OPTIMIZATION OF THE NUMBER OF AIRCRAFT MOTIONS BY MEANS OF THE SHO SIMULATION MODEL

Edina JENČOVÁ, Jozef GALANDA*, Radoslav ŠULEJ, Juraj VAGNER
Technical University of Košice, Faculty of Aeronautics, Rampova 7, 041 21 Košice, Slovak Republic
**Corresponding author.* E-mail: jozef.galanda@tuke.sk

Summary. The aim of this contribution is to discuss the possibilities and to support the use of the simulation model of the mass control system to optimize the number of aircraft movements at an airport. The first part of the contribution consists of general information about the solved problem. The other parts describe the algorithm of the mass control system simulation model and the animation of the simulation model. The last part is focused on the optimization of the number of aircraft movements at the selected airport. According to the simulation results there are discussed possible solution to increase the use of aircraft stands and thus to achieve greater revenues at the airport.

Keywords: simulation; model; optimization; mass control system; aircraft movements

1. INTRODUCTION

The Theory of Mass Servicing or Queuing Theory (TMO or QT) is dealing with the quantitative evaluation of systems capable of satisfying mass scale requirements in terms of providing some sort of services. All queuing models are focused on determining the most suitable characteristics (indicators), specific for a certain kind of model. Those most suitable ones are representing a trade-off between the quality of servicing, which is generally directly proportional to the number of channels and use of the servicing lines (channels), which then are indirectly proportional to their quantity. In this regard every task of the queuing theory is the ones of optimization. In case of optimization tasks the most frequent assignments involve determination (dimensioning) of the optimal quantity of lines (channels) $\boldsymbol{n}$, optimal performance of the line(channel) of the servicing (servicing intensity $\boldsymbol{\mu}$), or. Determining the optimal intensity of the input flow $\boldsymbol{\lambda}$. At special types of queuing models there can be cases involving a variety of specific aims of optimization. The SHO simulation models is based on generating times when requirements come into being, monitoring the status of servicing stations, generating the time of servicing and registration of the data on the course of simulated servicing of the requirements, all that important for computation of the criteria for the SHO [3].

2. DESCRIPTION OF THE ALGORITHM FOR THE SIMULATION MODEL OF A QUEUING SYSTEM

This chapter is providing the description of the algorithm for a quieting system simulation model consisting of the following steps [1][2]:

1. Defining the values of parameters characterizing the queuing system and the input flow of requirements.
2. Making use of the generator of random numbers the computer is provided random time intervals for the entries of the separate requirements into the queuing system (in program 6.1 these values are generated with exponential distribution with SI parameters). These random time intervals are gradually summed up thereby obtaining the individual discrete values of T1, T2, ..., T_n of the modelled time. Each of the discrete values T_i is marking the event of when an element (requirement) is entering the queuing system. The requirement is either serviced

without waiting (at least one of the servicing stations is free), or it is enqueued (when all the servicing stations are engaged) and is waiting until one of them is relieved.

3. Monitoring of the states of servicing stations is made in via two variable of field type marked as Beginning(i) – for entering the times of servicing and Ending(i) – for entering the times when the servicing of requirements are ended, where `i` denotes the serial number of the servicing station.

Ser. No. of the servicing station	1	2	3	..	PS
Beginning(i)					
Ending (i)					

Figure 1 States of servicing stations example [2]

4. The number of free stations of servicing at the moment when the requirement is entering can be found out by comparing the value of T_i with those of Ending (i). The number of values for Ending (i) smaller than T_i is equal to the quantity of free stations. The station selected for servicing is the one first ending its servicing, i.e. the station with the lowest value of Ending (i). In case when at least one station is free, the moment when the servicing is started is equal to that when the requirements is entering i.e. Beginning (i) $=T_i$. In case when none of the servicing stations is free at the time when the requirement is entering, the requirement is enqueued and the time of beginning the servicing is equal to the time of Ending of a station that has been selected by the rule of the lowest value of Ending (i).
5. Also generated on the computer is the random time of servicing T_{ob}. By adding T_{ob} to the time of Beginning (i), we obtain the new moment of ending the process, the Ending (i). During T_{ob} the i-th station no further requirement can be received, if there is any.
6. In the course of the requirement servicing simulation we are registering (updating) the PO data PO – registration of the number of service requirements (increasing the value of PO by 1 if the requirement servicing is ended), PC – registration (summary) of cases of when waiting occurred (number of requirements serviced by way of waiting) – if any of such cases occurred, the number of PC will be increased by 1, NP – The total number of requirements from the beginning of the shift (game) – we increase the value of NP by 1 if e new requirement entered the SHO, CC – registration (summary) of the total time of waiting requirements (if waiting occurred, the CC is added by the time of waiting), CO – registration (summary) of the total time of operation of the servicing stations – added to the CO is the time of requirement servicing, XZ – the moment when the servicing starts (registered is the last value when the servicing started), XU - the very moment when servicing ended (registered is the last value of ending the servicing, that which marks the end of the working shift simulation and which simultaneously gives the time when the servicing of the last requirement was ended, i.e. the time when the working shift ended as well).
7. After completing the simulation of the requirement servicing and having registered the data characterizing the course of the servicing, we are investigating if there arose conditions for ending simulation of the given working shift (gamey), i.e. whether the determined maximum number of requirements (PP) has been achieved (serviced) or the maximum time of one working shift (game) has been achieved. If none of the given conditions have been fulfilled, we go on simulating the servicing of the next requirement (subparagraphs 2 up to 7).
8. After fulfilling the conditions of ending the simulation of a working shift (game), based on the registered data on the course of the servicing, we compute the values of the required criteria (indicators) of SHO efficiency for the given shift, marked as Criterion (1) up to Criterion (14):

