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Simulation Modeling and Analysis of In-Flight Service Operations for Commercial Passenger Flights

M. Savsar*, Esra E. Aleisa

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Abstract Nowadays, in-flight comfort has become an essential characteristic to survive in domestic airline businesses. Air hostesses' quality of service and response time to customer demand plays a vital role in enhancing quality of the flight experience and passenger satisfaction. However, additional requirements on air hostess expose them to fatigue which could eventually result in job dissatisfaction that also will reflect onto the customer. This research studies the detailed tasks of airhostesses that take place from take-off to landing and answers such questions as usefulness of discrete-event simulation in assessing the performance measures of an airline hostess team and in improving them. Different activity scenarios are developed through simulation to provide a better organization of the multi-tasks that the airhostess provide to customers throughout the flight. This study is conducted on an airbus aircraft.

Keywords Simulation, In-Flight, Aircraft, Air Hostess, Passenger Flight, Statistical Validation, ANOVA

1 Introduction

Airline companies are striving to improve their in-flight services to maintain sustainable competitive advantage in today's fiercely competing market. The role of the air hostesses plays a vital role in achieving this objective. In this study, we analyze the tasks and work procedures scheduled on typical domestic flights that are required from the air hostesses in an attempt to improve service levels without elevating the work burden on them. We preferred to use discrete-event simulation to model and analyze the air-hostess in-flight activities because of following simulation advantages:

1. Simulation has the ability to identify system parameters such as utilization and flow-time in a system (Mosier [1]; Shafer and Meredith [2]; Savsar [3]; Aleisa [4]; Aleisa and Lin [5]).

*** Corresponding Author. (✉)**
E-mail: msavsar@gmail.com (M. Savsar)

M. Savsar
Professor , Department of Industrial and Management Systems Engineering, College of Engineering & Petroleum, Kuwait University, P.O. Box 5969 Safat 13060, Kuwait

Esra E. Aleisa
Assistant Professor, Department of Industrial and Management Systems Engineering, College of Engineering & Petroleum, Kuwait University, P.O. Box 5969 Safat 13060, Kuwait

2. Simulation has the ability to reveal potential problems and bottlenecks in a system prior to its implementation (Savsar [6]; Savsar [7]; Aleisa [8]).
3. Simulation can be used to evaluate various strategies and resource allocations for the operation of a system (Savsar [9]; Abdulmalek et al. [10]; Aleisa [11]).
4. Simulation can be used to compress or expand time, which gives the analysts the convenience of studying a given system for a long-run or under specific short-term scenarios (Pegden, et al. [12]).
5. Simulation can be used to incorporate any stochastic behavior and uncertainty by integrating the probability distributions that best describe the activity times (Shafer and Charnes [13]; Savsar [14]; Savsar [15]).
6. Simulation models can be used to generate random flow volumes to be used in a system under study to evaluate alternative scenarios (Savsar [16]; Savsar [17]).

The aim of the simulation study in analyzing air hostess tasks in this study is to achieve the best combination of the following objectives:

1. Reduce response time to passenger requests
2. Reduces bottlenecks in airplane corridors that often take place between airhostess serving passengers and the passengers themselves.
3. Reduce crew travel distance and time
4. Utilize the resources (hostesses) efficiently without overworking them.

Discrete-event simulation was applied requisitely in the areas of aircraft industry and airline business. Increased demand on air travel forced pioneers to investigate air-taxi services. The operations of such services were evaluated using discrete event simulation (Boyd, al. [18]; Consiglio, et al. [19]). Such aircrafts were characterized with narrow bodies. Rijsenbrij and Ottjes [20] have used discrete-event simulation to try different concepts of baggage transport to and from such narrow body aircrafts. Moreover, newly established security procedures have affected the business as usual tasks have grown in airport terminals. De Barros [21] used discrete-event simulation to evaluate the impact of newly established security measurements on the planning and operation of airport passenger terminals.

