Group 26 - Simulation of St-David Veterinary Centre

Introduction

The objective of this project is to produce a model which simulates an operation with real data within Simul8, whilst utilising its range of functions. Once achieved, we will conduct analysis on the results we observe, and then look to alter components of the system to see if there are practical alterations to the operation that may led to a more efficient outcome. We will then produce a summary of our findings and provide recommendations to the organisation. For us to achieve this effectively, it was imperative that we accessed reliable data, and therefore we aimed to ask relevant and informative questions as part of our survey. It was also essential that we followed correct procedure when producing the model to ensure its validity and accuracy.

This report can be split into four sections, 'Research Objectives', outlining our aims for the model and research interests. 'Data Collection Methods', which outlines our approach to collecting the data used for the model, 'Model Description, Features and Data' which will discuss the findings from our simulation, explain and visualise the data we have gathered. And, lastly, 'Simulation Experiments and Results' which will operate alternative simulations aligned to our research objectives to suggest alterations that can promote efficiency.

Research Objectives

Given the information we accrued from a primary source, we generated research objectives which aligned to the businesses own aims and objectives. This allowed us to streamline our approach to ensure the simulations we conducted were relevant and as impactful to the organisation as possible.

As mentioned previously, it was crucial we followed simulation modelling standard procedure. Our aims and objectives were expected to be initially defined by the questions we wanted to ask to understand the business to a greater degree. (these will be later demonstrated in Data Collection Methods) This would then be altered by understanding the organisations goals and objectives.

The data collection and analysis would help us create the model and allow us to assign relevant distributions and demonstrate the flow of business operations from start to finish. Verification of the model aimed to be demonstrated through further discussions with our source to check for alignment to reality, and validation would be undertaken through altering the system to ensure that it was reflective of what we expected in terms of model performance for each step. Lastly, stress testing would be undertaken which would be reflective of our renewed objectives from the surveying work undertaken with our source. The aim ultimately being that we would provide informative, reliable, and impactful information that aligned to the business goals.

Below you will find our objectives that came about from the survey questions that we asked alongside the procedures we followed during model generation. (Refer to Figure 1.)

Objectives

Evaluate Appointment Scheduling

- Assess the efficiency of the appointment scheduling system.
- Optimize scheduling to minimize patient wait times and maximize vet utilization.

Examine Resource Utilization

- Monitor and optimize the allocation of examination rooms, vet availability, and other resources.
- Ensure that resources are utilized effectively during operating hours.

Improve Wait Time and Service Quality

- Minimize patient wait times in the waiting area and examination rooms.
- Enhance the overall service quality provided to patients and their owners.

Analyze Patients Flow and Emergency Handling

- Evaluate the flow of patients through the clinic, from check-in to check-out.
- Identify bottlenecks and areas for improvement in the patient journey.
- Evaluate the clinic's ability to handle emergency appointments.
- Determine the impact of emergency cases on regular appointments and overall clinic operations.

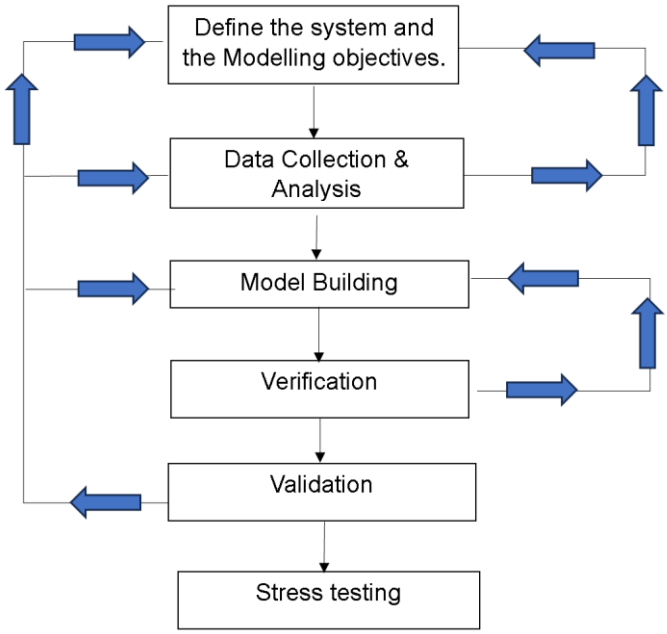
Understand Appointment Type Distribution and Optimize Staffing Levels

- Analyze the distribution of different appointment types (preventative, pain relief, medication review) to understand the clinic's focus and workload.
- Evaluate the number of receptionists and vet staff during different hours of operation.
- Optimize staffing levels to meet demand and ensure efficient operation.

