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SIMULATION MODEL OF SIMULTANEOUS TAKEOFF PROCEDURES OF VARIOUS AIRCRAFT TYPES

SUMMARY

This paper deals with takeoff procedure of various aircraft and rotorcraft types from the same runway. The three-type queue, at three different holding positions i.e. the simulation model for these conditions has been created. Simulation analysis of resulting values determines the optimal start-up time for each participant and its purpose is potential reduction of fuel consumption.

KEY WORDS

simulation, take-off procedure.

1. INTRODUCTION

The better efficiency, the more rational consumption! This could be the motto for efficiency in every aspect of human activity. Success is measured by efficiency, and the price is the summary of everything invested. Therefore, achievement of strictly determined goals includes serious planning and various calculations based on incoming tasks. Furthermore, saving is not a part of inheritance, but the squander directly reduces the achieved goals. All the segments of working process are to be optimised, including techniques, machinery and tools, technology, material and human resources.

The logical solution is not always the best one. Sometimes it is very close to Machiavelli's theory that the goal justifies any means. The system optimisation is a search for the optimal solution in existing circumstances, the one that achieves the best efficiency, optimal cost-benefit proportion, and realises the highest goals.

Knowing and understanding the system, its structure, sub-systems and correlation between them, interacting of the system and its environment, these are all the factors important for creating the system's model. And the simulation model is of great assistance to the research.

"Modelling is a process closely related to thinking process and solving problems. Mental models are structures constructed by human brain to connect series of facts that the human being encounters, and eventually to act accordingly. These models enable e.g. understanding of the physical world, human communications and planning of actions.

Research of nature and its rules, development of technology have made material and formal models possible. They have been developed out of the necessity for precise analysis description of complex problems and their solution. They have made models live longer and models have become the means of communications for a great number of people who deal with a particular problem."[1] "Simulation models have to provide correct presentation and successful realisation of the time shift. It is also important to provide parallel activities and description of processes that compete for the same resources. ... Simulation modelling cannot produce analytically expressed solutions in which dependent variables are functions of independent variables. The solution is achieved by experimenting with the model of the system. Results of the simulation experiment are sets of dependent variables for appropriate values of independent variables."[2]

Some of the definitions of simulations are listed below:

..."Simulation is a presentation of dynamic behaviour of a system that is moving from state to state according to well defined organisational rules."

..."Simulation is a technique of constructing and applying the model of the real system, in attempting to study the system's behaviour without interference with the system's environment."[3]

According to some authors, modelling in a way means departing from the scientific field and becoming a kind of art. There is a visionary spirit in the process of creating the model that represents the real system of the real world. The model provides the control of system input and output and manoeuvring over time.

This paper presents the simulation model of multiple takeoffs with various types of aircraft. The system internal regulations and causalities are standardised for the pilot's training process. The pilot's training process is a highly intensive activity, with numerous takeoffs, but under the criteria ruled by safety separation minima. In this simulation the real system data are used as input values. "Monte Carlo" simulation process flows according to the distribution of random variables. Results of the process are output values that represent reaction of the system to appropriate input values. Output values are processed after each simulation cycle, the image of the system is created, the system internal causalities and rules become available. The input values for the following cycle are chosen from the set that can produce a different set of output values. The output values set is studied at the end of each cycle. These study results are used for the real system standardisation.

"Monte Carlo" simulation is simple and understandable, and therefore user-friendly. The personnel operate with the values in everyday activities, and there is no necessity for mathematical expressions. Processing the set of input values contains no complex mathematical methods. The result of the simulation is a set of time data, quite simple and easy to understand and there is a possibility of varying the system standards. The number of types and the number of planes can also vary. All these characteristics make "Monte Carlo" method applicable.

2. THE TAKEOFF MODEL

One has to design the determined model in accordance with standards applied to the actual system. Flying is performed on three types of aircraft at the training airport at the same time i.e. U-75, PC-9 and Bell-206. Their technical differences produce certain differences in runway occupancy intervals. Takeoff technology for this runway is shown.

