MSA:8245 Analytical Methods for Optimization & Simulation

Final Project

Chris McMahon, Jennie Franco, William Hillegas

August 13, 2022

ABSTRACT

The goal of this study is to recreate Terminal 3 of Hub Airport in order to optimize wait times by focusing primarily on the check-in and security processes. This was accomplished by performing several simulations with a software program called Simio. The airport's present configuration requires travelers to wait a significant time before they reach their departure gate. As a consequence, we concentrate on the airport's bottleneck and recommend a plan for installing two additional security stations and a counter to reduce wait times by more than 50%. Thus, if Hub Airport could accommodate the number of manual counters and security stations during the day, the processes at Terminal 3 would be much improved.

INTRODUCTION

The aim of this study is to recommend an improvement plan for Terminal 3 at Hub Airport. This paper will highlight key insights derived from the simulation results.

1. BUILDING THE MODEL

Passengers enter the Hub Airport to check in, then continue to security and, finally, to their departure gate. There are three ways to conduct the check-ins.

- Manual check-in refers to travelers who check in at the manual desk (35% of passengers)
- Kiosk check-in refers to travelers who check in at a kiosk system (50% of passengers)
- Online check-in refers to travelers who checked in advance (online) and can proceed directly to tsa (15% of passengers)

The passengers are modeled as a single entity that splits to the various check-in systems via a basic node (by link weight). Three time paths are assigned a weight (.35, .50, or .15) from the node to signify the percentage of travelers who use the manual, kiosk, or online check in. In addition, to simulate the number of passengers arriving at Hub Airport, we utilized a source object with an exponential interarrival time.

Each check-in system is modeled as a server object. In the server object, we specify the processing time distribution as well as the initial capacities via a standard property, which allows us to experiment with the capacity for various scenarios. The simulation model is shown in *Appendix Figure 1*.

The check-in servers are then linked to a single server object named ”Security”. Travelers that checked in via the manual counter must walk an additional 2 to 6 minutes to reach the security check point. Travelers who checked in via the Kiosk system must walk approximately 1 to 3 minutes to security. These times are modeled given the distributions shown in the table below.

TABLE I: Distribution

Check-in Type	Time to Check-in	Time to Security
Manual	Uniform Distribution(1,2)	Uniform Distribution(2,5.8)
Kiosk	Uniform Distribution(1,2)	Uniform Distribution(1,3)
Online	NA	Uniform Distribution(3,5)

The processing time at security follows a Triangular distribution, with an initial capacity of 6 stations; once again, we utilize a standard property to experiment with extra resources to determine whether the travelers can be processed through security faster.

The travelers exit to their departure gate after security. This is modeled by the sink object where the entity terminates.

2. Running the Model

The baseline model for this simulation consists of 2 manual counters, 2 kiosks, and 6 security stations. The model was then run for eight hours and for 50 replications. The results of the baseline model are shown in the figure below.

Baseline Model					
	Number in queue	Time in queue (*min*)	Utilization	Number in system	Time in system
Kiosk	0.179	0.178	50%		
Counter	4.9	6.9	92%	136	68.69
Security	113	57	98%		

According to the results of the baseline model, on average 136 passengers enter Terminal 3 of Hub Airport. Passengers who must check-in before proceeding to security spend approximately 6 minutes longer at the manual counter versus the kiosk. The largest time spent, however, is at security, where on average 113 travelers wait roughly 57 minutes in queue.

To reduce wait time, the model has been changed to handle the scenarios listed in *Appendix Figure 2*. To ensure that we covered all possible cases, we adjusted the percentage of travelers who checked in advance or accessed the kiosk. *Appendix Figure 6* depicts the possibilities we investigated. In addition, to avoid diminishing computer performance, the numerous scenarios were divided into three experiments. For each experiment, nine scenarios were run, as illustrated in *Appendix A Figure 3, 4, and 5*.

A. Experimental Design

If the airport merely wishes to devote resources to the check-in process, it is in their benefit to reduce the time spent in line for manual check-in. By adding another counter, the time in queue is reduced by more than 100%, from 6.9 to 0.52 minutes.

Counter+1					
	Number in queue	Time in queue (*min*)	Utilization	Number in system	Time in system
Kiosk	0.179	0.178	50%		
Counter	0.367	0.52	62%	135	68.57
Security	117	59	98%		

The difference between an additional kiosk is very little given that it was already decent. This process's bottleneck is at security. As a result, we will spend more time here determining which scenario is best for Hub Airport.