Manivannan and Zeimer [22] applied discrete-event simulation techniques to evaluate and improve the plane offloading operations in a central air cargo hub. In addition, discrete-event simulation was applied to improve fleet maintenance schedules with respect to performance measures such as aircraft cycle time and mechanics labor utilization as studied by Bazargan and McGrath [23] and to improve maintenance operations of a fleet of fighter aircrafts in crises situations as studied by Mattila, et al. [24]. It was also applied to test different scenarios to examine different aircraft policies in the battle field by Mishra, et al. [25]. To the best knowledge of the authors, there has not been any studies related to aircraft hostess activity analysis and hostess utilizations improvements.

This paper presents a simulation model that is used to analyze aircraft hostess activities during a flight with the aim to improve passenger service without increasing workload burden on air hostesses. Several improvement scenarios were suggested and simulated. The simulation model is applied to two passenger classes: first/business class and economy class. After validation of the as-is system, several improvements scenarios including automation and other procedures are modeled and compared with the as-is model. Finally the best improvements are chosen through the application of ANOVA.

2 Aircraft and Air Hostess Duties

This research is conducted on the Airbus 300 (A300) as it is the most commonly used aircraft type in the Middle East. A300 accommodates 232 passengers, its length is 54.10 m and height is 16.54 m. A300 consists of four zones:

- Zone A (F/C) rows from 1-3: 18 seats
- Zone B(J/C) rows from 6-8: 18 seats
- Zone C (E/Y) rows from 9-20: 96 seats
- Zone D(E/Y) rows from 21-33: 100 seats

It also includes six lavatories including one for handicapped.

Before passengers enter the airplane, many safety procedures and scheduling take place. First, a one-hour briefing session takes place in the in-flight services department. In this session each crew member is assigned to specific tasks. Furthermore, the crew is tested orally on safety questions. A crew member failing to answer any of these questions is offloaded from the program, and sent back to retake a safety exam.

The crew then enters the airplane before the passengers arrive to perform routine checks on the inside of the airplane according to a checklist that they have. If the airplane is ready, the crew will give clearance to the chief, which will then report clearance to the aircraft captain in order to call for the passenger's boarding. The checklists are divided according to different classes, and the phase in which the services should be offered. Longer flights have different checklists with different services. The duties of an air hostess will differ according to class. The duties of an air hostess for the economy class are provided in table 1.

3 Data Collection

The data collection was conducted during actual flights that took place on airbus aircraft that traveled to various destinations from Kuwait. The data collection included the time required for scheduled in-flight air hostess tasks, as shown in table 2 in minutes. In addition, the data collection included the inter-arrival times for passengers calling air hostesses for questions, beverages, extra pillows and blankets, screen, chair problems and other types of assistance, and the time for an air hostess to serve a passenger. Moreover, inter-arrival times to lavatories and the times these lavortories were occupied by the passengers were also collected. Also, the study considered times that the aisles were blocked by the food cart and impeded passenger service.

