An Investigation of Traffic and Optimization Opportunities of a Passenger Service System in JFK Airport

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Abstract

Air traffic worldwide is increasing more and more in recent years. In 2017, a total of 4,1 billion passengers were carried. Never in history such a high number been achieved. Especially the rising population of so- called low- cost airlines have caused a veritable hype. Not only does this place an increasing burden on the environment, it also poses difficult tasks for the world's airports. This crowd of people first has to be processed without causing a complete chaos. This need to think of ways to overcome this challenge has led us to explore so- called automated border systems. These service systems aim to accelerate immigration control and thus prevent longer waiting times. We describe the functioning as well as the advantages and disadvantages of the existing service systems. We collected, presented and analyzed of the data that were used for modeling. Main part of this paper is the creation of simple mathematical models. Both a single server and multi-server models are created at three different times. Subsequently, these outcomes are compared to see which one was most effective.

Keywords [1]

Passenger Service System, JFK Airport, automated border systems, single server and a multi-server model

1. Introduction

Automated Passport Control (APC) is a U.S. Customs and Border Protection (CBP) program that expedites the immigration process for U.S., Canadian and eligible Visa Waiver Program international travelers by providing automated process through CBP`s Primary Inspection area" [1].

Back then people had to fill out declaration forms by hand, whereas now people just go to one of those so- called "APC kiosk" in the immigration area. At this kiosk, their passport is scanned to acquire all the relevant information. People must take a picture and scan their fingerprints to check for verification. After that they need to answer a few questions about their stay, like for example "how long will you stay in the US?" or "how much cash do you have with you?" After the verification, travelers get a receipt which they have to bring with their passport to an officer's booth to finalize the process.

The system was first introduced in late-2013 at the John F. Kennedy Airport in New York City. Meanwhile the service is available at in total 43 airports in the United States and Canada, including the most important and busiest ones, LAX, MIA and YVR. Unfortunately, not everyone is eligible to use this service except the following passenger groups [1]:

- U.S. Citizen
- Canadian Citizen
- U.S legal permanent residents

People having a Green Card

- People with an ESTA Visa

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Travelling Visa which allow you to stay in the country for 90 days

- People with B1 or B2 Visa

A non- immigrant visa for persons who wish to enter the United States either for business purposes (B1) or for private purposes (B2)

- People with D Visa

These types of visas are distributed to airlines and also to staff of ships, because people often travel into the United States but do not stay for long. So far, these types of systems have mainly been used in airports and in addition to many advantages, they also have a few disadvantages [2]:

Pros: Reduce of processing and queueing time
Introduction of some level of verification
More effective use of floor space
Increase of security thorough implementation of Registered Traveler Programs
Reductions of costs (Immigration & budget costs)

Cons: Threats through hacker and viruses
Limitations in terms of usability of the service

Big differences of duration time between allowed and non- allowed travelers in general 8- 10 % off all processed fail. This can happen due to several reasons. First there might be problems with the system [3]. Either there is a failure of the biometric algorithm or there are problems while scanning the document, maybe also because they are in a bad shape. On the other hand problem might also occur on the individual side, because they do not understand the process of such a system. So there is room for improvement in the following areas:

- Biometrics

- Improvement of the biometrics algorithms, to increase speed and accuracy
- Implementation of functions to avoid hacker attacks

- Usage

- Allow a better training on the operability of these service systems
- The interactions between human and machine at the lowest possible level

2. Motivation and milestones

Throughout our process of finding the right service system and the right approach [4] that suit our needs in terms of what we were planning to focus our analysis on, we encountered a lot of "roadblocks" so to speak [5]. These roadblocks, which are also milestones in a way, led us to change our focus, approach and elected service system several times , which will be discussed further in the following.

- *First approach:*

The first idea that came to mind was to analyze traffic and possible optimization opportunities of a passenger service system (PSS), more precisely the airline reservations system within a passenger service system [6]. Following our unified decision on the field of research, we proceeded to gather data and information about how passenger service system work, which kinds of PSSs there are and how incoming traffic is processed.

Outcome: Unfortunately, we were unable to find feasible and useful empirical data on any customer traffic and how the service system design approaches its processing. It seems that this kind of data would not be accessible to the public.

- *Second approach:*

After we figured that we wouldn't find useful data on passenger service systems and its subsystems [7], we diverted our focus on a more practical approach. The service system we chose to focus on this time was the Vienna International Airport (VIE). We were interested in the amount of time each passenger must spend on average being in the service system Vienna International Airport, from the moment the passenger steps foot into the airport buildings until he or she leaves via plane etc. Next, each of us once again searched for information about the many different processes and activities a passenger must go through in the Vienna International Airport.

