Foundations of Operational Research and Analytics Coursework 1

A Simulation of the Apple Store

Group 13

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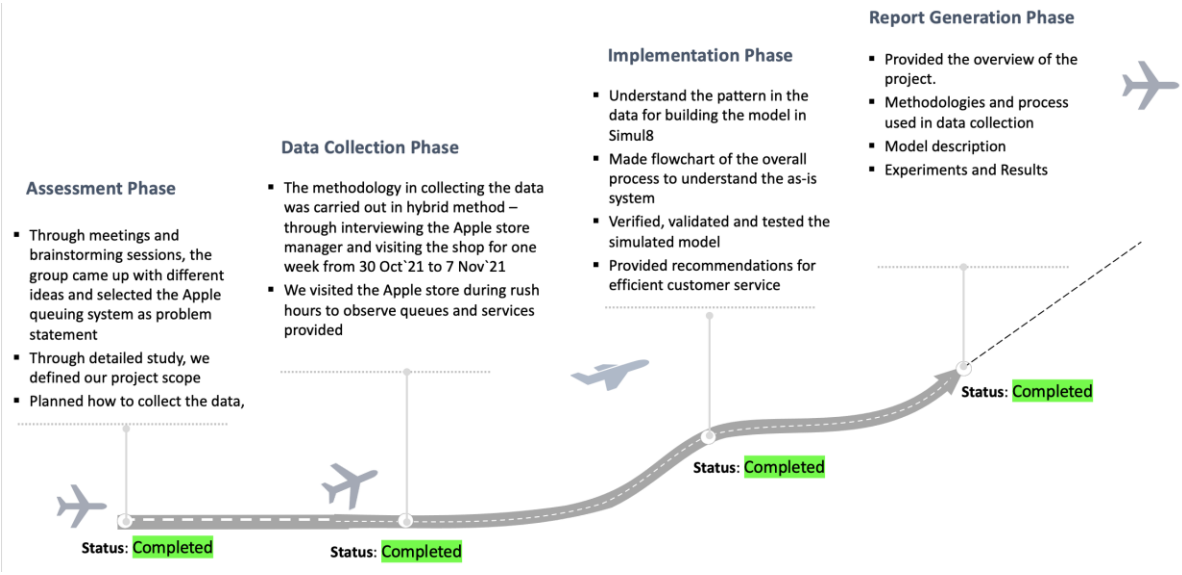
1. Introduction

In this coursework, we were given the task to use Simul8 to model a system of our choice. It was important for us to select a system that would provide collectable real-life data whilst being complex enough to provide a compelling model. Additionally, it was also essential for the system to somehow incorporate the effects of the pandemic, for our report to reflect the world of today. We came to the decision to select the Apple store as we one of our members had a personal real-life experience with their phone there, and the queuing system was a little bit taking too long sometimes, since it is the only apple store in Cardiff

1.1. Snapshot of Coursework Journey



1.2. System Background

The Apple Store in Cardiff separates customers into two queues: Customer service support on the left (upper line in figure 1.1), and Purchase collection In-Store/Online on the right (lower line in figure 1.1). There is an usher at the door to direct customers into their respective queue.

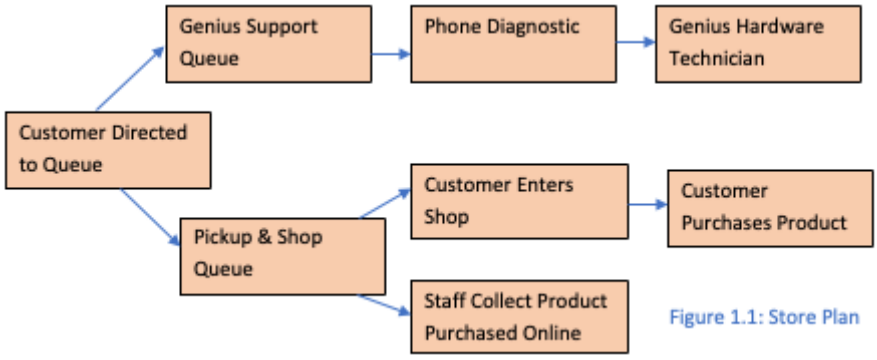


Figure 1.1: Store Plan

1.2.1.Customer Service Queue

In order to see the customer service technicians for a problem related to a product, the customer must follow the queue, once the customer has reached the front of the queue, they will be met by a Store Employee who will run a quick diagnosis on the phone. Here they will determine whether the issue is a software or a hardware problem. If it is a software problem (viruses, apple account issues, etc.) the customer will be directed to a software technician.

