CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

MAT021

Foundations of Operational Research and Analytics

Group - 12

Analysis of the Reception in a Student Residency Complex

Shang Li C21114121 | Safi Ammar Mohammed C21034767 | Raj Mahendra Gohil C21098035 | Liquan Yin C21053774 | Kundan Kumar C21075444

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1. Introduction

From the past experiences of students living in student accommodations, we collectively decided to formulate a simulation model of the reception services. The model selected is of a private organization, "The West Wing" which accommodates, at least, three hundred residents. The current reception system has typical working hours of 9 AM to 5 PM with two receptionists working full time and one security guard post working hours.

1.1 Model Aims

- To model the resident queuing system of the organization based on the data collected on a weekday between the hours of 10 AM to 8 PM.
- To analyze resident queuing times under different scenarios. In particular, some of the services require extended periods of absence of the staff from the reception.
- To test different scenarios and see how best to minimize waiting times for residents with current levels of demands and how it would change if the workflow were to increase or if service timings changed.
- Estimating the additional resources that would be required to improve efficiency of the reception while keeping in mind the utilization of staff and suggest appropriate and feasible solutions.

2. Data Collection and Analysis

2.1 Data Collected

Four parameters were collected in real time to define variables required to build the model. These parameters included arrival time, activity start time, activity end time, and the activity performed.

S. No.	Arrival Time	Activity Start Time	Activity End Time	Activity
1	11:39:50 AM	11:39:54 AM	11:41:16 AM	Borrow
2	11:55:00 AM	11:55:00 AM	11:57:22 AM	Call
3	11:59:45 AM	11:59:47 AM	12:02:40 PM	Enquiry
4	1:04:05 PM	1:04:35 PM	1:08:08 PM	Locked Out Service
5	1:05:33 PM	1:06:39 PM	1:07:27 PM	Enquiry
6	1:18:32 PM	1:18:33 PM	1:18:58 PM	Borrow

Fig 1: Real Time Data Collection

The data for all parameters was collected simultaneously on Thursday, 4th November. We time stamped (HH-MM-SS) the arrival of each resident on to the reception followed by the activity start time and end time and finally the activity that was performed. We took two hour shifts from 10 AM to 8 PM, observing the reception and collected 123 observations.

Each parameter collected is defined as follows:

- **Arrival Time:**
  Arrival time is the time of arrival of residents or in case of 'Call', the time of call received, on the reception for requesting a service.

- **Activity Start Time:**
  Here, the time when the activity starts is noted. For example, when a resident is at the front of the queue and states what service they require to the receptionists.

- **Activity End Time:**
  The time when the activity is completed by a receptionist and the resident leaves the reception.

- **Activity:**
  It is the type of activity the residents require the receptionists to perform. This includes:
  - **Enquiry:** When the resident wants some information from the staff, like the rent they are due, or if they would like to raise a maintenance request etc.
  - **Package Collection:** All the packages arriving at the organization are delivered to the reception. So, this activity lets residents collect packages from the reception. This activity only functions between 2:00-4:00 PM, and 6:00 to 8:00 PM every day.
  - **Mailbox Check:** The receptionist provides a key to the resident's mailbox which they have stored in a cabinet. The resident collects their mail and returns the key. Like package collection, this activity only functions between 2:00-4:00 PM, and 6:00 to 8:00 PM every day.
  - **Call Service:** Calls are taken by the reception for enquiries. This is only available during working hours of the receptionists.
  - **Locked Out Service:** The organization uses a contactless card for each of their rooms and hence residents getting locked out is very common. The receptionist follows the resident to their room to unlock the door for them.
  - **Borrow Items:** The residents can borrow games or cleaning equipment from the reception such as Pool Cues, Table Tennis bats, or Vacuums etc. This requires the receptionist to register the residents name and store their ID card.
  - **Return Items:** This is simply the resident returning the equipment they borrowed and taking their ID back.

2.2 Defined Variables

Using the parameters, we defined variables that are used as an input to the Simul8 model. These variables included:

- **Arrival Interval Time:**
  This is the difference of arrival times between two consecutive people. After subtracting the timestamps of consecutive resident arrivals, we converted the unit of time to seconds.
- **Activity Durations:**
  For each activity, the time difference between start time and end time was calculated and converted into seconds.