Outcome: Again, we were confronted with the problem of low data availability, at least concerning the data we were looking for, like empirical studies on waiting times of each passenger processing activity inside the airport. Additionally, it became obvious that the whole approach was too ambitioned and diversified.

- *Third and final approach:*

Following our realization that our second approach was too ambitioned, we decided to tighten the scope of our analysis and narrow it down to one institutional branch inside an airport. Throughout our extensive research, we realized that most data would be available for airports in the U.S., which is why we decided to focus our research efforts on the JFK International Airport in New York. After that, we discovered that the official Website of the U.S. Customs and Border Protection offers extensive empirical data on its procedures, which will be discussed further in the Data Collection and Description chapter, we decided to limit our analysis on the Immigration procedure at the U.S. Customs and Border Protection area at the JFK International Airport. To be precise, we wanted to analyze how much time each passenger spends in the immigration procedure, which is our service system here, on average. This includes scanning passports and processing through the immigration booth. Also, in 2013 APCs were introduced, so we wanted to compare said times spent in the service system from before and after the introduction..

3. Data collection and description

As already was mentioned, data collection proved to be more difficult than we anticipated on many occasions [8]. To be clear, there is very much information to be found when looking for aviation data and statistics, but most of the reports were too general, focusing more on economic numbers and didn't include the information we were looking for, namely passenger traffic, waiting times in immigration etc. Eventually, we discovered the official Website of the U.S. Customs and Border Protection, which was the initial breakthrough in our search for data [1].

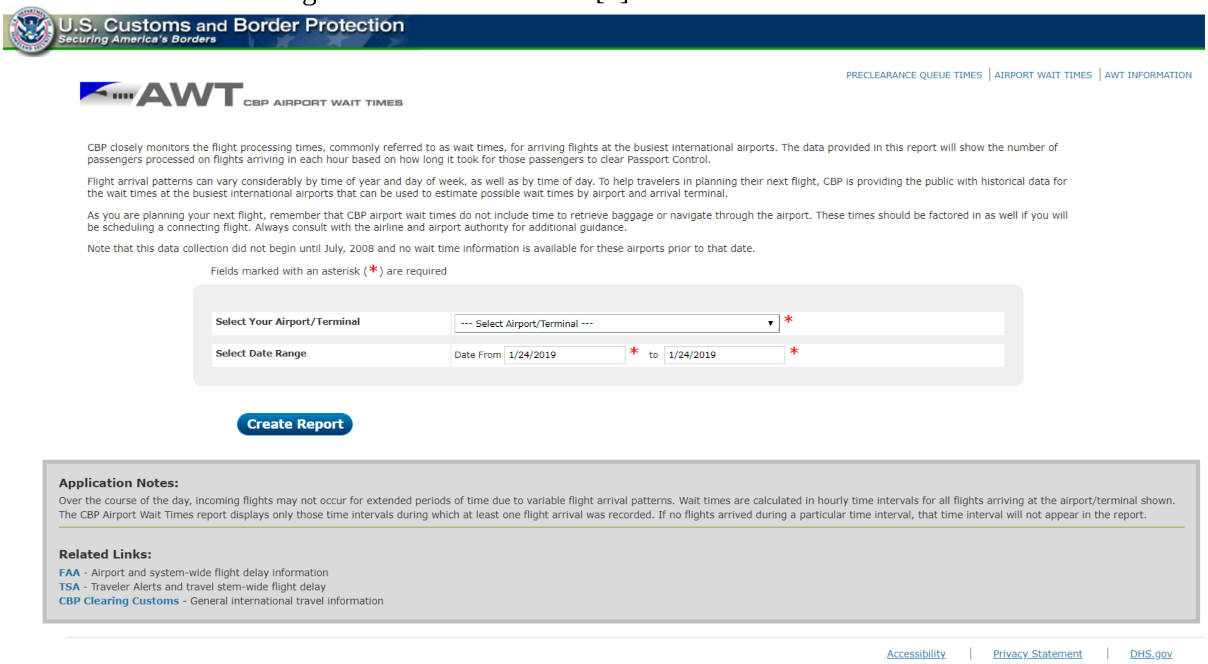

Figure 1: Data Description. Source: [1]

The depiction above shows the said Website. All data sets, which are made publicly available here, were collected by the U.S. Customs and Border Protection instances themselves and can be considered reliable. Acquiring access to the desired data set is very quick and easy, as users choose which airport and terminal in which time span they want data on and it's immediately available for download. Said data sets include date and time with average and maximum waiting times for U.S. Citizens, Non-U.S. Citizens and both. This way, it is possible to distinguish service times for these two groups of persons, which can lead to new implications being made on how much time immigration time differs for them.