Table 1 Detailed air hostess duties in the aircraft

On Ground	Complete checklist	**In-flight seat belt OF**	Place baby cots, offer blankets, pillows & check toilets immediately after take-off.
	Standard galley preparation		Offer children give-aways.
	Place juice, beverages, water on ice		Proceed with service as per procedure.
	Check cleanliness of cabin, seat pockets, hangers, headrest covers, open bins, outlets & window shades.		Inspect cleanliness of toilets after each use and when needed.
	Check pillows, blankets, baby cots, spares etc.		Prepare& distribute documentation & restow.
	Check cleanliness/ serviceability of toilets, place cosmetics & spray.	**Decent**	Inform Purser of any U/S equipment.
	Check J/C headsets, J/C &E/Y & complete forms.		Clear up galleys, uplift via Purser if needed.
	Check toolkit, menu cards & complete forms.		Clear up cabin, restow pillows, blankets, etc…
	Prepare reading material & headsets.	**Seat Belt Sign On**	Distribute jackets.
	Prepare drinks trays with glasses.		Collect& restow toilet cosmetics.
	Conduct random check of seats serviceability.		Collect& restow menu cards cosmetics.
	Liaise with deck crew regarding their meals & offer beverages.		Seal dry stores, beverage trolleys, tool kit container &secure galleys.
Boarding	Welcoming, checking boarding cards, addressing pax by name, assisting in seating, coats& hand baggage.		Complete zone checks according to emergency zone.
After Boarding	Distribute newspapers on lined trays.		Give zone clearance to purser.
	Prepare & offer welcome drinks, collect glasses.		Take emergency stations for landing after passing clearance.
	Prepare hot & cold face towels.	**After Landing**	Distribute coats/belongings.
	Distribute face towels & collect.		Change mode selector upon announcement & cross check.
	Close door when instructed.		Give clearance to purser.
	Change mode selector upon announcement, cross check.		Obtain clearance to open door.
	Offer dates/Arabic delights.		Assist passengers during disembarkation& farewell.
	Offer Arabic coffee & collect cups.		Collect headsets.
	Distribute headsets.		Check cabin for left behind pax belonging.
	Safety demonstration(special demo for blind, deaf)		Clear up cabin from CRDs , newspapers,
	Clear up cabin		Seal give aways containers & complete forms.
	Clear up& secure galleys.		Collect headsets, complete form& seal container.
	Complete zone clearance to zone responsible.		Seal newspaper bag.
	Give zone clearance to Purser		Check serviceability of toilets& inform Purser of any defect.
	Take emergency stations for take-off		Collect personal belongings.

Table 2 Average air hostess in-flight task times in minutes

Class	Wet towels	headsets	Immigration cards	Food cart	Beverage trolley	Tea	Other Beverages
First and business class	7.3	3.67	5.3	24.3	28.67	10.3	9.53
Economy class	7.7	7	6.65	32.3	35	15.6	14.4

4 Model Assumptions and Data Fitting

The simulation study is assumed to take place during normal flight conditions. No emergency situations took place including the need for oxygen mask or CPR. Due to the random nature of data collected for passenger requesting air hostess assistance and using lavatories, the data were fitted into distributions using the Arena Input Analyzer statistical add-in (Kelton, et. al. 2002) The data fitting is provided in table 3 and the graph of inter-arrival of service calls by economy class passengers is given in figure 1.

Table 3 Fitting random data into statistical distributions

Task	Distribution (min)	Squared Error
Hostess call inter-arrival (F/J)	TRIA(0.5, 5, 22.5)	0.012512
Hostess call inter-arrival (Economy)	-0.5+EXPO(4.51)	0.006046
Hostess response time to calls (F/J)	-0.5+5*BETA(7.91, 11.6)	0.001523
Hostess response time to calls (Econ)	-0.5+7 *BETA(1.15, 1.83)	0.003209
Time in Lavatory (F/J)	NORM(3.47, 0.882)	0.001538
Time in Lavatory (Econ)	NORM(4.56, 2.01)	0.011896

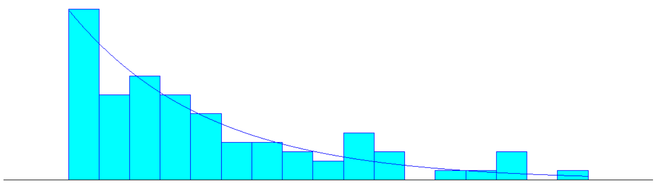

Fig. 1 Data fitting of inter-arrival service call times for air hostesses from passengers of the economy class

5 Simulation Models

Two simulation models were created to mimic the activities conducted by air hostesses within the aircraft. The first model was for the first and business classes (F/J) and the second model was for the economy class. The entities of the simulation system are passenger orders and tasks scheduled to the air hostesses. On the other hand the system resources are the air hostesses themselves and the aircraft lavatories.