2.3 Model Parameters

Since the package and mail collection had limited time in a day, the arrival interval times differed significantly prior to and during the specified times. Hence, we divided Arrival Interval Times into two instances. We used @Risk in Excel to fit distributions to the defined variables. The distributions after fitting Arrival Interval Time (Units of seconds) during package collection period is shown in Fig 2.

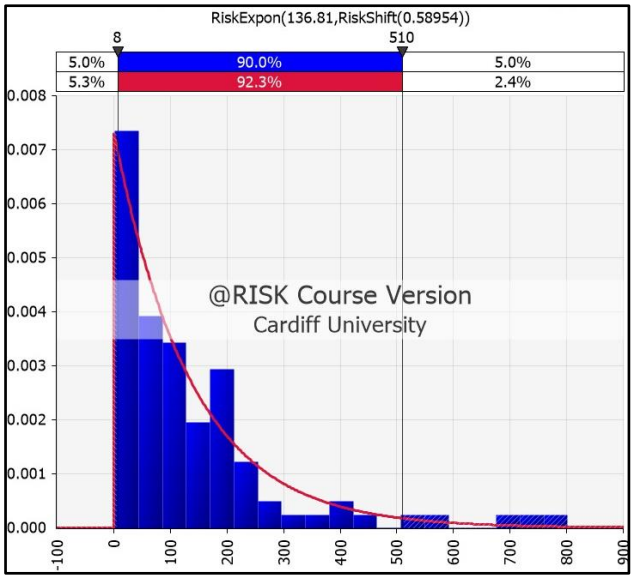

Fig 2: Arrival Interval Time (Package Collection Times)

The data fitted for Arrival Interval Times for the time periods of 2-4 PM and 6-8 PM (package collection times) resulted in an exponential distribution with an average of 136.81. Similarly for the time periods between 10 -2 PM and 4-6 PM, the distribution was Lognormal (Average = 1188, SD = 8118.4).

Since we had data limited to only one day, we used probability distribution to get the frequency of services that were required by the residents (Table 1). Only the entries in the intervals of 2-4 PM, and 6-8PM were considered. This is used to route out from the reception activity in the Simul8 model.

Table 1: Probability Distribution of Services

Activities	Count	Percentage
Borrow	5	5.05%
Call	3	3.1%
Enquiry	5	5.05%
Locked Out Service	8	8.2%
Mailbox	27	27.6%
Package	46	46.9%
Return	4	4.1%
Total	98	100.0%

For each of the services offered, taking in account the durations of each activity, the data was fit, and the following distributions were observed (Fig 3):

1. **Enquiry Duration** - Exponential (115.6)
2. **Package Collection Duration** - Pearson5 (4.689, 412.22)
3. **Mailbox Check Duration** - Pearson5 (3.7224, 115.97)
4. **Call Service Duration** - Exponential (195.2)
5. **Locked Out Service Duration** - Normal (188.583, 51.636)
6. **Borrow Duration** - Exponential (34)
7. **Return Duration** - Exponential (2.8)