For our analysis, we thought it would be beneficial to the cohesiveness of the analysis to discriminate between U.S. and Non-U.S. citizens, because according to the data, on average, Non-U.S. citizens can take a little bit longer to be processed, thus spending more time in the service system. The data sets also include total number of passengers, flights and number of opened processing booths in the respective period, which can vary from hour to hour, ranging from 10 to 30 opened booths depending on incoming passenger traffic and number of flights. Also, the data sets contain time intervals in which customers are supposedly processed, ranging from 1-15 Minutes up until 120 minutes plus. Unfortunately, these intervals are not very useful to us, because it would be impossible to approximate the processing time per passenger this way. Nevertheless, these data sets are the foundation of our analysis and server models, which are discussed in the respective chapter.

Having defined our metrics before, we now make some assumptions about our queuing model. All assumptions are applied to both M/M/1 and M/M/3 model. Our comparison takes into account the years 2012, 2015 and 2018 and adopts all the above scenarios. The year 2012 is considered as well in our calculations, and should show us how the situation has changed before the new system adaption in 2013. We also differentiate between US citizens and Non-US citizens in our comparison. The outcome will show us through performance measures where we could reduce waiting times

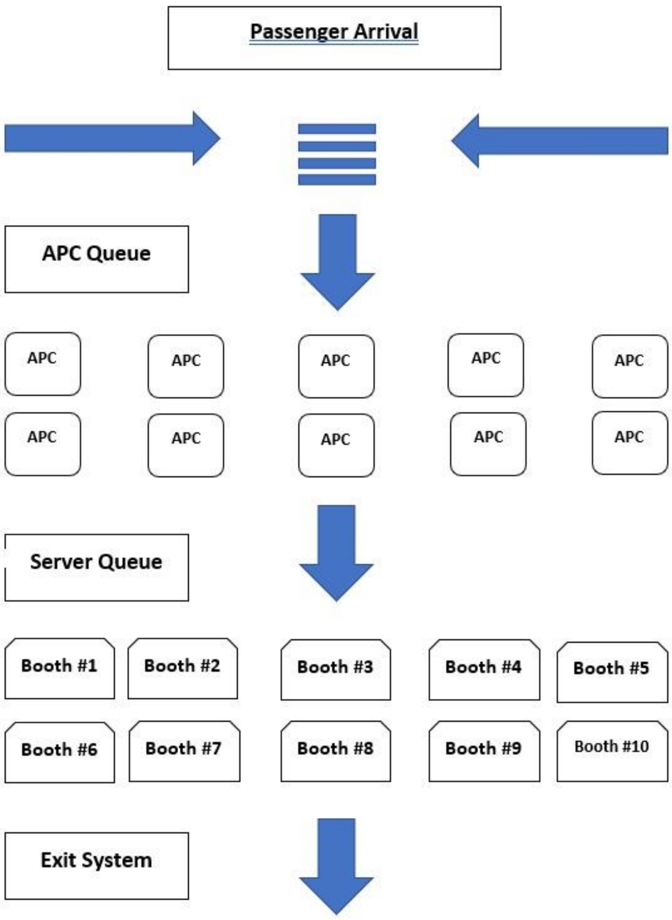

Figure 2: Passenger Arrival Flow Model

4. Single & Multi- server models and results

In our model, we tried to capture a finite number of JFK Airport passengers (Terminal 1) in the queue and run them through our servers as fast as possible. The second of January serves as a starting point for our observation and from this, we built our analysis using the M/M/1 and in the M/M/3 models. We also assumed a distribution of passengers of 30% Non-US passengers and 70% US citizens. Overall, according to the dataset we received from the US Air Authority, there are 512 (2012), 650 (2015) and

625 (2018) passengers in Terminal 1 running through our servers. This gives a total of 23.93 (2012), 28.80 (2015) and 41.37 people per booth (server) per hour. In order to determine our service rate, we take the average waiting time of the respective year at hand and calculate the following values:

$$\mu US(2018) = \frac{28{,}96\ passengers}{33{,}33\ minutes} = 0{,}87$$
$$\mu NonUS(2018) = \frac{12{,}41\ passengers}{40\ minutes} = 0{,}31$$
$$\mu US(2015) = \frac{20{,}16\ passengers}{43{,}88\ minutes} = 0{,}46$$
$$\mu NonUS(2015) = \frac{8{,}64\ passengers}{50\ minutes} = 0{,}17 \qquad (1)$$
$$\mu US(2012) = \frac{16{,}75\ passengers}{23{,}93\ minutes} = 0{,}7$$
$$\mu NonUS(2012) = \frac{7{,}18\ passengers}{30\ minutes} = 0{,}24$$