Sometimes the issue is a small software problem, and it is resolved at the phone diagnosis stage without the need of a technician. If it is a hardware problem, then the customer will be directed to the appropriate queue of the hardware technicians depending on which hardware problem they have. A major hardware problem means the phone is severely damaged beyond any possible repair. This results in a phone replacement by a new one. This operation is done by a specific technician who checks the status of the phone if it is indeed in unrepairable state, and proceeds to the replacement. This takes around 10 minutes almost in every case, so we are going to consider it as a fix distribution with value = 10 minutes.

However, if the phone is in repairable state, a hardware technician takes care of the fixing and the duration may vary depending on the severity of the damage.

1.2.2.Pickup & Shopping Queue

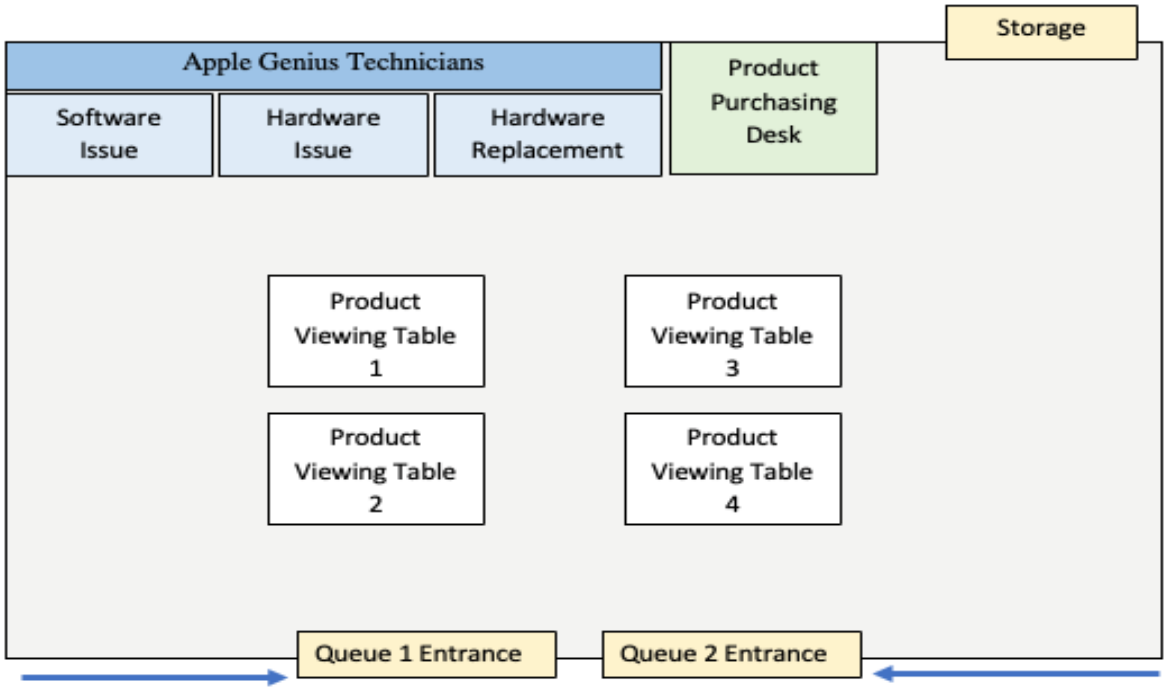


Figure 1.2: Store Plan

Customers willing to purchase a phone (either coming to the store to look for it and buy it in person, or have already bought it online and just came to pick it up), enter the purchase queue, where it split at the beginning for the online and onsite purchase.