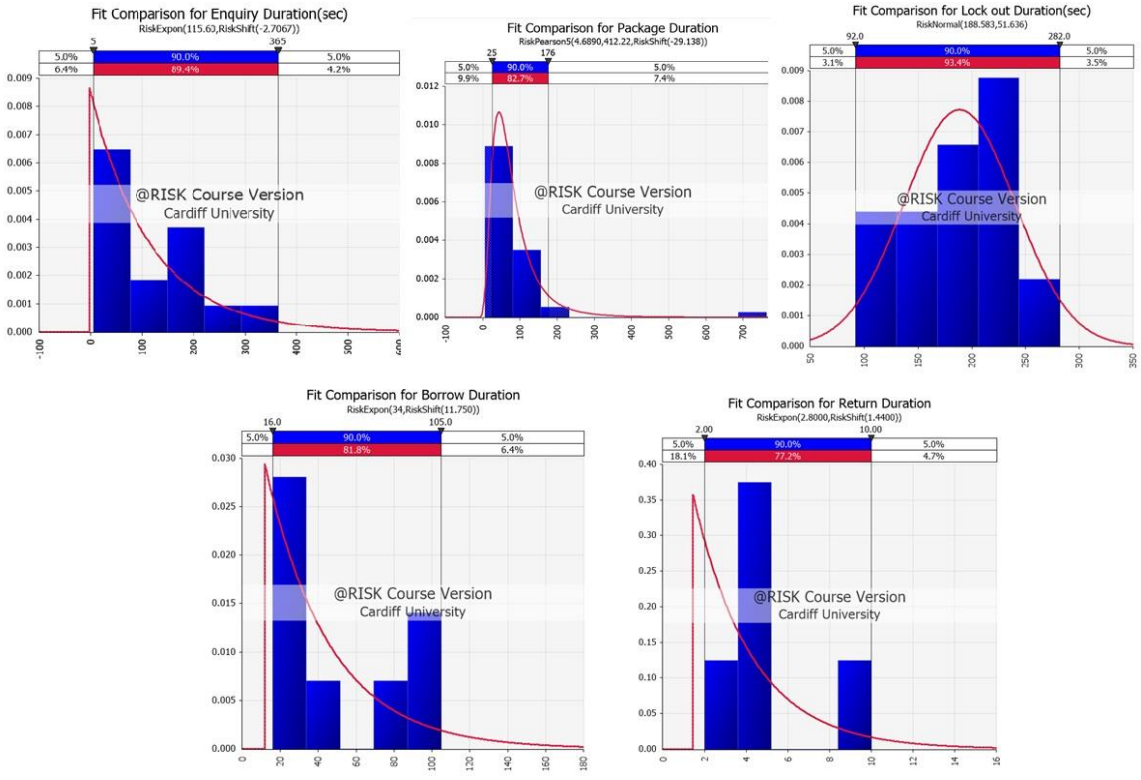

Fig 3: Distributions of Activity Durations

3. Simulation Model

3.1 Assumptions

1. If a resident wanted to request more than one service, the first activity was marked as ended and a new activity was taken into consideration. For such cases, the second request was omitted from the arrival interval time calculation since the same resident was involved. This means that a resident can request only one service in the simulation.
2. The residents approach the reception for many more services, but these services do not require any action by the receptionist and are just conversational. All such services were clubbed into one activity for the model known as 'Enquiry'.
3. In the Non-Package Collection time periods, the Package and Mailbox percentages are ignored, and the reception activity only routes out to the rest of the services.
4. Due to the low observations of Borrow, Return and Call Services, the distributions fit by @Risk were less accurate but they still fit to some extent and hence were taken into consideration.
5. More data was also collected for Borrow and Return services such as what item was borrowed or returned, but these attributes did not add any functionality or effect the model in any way since the duration of the service did not depend on the item. Hence these attributes were deemed to be extras.
6. The Simul8 model is set to simulate events between 10:00 to 20:00 only even though the reception runs 24/7. We chose this time period because we had complete data in this interval to simulate a realistic environment.

3.2 Model Description

The system represents the journey of a resident from entering the queue for the reception up until their required service has been completed by the staff. It does not reflect in any ways the activities of the resident if they leave the queue, and it does not consider breaks for the staff.