The arrival rate results from the same calculation except that we divide by 60 minutes, so we get the following values:

$$\lambda_{US}\ (2018) = \frac{28{,}96\ passengers}{60\ minutes} = 0{,}48$$
$$\lambda_{NonUS}\ (2018) = \frac{12{,}41\ passengers}{60\ minutes} = 0{,}21$$
$$\lambda_{US}\ (2015) = \frac{20{,}16\ passengers}{60\ minutes} = 0{,}34$$
$$\lambda_{NonUS}\ (2015) = \frac{8{,}64\ passengers}{60\ minutes} = 0{,}14 \qquad (2)$$
$$\lambda_{US}\ (2012) = \frac{16{,}75\ passengers}{60\ minutes} = 0{,}28$$
$$\lambda_{NonUS}\ (2012) = \frac{7{,}18\ passengers}{60\ minutes} = 0{,}12$$

In the following visualizations, the different assumptions are compared, we do not go into the analysis here. We will discuss these in the next section of the paper and then discuss possible suggestions of improvement. So, we basically only calculate the performance measures [9] in this section, for both M/M/1 and M/M/3:

- Service factor p describes the utilization of the server, and besides that also the probability of the server being busy or the probability of someone being served; one assumption that needs to be satisfied is the mean rate of arrival to be smaller than the mean service rate

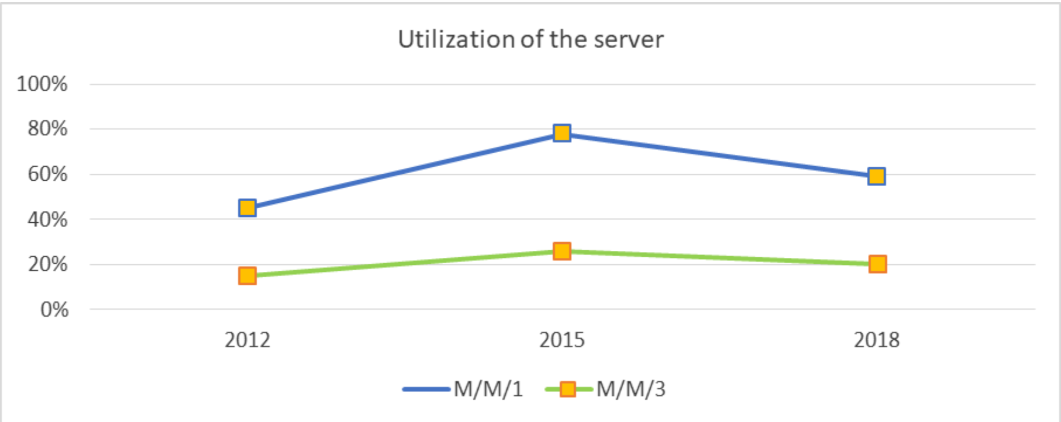

Figure 3: Comparison of Utilization Rate

- E(n) Average number of US and Non- US passengers in the system (per minute):

M/M/1 and M/M/3:

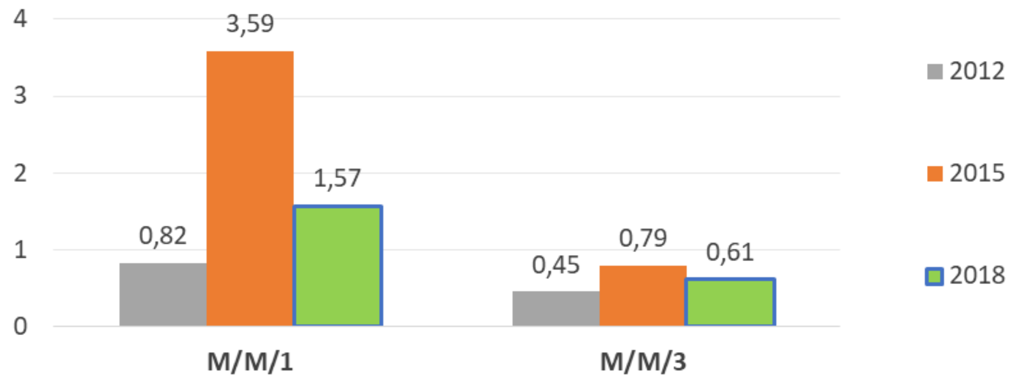

Figure 4: Average number of all passengers

The charts above demonstrating the average number of passengers in the system shows how many passengers per minute are in the system. The average we took on January 2nd, 2015 shows a much higher passenger rate in the system than on the same day in 2012. In 2015, after the APC Kiosk integration, amount passengers in the system was 4,3 times higher than in 2012 before integration.