For Airbus 300, there are three air hostesses for (F/J) classes and six for the economy class. As discussed earlier, the simulation model was developed and carried out based on the collected data for normal flight conditions with no emergencies. Handicapped were given priority of service within each class. The simulation model was created using Arena Rockwell Software (Kelton et. al. [26]). A snap shot of the simulation model for the F/J class is shown in figure 2. The economy class simulation has similar logic but is not shown here to avoid repetition. The output of the model is given in table 4.

Table 4 Simulation output from simulating the as-is system of in-flight airhostess activities (average values)

Parameter	F/J class	Economy Class
Number of tasks served	35	71
Waiting time (min)	9.21	8.60
Number of order tasks in hostess queue	1	2
Hostess utilization	0.5110	0.6685

Table 4 shows that during a 4-hour flight on airbus 300, an airhostess was busy conducting average of 35 requests for F/J class while 71 for economy class. It can be seen that the hostesses were able to satisfy all requests except for 1 in the first class and 2 in economy. This was probably due to placing orders during times when services were not provided, such as take-off and landing. Also, the average waiting time for service was 9.21 and 8.6 for F/J and economy classes respectively because many customers would place requests during times when hostesses were conducting longer scheduled tasks such as serving lunch or dinner to all aircraft passengers. The indicated utilizations exclude times when air hostesses are forced to remain seated according to aviation regulations during take-off and landing times.

6 Simulation Model Validation

Statistical analyses were conducted to ensure that the model was a valid representation of reality. A t-test between the parameters of the *real system* and the *simulation model* are provided in this section. The simulation was replicated 10 times and the results are shown in table 5, where "R" denotes data collected from the real system and "A" denotes data collected from the simulated system through the Arena package. To accomplish validation, we need to compare two populations (the real and simulated), by drawing random samples from each population. Depending whether or not the sample sizes and variances are equal, different formulas need to be used.

