Optimization of the parameters of aircraft ground handling by cost function

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Abstract

The process of aircraft handling when preparing for further flight is a good example of using the theory of mass control to assess the effectiveness of aviation activity and its individual subsystems. All models of the system of mass control are aimed at determining the most appropriate characteristics (indicators) specific to a particular type of model. The most suitable values of the characteristics are in fact a compromise between the quality of services, which is generally proportional to the number of channels and the use of the service lines (channels) that is inversely proportional to their number. In this sense, each task of the theory of mass control is an optimization task. The most commonly used tool of the optimization of systems of mass control is the cost objective function. The aim of this contribution is to highlight the possibilities of using the cost function to optimize the parameters of aircraft ground handling system.

Keywords: Theory of mass control, Optimization, Aircraft ground handling, Cost function, Analysis.

JEL Classification: C1, C61

1 Introduction

The task of the theory of mass control is to examine models in which the operating system may have one or more handling lines (equipment and associated personnel), by which the demand are operated focusing on costs and benefits and their changes depending on the number of parallel lines. The main task of system of mass control is to find the minimum between occurring cost components. The amount of individual cost items varies according to the capacity of the operation system, i.e. according to the number of parallel lines of operation. If the capacity (number) of handling lines is small, then the operating costs are small but it creates heavy costs caused by waiting customers (penalties for delays caused to passengers and aircraft). If the capacity (number) of handling lines is large, then the costs of the handling lines are high, but the costs caused by waiting (delayed) customers (aircraft and passengers) are small or none. The total cost is the lowest

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only if there is optimum number of parallel lines of the operation, which depends on the specific shape of the curves, i.e. the concrete expression of the dependence of the individual costs on the capacity (number of parallel lines) of the operation system given.

2 Aerodrome Operation Costs Analysis

Each task of system of mass control is an optimization task. These tasks are most often focusing on (Bačik & Jezný, 2011):

- dimensioning of the optimal number of parallel lines (n), if we know the intensity of operation and the intensity of the input current of demands,
- determining the optimal intensity of the input current of demands (λ), if we know the number of parallel lines and mean handling time of one demand,
- determining the optimal operation intensity (μ), i.e. mean time to serve one demand, if we know the intensity of the input current of demands and the number of parallel lines for operation.

The most commonly used tool of the optimization of systems of mass control is the cost objective function. The various types of costs, which are included in the cost function, can be divided into three groups:

1. Group of costs, the amount of which is proportional to the number (capacity) of handling lines such as:
   - C1 - the costs of free handling lines - line that is not used and it gives rise to costs as time wage of serving staff, amortization of the cost of equipment and the like. This cost increase in proportion to the number of lines.
   - C2–the costs of occupied handling lines- line that is used and includes for example the cost of the consumed energy, raw materials, etc., consumed in operating the demands.
2. Group of costs, the amount of which is inversely proportional to the number (capacity) of handling lines such as:
   - C3 - the costs of downtime demands while waiting for the operation - includes costs such as the cost of aircraft waiting to release the track or stalls to carry out maintenance and so on. (Penalty - a fine for breach of contract caused delays of aircraft and passengers). These costs fall due to the number of lines.
   - C4 - costs of loss of demand in the system without waiting and in a mixed system - if there are many lines occupied, passenger can use the handling of another airport or another airline.
3. Group of costs, the amount of which does not depend on the number (capacity) of handling lines such as:
   - C5–costs of transportation of demands- e.g. the cost of passenger transportation at the air-port.
   - C6 - general costs of handling system independent of the number of lines.

3 Cost Analysis of the System for the Ground Handling of Aircraft

The costs of performing the technical operation of aircraft vary depending on the type (size) of operated aircraft as well as the range of services which are provided. This depends on the amount of time that is available to handling staff to perform handling (arrival / departure, stopover) or by contractual arrangements between the airline and the airport operator or company that carries out these activities. These costs also depend on the number of staff allocated to implementation of the technical handling of aircraft, quality of used equipment, materials and mechanisms in the performance of handling etc.

An integral part of process optimization is the understanding of the costs that accompany the process and their impact on the efficiency of aircraft ground handling. We need to know how changing the system parameters will change the amount of the total costs. The optimal structure of ground handling of aircraft is one that gives us the best financial results. That means the biggest difference between income and expenses.