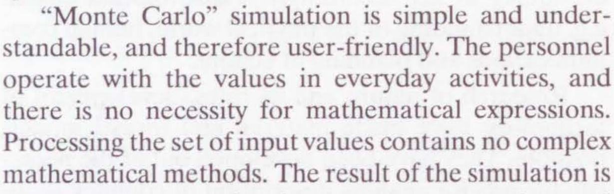

Figure 1 - Runway and taxiways

Figure 1 represents taxiways and runway in use. Taxiway A is used by PC-9s, B by BEll-206s and C by U-75s. This reduces the traffic on each holding position. Training process is performed in such a way that each squadron (aircraft type) has its own plan. And each squadron begins flying at 08.00 UTC. Takeoff interval between PC-9s is 5 minutes, between Bell 206s it is 5 minutes and between U-75 it is 3 minutes. The aircraft has to hold short of the runway until the preceeding aircraft is completed. In this case it is the moment when the aircraft departs from the extended centreline runway track. The three type intervals for takeoff operations are these: PC-9: 1 minute, Bell-206: 0.5 minute and U-75: 1.5 minute.

Figure 2 represents the model for calculating the total takeoff time.

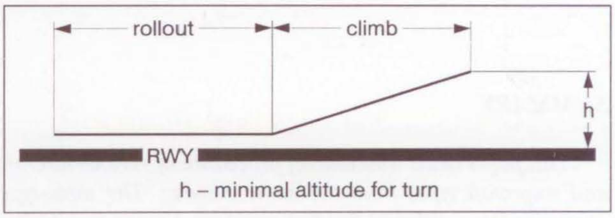

Figure 2

Total takeoff time consists of the time for entering the runway, the time for pre-takeoff checks, the rollout time and the max power climbing to minimum turning altitude time.

3. QUEUES, ARRIVAL TIMES AND RANDOM NUMBERS GENERATOR

The special characteristic of this system is that users wait in three different queues for a single service place. As Figure 3 shows:

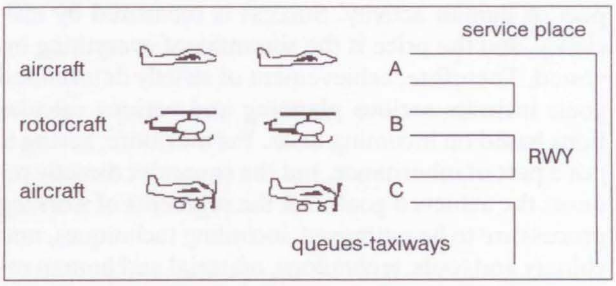

Figure 3 - Aircraft queuing at A, B, C holdings

A queue is determined by the aircraft type. PC-9 has priority for being served, then Bell-206 and the last one is U-75. The restriction of this system is that only one user can be served at a time i.e. it is a single channel system. Table 1 shows the servicing time for each aircraft.

The cadet's motto is: "One had better not be late", and therefore intervals between two aircraft approaching holding positions are from 0.5 min to 3 min, as shown in Table 2.

Table 1 - Aircraft servicing time

The serving time-y	Probability of the service interval p(y)	Cumulative probability P(y)	Random numbers
0.5 min	5/20=0.25	0.25	00-25
1 min	8/20=0.4	0.65	26-65
1.5 min	7/20=0.35	1.00	66-99

Table 2 - Aircraft delays in the lower part of the scale

Incoming delay x	Interval's probability x – p(x)	Cumulative probability P(x)	Random numbers
0.50 min	0.1666	0.17	00-17
1 min	0.1666	0.33	18-33
1.5 min	0.1666	0.50	34-50
2 min	0.1666	0.66	51-66
2.5 min	0.1666	0.83	67-83
3 min	0.1666	1.00	84-99

There are different types of random number generators that can be applied to this simulation, and each has its own advantages. The table of random numbers is used for the simulation in this paper.

