CS 342 Lab Assignment 4 Report
Lab Group M5

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Introduction

Airport security screening processes play a critical role in ensuring the safety of air travel. As the number of air travelers continues to rise, optimizing the efficiency of security lines has become paramount to enhance passenger satisfaction and overall airport operations.
In response to this challenge, we have developed a simulation program that models the dynamics of a busy airport security checkpoint, allowing for a detailed analysis of queuing systems and the impact of various optimizations. By focusing on key parameters such as Arrival Rate (λ) and Service Rate (μ), our simulation aims to provide insights into how different configurations and strategies can improve the passenger experience and operational efficiency of airport security screening.
This report presents the methodology, results, and implications of our simulation, offering valuable information for airport authorities seeking to enhance their security line management.

Parameters Defined

The Arrival Rate (λ) and Service Rate (μ) can be set by the user in all cases which impacts the final statistics obtained, I.e, Average Weighting Time, Average Queue Length and the System Utilization. The total number of security scanners (m) can also be set by the user.

Apart from these we have also enabled the option to set a finite buffer size (K).

The user also has the ability to set the simulation duration, at the end of which the program stops and the statistics are shown.

Therefore the user set parameters are:

1. Simulation Duration
2. Queue size (K)
3. Arrival Rate (λ)
4. Service Rate (μ)
5. Number of Security Scanners or Servers (m)

Data Obtained and Analysis

In all cases the simulation duration is 100s.

Case 1: Single Queue, Single Server, λ = 5, μ = 8

Queue Length	Average Waiting Time	Average Queue Length	Average Server Utilization	Passengers Dropped
infinite	0.253363	1.21046	0.609592	0
3	0.118828	0.544109	0.584843	23
10	0.218038	1.03378	0.604709	5
20	0.252137	1.20304	0.610993	0

Case 2: Single Queue, Multiple Server (m = 2), λ = 5, μ = 8

Queue Length	Average Waiting Time	Average Queue Length	Average Server Utilization	Passengers Dropped
Infinite	0.0213431	0.110401	0.306828	0
3	0.018214	0.0943197	0.305892	2
10	0.0211972	0.107736	0.30531	0
20	0.021163	0.110507	0.305342	0

Case 3: Single Queue, Multiple Server (m = 5), λ = 5, μ = 2

Queue Length	Average Waiting Time	Average Queue Length	Average Server Utilization	Passengers Dropped
Infinite	0.0438525	0.215374	0.485423	0
3	0.0165075	0.0853745	0.480075	8
10	0.0441266	0.216584	0.485412	0
20	0.0439743	0.216633	0.48557	0

Case 4: Single Queue, Multiple Server (m = 5), λ = 20, μ = 10

Queue Length	Average Waiting Time	Average Queue Length	Average Server Utilization	Passengers Dropped
Infinite	0.00129048	0.0521994	0.380106	0
3	0.0011051	0.0503027	0.380601	2
10	0.00139602	0.0556267	0.3801	0
20	0.00140831	0.0561563	0.379886	0

Case 5: Single Queue, Single Server, λ = 8, μ = 5

Queue Length	Average Waiting Time	Average Queue Length	Average Server Utilization	Passengers Dropped
infinite	16.1746	131.716	0.97856	0
3	0.426041	1.91877	0.924287	316
10	1.69139	8.11084	0.976343	280
20	3.5635	17.3279	0.978469	286

Case 6: Single Queue, Multiple Server (m = 2), λ = 8, μ = 5

Queue Length	Average Waiting Time	Average Queue Length	Average Server Utilization	Passengers Dropped
Infinite	0.253692	1.95027	0.7624911	0
3	0.0878443	0.640656	0.708476	53
10	0.225495	1.70576	0.754779	8
20	0.252235	1.93707	0.763891	0

Case 7: Single Queue, Multiple Server (m = 5), λ = 8, μ = 2

Queue Length	Average Waiting Time	Average Queue Length	Average Server Utilization	Passengers Dropped
Infinite	0.158645	1.21573	0.763931	0
3	0.0570705	0.429445	0.734995	33
10	0.125893	0.957975	0.755762	6
20	0.157916	1.20928	0.763525	0

Case 8: Single Queue, Multiple Server (m = 2), λ = 20, μ = 10

Queue Length	Average Waiting Time	Average Queue Length	Average Server Utilization	Passengers Dropped
Infinite	0.481719	8.99414	0.936533	0
3	0.0636297	1.02812	0.806656	290
10	0.204074	3.69016	0.89932	68
20	0.352547	6.52867	0.933681	18

Case 9: Multiple Queue, Multiple Server (m = 2), λ = 5, μ = 8

Queue Length	Average Waiting Time	Average Queue Length	Average Server Utilization	Passengers Dropped
infinite	0.053727	0.131921	0.313417	0
3	0.0540309	0.131954	0.313767	0
10	0.0537402	0.132735	0.314596	0
20	0.0544722	0.133471	0.314143	0

Case 10: Multiple Queue, Multiple Server (m = 2), λ = 8, μ = 5

Queue Length	Average Waiting Time	Average Queue Length	Average Server Utilization	Passengers Dropped
Infinite	0.308168	1.17789	0.775024	0
3	0.217712	0.80867	0.75597	25
10	0.307429	1.17424	0.774979	0
20	0.301628	1.15352	0.774464	0

Case 11 Multiple Queue, Multiple Server (m=5), λ = 8, μ = 2

Queue Length	Average Waiting Time	Average Queue Length	Average Server Utilization	Passengers Dropped
Infinite	0.157874	1.20928	0.763995	0
3	0.0573358	0.431757	0.735641	33
10	0.126514	0.963363	0.755942	6
20	0.156829	1.20379	0.762775	0

Case 12: Multiple Queue, Multiple Server (m=2), λ = 20, μ = 10

Queue Length	Average Waiting Time	Average Queue Length	Average Server Utilization	Passengers Dropped
Infinite	0.46484	4.3386	0.934869	0
3	0.151474	1.27487	0.84972	199
10	0.378037	3.49653	0.932037	18
20	0.496132	4.62874	0.938591	0

Conclusion

In case of Single Queue with λ < μ:

- We can see that as soon as the buffer size is finite the number of packets dropped increases.
- If we increase the number of servers the number of packets dropped decreases and the average server utilization decreases.
- The average server utilization also increases as we increase the buffer size.
- In the case of single queue and single server, queue length of 10 < K < 20 is optimal as the passengers dropped is becoming 0 and server utilization is increased, and for case of multiple servers it is between 3 and 10.

In case of Single Queue with λ > μ:

- If the arrival rate is higher than the service rate the average queue lengths are higher as more processes will be waiting.
- In the case of single server, the passengers dropped in case of finite buffer is very high.
- This decreases if we use multiple buffers, and the average queue length also decreases as more passengers can be processed.
- In case of Single Server there is no finite buffer which results in 0 passengers dropped.

In case of Multiple Queues:

- We can observe that as soon as we add one extra queue, the passengers dropped decreases significantly, thus using multiple queues is optimal.
- Even in case of large arrival rate, there exists an optimal queue length which results in 0 passengers dropped.

In conclusion increasing the buffer length(queue length) in general decreases the passengers dropped, and increases the utilization of server. Increasing the number of servers(scanners) also decreases the passengers dropped but decreases the average utilization of the servers as they share the passengers that arrive.
Increasing the number of queues always decreases the passengers dropped and also the server utilization by a significant amount.

Thus this simulation is a good model of the Airport Security Line optimizations and accurately demonstrates how changing the parameters such as the queue length, number of queues and number of scanners given the passenger arrival and service rates.