B. Explaining the results of the Experimental Design

The ideal option from all twenty-seven scenarios observed is to focus on the bottleneck; as a result, the scenario that decreases time in queue and overall is when an additional manual counter and two additional security stations are added to the Terminal. This reduces the time in system from 68.69 minutes to 16.73 minutes. That is a considerable reduction. Furthermore, the number of individuals in line at security drops from 113 to 13, with each person waiting around 7 minutes to be cleared by TSA. The results of this scenario is shown in the table below.

Security+2 and Counter+1					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.18	0.18	49%		
Counter	0.36	0.51	61%	33	16.73
Security	13	6.82	95%		

Then we concentrated on the instances in which we modified the percentages. It was discovered that increasing the online check-in by 10% had a greater effect. This reduced the overall time spent in the system by 5%. Anything above this flooded the security checkpoint, increasing the time in line. When we incorporated both the percentage change and extra counters/security stations, we got similar results. According to these findings, if the airport could afford to market the online method, the wait time would be reduced by 5%.

3. Recommendation Plan

Hub Airport would benefit substantially from installing an additional manual counter and two additional security stations, which would reduce wait times by more than 50%. It is in the best interests of the Airport to accommodate the number of security stations operating during the day in order to improve the check-in and security processes at Terminal 3.

APPENDIX A

Fig. 1: Hub Airport Terminal 3 Simulation

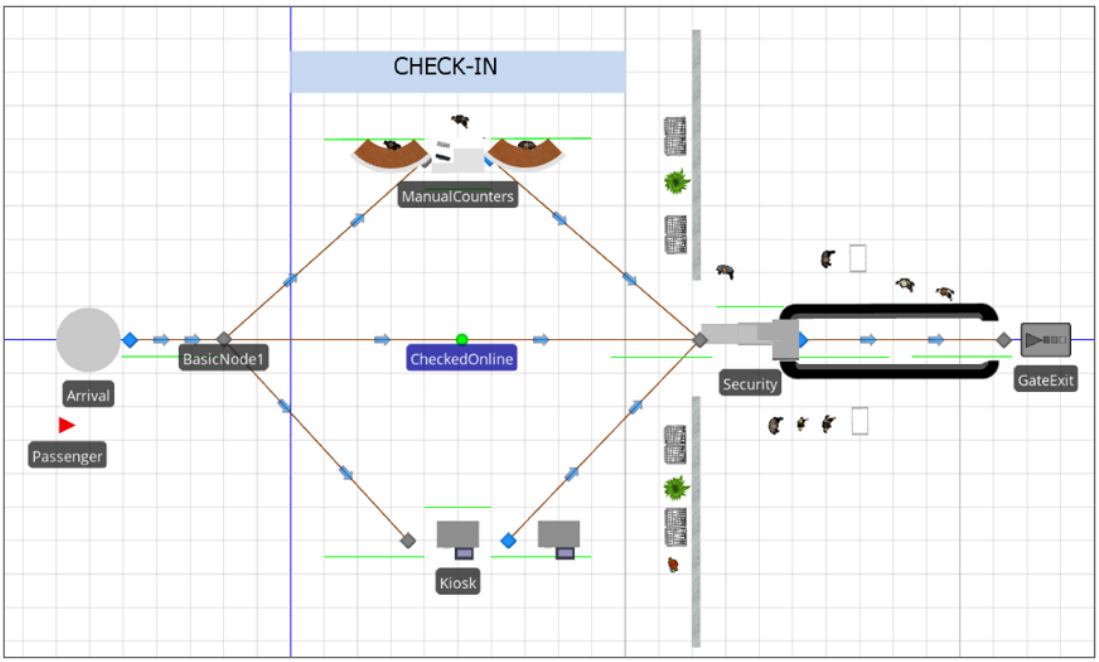

Fig. 2: Experimental Design Table

Scenario	*Counters*	*Kiosks*	*Security*
Baseline	2	2	6
Counter +1	3	2	6
Counter +2	4	2	6
Kiosk +1	2	3	6
Kiosk +1 and Counter +1	3	3	6
Kiosk +1 and Counter +2	4	3	6
Kiosk +2	2	4	6
Kiosk +2 and Counter +1	3	4	6
Kiosk +2 and Counter +2	4	4	6
Security +1	2	2	7
Security +1 and Counter +1	3	2	7
Security +1 and Counter +2	4	2	7
Security +1 and Kiosk +1	2	3	7
Security +1 and Kiosk +1 and Counter +1	3	3	7
Security +1 and Kiosk +1 and Counter +2	4	3	7
Security +1 and Kiosk +2	2	4	7
Security +1 and Kiosk +2 and Counter +1	3	4	7
Security +1 and Kiosk +2 and Counter +2	4	4	7
Security +2	2	2	8
Security +2 and Counter +1	3	2	8
Security +2 and Counter +2	4	2	8
Security +2 and Kiosk +1	2	3	8
Security +2 and Kiosk +1 and Counter +1	3	3	8
Security +2 and Kiosk +1 and Counter +2	4	3	8
Security +2 and Kiosk +2	2	4	8
Security +2 and Kiosk +2 and Counter +1	3	4	8
Security +2 and Kiosk +2 and Counter +2	4	4	8

Fig. 3: Experiment one results

