulted in increased flight frequencies and result in increased air traffic means. Increased density is estimated to have nearly approached the carrying capacity of Soekarno-Hatta Airport, so we need to increase the capacity it has, one of which runway capacity.

There are several factors that affect runway capacity by air traffic separation rules are applied, the number and configuration of runways, runway operation pattern, the number and location of the exit taxiway, navigation aids, weather conditions, a mixture of aircraft operating, and so forth. Separation of air traffic is very influential on runway capacity, which by reducing the separation between aircraft can increase runway capacity. However, reducing the separation between aircraft must consider factors that can ensure flight safety. The number and configuration of runways is another factor that influenced enough runway capacity. More and more runway, capacity has certainly bigger.

In addition, the number and location of the exit taxiway was can influence runway capacity. Location of exit taxiway appropriate for different categories of aircraft to reduce the time use of the runway, causing increasingly rapid runway can be used for other aircraft. Because of the many factors that influence the capacity of the runway, which can be used to increase runway capacity, it is necessary to do comparative analysis to find the factors which produce the largest increases and can be applied at the Soekarno-Hatta Airport with simulation programs using genetic algorithms.

2. Research Method

In this issue used Multiple Attribute Decision Making (MADM) to determine which efforts to increase runway capacity is greatest, will select a set of alternatives based on several attributes.

Let $S = \{S_1, S_2, ..., S_m\}$ is the set of alternatives; $C = \{C1, C2, ..., Cn\}$ is the set of attributes (criteria), and $A = \{a_{ij} \mid i=1,2,...,m; j=1,2,..,n\}$ is a decision matrix with a_{ij} is the numerical value of alternative i at j attribute.

Previously, the matrix A is normalized in advance, so that the value of a_{ij} lies in the range [0 1]. Suppose the matrix B is a matrix which elements are the elements of matrix A is normalized, using the formula:

$$b_{ij} = \frac{a_j^{Max} - a_{ij}}{a_j^{Max} - a_j^{Min}}; \text{for } C_j \text{ is the attribute expenses} \tag{1}$$

$$b_{ij} = \frac{a_{ij} - a_j^{Min}}{a_j^{Max} - a_j^{Min}}; \text{ for } C_j \text{ is the attribute gain} \tag{2}$$

By :

$$a_j^{Max} = \max\{a_{ij}, a_{2j}, ... a_{mj}\} \tag{3}$$

$$a_j^{Min} = \min\{a_j, a_{2j}, ... a_{mj}\} \tag{4}$$

$$i = 1,2,...,m; j = 1,2,...n.$$

a. Attribute Weighting Calculation Approach Subjective, Objective, and Subjective-Objective Integration

To resolve this problem, then that should be established before the value of each attribute and alternative and pairwise comparison matrix between attributes (especially for the subjective approach). If both of these are known, it must first be sought prior weight of each attribute.

So far, there are several methods that have been used to determine the amount of weight, among others: weighted least square, Delphi, LINMAP (Linear Programming Techniques for Multidimensional Analysis of Preference), Mathematical Programming, etc.

Basically, there are 3 approaches to find the value of attribute weights, namely the subjective approach, objective approach and the approach of integration between subjective and objective. Each approach has advantages and disadvantages.

In the subjective approach, the weight value is determined based on the subjectivity and decision-makers, so that some factors in the process of ranking alternatives can be determined freely. While the objective approach, the weight value is calculated mathematically, so ignore the subjectivity and decision-makers.

Further optimize the MADM problem solving, determining the weight value can be done by integrating between subjective and objective approach.

Suppose the decision maker to give a decision matrix $D = \{d_k \mid k,j = 1,2,...n\}$ } which is based on Saaty matrix, with elements D follow restriction:

$$d_{ij} > 0; d_{jk} = 1 / d_{kj}, \text{ and } d_{kk} = 1; k,j = 1, 2, ..., n.$$

$d_{kj\ kj}$ indicates the weight realatif attribute C_k on attribute C_j.
Let w_j (j = 1,2,...,n) are weights indicating relative importance and attribute C_j, with

$w_j. \in G = \{w_j \geq 0, j=1,2,...,n; \sum_{j=1}^{n} w_j = 1)$, then the next step is how to find the value of this weight w_j.

b. Subjective Approach

In the subjective approach, weights w_j (j=1,2,...,n) can be solved by using the method of Weighted Least Square (Chiu), namely:

$$\text{Minimizing: } z_1 = \sum_{k=1}^{n} \sum_{j=1}^{n} (d_{kj}w_j - w_k)^2 \tag{5}$$

$$\text{With restrictions: } \sum_{j=1}^{n} w_j = 1 \tag{6}$$
$$w_j \geq 0$$

c. Objective Approach

In the objective approach, weights w_j (j=1,2,...,n) can be solved by formula (Fan) as follows:

Minimizing:

$$z_2 = \sum_{i=1}^{m} \sum_{j=1}^{n} (b_j - b_{ij})^2 w_j^2 \tag{7}$$

With restrictions: $\sum_{j=1}^{n} w_j = 1 \tag{8}$

$$w_j \geq 0$$

with $b_j = \max \{b_{ij}/b_{2J}, \ldots, b_{mj}\}$ which is the 'ideal' and attribute C in the matrix B. The objective function z_2 shows the minimum deviation between the ideal value of alternatives and rank value of each alternative.

d. Integration Between Subjective and Objective Approach

To find the weights w_j (j=1,2,...,n) with the integration between subjective and objective approach, can be solved with a programming model with 2 objective functions as follows:

$$\text{Minimizing:} \begin{pmatrix} z_1 = \sum_{k=1}^{n} \sum_{j=1}^{n} (d_{kj}w_j - w_k)^2 \\ z_2 = \sum_{i=1}^{m} \sum_{j=1}^{n} (b_j^* - b_j)^2 w_j^2 \end{pmatrix} \tag{9}$$

With restrictions: $\sum_{j=1}^{n} w_j = 1 \tag{10}$

This form can be brought into the model:

$$\text{Minimizing:} \quad z_3 = \alpha \sum_{k=1}^{n} \sum_{j=1}^{n} (d_{kj}w_j - w_k)^2 + \beta \sum_{i=1}^{m} \sum_{j=1}^{n} (b_i - b_{ij})^2 w_j^2 \tag{11}$$

With restrictions: $\sum_{j=1}^{n} w_j = 1 \tag{12}$

$$w_j \geq 0$$

With α and β is the relative importance of factors on the subjective and objective approach, with caveats:

$$0 < \alpha, \beta < 1; \alpha + \beta = 1;$$

This model can be solved by using Lagrange function as follows:

$$L = \alpha \sum_{k=1}^{n} \sum_{j=1}^{n} (d_{kj}w_j)^2 + \beta \sum_{i=1}^{m} \sum_{j=1}^{n} (b_j^* - b_{jj})^2 w_j^2 + 2\lambda \left(\sum_{j=1}^{n} w_j - 1 \right) \tag{13}$$

with λ are the Lagrange multipliers.

Suppose $\dfrac{\partial L}{\partial w_g} = 0$; g 1,2,...,n; then:

$$a \left[\sum_{k=1}^{n} (d_{kg}w_g - w_k)d_{kg} - \sum_{j=1}^{n} (d_{gj}w_j - w_g) \right] + \beta \sum_{i=1}^{n} (b_g^* - b_{ig})^2 w_g^2 + \lambda = 0 \tag{14}$$

Together with, to-(n +1) equations can be written as:

$$\begin{bmatrix} Q & e \\ e^T & 0 \end{bmatrix} \begin{bmatrix} W \\ \lambda \end{bmatrix} = \begin{bmatrix} O \\ 1 \end{bmatrix} \tag{15}$$

with $W = (w_1, w_2, ..., w_n)^T$; e $(1,1, ...1)^T$; $Q = \{q_{ij} \mid i,j = 1,2,...,n\}$; and $O = (0, 0,..., 0)^T$. While the elements and the matrix Q is:

[dj +n-2]+13(b-bk) jika 1J 526

$$q_{ij} = \left\{ \begin{array}{c} \alpha\left(\sum_{k=1}^{n} d_{ki}^2 + n - 2\right) + \beta\sum_{k=1}^{m}(b_i - b_{ki}); \\ -\alpha(d_{ij} + d_{ji}); \end{array} \right\} \quad \text{if i=j}$$

Thus : $\begin{bmatrix} W \\ \lambda \end{bmatrix} = \begin{bmatrix} Q & e \\ e^T & 0 \end{bmatrix}^{-1} \begin{bmatrix} o \\ 1 \end{bmatrix}$ (16)

d. Looking for Weight with Genetic Algorithm

To find the value of weight (w), previously used temporary variables, namely the variable x ($x_1, x_2, ...,$ x_n) where n is the number of attributes. Chromosome representation and v is a variable x in the form of binary strings. Chromosomes are divided into gene n ($v_1, v_2, ...,v_n$). The length of each gene is the same. Range allowed for each x1 is [ab], with a and b are arbitrary real numbers, and accuracy (precision), eg 2 digits after the decimal point, then the length of the gene to-i (L_i) can be formulated as:

$$L_i = \left| {}^2Log\left[(b - a)10^2 + 1\right]\right|$$ (17)

While the value of x_i can be formulated as:

$$x_i = a + \left[(b - a)/(2^{li} - 1)\right] * V_i$$ (18)

So long for each gene v_i for x_i in the interval [0 1] are:

$$L_i = \left[{}^2Log\left[(1 - 0)10^2 + 1\right]\right]$$
$$= \left[{}^2Log[101]\right] = 7$$

So if there are 3 attributes (3 genes), the length of chromosomes is 3 x 7 = 21.