Criterion [1] – probability of waiting (probability of queue occurrence): ***Criterion [1] = PC / NP*** (1)
Criterion [2] – total time of waiting (idle time of requirements): ***Criterion [2] = CC*** (2)
Criterion [3] – average time of requirements´ waiting for being serviced: ***Criterion [3] = CC / NP*** (3)
Criterion [4] – average time of waiting in the queue: ***Criterion [4] = CC / PC*** (4)
Criterion [5] – average amount of requirements in the queue: ***Criterion [5] = CC / XU*** (5)

Criterion [6] – coefficient of capacity utilization (loading) of the servicing stations:

Criterion [6] = CO / (PS * XU) (6)

Criterion [7] – average number of service stations engaged: ***Criterion [7] = CO / XU*** (7)

Criterion [8] – the total idle time for the service stations: ***Criterion [8] = XU * PS – CO*** (8)

Criterion [9] – coefficient of idle time for service stations: ***Criterion [9] = 1- CO / (PS * XU)*** (9)

Criterion [10] – costs of service stations during idle times: ***Criterion [10] = NCS * Criterion [8]*** (10)

Criterion [11] – costs of idle time for requirements: ***Criterion [11] = NCP * CC*** (11)

Criterion [12] – total costs of operation for the SHO:

Criterion [12] = NCS*Criterion [8] + NOS*CO + NCP*CC (12)

Criterion [13] – total operating results:

Criterion [13] = NP * VZP – Criterion [12] (13)

Criterion [14] – efficiency of the system: ***Criterion [14] = NP / XU*** (14)

9. After completing the computation of the values for the Criterion (1) up to (14), they are registered for the given working shift (game) to find out if the required number of working shift simulations (PH) has been fulfilled. If this condition has not been fulfilled, we go on with the simulation of the next working shift (subparagraphs 2 up to 8).
10. After completing the simulation of a required number of working shift we go on with the part of program called „Statistics“. This is based on the registered values for the Criterion (1) up to (14) will compute for the working shift the resulting average values of these criteria and their deviations (variance) from/around the average value.

It is apparent that we are able to gradually monitor how the system of queuing is approaching the statistically steady-state condition in a way that the “Statistics “ program is repeated for several times in a succession always in a larger number of individual simulation steps. The simulation approach to solving systems of queuing has practically no limitations as to the complexity of the systems. Consequently, in a number of cases, which can be fairly complex, digital simulation is the only viable solution.

3. ANIMATING THE OPERATION OF THE SHO SIMULATION MODEL

One of the fundamental problems of digital simulation is monitoring the model time and generating the illusion on the parallel computation. The problem-oriented simulation languages enable to cope with these complexities quite fairly. Simple tasks, however, can be handled even in the language of Turbo Pascal 7.0. In the modelled m of queuing system the variables are changing values discretely at certain time moments. Time will be modelled by a set of real numbers (i.e. numbers provided by the real data type). Thus, the state of the (SHO) model will change discretely at a given moment of time. Such a change in the state of the model we will call events. Events can be e.g. change in the value of one or several variables at a given time, entries of requirements into the system, Beginnings or Endings of the service operation, step-change of the monitored variable etc. The individual occurrences of events define the individual states and the appropriate times of occurrences for the events. On this basis it is apparent that representation of an event in the model makes it necessary to store at least two basic data such as the ***type of event*** and the ***time of occurrence of the event***.

Refinement of the animation of the model operation it is advisable to define, apart from the above, the attribute of priority, which can be used in cases when one has to decide about the order of activating operations relevant to the events with equal time of occurrence [5].