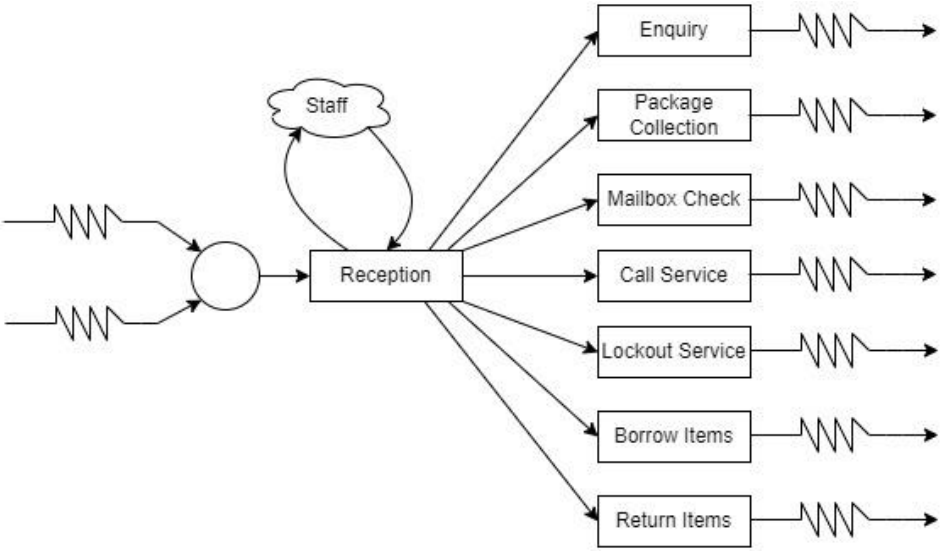

Fig 4: Activity Flow Diagram

There are seven possible services that a resident can request. The activity flow diagram gives us a basic outlook on how a Simul8 model can be built and displays the queues, activities and resources required (Fig 4).

- The residents queue before the reception at an arrival point. There are virtually two arrival points since these points work in different intervals of time.
- The resident then informs the staff of the service they seek.
- The staff is a floating resource that is required for all other activities, hence as they receive a request, they move onto performing the service.
- Once the staff completes the activity, the resident leaves the reception for the next person in queue to continue.

3.3 Model Functionality

The Simul8 model is formed on the basis of the activities mentioned and the data analyzed. The distributions obtained from @Risk are used to formulate the model (Fig 5).