If a vector, with 3 genes:
    V = 0 0 1 0 1 0 1 1 0 1 0 0 1 1 0 1 1 0 0 0 1

then:
    V_1 = 0 0 1 0 1 0 1   = 21
    X_1 = 0 + [(1-0)/(2^7-1)]*21   = 0,17
    V_2 = 1 0 1 0 0 1 1   = 83
    X_2 = 0 + [(1-0)/(2^7-1)]*83   = 0,65
    V_3 = 0 1 1 0 0 0 1   = 53
    X_3 = 0 + [(1-0)/(2^7-1)]*53   = 0,42

Because of the limitations:

$$\sum_{i=1}^{n} W_i = 1$$

then the value of x needs to be modified with the following steps:
1. Calculate the total number of x (TotX)
    TotX = 0,17 + 0,65 + 0,42 = 1,24.
2. Calculate: with i1,2,...,n.

-     $W_1 = \dfrac{0,17}{1,24} = 0,14$

- $W_2 = \dfrac{0,65}{1,24} = 0,52$

- $W_3 = \dfrac{0,42}{1,24} = 0,34$

Fitness values are used, depending on the search approach to weight value is used (subjective, objective, or integration between subjective and objective). Because the issues raised was the optimization, the fitness function is used, are:

➢ Subjective Approach:

$$\text{Fitness} = \frac{1}{\sum_{k=1}^{n}\sum_{j=1}^{n}\left(d_{kj}W_j - W_k\right)^2} \tag{19}$$

➢ Objective Approach:

$$\text{Fitness} = \frac{1}{\sum_{k=1}^{m}\sum_{j=1}^{n}\left(b_j - b_{ij}\right)^2 W_j^2} \tag{20}$$

➢ Integration Approach Subjective & Objective:

$$\text{Fitness} = \frac{1}{\alpha\sum_{k=1}^{n}\sum_{j=1}^{n}\left(d_{kj}W_j - W_k\right)^2 + \beta\sum_{k=1}^{m}\sum_{j=1}^{n}\left(b_j - b_{ij}\right)^2 W_j^2} \tag{21}$$

The selection process of new chromosomes was conducted with using roulette wheel method, crossover method performed by the method of crossing a single point, and mutation is done by binary mutation method. In this algorithm also performed preserving the best chromosome.

e. Process ranking
Ranking process aims to be the best alternative was chosen as a solution. To obtain the order of ranking, the earlier need to be calculated in advance the value of alternative i, g1,
(i = 1,2 ,..., m) with the following formula:

$$g_i = \sum_{j=1}^{n} W_j b_{ij}$$

Largest value of g_i indicates the i-th alternative ranked best.

3. Simulation (Performance)
There are 4 effort that would be an alternative, namely:
S1 (Reduction of Separation),
S2 (Additions Exit taxiway),
S3 (Additional Runway) dan
S4 (Pattern Changes Runway Operations).

There are 5 criteria decision making, namely:
- C1 = The time needed,
- C2 = Capacity enhancement,
- C3 = risk of each alternative,
- C4 = advantage to be gained,
- C5 = Fee required.

From the data obtained for each alternative on each criterion, were as follows:

Alternatives	Attribute (Criteria)				
	C1	C2	C3	C4	C2
S1	0,90	1700	18	50	500
S3	0,75	2500	20	40	450
S1	0,90	1050	25	60	500
S3	0,75	1000	10	75	300

Thus, the obtained matrix A:

$$A = \begin{bmatrix} 0,90 & 1700 & 18 & 50 & 500 \\ 0,50 & 2500 & 20 & 40 & 450 \\ 0,75 & 1050 & 25 & 60 & 500 \\ 1,00 & 1000 & 10 & 75 & 300 \end{bmatrix}$$

Pairwise comparison matrix given by decision makers are as follows:

$$D = \begin{bmatrix} 1 & 2 & 2 & 3 & 6 \\ 1/2 & 1 & 1 & 2 & 3 \\ 1/2 & 1 & 1 & 2 & 3 \\ 1/3 & 1/2 & 1/2 & 1 & 3 \\ 1/5 & 1/3 & 1/3 & 1/3 & 1 \end{bmatrix}$$

(i) Find matrix B

And the information available, the next step is to make matriks B as a result of the normalization of the matrix A.