After using the M/M/3 model, the additional servers helped flatten the range of passengers in the system. The model provides a good example of how JFK can open and close booths depending on the passenger arrivals to minimize the number of passengers in the service system

In the following tables, we split up between US and Non-U.S.-Citizen to see the differences between these two types of group.

- E(n) Average number of US passengers in the system (per minute):

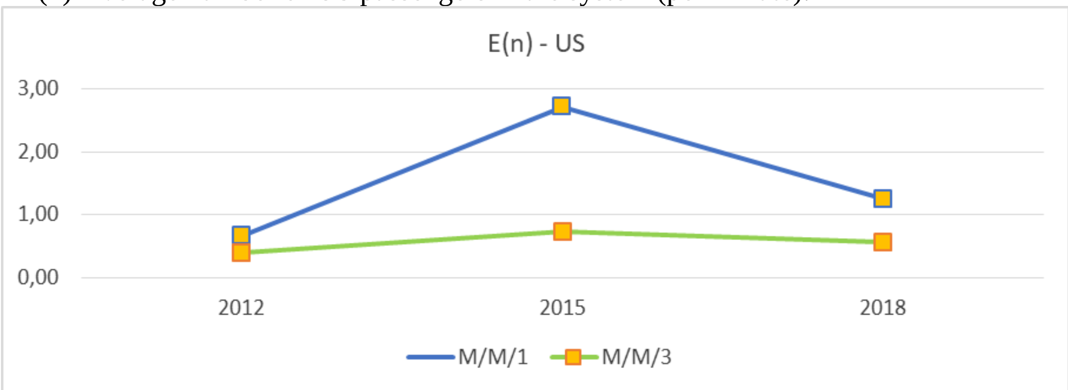

Figure 5: Average number of US Citizen

- E(n) Average number of Non-US passengers in the system (per minute):

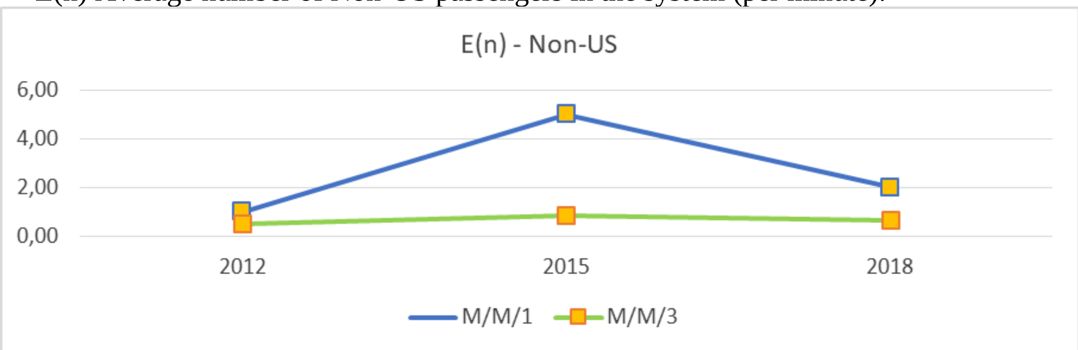

Figure 6: Average number of Non-US Citizen

- E(m) Total number of expected passengers in the queue (per minute):

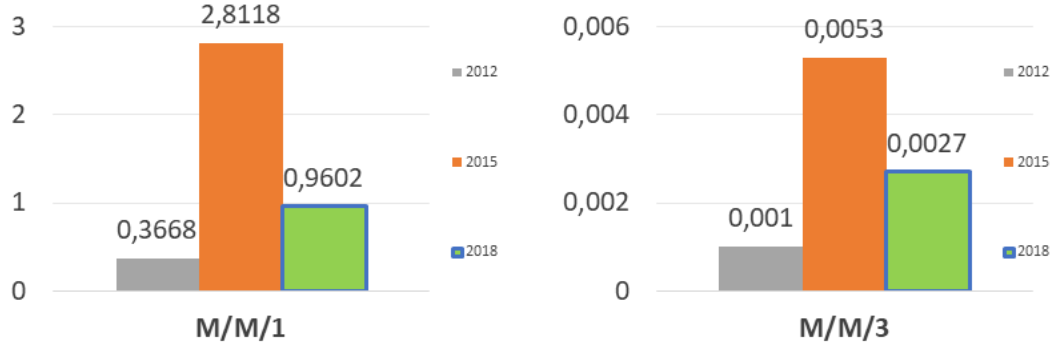

Figure 7: Average number of all passengers in queue (min)

The expected passengers in the queue predicts the number of passengers per minute the servers can expect. The expected passengers in the queue was greatly reduced when applying two additional servers. This small scale provides an important outlook of how JFK Customs can increase and decrease its number of officers depending on the expected passengers in the queue.