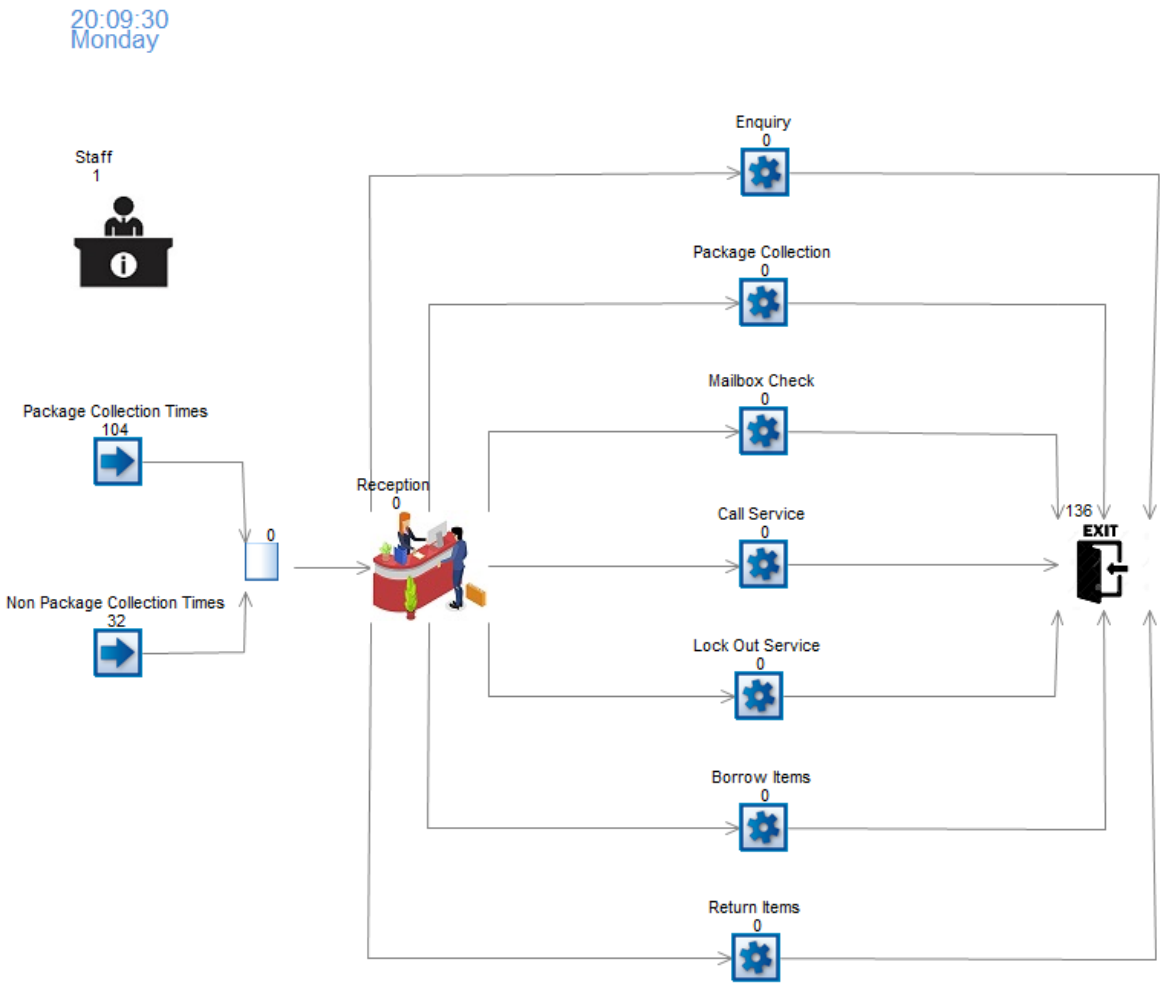

Fig 5: The Simul8 Model

The working time of a day is set from 10:00 AM to 8:00 PM (10 Hour duration). All time units are set in seconds, including distributions for each activity.

All the activities and the Staff resource work based on a shift schedule. The shifts initialized in the Simul8 program are:

- Package Collection Time (1&2)
- Receptionist Shift
- Security Shift
- Non-Package Time (1&2)
- Security Weekend Shift

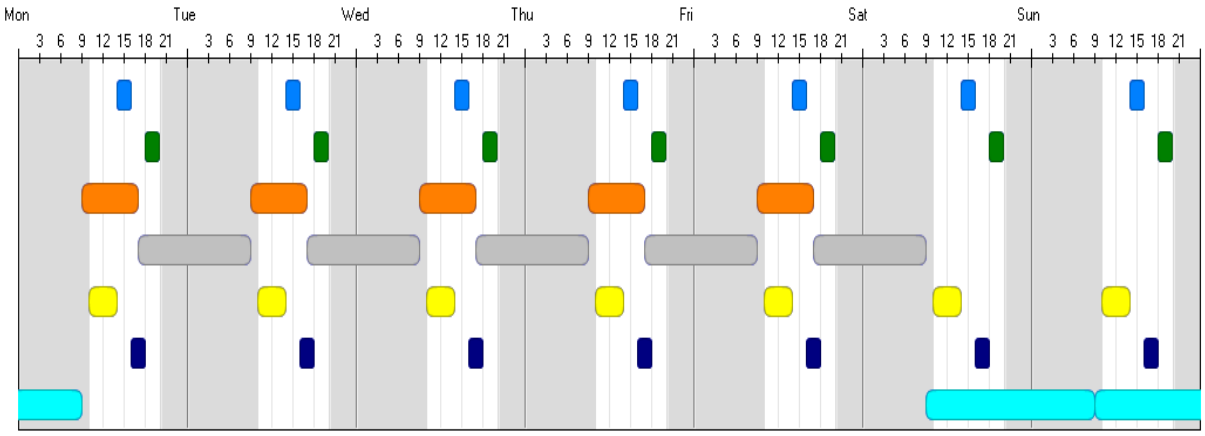

Fig 6: The Shifts Gantt Chart

- Package Collection Time 1: This shift runs from 14:00 to 16:00 every day. This is the first interval of time in which the activities 'Package Collection' and 'Mailbox Check' are set to accept work items.

- Package Collection Time 2: This shift runs from 18:00 to 20:00 every day. This is the second interval of time in which the activities 'Package Collection' and 'Mailbox Check' are set to accept work items. The staff availability is reduced to 1 during this interval because of the security shift.

- Receptionist Shift: This shift runs from 09:00 to 17:00 on weekdays only. This is the interval of time when the 'Staff' resource has 2 members available. After 17:00, the security takes over the reception and only has 1 member. This is also the interval of time when the 'Call Service' activity is set to accept work items, since Security does not have access to perform this activity.