Given the demand of air carriers for aircraft ground handling it is not possible to increase revenue by raising fees for the handling, as this could lead to a reduction in demand. The only possible way of increasing profit is to reduce costs by optimizing the number of operating offices needed for the operation of aircraft and thus the number of stationary and mobile technical equipment and operating personnel (Bačík, 2009).

4 Input Data of the Model of Aircraft Ground Handling System

We researched the aircraft ground handling system as a single-phase system of mass control with several parallel handling stations and we will seek the optimum number for the operating conditions. To find out the system of mass control´s (SMC) efficiency, it is necessary first of all to know the values of input parameters entered into relations for calculation. The values of these parameters entered as input parameters should best correspond to the real situation in the airport company or anticipated state of Airport Company, which we want to explore Antosko, Korba, & Sabo, 2015):

- **N (NOS) -**number of parallel operator station - we want to find out optimum number of GHA workplaces. That is why we observe the changes of criteria values for different NOS, for example in the range 2 to 12,
- $\mathbf{t_{han}}$ - (**MH)** mean (most likely) time of handling of one aircraft,
- $\mathbf{t_{int}}$**- (MI)**the mean interval between two demands for carrying out the handling of aircraft,
- **CDS** - the total cost of downtime per aircraft ground handling station per unit of time - the value of the input parameter calculated from data obtained from the annual report for the year.
- **CHS** - cost of one handling station per time unit during the handling of the aircraft – we only estimate the value of the parameter, for example that it is 25% higher than the amount of the parameter CDS, because the costs of handling stations during downtime are not as high as when parking place is used.
- **DCD** - downtime costs of one demand - the value of this parameter also an estimate. It is estimated from the amount of fines paid for caused delays of aircrafts and the total delay time of aircraft per year (for the period).
- **RHD** - revenue from one handled demand- the value of this parameter is the average amount paid to the airport operator for aircraft.
- **NA** – number of handled aircraft.
- **TI**– examined length of time interval, e.g. rush hours, work shift or working day.

Note: CDS, CHS a DCD refer to the same time unit as MA, MI a TI, (e.g. if the cost is measured in terms of amount per 1 hour, then the time interval for other parameters is also 1 hour).

5 Analysis of Relations between the System Parameters of Ground Handling of Aircraft and Values of the Cost Function

The optimal number of parallel lines (parking places) for ground handling of aircraft is determined by comparing the values of the profit of each variant scheme, calculated according to the formula:

P = I – C *(1)*

where:

- P – is profit if the result is positive or it is a loss if the result is negative,
- I – income for services,
- C – operating costs and resources the company spent on realization of services

The total income is calculated by multiplying the number of handled airplanes and charges (prices) for handling one aircraft:

I = NA*RHD *(2)*

The total cost is calculated as the sum of the individual costs:

C = C1 + C2 + C3 + C4 + C5 + C6 *(3)*

while:

***C1** - the costs of free handling lines*

C1 = CDS*TDT *(4)*

where:

TDT – total downtime of handling stations operating in a given time interval.

***C2** – the costs of occupied handling lines*

C2 = CHS*THT *(5)*

where:

THT – total time of aircraft handling in a given time interval.

Sum of TDT and THT is equal the full time pool of handling stations (HST), which is calculated by multiplying the number of service stations (NS) and the length of time interval (TI). Their particular value is calculated using the load factor of handling stations ψ **:**

$$\psi = \frac{\lambda}{\mu} \quad (6)$$

Substituting into the equation for C1 and C2 gives us:

C1 = CDS*NS*TI*(1- MH/MI) *(7)*

C2 = CHS*NS*TI*(MH/MI) *(8)*

***C3** - the costs of downtime demands while waiting for the operation*

C3 = DCD* WTD *(9)*

where: WTD – waiting time of demands (delay of aircraft)

Because the total delay of aircraft (WTD) due to waiting for the execution of handling by GHA system cannot be calculated, it is not possible to determine a value of cost N3 and its amendments according to the value NS, MI and MH. The approximate value of the WTD can only be estimated according to the likelihood that all handling stations have been used (Pn). Waiting time will be proportional to the value of that likelihood.