Also, here again a distinction between U.S. and Non-U.S.-Citizen is made to see the differences

- E(m) Total number of expected US passengers in the queue (per minute):

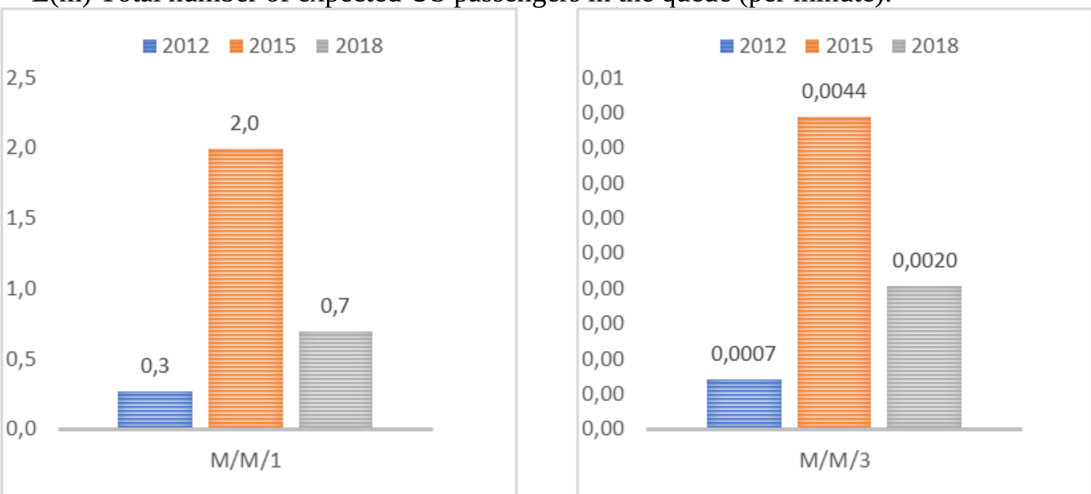

Figure 8: Expected Number of US Citizen in queue (min)

- E(m) Total number of expected Non-US passengers in the queue (per minute):

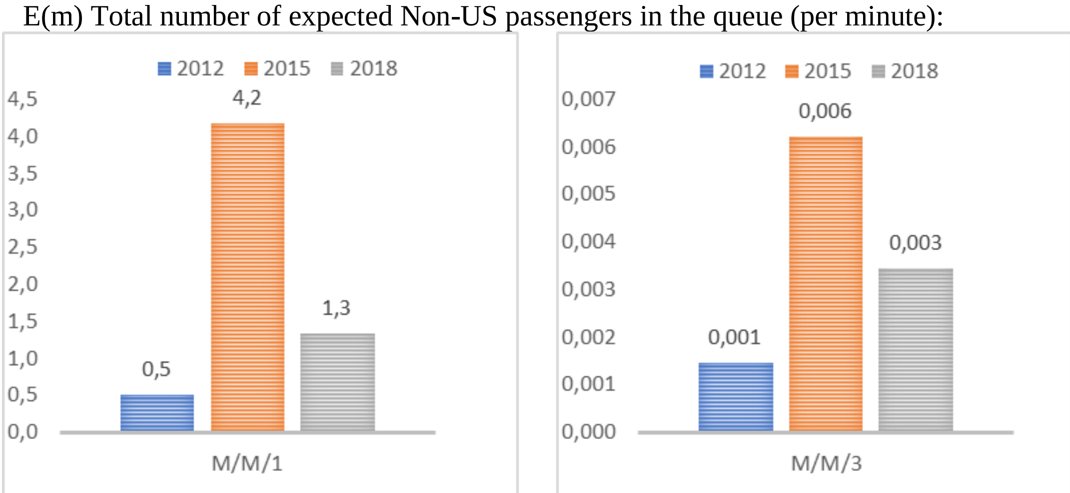

Figure 9: Expected number of Non- US Citizen in queue (min)

- E(w) Average waiting time of passenger in the queue (min):

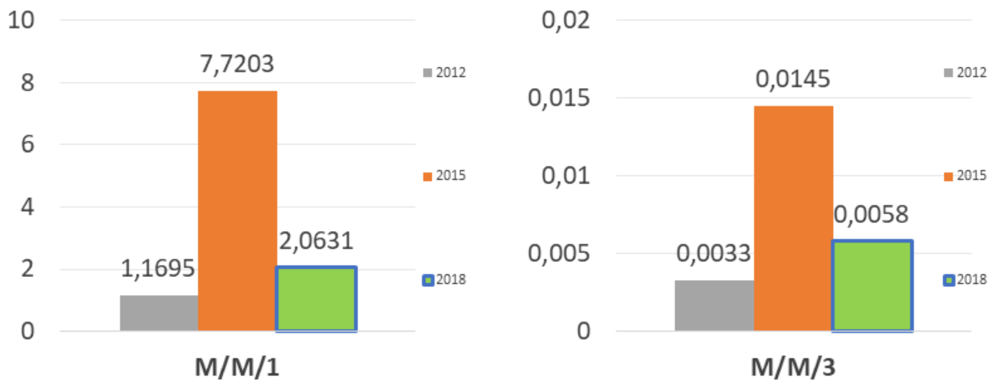

Figure 10: Average waiting time of all passengers in queue (min)