Due to the Coronavirus pandemic, the government has recommended to businesses to have the least number of possible customers inside the store, to reduce transmission, without causing business disruption or bad customer service. There is no strict limit capacity abided, the decision whether to allow more customers to enter is decided by the average number of people waiting in the queue

For online purchasers, once customer reaches the front of the queue, a store employee will scan their QR Code, verify identity and then collect the item. This operation being fairly quick, doesn't take more than 3 minutes in most cases, so considered it's time distribution as being fixed to 3 minutes.

1.3. Model Aims

The main aim for this model is to achieve quality customer service standards with efficient usage of available resources. Since main aim of our project is to achieve high customer satisfaction, we thought that it would be a good idea to reduce our scope and collect data within peak times only, as that is when the queues are at their longest.

Our main goals in the model are:

1. Find the optimal number of customers allowed in the store simultaneously so that 95% of customers wait under 10 minutes, whilst keeping in line with the government recommendation to keep capacity low.
2. Find the optimal number of technicians required, so that minor hardware issues do not exceed 2 hours at least 90% of the time.
3. Find the optimal number of technicians required, so that software issues do not exceed 30 minutes 95% of the time.

2. Data Collection Method:

In order to create this model a lot of data is required. This includes:

- Inter-Arrival Time
- Queue Time
- Queue Split Ratio
- Service Time for Phone Diagnosis/Hardware/Software/Purchasing/Collection
- Number of Resources Available

The below table shows the snapshot of our data collected (in minutes)

Inter-arrival time	Phone diagnosis duration	Software fixing duration	Onsite purchase	Customer service queue waiting time	Store purchase queue waiting time
3.94	1.85	3.20	5.62	2.40	6.24
0.31	2.36	4.94	6.29	1.24	2.93
2.47	3.92	3.95	12.19	3.19	0.24

We collected this data in a hybrid method – we both interviewed the Apple Store manager and observed each queue in the store. It took place over the course of a week; of around 4 hours a day from Monday to Sunday.

Firstly, we interviewed the Apple store manager to see what data we could obtain, and most importantly find out if we were allowed to collect it. Unfortunately, he was very hesitant to pass on any valuable data for data protection reasons but did allow us to collect our own. He was, however, able to give us some small details to help with our model. We found out from him that Item Collection takes roughly 3 minutes, and Hardware Replacement takes around 10 minutes. Further, we found out that around 8 Employees are work in the product viewing area during rush hour, and 3 customer service Technicians.

Next, we decided to collect the Inter-Arrival times. This is the time taken between customers entering the queue. For precise timings we decided to use a stop clock, pressing lap for every new customer, and then transferred the results to Excel. Our initial idea was to do this for individual queues, but this turned out to be very difficult to track. Therefore, one of us tracked the number of customers for each queue to work out the ratio, and we applied to the inter-arrival times in the model, to find the result for each queue. Then we collected the amount of time spent on each queue to find the average time spent waiting to be able to validate our model at a later stage.

2.1. Data Collection Process

The below table represents the activities performed on each day while collecting the data

Day	Activities
1	Interviewing the Apple store manager. We observed the functioning of the store and got an overview of different queues
2	Collection of inter-arrival times
3	Data collected was time required for fixing software issues
4	Data collected for the time required on repairing minor hardware issues
5	Data collected on this day was observed for the purchase queue
6	Collection of inter-arrival times
7	Validated information given to us by the store manager on Hardware Replacement waiting times, Item collection queue

We tracked 200 people coming to the store before being ushered to the appropriate queue. The queue ratio was collected as follows: out of the 200 customers, 167 went to the purchase queue (right queue). From 167 people, 156 to the onsite purchase queue, and 11 to the online pick-up service. 33 customers were in the customer service queue. Same method was used for the routing out at the phone diagnosis stage.