WTD = TI*Pn *(10)*

After substituting into the equation C3 we get:
C3 = DCD*TI*Pn *(11)*

while:

$$P_n = \frac{\frac{\alpha^n}{n!}}{\sum_{k=0}^{n} \frac{\alpha^k}{k!}} \tag{12}$$

where: $\alpha = \frac{\lambda}{\mu} = \lambda \overline{t}_{ob}$ *(13)*

***C4** - costs of loss of demand*
C4 = NRD*CRD *(14)*

where:
NRD – Number of rejected demands (aircraft),
CRD – the cost of a rejected demand (aircraft).

Taking into account only scheduled air traffic, the cost C4= 0.

***C5** – costs of transportation of demands*
Costs of transportation of aircraft at the airport can be considered part of the CDS and CHS. Then the cost C5 will be C5= 0 (Knabe & Schultz, 2016).

***C6** - general costs of handling system independent of the number of lines*
Also, the overall cost of the aircraft ground handling system can be considered part of the CDS and CHS. Then the cost C6 will be C6= 0.

The intensity of the input current of demands and intensity of the handling related to each unit of time (minute, hour or day) is calculated as follows:

λ_{Am} – intensity of the input current of aircraft, number of aircraft in 1 minute;
λ_{Ah} – intensity of the input current of aircraft, number of aircraft in 1 hour;
λ_{Ad} – intensity of the input current of aircraft, number of aircraft in 1 day;
t_{int}– the mean interval between two demands;

t_{han}– the mean time needed for handling of 1 demand;
n – the number of parallel lines for a given period of handling.

For intensity of the input current of aircraft is true that:

$$\lambda_{Am} = \lambda_{Ah} / 60 \quad (15)$$

$$\lambda_{Ad} = \lambda_{Ah} * 24 \quad (16)$$

Wherein it is sufficient to know one of these variables, e.g. λ_{Ah} – the number of aircraft entering the queuing within one hour (Řiha, Němec, & Soušek, 2014). For the calculation of the intensity of handling we will use relations:

$$\mu_m = 1 / t_{han} \quad (17)$$

$$\mu_h = \mu_m * 60 \quad (18)$$

$$\mu_d = \mu_h * 24 \quad (19)$$

while:
t_{han} – is mean time of handling of one demand in minutes,
μ_m - is intensity of handling by one handling station in given phase (number of demands handled in one minute).

We will calculate the load factor of aircraft ground handling lines (ψ) as:

$$\Psi = \Lambda_{AM} / (N * M_M) \quad (20)$$

In the example above, it is appropriate to create a spreadsheet in Microsoft Excel for all necessary calculations, where after entering the input data; the program will generate the other output values. This will simplify our analysis of the impact of proposed changes in the number of parallel lines of ground handling of aircraft and their dependence on the changing values of the input data.

Table 1 The values of the input data for calculation

t_{int}	t_{han}	**CDS**	**CHS**	**DCD**	**RHD**	**NA**	**TI**

Source: Own elaboration

The second table calculates the values of the output data ψ , TDT,THT, C1,C2,Pn, C3, C,I,P. In the first line for the number of handling stations (NOS) n=2, in the second line for n=4 etc. up to the highest value, e.g. n=12.

Table 2 Calculated variations for different variants of ground handling of aircraft

n (NOS)	ψ	**TDT**	**THT**	**C1**	**C2**	**Pn**	**C3**	**C (tot.)**	
2									
4									
6									
8									
10									
12									

Source: Own elaboration

If the tables are available in Microsoft Excel, where you can enter the real values of the input data, then the required parameters are calculated automatically. After changes (corrections) of input data values we get new values of output parameters. For faster analysis of dependence of output parameters values (N or other) on the number of parallel lines (N) and to determine the optimal value, it should be displayed graphically using bar graphs (Hulínská & Kraus, 2016).

6 Conclusion

The task of the theory of mass control is to examine models in which the operating system may have one or more handling lines. Each task of the theory of mass control is an optimization task. An integral part of process optimization is the understanding of the costs that accompany the process and their impact on the efficiency of aircraft ground handling. The optimal structure of aircraft ground handling system is one that gives us the best financial results.

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