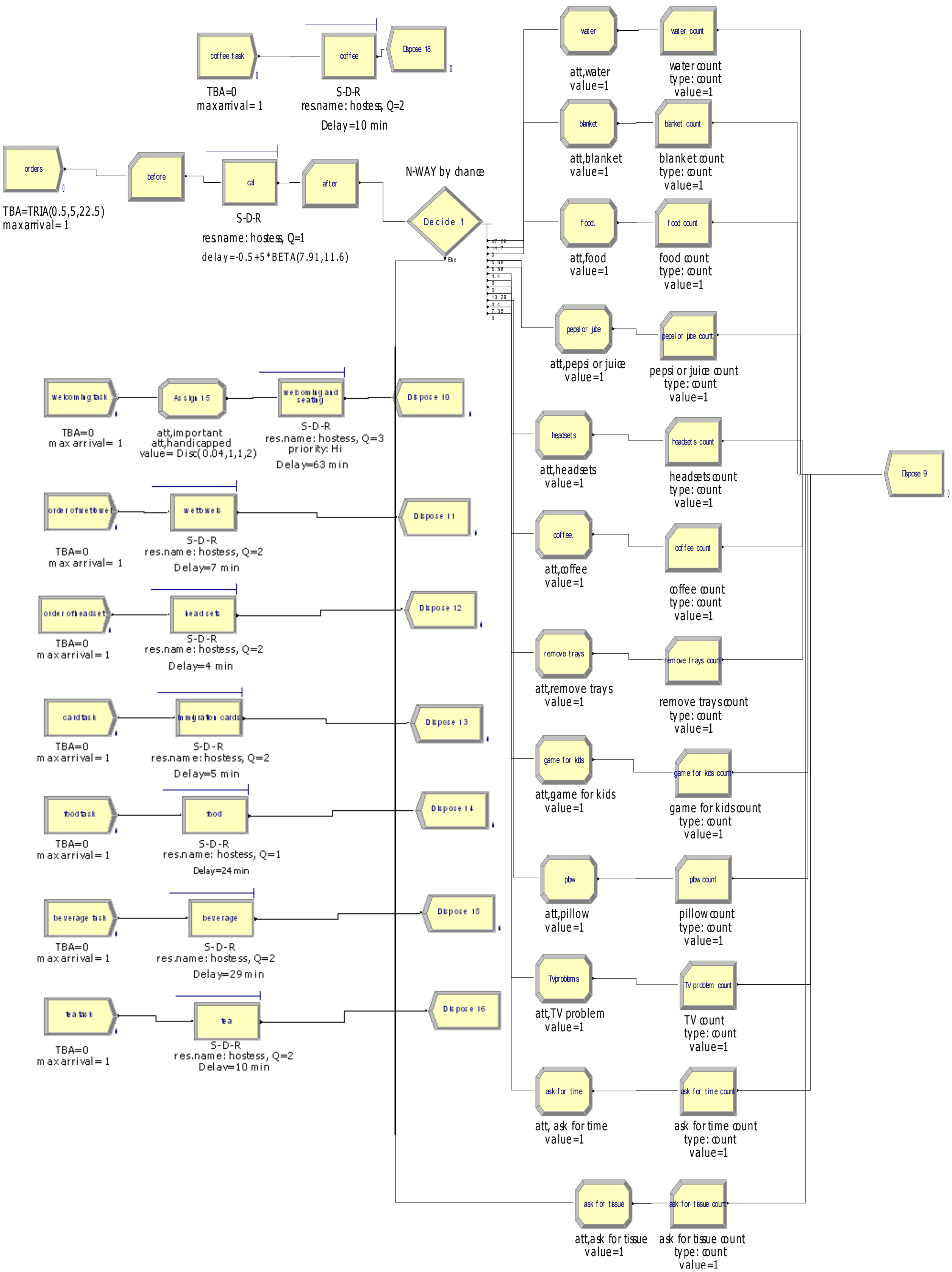

Fig. 2 ARENA-Based discrete-event simulation model for airhostess activities for the (F/J) class during a flight

Let m_i indicate the population mean for the parameter of interest; $\bar{X}_i$, s_i and n_i indicate mean, standard deviation and sample size of sample i respectively; Sample values form the *real system* (i=1) for number of answered calls by air hostess for the F/J class:

$\bar{X}_1 = 25.83$ calls; $s_1 =$ 3.25 calls; $n_1 =$ 6

Sample values form the *simulated system* (i=2) for number of answered calls by air hostess for F/J class:

$\bar{X}_2 = 27$ calls; $s_2 =$ 1.9 calls; $n_2 =$ 6

To conduct a statistically sound validation, the equality of two population variances needs to be verified, prior to checking the equality of means. At a 95 % confidence level we *fail to reject* that the two variances are unequal, therefore, the variance for the real and simulated system are pooled. The pooled standard deviation S_p=2.6615.

The *t*-distribution statistic will result in:

$$t_0 = \frac{\bar{X}_1 - \bar{X}_2}{sp\sqrt{1/n_1 + 1/n_2}} = -0.76 \qquad (1)$$

The *t-test* for 95% confidence intervals for $m_1 - m_2$ is calculated as follows:

$$m_1 - m_2 = \bar{X}_1 - \bar{X}_2 \pm t_{\alpha/2, n_1+n_2-2} S_p \sqrt{(\frac{1}{n_1} + \frac{1}{n_2})} \qquad [2]$$

Substituting values in the above equation yields:

$$-4.58 \leq m_1 - m_2 \leq 2.26$$

Also, the *p-value* =0.465 is larger than the significance level 0.05 which means that we f*ail to reject* the hypothesis that means of the two populations are equal. In other words, mean values obtained from simulation is equal to the mean values obtained from real life, which verifies that the simulated model is a valid representation of reality.

The statistical validation procedure indicated above was repeated for all parameters provided in table 5 for all classes First (F), Business (J) and Economy. The results are shown in table 6. Again, the statistical analysis at a 95% confidence level indicates that the simulated system is a valid representation of reality.