Criteria to-1, 3, and 5 are the criteria of cost, while the criteria to-2, and 4 are the criteria of profitability. So that the normalization process becomes:

$$A = \begin{bmatrix} 0,90 & 1700 & 18 & 50 & 500 \\ 0,50 & 2500 & 20 & 40 & 450 \\ 0,75 & 1050 & 25 & 60 & 500 \\ 1,00 & 1000 & 10 & 75 & 300 \end{bmatrix}$$

$$B = \begin{bmatrix} \frac{1-0,90}{1-0,50} & \frac{1700-1000}{2500-1000} & \frac{25-18}{25-10} & \frac{50-40}{75-40} & \frac{500-500}{500-300} \\ \frac{1-0,50}{1-0,50} & \frac{2500-1000}{2500-1000} & \frac{25-20}{25-10} & \frac{40-40}{75-40} & \frac{500-450}{500-300} \\ \frac{1-0,75}{1-0,50} & \frac{1050-100}{2500-1000} & \frac{25-25}{25-10} & \frac{60-40}{75-40} & \frac{500-500}{500-300} \\ \frac{1-1}{1-0,50} & \frac{1000-1000}{2500-1000} & \frac{25-10}{25-10} & \frac{75-40}{75-40} & \frac{500-300}{500-300} \end{bmatrix} = \begin{bmatrix} \frac{1}{5} & \frac{7}{15} & \frac{7}{15} & \frac{2}{7} & 0 \\ 1 & 1 & \frac{1}{3} & 0 & \frac{1}{4} \\ \frac{1}{2} & \frac{1}{30} & 0 & \frac{4}{7} & 0 \\ 0 & 0 & 1 & 1 & 1 \end{bmatrix}$$

(ii) Settlement with Subjective Approach
a. Find the value of weight (iv)

    Search the weighting is done by using genetic algorithm, with parameters as follows:
➢ Popsize = 50
➢ Chance of crossover (pc) = 0,5
➢ Chance of mutation (pm) = 0,01
➢ Preservation Opportunities chromosome = 0,2
➢ Maximum generation = 100

With the initial population:

No.	Chromosome
1	1 0 1 1 1 1 1 1 1 0 0 1 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 1 1 1 0 0 1 1 0
2	0 0 1 0 1 0 1 1 0 0 0 1 1 1 1 1 1 1 1 0 1 0 1 1 0 0 0 1 0 1 0 0 1 0 1
3	1 1 0 0 1 0 0 0 1 1 0 1 1 0 0 1 1 0 0 1 0 1 0 0 0 1 0 1 0 1 0 0 1 1 0
4	0 0 1 1 0 1 1 0 1 0 1 1 1 1 0 1 0 1 0 0 0 0 1 1 0 1 1 0 0 0 0 0 0 0 0
5	0 1 1 1 1 0 1 0 1 1 0 1 1 0 1 1 0 1 1 1 1 1 1 0 0 1 0 0 0 1 1 0 1 0 0
5	0 0 1 1 0 1 1 0 0 1 1 1 1 1 1 0 1 0 1 1 1 0 1 0 1 0 1 0 0 1 1 1 1 0 0 1
7	0 1 0 1 1 1 0 0 1 0 0 1 1 0 1 0 1 0 0 0 1 1 1 1 0 0 1 0 1 1 1 1 1 1
8	1 0 1 1 1 1 1 1 1 0 0 1 0 1 0 1 0 1 0 0 0 0 0 1 1 0 0 1 0 0 0 1 1 0 1
9	1 0 0 0 0 1 1 1 1 0 0 0 0 0 0 1 0 1 0 0 1 0 1 1 0 1 1 1 0 0 0 0 1 1 0
10	0 1 1 1 1 1 0 1 1 0 1 0 1 0 0 1 0 0 1 1 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1
11	1 0 0 1 1 0 1 0 1 0 1 1 1 0 0 0 1 0 1 0 1 0 1 1 1 0 1 1 1 0 0 0 1 0 0
12	1 1 0 1 1 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 1 0 0 1 0 1 1 0 0 1 0 0 0 1
13	0 0 1 0 1 1 0 0 1 1 0 1 1 1 1 1 0 0 0 0 1 1 0 0 0 1 0 1 1 0 1 1 1 1
14	0 0 0 0 1 0 1 1 0 1 1 0 1 0 0 0 0 0 0 1 0 0 0 0 0 1 1 0 1 1 0 1 0 0 0
15	0 1 1 0 1 1 0 1 0 0 0 1 1 0 1 0 1 1 0 0 1 0 1 0 1 1 0 1 0 1 1 1 0 0 1
16	1 1 0 0 1 1 1 1 1 1 1 1 1 1 0 0 1 1 0 0 1 0 0 1 0 1 0 0 0 0 1 0 0 1 0
17	0 0 0 1 1 0 1 1 0 0 1 0 0 1 0 1 0 0 0 1 1 1 0 0 1 0 0 0 1 1 1 1 1 1 0
18	1 1 0 1 1 0 0 1 1 1 1 0 0 1 0 0 0 1 0 0 0 1 0 1 0 0 1 1 0 0 1 1 1 1 0
19	0 1 1 0 0 0 1 1 0 1 1 1 1 0 0 0 1 1 0 0 1 0 0 0 1 0 1 1 0 0 0 1 0 0 1
20	0 0 0 0 1 0 1 0 0 0 0 1 1 0 1 0 0 0 1 1 1 0 0 1 1 1 1 1 0 1 1 0 1 0 1
21	0 0 0 0 1 0 1 0 1 0 1 1 1 1 0 0 1 0 0 0 1 1 1 1 0 1 0 1 1 1 1 1 0 0 0
22	0 0 0 1 0 0 1 0 0 1 1 1 1 0 1 0 0 1 0 0 0 0 1 1 0 1 0 0 1 0 1 0 0 1 1
23	1 1 0 1 1 1 1 1 1 0 1 0 1 1 0 0 1 1 1 0 1 1 0 0 1 1 1 1 0 1 0 1 1 0 0 1
24	1 0 1 0 0 1 0 0 0 1 0 0 1 0 0 1 0 0 0 0 0 0 1 1 1 1 1 1 1 1 0
25	0 0 1 0 1 1 0 1 0 0 1 0 1 1 1 0 1 1 1 1 1 1 0 0 1 1 0 0 0 1 0 0 1 0 0
26	1 1 1 1 0 0 0 1 1 1 1 1 1 1 1 0 0 1 0 1 0 1 1 0 0 0 0 1 1 0 1 1 1 1 1
27	1 1 1 0 1 0 1 0 1 0 1 0 1 0 1 1 0 0 0 1 0 1 0 0 0 0 0 1 1 0 1 1 1 0 0
29	1 1 1 0 1 0 1 1 0 0 1 1 1 1 1 1 1 0 1 0 0 1 1 0 0 1 0 1 1 0 0 0 1 0
29	1 1 1 1 0 0 0 0 0 1 0 1 1 1 1 1 1 0 0 1 0 0 0 0 1 0 0 1 1 0 0 0 1 0 0
30	1 1 0 1 0 0 1 1 0 1 1 0 0 1 0 1 1 0 0 1 0 1 1 0 0 0 1 1 0 0 1 1 0 0 0
31	0 0 1 0 1 1 0 0 0 0 1 0 1 1 1 1 0 0 0 1 1 0 0 0 1 1 1 1 0 0 1 0 1 1 1
32	0 0 1 1 1 0 0 1 0 1 1 0 1 1 0 1 1 0 0 0 1 1 0 0 1 0 0 1 0 1 1 0 1 0 0
33	0 0 0 0 0 0 1 1 0 1 0 0 1 1 1 0 1 0 1 1 1 0 1 1 1 0 1 1 1 0 0 0 0 0 1
34	1 0 1 0 1 1 1 1 1 0 1 1 1 0 1 0 0 0 1 0 1 1 0 0 0 0 0 0 1 1 1 1 1 1 1
35	0 1 1 1 0 0 1 1 1 0 0 0 1 1 1 0 0 1 0 0 1 0 1 1 0 0 1 0 0 1 1 1 0 1 0
36	0 1 1 0 1 1 0 1 0 1 0 0 0 1 1 0 0 0 0 1 1 1 1 1 0 0 1 1 0 1 0 0 1 0 0
37	0 1 1 0 0 1 1 1 0 1 0 0 1 0 1 1 1 1 0 0 0 1 1 1 1 0 0 0 0 1 1 1 0 0 0
38	0 0 1 1 0 0 0 0 0 1 1 1 1 0 1 1 0 1 1 0 1 1 0 0 0 1 0 0 0 1 1 0 0 0 0
39	0 1 1 0 0 1 1 1 1 0 0 0 1 1 0 1 1 0 0 0 0 1 0 0 1 1 1 0 1 0 1 0 0 0 1
40	1 0 1 1 1 1 0 1 1 1 0 1 0 0 1 0 0 1 0 1 0 0 0 0 1 1 0 1 0 0 0 0 1 1
41	1 1 1 0 1 1 0 0 1 1 1 1 0 1 1 1 0 0 0 1 0 0 0 0 1 1 0 0 1 1 1 0 1 0 1
42	0 1 1 0 0 1 0 1 1 0 0 0 1 0 1 0 1 1 1 1 0 1 0 0 0 1 0 0 1 1 0 0 1 1 0
43	1 0 0 0 0 1 0 1 1 1 1 1 0 1 0 0 1 0 1 0 1 0 0 1 1 1 0 0 1 0 1 0 0 0 0
44	1 1 0 1 1 1 0 0 1 1 0 1 0 0 1 1 0 0 1 1 1 0 0 1 1 1 0 1 0 1 1 0 0 1 0
45	1 1 0 1 1 0 1 0 1 1 0 0 0 0 0 1 0 1 0 0 1 0 1 0 1 1 1 1 0 0 0 0 0 0 1
46	0 1 0 0 0 0 1 0 1 0 0 0 0 0 1 0 1 0 0 0 1 0 0 0 0 0 1 0 0 0 0 1 0 0 1 1
47	1 0 0 0 1 1 1 1 1 0 0 1 0 0 0 0 1 0 1 0 1 0 1 1 0 0 1 0 1 0 0 1 0 1 0 0
48	1 0 0 0 0 1 1 1 1 1 0 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 0 0 1 1 1 1 1 1
49	1 0 1 0 1 1 1 0 0 0 1 1 0 0 1 0 0 1 0 0 0 0 0 1 0 0 1 1 1 0 1 0 0 0 1 1
50	0 1 0 0 1 0 1 1 1 1 1 0 0 0 0 1 1 0 0 1 1 0 0 1 0 0 1 0 0 1 1 1 1 0 1