For our model, for every event the following three data are registered:

- Time of change/ Caszmeny(NZ) – type: real, to register time of the change,
- Type of change/ Typzmeny(NZ) – type: word, to register type of change,
- Serial number of the requirement/ Cislopoz(NZ) – type: word , to register the serial number of the requirement the change is related to. Whereas NZ is the serial number of the change. Its maximum value is given by the declaration of variables of type pole (max. 500).

The variable of Typzmeny (NZ) can take the values such as 0 – occurrence of a new requirement (entering the requirement into the SHO), 1 – enqueuing the requirement for service into a line, 2 – selection of the requirement from the queue for service, 11 (up to 19) – beginning the operation of the service station No.1 (up to 9) and 21 (up to 29) – ending the operation of the service station No.1 (up to 9).

The given types of events are the basic elements of describing the dynamics of the model behaviour. Another issue to be solved at the model animation is the flow of time in the simulation model. Our task when developing the model of behaviour will be in finding a proper way of illustration for the events mentioned, however, not in the order as they were registered during the simulation (i.e. by the value of the serial number of NZ), but by the time when they occurred. As time has a given direction of flow, based on a simple consideration we find out that it is advisable to have the individual events arranged into a list by their time of occurrence, or, at events with the same time of occurrence considering their priorities (in the program it can be handled by adding or subtracting a very small value from the time of event occurrence). Such an arrangement of events is referred to in the literature as the Calendar of events. The similar time (Time as a variable) is gradually taking the values of event occurrences as by the arranged list and by the value for the variable of Typzmeny(i) , the appropriate change in the SHO state is also indicated on the monitor. After completing the required quantity of games (shifts), the program will compute and present the statistical characteristics (minimum and maximum value, arithmetic mean and histogram) of monitored criteria [5].

4. OPTIMIATION OF THE NUMBER OF AIRCRAFT MOVEMENTS BY WAY OF A THE SHO SIMULATION MODEL

The optimal structure of aircraft ground handling is so as to provide the best economic result, i.e. the highest differences between the revenues and costs. At a given demand for ground servicing of aircraft placed by the airliners one cannot increase revenues by raising the prices for the services, as it could result in decrease in the demand in question. The only possible way of increasing the profit is to decrease the costs by way of optimizing the quantity of operational sites of aircraft ground handling and thereby the quantity of stationary or mobile technical equipment and the servicing staff as well.

The presented simulation model, the SHO, can be used for investigating the variants of the POL system and find out, which variant is going to yield the best economic benefit. Moreover, we are able to monitor the effects of changes in other criteria. The POL system will be examined as a single-phase system of queuing with several parallel service stations in search of their optimal quantity for the given conditions of operation [4].

4.1. Subsection title, bold text

To determine the efficiency of the SHO, it is important primarily to know the values of the input parameters entered into the simulation. The following values given as input parameters roughly correspond to the situation at our airport companies:

- PS (number of parallel service stations) – to find the optimal number of POL workplaces, we will monitor changes in the values of criteria for the PS in the interval 2 up to 12,
- A, B, C (minimal, most probable and maximal time of service) – in case of favourable conditions, an aircraft can be handled within 30 minutes, however , the most frequent cases take place within 50 minutes, whereas the most pessimistic estimate is 70 minutes.
- PP (number of requirements) – on average it is 8 requirements within a 24 hrs period of time, whereas only regular flights are taken into account.
- SI (mean time interval between requirements) – representing 3 hours
- NOS (total costs per one service station) – the value of this input parameter is calculated from the data of the annual report, namely from the costs of material, energy, repair and

maintenance, wages, depreciation of LT tangible and intangible properties. The sum total of the costs related to technical handling per year was roughly 483 111€.

- NCS (costs of idle time of a service station per unit of time) – this parameter value can only be estimated to be 25% less than the sum for the NOS parameter, as idle time for servicing does not cost so much than in case of the parking area utilized in full.
- NCP (costs of idle time of a requirement per unit of time) –this parameter value can also be estimated only from the amounts of penalties paid for the aircraft delays and the total time of delays. It is about 10 512€/year, i.e. idle time of two requirements for the given period. Its amount depends on the length of the idle time, i.e. from the services to be provided for the passengers aboard the aircraft. It involves cases ranging from situations when the passengers are given refreshment only to events with idle time is extended and the passengers are to be provided either accommodation or alternate means of transportation.
- VZP (revenue per a single serviced requirement) – amounting roughly to 1000€
- TH (number of games) – for the purpose of simulation, the number of games selected is 4

Note: NOS, NCS and NCP can be related to the same time unit as the SI, A, B, C (e.g. if the costs are expressed in Euro per 1 Hour, then the time for rest of the parameters is also expressed in hours) [6].