Baseline Model					
	Number in queue	Time in queue (*min*)	Utilization	Number in system	Time in system
Kiosk	0.18	0.18	50%		
Counter	4.9	6.9	92%	136	68.69
Security	113	57	98%		

Counter+1					
	Number in queue	Time in queue (*min*)	Utilization	Number in system	Time in system
Kiosk	0.18	0.18	50%		
Counter	0.37	0.52	62%	135	68.57
Security	117	59	98%		

Counter+2					
	Number in queue	Time in queue (*min*)	Utilization	Number in system	Time in system
Kiosk	0.18	0.18	50%		
Counter	0.08	0.12	46%	134	68.19
Security	117	59	98%		

Kiosk+1					
	Number in queue	Time in queue (*min*)	Utilization	Number in system	Time in system
Kiosk	0.03	0.03	33%		
Counter	4.6	6.5	91%	133	68.01
Security	111	57	98%		

Kiosk+1 and Counter+1					
	Number in queue	Time in queue (*min*)	Utilization	Number in system	Time in system
Kiosk	0.03	0.03	33%		
Counter	0.39	0.54	62%	135	68.4
Security	118	59	98%		

Kiosk+1 and Counter+2					
	Number in queue	Time in queue (*min*)	Utilization	Number in system	Time in system
Kiosk	0.03	0.03	32%		
Counter	0.07	0.10	46%	132	67.23
Security	115	58	98%		

Kiosk+2					
	Number in queue	Time in queue (*min*)	Utilization	Number in system	Time in system
Kiosk	0.00	0.00	25%		
Counter	4.80	6.7	91%	134	67.87
Security	112	57	98%		

Kiosk+2 and Counter+1					
	Number in queue	Time in queue (*min*)	Utilization	Number in system	Time in system
Kiosk	0.01	0.01	25%		
Counter	0.40	0.56	62%	138	69.46
Security	120	60	98%		

Kiosk+2 and Counter+2					
	Number in queue	Time in queue (*min*)	Utilization	Number in system	Time in system
Kiosk	0.00	0.00	25%		
Counter	0.07	0.10	46%	133	67.77
Security	115	59	98%		

Fig. 4: Experiment two results

Security+1					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.18	0.10	49%		
Counter	5.32	7.49	91%	76	38.76
Security	53	26.70	98%		

Security+1 and Counter+1					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.18	0.18	49%		
Counter	0.36	0.51	61%	77	39.15
Security	58	29.40	98%		

Security+1 and Counter+2					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.18	0.17	50%		
Counter	0.08	0.11	46%	79	39.94
Security	60	30.40	98%		

Security+1 and Kiosk+1					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.03	0.03	33%		
Counter	4.56	6.41	91%	76	38.66
Security	53	27.00	98%		

Security+1 and Kiosk+1 and Counter+1					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.03	0.01	33%		
Counter	0.34	0.48	61%	78	39.87
Security	60	30.20	98%		

Security+1 and Kiosk+1 and Counter+2					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.03	0.01	33%		
Counter	0.07	0.11	45%	75	38.35
Security	57	28.80	98%		

Security+1 and Kiosk+2					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.00	0.00	24%		
Counter	4.35	6.18	90%	74	37.91
Security	52	26.40	98%		