Table 5 Comparisons of data from the real and simulated system over 10 replications for calls received by air hostess in the F/J class

Run #	Blanket		Game		Headsets		Beverage		Pillow		TV		Water		Calls waiting time in queue		No. of calls waiting in queue	
	R	A	R	A	R	A	R	A	R	A	R	A	R	A	R	A	R	A
1	3	5	1	0	0	2	2	3	0	2	2	4	14	9	5	8	0	1
2	5	2	4	3	1	0	7	5	2	1	3	5	12	15	8	8	0	1
3	3	6	2	1	1	3	6	3	1	0	5	2	8	10	11	8	1	1
4	2	4	1	4	2	1	3	4	1	2	5	2	15	13	10	9	2	1
5	6	1	3	2	0	1	2	6	3	2	1	0	11	15	9	7	1	1
6	3	2	0	4	2	1	3	3	1	1	0	2	5	15	6	10	1	1
7	1	6	0	0	3	1	4	5	1	2	0	2	6	11	12	11	0	1
8	1	3	1	5	1	2	4	5	1	2	2	1	10	5	10	11	1	1
9	4	6	2	2	1	2	3	2	2	1	4	5	13	7	8	7	2	1
10	4	5	11	2	3	0	4	6	2	1	4	0	10	15	8	12	2	1
Mean	3.2	4.0	1.5	2.3	1.4	1.3	3.8	4.2	1.40	1.40	2.6	2.3	10.4	11.5	8.7	9.1	N/A	
St.Dev.	1.6	1.8	1.27	1.7	1.1	0.95	1.6	1.4	0.84	0.70	1.9	1.83	3.69	3.31	2.16	1.79		
SE-Mean	0.5	0.6	0.4	0.54	0.3	0.3	0.5	0.44	0.27	0.22	0.58	0.6	1.0	1.2	0.57	0.68		
CI on Diff.	-0.85, 2.45		-0.62, 2.22		-1.05, 0.85		-1.02, 1.82		-0.73, 0.73		-2.05, 1.45		-2.2, 4.4		-1.47, 2.27		N/A	
Key :			R: Data from the real system						A: Data from the simulated system of the Arena model									

Table 6 Statistical validation between the real and simulated systems using the sample t-test (α=0.05) over 10 replications

Parameter	X_1 (real)	X_2 (simulated)	$\mu_1 - \mu_2$	*P-value*
Blankets	4.0	3.2	(-0.85, 2.45)	0.32
Games	2.3	1.5	(-0.62, 2.22)	0.25
Headsets	1.3	1.4	(-1.05, 0.85)	0.83
Beverage	4.2	3.8	(-1.02, 1.82)	0.59
Pillow	1.4	1.4	(-0.73, 0.73)	1
TV	2.3	2.6	(-2.05, 1.45)	.72
Water	11.5	10.4	(-2.2, 4.4)	.49
Wait in Q	9.1	8.7	(-1.47, 2.27)	0.66

7 Simulation Models of the Improvement Scenarios

By analyzing the production runs of the in-flight simulation model, we realized that several improvements could take place to improve the passenger service without elevated work burden on the air hostess. These improvements are based on possible automation of some in-flight services that are listed below. These improvements were formulated as-is simulation model scenarios to be compared with the as-is system. Six scenarios were simulated:

Scenario 1: Providing the overhead passenger belonging bins with a hydraulic closing mechanism that locks the bins automatically during take-off and landing.
Scenario 2: Providing a system for the passengers to choose their meal from the menu using the screen on the seat in front of them.
Scenario 3: Allowing passengers to place requests for beverages from the touch screen. This allows air hostess to satisfy multiple orders at the same time.