- Security Shift: This shift runs from 17:00 to 09:00 on weekdays only. This is the interval of time when the 'Staff' resource is limited to 1 member. After 09:00, the receptionists take over the reception.

- Non-Package Time 1: This shift runs from 10:00 to 14:00 every day. This is the interval of time in which all activities except 'Package Collection' and 'Mailbox Check' accept work items.

- Non-Package Time 2: This shift runs from 16:00 to 18:00 every day. This is the interval of time in which all activities except 'Package Collection' and 'Mailbox Check' accept work items. The 'Call Service' activity is an exception since it accepts work items only during the Receptionist Shift.

- Security Weekend Shift: This shift runs from 09:00 to 08:59 only on weekends. This 24-hour shift represents the availability of only one Staff member on weekends (Saturday and Sunday). In reality, there is a change of security guard every 12 hours, but this does not affect our model.

Using these shifts, the processes involved in the model step by step include:

- The staff resource is allocated the number available using the Reception Shift, Security Shift on weekdays and the Security Weekend Shift on weekends.

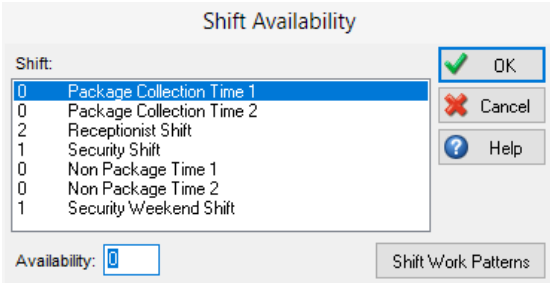

Fig 7: Staff Resource Allocation

- Similarly, the arrival point named 'Package Collection Time' is assigned the constraint of Package Collection Time 1 & 2.
- The arrival point named 'Non-Package Collection Times' is assigned the constraint of Non-Package Time 1 & 2.
- The work items are simulated to arrive based on these constraints and the two different Arrival Interval Time distributions we defined earlier.
- They then enter the reception queue.
- At the reception activity, the work items spend a fixed time of 10 seconds. This time buffer is given just to resemble real-time functionality, imitating the time for the receptionist to understand the resident's needs.
- The reception activity then routes out the work items based on the probability distribution defined earlier.
- The Staff then proceeds to perform the required activities.
- All the service activities now work on the basis of the shifts assigned to them. For example, the 'Package Collection' activity only accepts work items from 14:00 to 16:00 and 18:00 to 20:00.

- The Enquiry, Package Collection, Mailbox Check, Call Service, Lock Out Service, Borrow Items, and Return Items are assigned time distributions of Exponential (115.6), Pearson5 (4.689, 412.22), Pearson5 (3.7224, 115.97), Exponential (195.2), Normal (188.583, 51.636), Exponential (34), and Exponential (2.8) respectively (From Data Analysis).
- Once the work items are released from the service activities, they finish at an End Point.

4. Simulation Experiments and Results

4.1 Model Validation

To validate this model, the resources were adjusted such that no Staff was present in the system. The results after running this simulation were that the customers would be permanently stuck in the queue for reception, as expected (Fig 8).

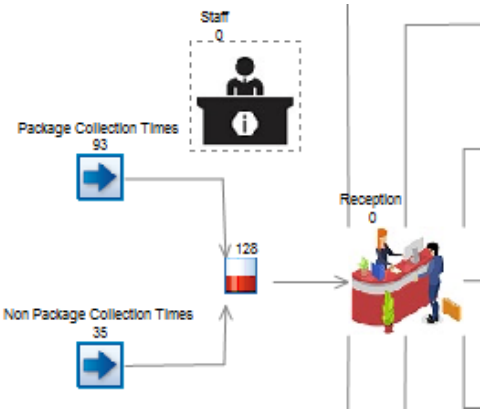

Fig 8: Blocked Queue for reception

The data collected was compared to the average results of a Trial consisting of 100 runs of the simulation for each day and following observations were made:

Table 2: Data Collected V/S Sim Results

Activities	Borrow	Call	Enquiry	Locked Out Service	Mailbox	Package	Return	Total
Data Collected	8	5	15	12	29	49	5	123
Run Trial (100)	12.4	7.55	11.44	16.81	27.12	41.5	9.14	125.96

Since the Run Trial has average values, they are float type numbers. The results of the simulation are very close to data initially visualized. This suggests that the model is

functioning correctly. As with any simulation model, it should be stressed that this will not be a completely accurate representation of the real-life situation.