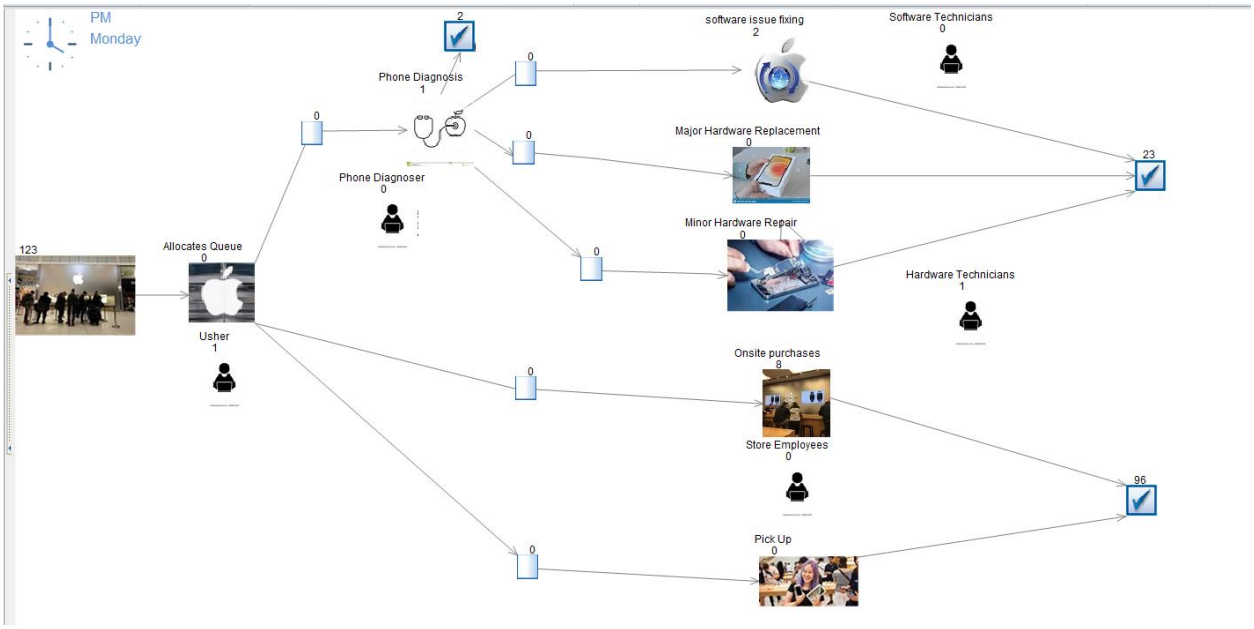
3. Assumptions

- Peak Hours during 12:00PM – 4:00PM on all days; Sunday to Saturday.
- An Apple store employee must be available for each customer whilst purchasing. Usually, when a customer enters the store, they will be accompanied by an apple employee to guide them for their wanted product, its characteristics, suggesting other relevant products, and so on. But as we noticed, this is not always the case, and sometimes customers prefer to do their shopping on their own. This adds a little bit of a complex to our model, because it is hard to implement a probability of using the resources available for a customer in simul8. This case was not frequent, so we expect our model to work just fine without it.
- Time distributions at each activity are independent from one another: this basically means that the inter-arrival time for example has no correlation to the time required to repair a phone screen, battery etc. Knowing this, we could split our data collection on several days, where each day we collected a specific kind of data. *Refer section 2.2 for more information.*
- Time required for pick-up service and major hardware damage fixing are both set to be equal 3 and 10 respectively.
- The software or hardware fixes is limited for iPhones only.

4. Model Description

Waiting times can be a huge concern for any company even when a customer receives good service. That service can be completely outweighed by the time it took to receive the service. We are trying to observe as-is queues and recommend best possible methods to achieve high customer satisfaction with minimum number of available Apple store resources and store capacity. The framework represents the time spent by the customer in apple store to browse and shop the products in a one-on-one session with a specialist, pick up the customer`s online order at the Apple store, get an advice or fix your device from an Apple expert.

Below is the snapshot of the simul8 model



4.1. Activities

The team explored inserting a 3-hour warm-up phase in the model and expected the queues to settle down over time.