Scenario 4: Allowing passengers to preview from the display screens whether or not the aisles are blocked by the food cart. This attempts to facilitate both hostess and passenger movement during the flight.
Scenario 5: Since the request for water is the most frequent task that an air hostess will answer, this scenario examines the case when bottled water is placed at every passenger's seat before passengers enters the airplane.
Scenario 6: Using an automatic inflating and deflating pillow that is attached to the passenger seat. This reduces the call for pillows which is also requested in a high rate.
Scenario 7: A combined scenario of all the previous 6 scenarios.

8 Output Analysis of Improvement Scenarios

A simulation model was developed for each of the seven scenarios discussed earlier in section 7. Each simulation model was run with specified parameters and replicated 10 times. The results for the F/J class are provided in table 7, while those for the economy class are provided in table 8. As shown in table, combining the six scenarios have tremendously affected system performance. For instance, the average response time of passenger calls has reduced from 9.21 to 0.1 minutes for the F/J class and from 8.6 minutes to 0.1 minutes for the economy class. In addition, the air hostess utilization was reduced by 12% for the F/J class and around 14% for the economy class. The number of calls for hostess service has been reduced due to the initial supply of inflatable pillows and bottled water on the passenger seats.

Table 7 Simulation model output of the as-is model and the seven improvement scenarios for the F/J class

F/J Class	As-is-Model	1st Scenario	2nd Scenario	3rd Scenario	4th Scenario	5th Scenario	6th Scenario	7th Scenario
Number of calls requested	27	27	27	27	27	25	24	25
Number of calls satisfied	27	27	27	27	27	25	23	25
Waiting time in calls queue (min)	9.21	6.7	8.95	8.69	6.3	9.8	9	0.0909
Number of Orders waiting in calls queue	1.008	0.73	0.97	0.94	.067	0.99	0.84	0.5519
Hostess Utilization	0.5110	0.4801	0.4890	0.4910	0.4703	0.5040	0.5010	0.4507

9 Analysis of Variance

We applied the analysis of variance (ANOVA) to statistically identify the most influential factors in improving the performance measures of the system. Each of the previously discussed scenarios is modeled as an ANOVA factor. ANOVA analysis was conducted for both F/J and economy classes and with respect to all performance measures. ANOVA was conducted using

Minitab package. Minitab results for the F/J class with respect to order waiting time and air hostess utilization are shown in Fig. 3.

Table 8 The simulation model output of the as-is model and the seven improvement scenarios for the economy class

Economy Class	As-is-Model	1st Scenario	2nd Scenario	3rd Scenario	4th Scenario	5th Scenario	6th Scenario	Combined Scenario
Number of calls requested	63	63	63	62	63	41	64	43
Number of calls satisfied	63	63	63	62	63	40	64	43
Waiting time in calls queue (min)	8.6	6.462	8.59	8.02	5.83	8.09	8.52	0.0982
Number of Orders waiting in calls queue	2.15	1.62	2.148	2.08	1.46	1.31	2.20	1.0058
Hostess Utilization	0.66	0.64	0.62	0.63	0.62	0.63	0.66	0.5689

One-way ANOVA: wait time versus fct

```
Source  DF      SS     MS      F      P
fct      5  108.73  21.75  10.47  0.000
Error   54  112.20   2.08
Total   59  220.93

S = 1.441   R-Sq = 49.22%   R-Sq(adj) = 44.51%


                               Individual 95% CIs For Mean Based on
                               Pooled StDev
Level   N   Mean  StDev  ------+---------+---------+---------+---
1      10  6.600  0.843      (-----*-----)
2      10  9.000  1.700                   (-----*-----)
3      10  8.700  1.494                 (-----*-----)
4      10  6.000  0.667  (-----*-----)
5      10  9.700  1.703                        (-----*-----)
6      10  8.800  1.814                  (-----*-----)
                         ------+---------+---------+---------+---
                             6.0       7.5       9.0      10.5

Pooled StDev = 1.441
```

Fig. 3 Minitab ANOVA output for comparing scenarios with respect to calls waiting time in queue for the F/J class (levels are scenarios)

As shown in Figure 3 the *p-value* is very small, which indicates that there is significant difference between the effects of each factor (scenarios in this case) with respect to waiting time. In the same figure, the multiple comparison diagrams show that the first and fourth factors have the most influence since they have the least values for waiting time. However, since very strong interaction occurs between the two factors, they are both candidates for being the best factors or scenarios.