Overall, this model provides an accurate representation of the queuing process at the reception and the conclusions drawn from this analysis provide good insights into how best to finds solutions and optimize the process.

4.2 Observations

Running the original Simul8 model, with the following output variables for a 100 runs trial, it was found that:

- The staff Utilization was just 22.19% on average (87.81% of the time the staff was idle).
- The average maximum queuing time for the reception was 576 seconds.
- The maximum queue size on average was around 6 residents.
- The average time a resident spent at the reception was noted to be 204 seconds.

Following these results, several simulation experiments were performed on the model, in order to test different conditions and how these affect the efficiency of the system.

While observing the system, it was observed that the number of residents queuing at the reception peaked during package collection times.

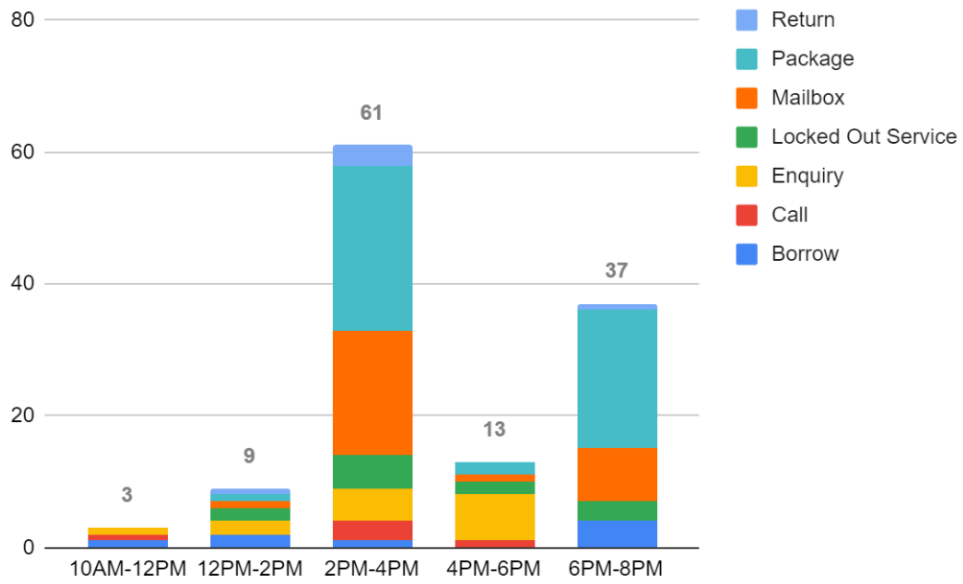

Fig 9: Data Visualization based on time of day

After dividing the collected data into time slots and graphing the filtered data (Fig 9), it was found that 14:00 to 16:00 time slot observed the highest number of residents followed by the 18:00 to 20:00 time slot. This clearly shows that the maximum number of residents queue at the reception during package collection times and the activity most requested is also package collection followed by mailbox check, both of which are services are available for limited times.

4.3 Experiments

>> Following the observations made, to combat the utilization of the staff, we can test adding or removing the resources. Keeping in mind that the organization might not be able to afford more than 4 Staff members at a time, values for number of resources are assumed. The results from these scenario tests based on a 100 runs trial have been summarized as follows:

Table 3: Staff resource test results

Number of Receptionists	Number of Security	%Utilization of Staff	Average time of resident in Reception Queue (seconds)	Maximum time of resident in Reception Queue (seconds)
2	1	22.19	155	885
2	2	18.64	13	212
1	1	38.13	182	889
1	2	28.86	120	802
1	3	23.28	116	801
3	1	15.65	62	569

The results vary a lot and depend on what the organization values more. If the organization values the residents queuing time more than the utilization of the staff, then a combination of 2 receptionists and 2 security guards would be ideal. If the organization values the utilization of staff more and finds the resulting queuing time reasonable, they can remove one of the receptionists and go with a combination of 1 receptionist and 1 security guard.