4. EXPERIMENTAL PHASE OF THE SIMULATION

The simulation starting time is 08.00 UTC and each holding- position (queue) is occupied by its type of aircraft at the time. Aircraft priority is already determined and the takeoffs are performed accordingly. Time sequencing of two successive aircraft is the criterion for all the takeoff operations to follow, and it is three or five minutes respectively. The number in the first column of Table 3 determines the sequence of assignment of random numbers. Random numbers in the fifth column define aircraft type and the service (takeoff) time. The arrival time expressed as UTC is determined by random time - x (column 3) and it is an interval between two aircraft of the same type. In fact, this interval is determined by the period between start-up times. Table 3 is arranged in accordance with

Table 3 - Simulation of short time arrival intervals

Aircraft sequence number and type	Random number	Random time x min	Aircraft arriving UTC h.min.sec	Random number	Service interval min	Service start, UTC h.min.sec	Service end UTC h.min.sec	Aircraft waiting time min
1.b	69	2.5	8.00.00	02	0.5	8,01.00	8.01.30	1
2.p	09	0.5	8.00.00	63	1	8.00.00	8.01.00	
3.u	91	3	8.00.00	95	1.5	8.01.30	8.03.00	1.5
6.p	26	1	8.01.00	53	1	8.06.00	8.07.00	5
10.p	28	1	8.02.00	30	1	8.12.00	8.13.00	10
4.u	72	2.5	8.02.30	98	1.5	8.04.30	8.06.00	2
17.b	73	2.5	8.02.30	06	0.5	8.07.00	8.07.30	4.5
5.u	08	0.5	8.03.00	69	1.5	8.07.30	8.09.00	3.5
12.p	19	1	8.03.00	75	1	8.17.30	8.18.30	14.5
18.b	08	0.5	8.03.00	10	0.5	8.13.00	8.13.30	10
7.u	03	0.5	8.03.30	98	1.5	8.10.30	8.12.00	7
13.p	66	2	8.05.00	32	1	8.22.30	8.23.30	17.5
8.u	63	2	8.05.30	77	1.5	8.13.30	8.15.00	8
19.b	73	2.5	8.05.30	39	0.5	8.18.30	8.19.00	13.5
20.b	28	1	8.06.30	79	0.5	8.23.30	8.24.00	17
14.p	71	2.5	8.07.30	75	1	8.27.30	8.28.30	20
9.u	72	2.5	8.08.00	83	1.5	8.16.00	8.17.30	8
15.p	52	2	8.09.30	94	1	8.32.30	8.33.30	23
16.p	02	0.5	8.10.00	28	1	8.37.30	8.38.30	28.5
11.u	90	3	8.11.00	71	1.5	8.19.00	8.20.30	8

arrival time and the nomenclature is retained, for random numbers reliability.

Simulation of these conditions produces highly extended waiting time and even more a large number of aircraft waiting. The problem of the actual system procedure is now displayed as numbers, numbers of waiting time, numbers of wasted fuel, adequate losses. Calculated waste of fuel for a training day is equal to costs of two PC-9 missions; one third of the hovering period for a rotorcraft cadet training on Bell-206, and remarkable costs for U-75 aircraft.

Table 4 - Aircraft delays in the upper part of the scale

Incoming delay x	Interval probability x – p(x)	Cumulative probability P(x)	Random numbers
2.5 min	0.1666	0.17	00-17
3 min	0.1666	0.33	18-33
3.5 min	0.1666	0.50	34-50
4 min	0.1666	0.66	51-66
4.5 min	0.1666	0.83	67-83
5 min	0.1666	1.00	83-99

In further development of the model, one might assume that the person in charge of the day's training noticed the accumulated waiting of aircraft and the flight instructors were instructed to react to the problem. As a result, cadets would increase start-up intervals and arriving intervals could be moved upward in the scale, as shown in Table 4.

Table 5 represents the simulation of the system regulated according to the new criteria.

The waiting time is reduced to fairly acceptable value.