The Tukey's test shown in Figure 4 gives further analysis related to the interactions. Tukey's test is an efficient statistical method to conduct pairwise comparisons among the means of all factors in the ANOVA design. Tukey's test proves that there is a strong interaction between the scenarios one and four. However, it shows that the fourth scenario has a slightly stronger effect.

```
Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of fct

Individual confidence level = 99.54%


fct = 1 subtracted from:

fct   Lower  Center  Upper  ---------+---------+---------+---------+
2     0.495   2.400  4.305                      (-----*-----)
3     0.195   2.100  4.005                     (-----*-----)
4    -2.505  -0.600  1.305            (-----*-----)
5     1.195   3.100  5.005                         (-----*------)
6     0.295   2.200  4.105                     (-----*------)
                            ---------+---------+---------+---------+
                                  -3.0       0.0       3.0       6.0


fct = 2 subtracted from:

fct   Lower  Center   Upper  ---------+---------+---------+---------+
3    -2.205  -0.300   1.605              (-----*-----)
4    -4.905  -3.000  -1.095    (-----*-----)
5    -1.205   0.700   2.605                  (-----*------)
6    -2.105  -0.200   1.705              (-----*------)
                             ---------+---------+---------+---------+
                                   -3.0       0.0       3.0       6.0


fct = 3 subtracted from:

fct   Lower  Center   Upper  ---------+---------+---------+---------+
4    -4.605  -2.700  -0.795     (-----*-----)
5    -0.905   1.000   2.905                 (-----*------)
6    -1.805   0.100   2.005              (-----*------)
                             ---------+---------+---------+---------+
                                   -3.0       0.0       3.0       6.0
```

Fig. 4 Tukey's pairwise comparison test of the effect of simulation scenarios with respect to waiting time in the F/J class

Similar analysis is conducted with respect to the air hostess utilization. The results are provided in Figure 5. Again, the *p-value* equals to zero, which indicates a significant effect between the factors. The analysis implies that the first scenario is the most affecting factor in this case. The preceding analyses were repeated for the air hostesses of the economy class but were omitted here to avoid repetition.

One-way ANOVA: utilization versus factor

```
Source  DF         SS         MS      F      P
factor   5  0.0183600  0.0036720  73.99  0.000
Error   54  0.0026800  0.0000496
Total   59  0.0210400

S = 0.007045   R-Sq = 87.26%   R-Sq(adj) = 86.08%

                             Individual 95% CIs For Mean Based on Pooled
                             StDev
Level   N     Mean    StDev   +---------+---------+---------+---------
1      10  0.45400  0.00516   (--*--)
2      10  0.48700  0.00675                       (--*--)
3      10  0.49000  0.00816                         (--*--)
4      10  0.46900  0.00876             (--*--)
5      10  0.50500  0.00527                                    (--*--)
6      10  0.49900  0.00738                                (--*--)
                              +---------+---------+---------+---------
                            0.450     0.465     0.480     0.495

Pooled StDev = 0.00704
```

Fig. 5 Minitab ANOVA output for comparing scenarios with respect to hostess utilization for the F/J class

10 Conclusions

In this research we have conducted a discrete event simulation study and subsequent statistical analysis for the activities of air hostesses during aircraft flights. The aim was to improve passenger service without increasing workload burden on air hostesses. Several improvement scenarios were suggested and simulated. The simulation models were statistically validated and compared to real data collected during actual flights. The outputs of the improved scenarios were statistically verified and modeled using ANOVA. The study has resulted in improved service and less fatigue on air hostesses in first, business and economy classes. The authors believe that these results could be extremely useful for airliners that want to improve their in-flight service operations.

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