However, for the rest of the experiments lets assume the middle ground as the best possible result of the test i.e., a combination of 1 receptionist and 2 security guards yielding a utilization of 28.86%, and an average queuing time of 120 seconds.

>> An influx of residents during the package collection times was also seen during the observations. If the arrivals of residents were to increase by 50% during package collection times, how would the model perform? Considering the results of the above experiment, the staff resources are set to a combination of 1 receptionist and 2 security guards.

To increase the arrival of residents during package collection times by 50%, the exponential (136.81) inter arrival time is changed to exponential (91.207). This is because increase of residents is inversely proportional to the average of the exponential distribution. Hence (136.81*2)/3 = 91.207.

After running the 100 runs trial test, it was observed that:

- The number of residents arriving during package collection times increased from 107 to 153.
- The staff utilization went up from 28.86 to 40.69%.
- The average queuing time saw a bump from 120 seconds to 423 seconds and the maximum queuing time went from 802 seconds to 1952 seconds.
- It was also observed that the maximum queue sized increased from 7 to 17.

The results prove that the model will manage the increased load though with some caveats. The maximum queuing time can go up to 30 minutes, and the maximum queue size can go up to 17 residents. These can have a negative effect on the organization in real-life scenarios.

>> The original model can also be optimized in another way, by changing the package collection times. Since there are 2 receptionist and 1 security guard in the original model, if the package collection times were changed to only utilize the receptionists, it can have a major impact on the utilization of the staff as well as the average queuing time of the residents. The following results are obtained after changing the package collection times to 11:00 to 13:00 and 15:00 to 17:00.

- The staff utilization increased slightly 22.19 to 22.85%.

- The average queuing time decreased from 155 seconds all the way to 21 seconds and the maximum queuing time went from 885 seconds to 326 seconds.
- It was also observed that the maximum queue sized decreased from 7 to just 4.
- The average time a resident spends in the system is 148 seconds.

This is a very pleasing result in terms of reduction of queuing time and maximum queue size.

4.4 Conclusions

From the data provided and the tests conducted, the following plans can be used to optimize the queueing system:

- The most effective solution in terms of utilization is to decrease the number of receptionists to 1 and keep the number of security guards the same while also keeping the timings same.
- Assuming that the organization values the reception queue more, then keeping the Staff resource same and changing the package collection times is the best possible solution in terms of queueing time and queuing size.

4.4.1 Recommendations

Out of these two options, the company may consider getting rid of one of the receptionists, as this increases the staff utilization, while maintaining a moderately high queuing time. However, doing so might have some negative effects.

For example, as seen by the experiment when the residents arriving were increased by 50%, the model could barely handle the load with 2 receptionists. This means that if the organization were to face a similar problem with just one receptionist, the queueing times as will increase tremendously and result in a bad review of the residents towards the organization.

The second option is the most safe and feasible since it does not require any change in resource. By just tweaking the package collection times, the organization benefits by receiving positive reviews from the residents as they no longer have to spend a long time waiting, even during busy hours.

When considering the removal of a Staff member, the overall cost needs to be factored in. An intermediate receptionist can cost the organization somewhere between £20-22,000 per

annum. This profit margin can seem great, but in the long term might have an effect on the reviews of the residents, since the reception services can take a hit under a high load.

The safer option for the organization is to just change the package collection time so that the receptionists can take care of the influx of residents during their shift.

Therefore, removing a Staff member can be profitable but also risk the reputation of the organization. All of these factors should be considered along with the simulation experiments when deciding on any changes in the real-world queueing system.

4.4.2 Drawbacks

Since it was only possible to collect the data for one working day, running the model for one week based on a single day's data would produce inaccurate results. Similarly, the reception runs 24/7, but data was not sufficient to run the model for 24 hours in a day.

Even though we had information about the shifts of security during the weekends, we could not test the model for weekends since we did not have resources to collect the data on those days.

These factors can be considered in the future to further optimize the queuing system using simulation.