- E(w) Average waiting time of US passenger in the queue in minutes:

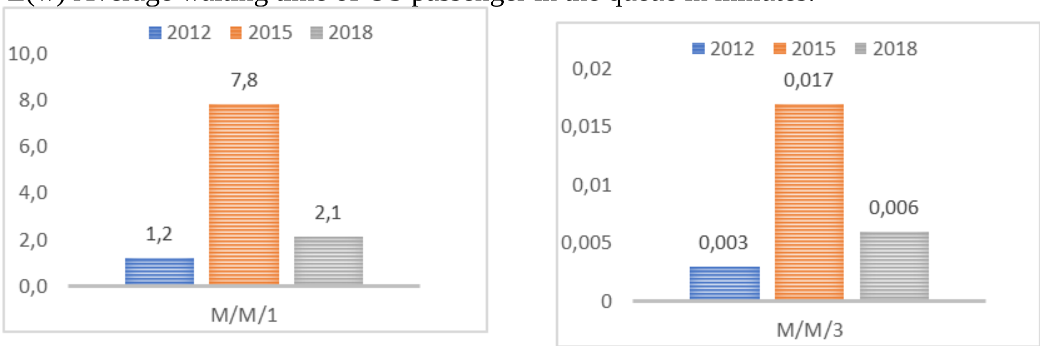

Figure 11: Average waiting time US- Citizen in queue (min)

- E(w) Average waiting time of Non-US passenger in the queue in minutes:

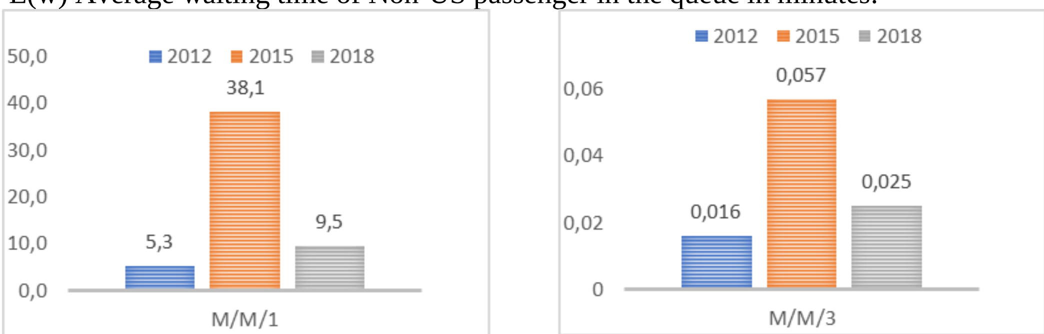

Figure 12: Average waiting time of Non- US Citizen in queue (min)

- E(v) Total time that a passenger has to spend in the system including the service in minutes:

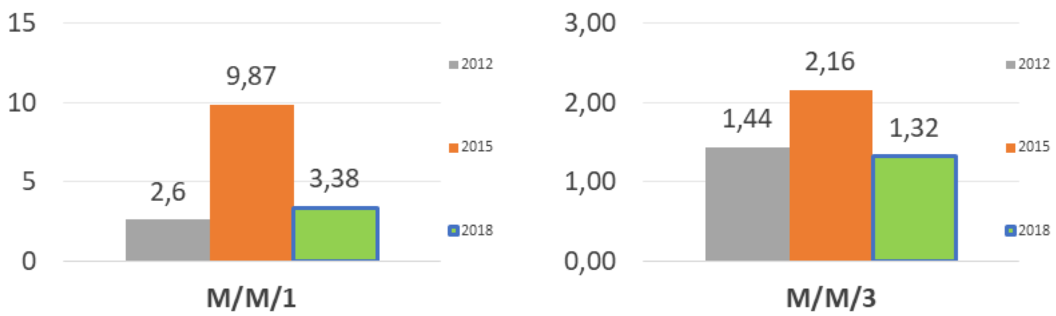

Figure 13: Total time per passenger in system (US and Non US)

E(v) Total time that a US passenger must spend in the system including the service in minutes:

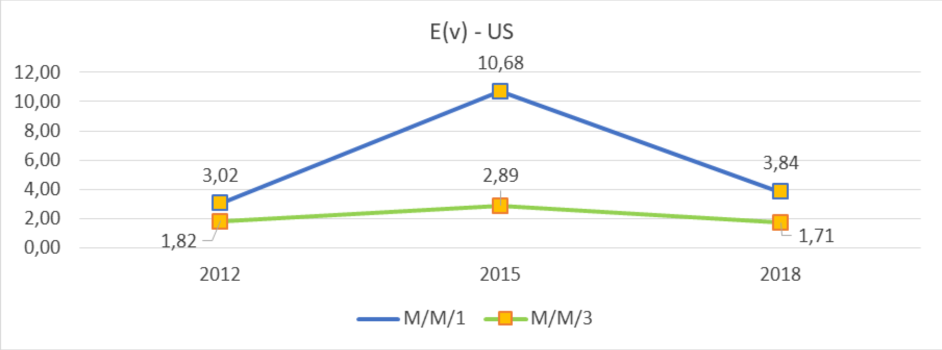

Figure 14: Total time per US Citizen in system

E(v) Total time that a Non-US passenger has to spend in the system including the service in minutes

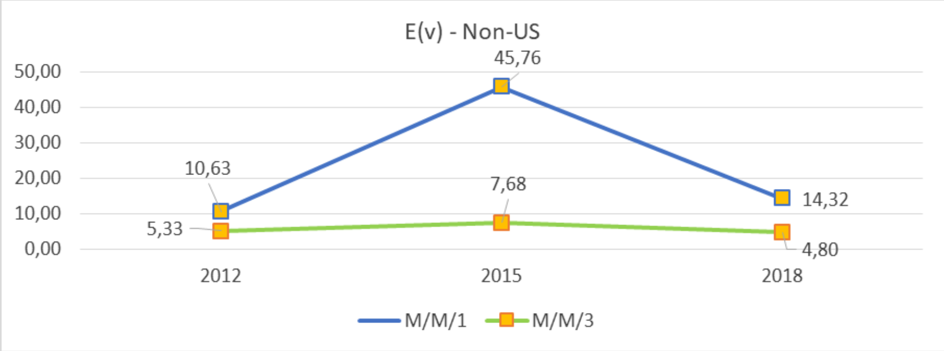

Figure 15: Total time per Non- US Citizen in system

5. Discussion

After comparing the single server queuing model [10] with the multiple server model [11], we noticed a few significant results. The utilization of the server model became much more efficient after more servers were introduced. This small scale represents a useful model for customs and immigration systems when air travel is becoming much more affordable and passengers expect quick processing.

The server queuing formulas provided some surprising results which complemented our original assumption. JFK's passenger waiting time was greatly reduced from 2012 to 2015. Surprisingly, in 2018, the waiting time increased up to 26 minutes. We believed that the passenger waiting time would continue to decrease, because passengers would become more familiar with the new technology. The US Border and Customs Immigration department has also been allowing more nationalities to implement the kiosks. These reasons made us believe that the large investment JFK made to introduce the kiosks hasn't reduced the average efficiency in Terminal 1. Although, many of the results haven't proven a constant decrease throughout the introduction of the Automated Border Customs kiosks between 2012 and 2018, the amount of passengers and flights varied between each year. Assuming that the kiosk would reduce the amount of waiting time for the passengers which would reduce immigration operation costs, waiting times were reduced significantly immediately after introduction of APCs, but as of 2018, these effects have been attenuated as there is more passenger traffic compensating for them.

6. Conclusion

The data we used provided a great starting point for future research. Our assumptions only utilized an average rate of passengers for one day of the year for its operation between 6:00 and 23:00. By using this small average, the overall comparisons between 2012 and 2018 may not demonstrate a perfect analysis. In the future, utilizing an average from a week or month may provide a more accurate figure. One other constraint, which we noticed, was the number of passengers from each day varied greatly depending on amount flight arrivals per hour and their origin. The origin of passengers affects the overall waiting time, because some passport holders must provide fingerprints, visa paperwork, or other documents to the customs agent. Customs is notified when flights are supposed to arrive and therefore are prepared for an expected amount of passengers. However, flights are sometimes delayed and may interfere with the scheduled amount of booths to be open. These constraints are difficult to calculate within the single server queuing model [12]. The number of individuals traveling by air is increasing dramatically; therefore, airport customs and immigration departments must continue to invest in technologies to increase the passenger service rate. The models may provide a mathematical approach, but immigration policies and security also influence the service rate per year.

Future research will be conducted in the direction of applying artificial neural network [13] for solving prediction tasks.

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