The final value is obtained:
- ➤ Weight value:
  - • w_1 = 0,3923
  - • w_2 = 0,2077
  - • w_3 = 0,2077
  - • w_4 =0,1231
  - • w_5 = 0,0692
- ➤ Best fitness value: 63,3233
- ➤ Value of z_1: 0,0158

b. Process ranking

Furthermore, the ranking process is obtained:
- ➤ Alternative values:
  - • g_1 = 0,3075
  - • g_2 = 0,6865
  - • g_3 = 0,2734
  - • g_4 = 0,4000

➢ So the order of the alternatives is:
   S2-S4-S1-S3.
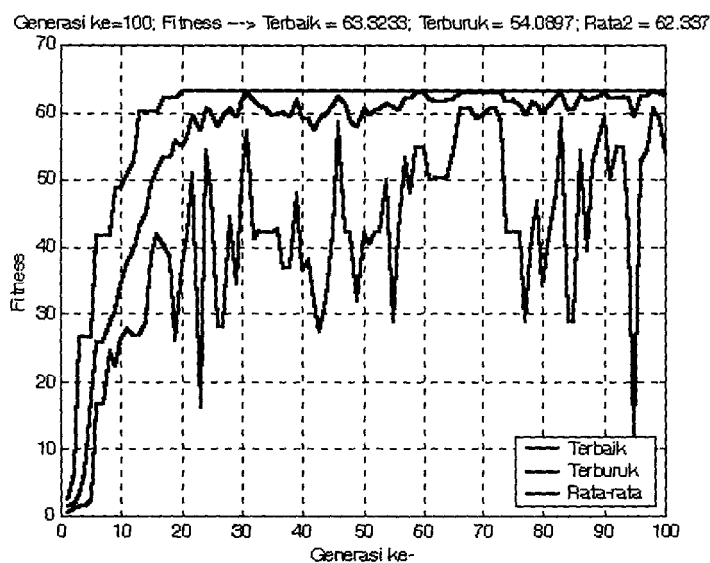So S2. (Change Pattern Runway Operations) will be selected to increase runway capacity.