Security+1 and Kiosk+2 and Counter+1					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.00	0.00	24%		
Counter	0.32	0.45	60%	75	38.13
Security	56	28.50	98%		

Security+1 and Kiosk+2 and Counter+2					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.00	0.00	24%		
Counter	0.08	0.11	46%	78	39.74
Security	60	30.20	98%		

Fig. 5: Experiment three results

Security+2					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.18	0.18	49%		
Counter	4.89	6.83	91%	35	17.91
Security	11	5.90	95%		

Security+2 and Counter+1					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.18	0.18	49%		
Counter	0.36	0.51	61%	33	16.73
Security	13	6.82	95%		

Security+2 and Counter+2					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.18	0.18	49%		
Counter	0.98	0.12	47%	33	16.91
Security	14	7.12	96%		

Security+2 and Kiosk+1					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.03	0.03	33%		
Counter	5.31	7.34	92%	36	18.27
Security	12	6.07	95%		

Security+2 and Kiosk+1 and Counter+1					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.03	0.03	33%		
Counter	0.38	0.53	61%	36	18.05
Security	16	8.23	95%		

Security+2 and Kiosk+1 and Counter+2					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.03	0.03	33%		
Counter	0.08	0.11	46%	35	17.66
Security	16	7.98	96%		

Security+2 and Kiosk+2					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.01	0.01	25%		
Counter	5.49	7.62	91%	38	19.37
Security	14.3	7.12	96%		

Security+2 and Kiosk+2 and Counter+1					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.00	0.00	24%		
Counter	0.40	0.56	62%	34	17.44
Security	15	7.62	96%		

Security+2 and Kiosk+2 and Counter+2					
	Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk	0.00	0.00	24%		
Counter	0.07	0.09	46%	33	16.76
Security	14	7.10	95%		

Fig. 6: Alternative Percentage for Check-in Methods

Check-in Type	Original	5% Increase (Kiosk & Online)	10% Increase (Online only)	35% Increase (Online only)
Kiosk	50%	55%	45%	35%
Counter	35%	25%	30%	15%
Online	15%	20%	25%	50%

Fig. 7: Alternative Percentage - Baseline Results

With the Baseline

Baseline Model

Percentage of passengers		Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk - 50%	Kiosk	0.179	0.178	50%		
Counter - 35%	Counter	4.9	6.9	92%	136	68.69
Online - 15%	Security	113	57	98%		

5% increase to Kiosk & Online Check-in

Percentage of passengers		Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk - 55%	Kiosk	0.311	0.3	55%		
Counter - 25%	Counter	0.551	1.112	64%	144	72.88
Online - 20%	Security	127	63	98%		

10% increase to Online Check-in Only

Percentage of passengers		Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk - 45%	Kiosk	0.11	0.13	45%		
Counter - 30%	Counter	3.66	5.60	84%	132	66
Online - 25%	Security	111	55	98%		

+35% increase to Online Check-in Only

Percentage of passengers		Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk - 35%	Kiosk	0.05	0.07	36%		
Counter - 15%	Counter	0.058	0.21	37%	133	70
Online - 50%	Security	118	62.24	98%		

Fig. 8: Alternative Percentage - Optimal Solution Results

With the Optimal Solution

Security+2 and Counter+1

Percentage of passengers		Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk - 50%	Kiosk	0.18	0.18	49%		
Counter - 35%	Counter	0.36	0.51	61%	33	16.73
Online - 15%	Security	13	6.82	95%		

Security+2 and Counter+1 | 5% increase to kiosk & online check-in

Percentage of passengers		Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk - 55%	Kiosk	0.25	0.23	54%		
Counter - 25%	Counter	0.09	0.17	44%	34	17.50
Online - 20%	Security	16	8.07	95%		

Security+2 and Counter+1 | 10% increase to online check-in only

Percentage of passengers		Number in queue	Time in queue	Utilization	Number in system	Time in system
Kiosk - 45%	Kiosk	0.13	0.14	45%		
Counter - 30%	Counter	0.16	0.27	52%	33	16.84
Online - 25%	Security	14	7.29	96%		

Security+2 and Counter+1 | +35% increase to online check-in only

Percentage of passengers		Number in queue	Time in queue (*min*)	Utilization	Number in system	Time in system
Kiosk - 35%	Kiosk	0.05	0.08	34%		
Counter - 15%	Counter	0.013	0.04	26%	31	15.9
Online - 50%	Security	14	7.15	96%		