4.1.1. Inter-arrival time

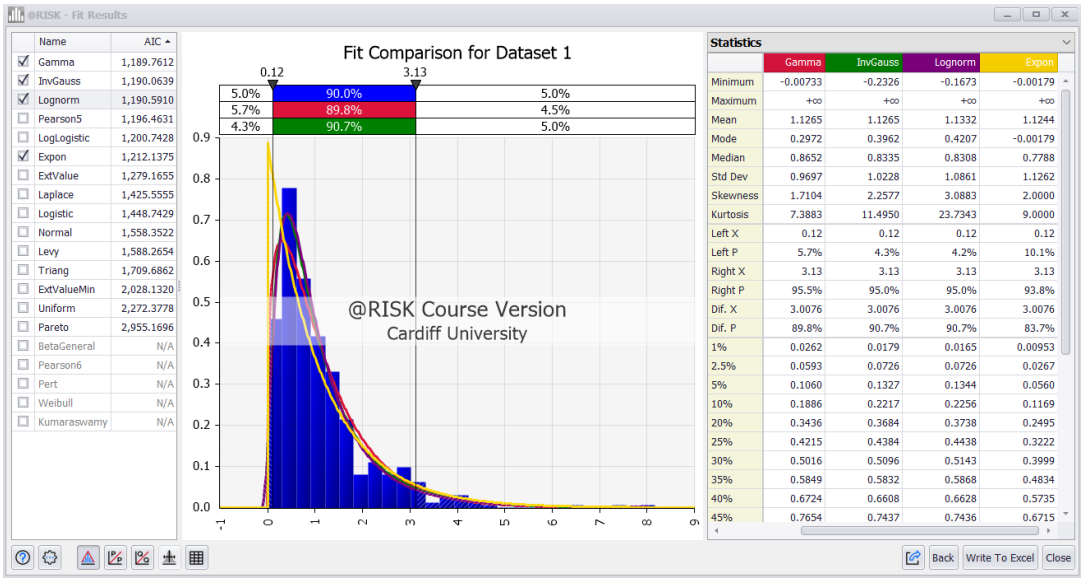
This shows the time taken between customers entering the queue.

We used @Risk software to get the best fit distribution for our model with AIC criterion, this criterion is as follows:

$$AIC = 2k - \log(likelihood)$$

The Akaike information criterion (AIC) is an estimator of prediction error and thereby relative quality of statistical models for a given set of data. The goal is to maximise the likelihood function of our data set, and so to minimise the AIC. But unlike other criterions, AIC takes into consideration the number of parameters estimated by the model. We have to keep in mind that we avoid benefiting models with high likelihood and high number of parameters and put all of them on the same line.

We did that for all of our datasets and found the best fit for each of them. For the inter-arrival time, we found that gamma is the best distribution with α = 1.3673 and β = 1.2137.



The graph represents the gamma distribution for inter arrival times

4.1.2. Allocating the queue

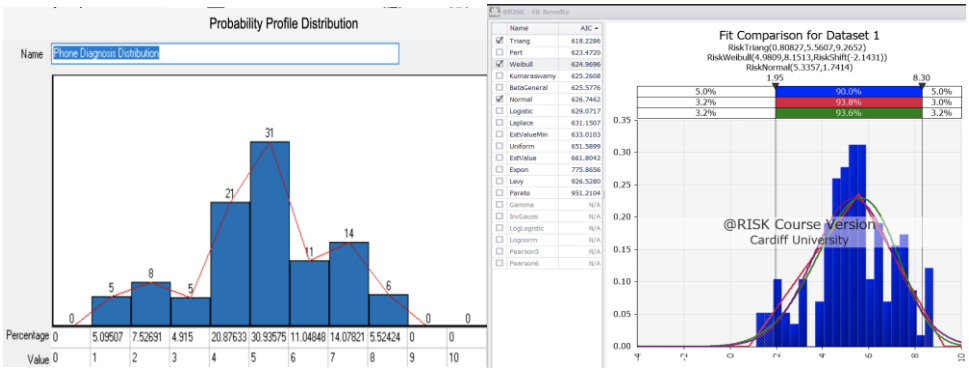
As soon as the customer visits the doorstep of the Apple store, with the type of service required the usher assigns the appropriate queue within 10 seconds. Since the allocation is finished in 10 seconds, the "Allocates the Queue" activity in our model is set at fixed value of 0.17. The customer is further assigned to customer service queue, store pickup queue or the in-store shopping queue.

4.1.3. Customer service queue

The customers in the queue seek to receive right support from an onsite technician regarding any hardware replacements, hardware repairs, or software issues. Once the customer enters the store in this queue, the Apple technician diagnosis the issue in the phone.