No.	Weight Value (W)					Fitness
	W_1	W_2	W_3	W_4	W_5	
1	0.208	0.219	0.145	0.204	0.224	0.491
2	0.069	0.234	0.413	0.162	0.122	0.640
3	0.322	0.174	0.161	0.222	0.122	1.913
4	0.161	0.280	0.238	0.321	0.000	0.586
5	0.161	0.143	0.294	0.265	0.138	0.714
6	0.087	0.100	0.149	0.272	0.392	0.123
7	0.134	0.113	0.116	0.360	0.276	0.203
8	0.347	0.369	0.146	0.091	0.047	2.400
9	0.253	0.362	0.155	0.208	0.023	1.324
10	0.230	0.394	0.141	0.000	0 234	0.367
11	0.284	0170	0.077	0.218	0.251	0.381
12	0.462	0.145	0.000	0.321	0.073	0.656
13	0.055	0.138	0.281	0.246	0.279	0.233
14	0.024	0.435	0.010	0.029	0.502	0.071
15	0.171	0.222	0.283	0.143	0.181	0.770
16	0.329	0.406	0.080	0.064	0.121	1.073
17	0.041	0.229	0.110	0.226	0.395	0.123
18	0.309	0.346	0.023	0.237	0.086	0.981
19	0.261	0.500	0.133	0.059	0.048	0,773
20	0.030	0.036	0.428	0.187	0.319	0.164
21	0.016	0.154	0.056	0.382	0.392	0.102
22	0.037	0.122	0.293	0.211	0.337	0.166
23	0.296	0.229	0.157	0.080	0.237	0520
24	0.269	0.059	0.249	0.010	0.413	0.125
25	0.072	0.247	0.313	0.250	0.118	0.64
26	0.234	0.248	0.144	0.189	0.185	0.791
27	0.283	0.101	0.237	0.157	0.222	0.569
28	0.251	0.170	0.262	0.107	0.210	0.671
29	0.359	0.069	0.341	0.027	0.204	0.566
30	0.286	0.243	0.136	0.270	0.065	1.420
31	0.129	0.065	0.582	0.088	0.135	0.370
32	0.080	0.261	0.141	0.207	0.310	0.208
33	0.003	0.281	0.295	0.200	0.220	0.328
34	0.190	0.241	0.151	0.140	0.278	0.317
35	0.169	0.294	0.217	0.148	0.172	0.824
36	0.153	0.229	0.190	0.326	0.102	0.632
37	0.119	0.191	0.280	0.280	0.131	0.642
38	0.086	0.108	0.391	0.244	0.172	0.426
39	0.143	0.277	0.134	0.218	0.227	0.403
40	0.248	0.219	0.219	0.187	0.128	1.918
41	0.291	0.150	0.241	0.030	0.288	0.302
42	0.121	0.238	0.228	0.165	0.248	0.368
43	0.206	0.391	0.066	0.087	0.250	0.334
44	0.320	0.151	0.299	0.084	0.145	1.698
45	0.443	0.195	0.167	0.191	0.004	2.348
46	0.268	0.268	0.276	0.033	0.154	1.133
47	0.232	0.235	0.137	0.330	0.065	0.750
48	0.189	0.280	0.234	0.119	0.178	0.848
49	0.355	0.049	0.294	0.159	0.143	1.293
50	0.129	0.418	0.178	0.063	0.213	0.403

Figure 1. Results of Processing Genetic Algorithm on Subjective
Approach

(iii) Settlement with Objective Approach
a. Find weight value (w)

    Search hobot value is done by using genetic algorithm, with parameters such as the subject approaches the result obtained by processing at each generation.

The final value is obtained:
➢ Weight value:
  • $w_1 = 0,2091$
  • $w_2 = 0,1779$
  • $w_3 = 0,2284$
  • $w_4 = 0,2332$
  • $w_5 = 0,1514$
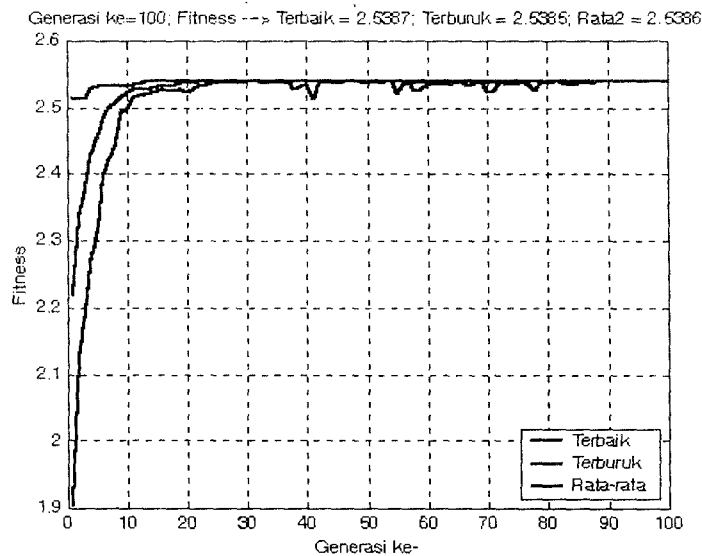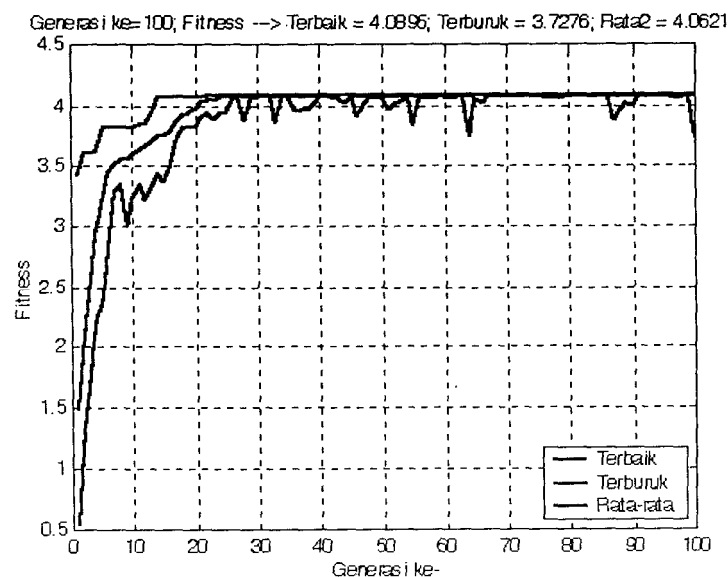➢ Best fitness value: 2,5387
➢ The value of z_1: 0,3939