4.2. Results of the simulations and suggested solutions focused on the optimization of the number of aircraft movements

Of the values of the input parameters entered, we have obtained in via the simulation model we have obtained information on the values achieved at the individual criteria for the given variant of the system of aircraft ground servicing, namely the output parameters as follows:

- Probability of waiting – formation of a queue
- Total time of waiting – idle time of requirements
- Average time of waiting for requirement servicing
- Average time of waiting in a queue
- Average quantity of requirements in a queue
- Coefficient of efficiency for service stations
- Average quantity of engaged service stations
- Total idle time of service stations
- Coefficient of idle time of service station
- Costs of idle time of service stations
- Costs of idle time of requirements
- Total costs of operating the SHO
- The entire economic result
- Efficiency of the system – number of serviced requirements per unit of time

Results of the simulation

The object of the simulation was to find out what is caused by increasing the quantity of aircraft requiring ground technical handling services:

- At simulation No. 1 the quantity of requirements has doubled in 24 hours of time from the current 8 to 16 for the same period of time.
- In the rest of the simulations, i.e. No. 2 the number of requirements has not increased, but calculating with a time period of 15 hours, a time interval when aircraft are landing and departing at the same time, consequently, no account of idle time for the parking areas is made. From the aforesaid it follows that in such time of the day the coefficient of service station efficiency is increasing, the idle time is decreasing simultaneously with the decreasing costs of idle time. As a result, there came to the reduction of total costs for the operation of the SHO.
- Our simulation was ended on the quantity of 24 requirements, i.e. at simulation No. 3, as it is improbable for this airport to go higher with the amount of aircraft movements as stated above. Idle

times at service stations occurs even at such number of requirements, while the costs incurred are reducing. The total costs of operating the SHO were reducing while the economic result was increasing. Efficiency of the system is increasing as well as the number of serviced aircraft per unit of time.

The suggested solutions

The results of this simulation has revealed that the increasing quantity of requirements on the aircraft servicing is bringing about higher efficiency of the parking areas and the revenues as well. In this regard, the suggested solution is to increase the current number of flights, attracting new airliners, which could make better use of the airport services, offering them advantages, as well as improving airport marketing towards higher revenues the ultimate goal of entrepreneurs, air carriers and airports.

4. CONCLUSION

If a accompany has decided to optimize its operation making use of the queuing theory, it is inevitable to focus on the concrete processes, communicate these intentions and the processes to all the interested persons, to ensure planning, monitoring and managing the entire process and last but not least exercising coordination when accomplishing changes from the current status for the required one.

The system of aircraft servicing optimized by a simulation model enables us obtaining knowledge of the status quo in the given airport company and based on further, simulated parameters present a status that can be achieved by way of introducing the necessary changes to achieve the required goals such as improvement and higher efficiency of the selected processes in the company.

ACKNOWLEDGEMENTS

This work was supported by the Slovak Research and Development Agency under the contract no. APVV-15-0527 – “New generation of departure control system for airports”. The authors would like to thank the project management and colleagues for support and valuable questions, remarks and suggestions.

REFERENCES

[1] Bačík, J., Jezný, M.2011. Modelovanie činnosti letectva. Vyskoškolská učebnica. Typopress Košice. 2011. ISBN 978-80-8129-010-7

[2] Bačík,J. Operačná a systémová analýza. Vysokoškolská učebnica. Technická univerzita v Košiciach, Letecká fakulta, Košice. 2009, Isbn 978-80-89346-17-2

[3] PUDŁO, Patrycja - SZABO, Stanislav. Logistic costs of Quality and Their Impact on Degree of Operationg Leverage. In: Journal of Applied Economic Sciences. Vol. 9, no. 3 (29) (2014), p. 470-476. - ISSN 1843-6110

[4] Endrizalová, E. et. al. 2016. Dynamic mathematical model of ground support equipment utilization in aircraft technical handling, Transport Means 2016, Juodkrante, Kansas University of Technology, 2016, p. 759-762. ISSN 1822-296X

[5] Bačík, J., Bajusz P. Oblasť použitia a predpoklady aplikácie teórie hromadnej obsluhy v letectve. Elektronický optický disk (CD-ROM). In: Aeronautika 2011: Medzinárodná vedecká konferencia: 20.-21. októbra 2011, Herľany. - Košice: TU, 2011 S. 1-5. - ISBN 978-80-553-0758-9

[6] Bačík, J., Bajusz P.Area of use and preconditions of application for the theory of mass service in aviation.2011. In: Acta Avionica. Roč. 13, č. 22 (2011), s. 94-99. - ISSN 1335-9479