Using @Risk, we found Triangular distribution is best distribution for phone diagnosis with values lower = 0.91 and upper = 9.2093 . During the inspection of the phone, if there are any software fixes which can be completed within a short duration (3minutes – 4minutes) then the Apple tech group fixes it on the spot and the customer exits the store.

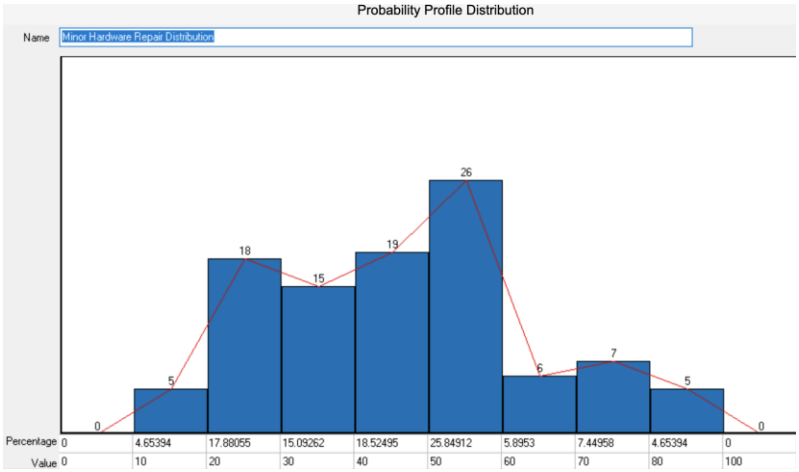
The graph represents the customer service queue distribution



Value represents the time taken to diagnose the issue in the phone by the technician

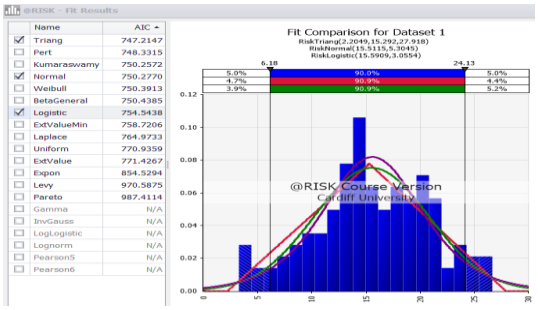
Once the inspection is completed, the customer is either redirected to hardware fixing or software fixing queue depending on the type of issue. If major hardware issue (for instance - if the screen is shattered or the gadget is completely dead) is found in the system and beyond repairing of the item, then the iPhone is replaced with a new iPhone set by the technician in 10 minutes. This is conditioned to availability of the item in the store at that point of time. The "major hardware replacement" activity in the simulate model is fixed at 10 minutes.

From the data, it is observed from the distribution that most of the minor hardware repair takes about 40 minutes.



The graph represents the minor hardware repair distribution

The Apple store follows a service-level-agreement (SLA) of 30 minutes to address any software fixes. Below figure 3.4 shows that the best fit distribution as Triangular with Akaike Information Criterion (AIC) of 747.21 explaining that most of the software related problems are fixed between 14-18 minutes.



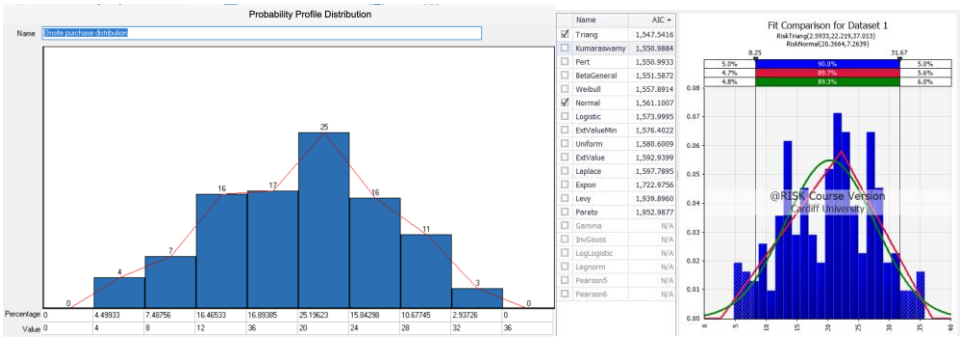
The graph represents the software fixes distribution

4.1.4. Store pickup queue

The customer in this queue picks up the ordered product from the Apple store. This activity was timed to take 3 minutes at the most and hence the “pickup” activity in the model is set to fixed value of 3 minutes.