Figure 2. Results of Processing Genetic Algorithm on Objecive Approach

b. Process ranking

Furthermore, the process of ranking done, and obtained:
➢ Alternative values:
  • $g_1 = 0,2980$
  • $g_2 = 0,5010$
  • $g_3 = 0,2437$
  • $g_4 = 0,6130$
➢ So the order of the alternatives is:
  S4-S2-S1-S3.
So S4 (Additional Runway) will be selected to increase runway capacity.

(iv)   Settlement with Integration of Subjective and Objective Approach
a.   Find weight value (w)
  Search the weighting is done by using genetic algorithm, with parameters such as the subjective approach,

Figure 3. Results of Processing Genetic Algorithm on Subjective and Objective Approach

  The final value is obtained:
➢ Nilai bobot :
  • $W_1 = 0,3639$

- $W_2 = 0,2080$
- $W_3 = 0,2202$
- $W_4 = 0,1315$
- $W_5 = 0,0765$

Best fitness value: 4,0895

The value of z_1 : 0,2445

b. Process ranking

Furthermore, the process of ranking done, and obtained:

> Alternative values
>   - $g_1 = 0,3101$
>   - $g_2 = 0,6644$
>   - $g_3 = 0,2640$
>   - $g_4 = 0,4281$
> So the order of the alternatives is:
>   S2-S4-S1-S3.

So S2 (Change Pattern Runway Operations) will be selected to increase runway capacity.

4. Results and Analysis

Based on data processing and analysis carried out in the previous chapter, it showed the following results:

1. From the calculation of runway capacity at this time using a mathematical formula derived runway capacity per hour Soekarno-Hatta Airport for arrival operations only by 42 operations, for departure operations are equivalent to 110 operations and for operations mixture of 64 operations.
2. Efforts to increase runway capacity by reducing air traffic separation refers to the FAA separation standards, resulting in an increase of 90.5% in arrivals and 34.4% operating in mixed operation.
3. Efforts to increase runway capacity by the addition of an exit taxiway and calculations using the FAA method resulted in an increase of 32.9% in VFR conditions and 32.4% in IFR conditions.
4. Efforts to increase capacity with the addition of an exit taxiway runway caused a decrease in the average runway occupancy time by 16.7%, which resulted in an increase runway capacity by 2.3% using the FAA separation standards, while using standard separation Soekarno-Hatta Airport did not occur changes in runway capacity.
5. Efforts to improve with the addition of the runway in accordance with the master plan development of the Soekarno-Hatta Airport, resulting in an increase of 53.9% to 60.6% condition VFR and IFR conditions.
6. Efforts to improve with changes in the pattern of runway operation resulted in an increase of 35.9%, when applying the pattern of operation in which one runway for departure operations only and the other runway for operation mix.

5. Conclusion

Based on data processing and analysis carried out in the previous chapter, it can be concluded as follows: The maximum number of operations that have served to date is of 64 operations per hour, which means it has reached maximum capacity owned by the current runway. Therefore, the management of Soekarno-Hatta Airport should immediately made attempts to increase the anticipated increase in demand in the future. Of the four efforts to increase runway capacity, efforts to increase the most efficient are the change in the pattern of runway operations and reduction of separation. But efforts to increase the yield the greatest improvement were the addition of runway capacity in accordance with the master plan development of the Soekarno-Hatta Airport.

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