5. CONCLUSION

Simultaneous takeoff system is a complex system that contains three subsystems that share the same service position - the runway. Although these subsystems are very similar in pre-takeoff procedures, they do not interfere as a result of proper sequencing. Start-up time of each aircraft is important for this system model and represents the beginning of "the life"

Table 5 - Simulation of long time arriving intervals

Aircraft sequence number and type	Random number	Random time x min	Aircraft arriving UTC h.min.sec	Random number	Service interval min	Service start, UTC h.min.sec	Service end UTC h.min.sec	Aircraft waiting time min
1.p	63	4	8.00.00	70	1	8.00.00	8.01.00	
3.b	58	4	8.00.00	12	0.5	8.01.00	8.01.30	1
5.u	16	2.5	8.00.00	71	1.5	8.01.30	8.03.00	1.5
4.b	16	2.5	8.02.30	10	0.5	8.07.00	8.07.30	4.5
2.p	32	3	8.03.00	37	1	8.06.00	8.07.00	3
9.u	60	4	8.04.00	98	1.5	8.04.30	8.06.00	0.5
10.u	00	2.5	8.06.30	80	1.5	8.07.30	8.09.00	1
6.b	66	4	8.06.30	10	0.5	8.12.00	8.12.30	5.5
7.p	93	5	8.08.00	27	1	8.11.00	8.12.00	3
8.b	05	2.5	8.09.00	04	0.5	8.17.00	8.17.30	8
13.u	30	3	8.09.30	98	1.5	8.10.30	8.12.00	1
12.p	10	2.5	8.10.30	45	1	8.16.00	8.17.00	5.5
11.b	52	4	8.13.00	13	0.5	8.22.00	8.22.30	9
14.u	97	5	8.14.30	71	1.5	8.14.30	8.16.00	
15.p	97	5	8.15.30	16	1	8.21.00	8.22.00	5.5
16.u	36	3.5	8.18.00	73	1.5	8.18.00	8.19.30	
18.p	34	3.5	8.19.00	74	1	8.26.00	8.27.00	7
17.u	54	4	8.22.00	86	1.5	8.22.00	8.23.30	
19.p	93	5	8.24.00	07	1	8.31.00	8.32.00	7
20.p	19	3	8.27.00	71	1	8.36.00	8.37.00	9

in the model. The interval between the start-up time up to the moment of the axis diverging turn is the period relevant for fuel consumption. If the model has a vague criterion concerning the start-up time determination, waiting queues (lengthy waiting time) are long and costs are inevitably high. But, if the model sets adequate criteria for the start-up, there should be appreciable difference.

Simulation model of the three-type aircraft system has a manifold role:

- to help understand the system functioning,
- to increase its successful running,
- to increase synchronisation and optimisation of human and material resources.

By the standards that characterise the system and define its functioning, one can understand the causality of subsystems and each subsystem structure. It is then understood how cadets and instructors perform and how aircraft are used. Furthermore, critical analysis of the model functioning, putting the specific requests upon particular segments represent the way in which the system functions regardless of the environment. There are practically no restrictions to varying the system characteristics. It is a kind of training for decision-makers at no cost and no negative results that might appear if performed in actual conditions.

Conclusions can be derived from this simulation model which can be of some value for actual running of the system. These results have been achieved without high costs, conclusions that might reduce fuel consumption, which is a significant part in the total costs of the pilot's training process.

SAŽETAK

SIMULACIJA MODELA SIMULTANIH POLIJETANJA ZRAKOPLOVA RAZNIH TIPOVA

Rad obrađuje problem polijetanja više vrsta zrakoplova s jedne poletno-slijetne staze. Postavljen je simulacijski model čekanja tri tipa zrakoplova na tri staze za voženje. Analizom simulacijskih rezultata želi se odrediti optimalni trenutak pokretanja motora pojedinog zrakoplova u sustavu polijetanja sa ciljem optimizacije potrošnje goriva.

NOTES

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