4.1.5. Onsite purchase queue

This queue is designated for those individuals who would like to see or purchase apple products in the store. From @Risk software we found that Triangular distribution with mode = 22.219 was the most appropriate distribution fitting well for the onsite purchase data.



The graph represents the onsite purchase distribution

5. Experiments and Results

Many findings were obtained after executing this discrete event simulation in simul8. These outcomes show the overall efficiency of the apple store employees as well as waiting time in queues. This research was carried out by running a number of different models with various resource allocations.

5.1. Current Efficiency of Store

After running the model, we got the following results.

The results shows the current waiting time for customers and apple store employees utilisation. It describes that resources working in the pickup and shopping section are getting over utilised and maximum waiting time in the queues is 15 minutes.

The results shows that the customer spend on an average of 28 minutes in the store. This results were shared and validated with the store manager which is found to be optimal.

For all of the activities, below are the results that we observed

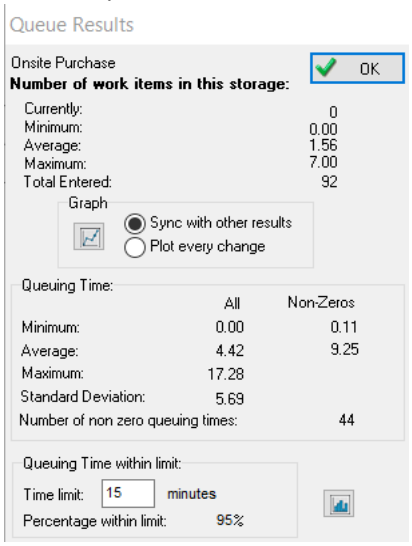
Onsite Purchase	
Average Queuing time	9.92
Maximum Queuing Time	26.93
% Queued Less Than 15 minutes	68.48
Maximum Queue Size	11.00
Average Queue Size	3.81

Software Fixes	
Maximum Queue Size	2.00
Minimum Queue Size	0.00
Minimum Queue Time	0.00
Maximum Queuing Time	13.58
Average Queuing Time	3.50
Average Queue Size	0.27
% Queued Less Than 10 minutes	88.89

Minor Hardware Repair	
Average Queue Size	0.17
Average Queuing Time	14.12
Maximum Queuing Time	29.70
Average Use	0.54
% Queued Less Than 20 minutes	66.67

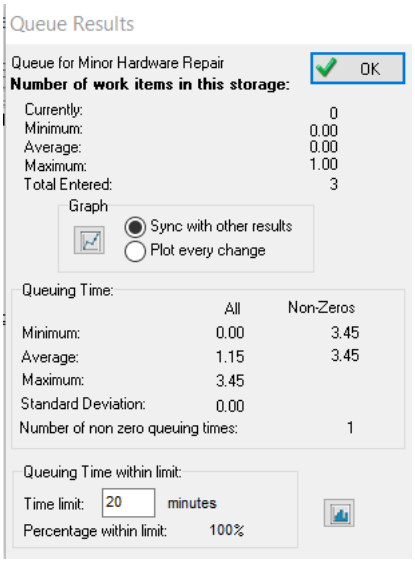
5.2. Recommendations

By increasing the number of people allowed inside the store by 1, we were able to exceed our target of 90% up to 95%, which leads to better customer satisfaction.



The same thing could be done for the minor hardware repair queue, which only has 66% of customers waiting less than 20 minutes. We will increase the number of hardware technicians by 1.

As you can see, this had a significant impact resulting in 100% of customers waiting less than 20 minutes.



It is important to note that there was no major product releases around the time that we collected data, that is one shortcoming of our report. If we were to model again around the time of a new iPhone release, it would be interesting to compare with the current model and see what adjustments would have to be made.