Enhance Overall Clinic Performance

- Use simulation results to make informed decisions and implement changes that enhance the overall performance of the veterinary clinic.

Simulation Modelling Procedures



Data Collection Methods

Through access to a primary source, we gathered detailed data from a survey we conducted to understand the mechanics of the business. After discussion between ourselves to understand what we wanted to obtain from our source we asked the following questions;

- What is the flow of business operations from start to finish?
- How long does each part of the process take? - Is there variation between each?
- What hours does the business operate?
- Is there a discrepancy between procedure times and the type of patient?
- Does the vet handle emergency appointments? And, how are these treated?
- What are staffing levels and shift patterns?
- How often are staff members provided breaks?
- What are the aims and objectives of the organization?

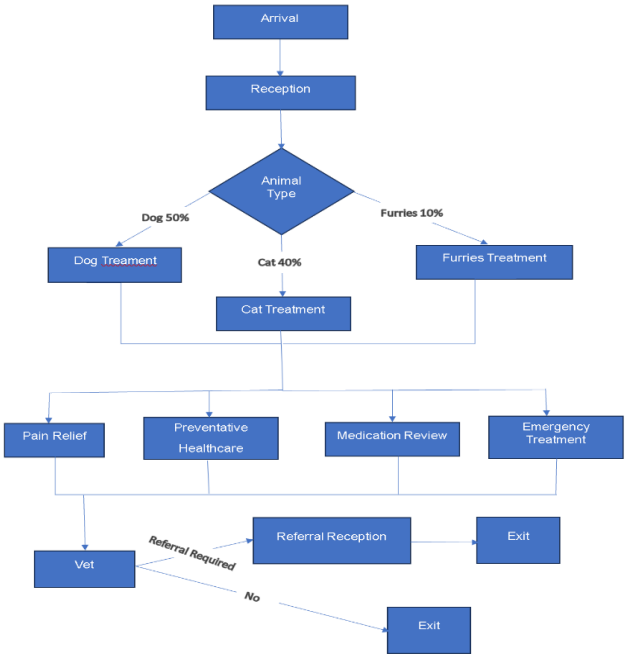
These questions gave us the necessary data required to build this model in Simul8 and go on to place it under relevant stress tests. It was important that we understood the metrics the business was evaluating itself on, this allowed us to simulate different scenarios the business could conduct to enhance its performance. From our survey, the source made it clear that the business operates under 15-minute appointment times and looks to treat all emergency appointments within 60 minutes of them entering the facility.

After conducting the survey and gaining a greater understanding of the business and its objectives, we were able to determine the parameters that would form the statistical distributions we would use as part of the model. This was done by understanding the time it took for each process to take place, the degree of variation and the level of accuracy the source could provide these with. Discussion and demonstration of these is explained in the next section.

Model Description, Features & Data

We initially sketched out the model to place our ideas visually and to confer with our source to see if it was representative before we put the ideas into Simul8. Below you will find the activity-flow diagram that we generated before placing this into Simul8.

Activity-Flow Diagram



For the Simul8 model, there is 1 start point, 3 dummy activities, 14 activities, 15 queues, 7 end points and 2 sets of resources, veterinarians, and receptionists.

The first consideration for the model was time assignment, by reviewing clock properties in Simul8 we were able to set the start time of each day (8:00 AM) and the duration of the day. (10 hours and 30 minutes) We could also set the relevant Time Units (Minutes) and the days per week in which we were operating between (Monday – Friday) to reflect the business operating times.

To demonstrate the inputs within the model we utilised Simul8's 'Start Point' function to demonstrate the influx of customers. To show this statistically, we assigned an exponential distribution to the start point with an average of 10 to demonstrate the inter-arrival times of customers. (Refer to Figure 1) After arrival, the customer is met at reception and undertakes registration with the receptionist and waits until being seen by the vet. To represent this process, the model uses a normal distribution with an average of 3 minutes and a standard deviation of 1 to demonstrate the variability in the process. (Refer to Figure 2.) For the model to represent the variability in the influx of different types of customers, it uses 3 dummy 'Activities' and the 'Routing Out' Simul8 function with Discipline 'Percent'. The dummy activities enabled for the splitting of different customers, Cats, Dogs and Furries (This represents a group comprised of rats, rabbits, gerbils and guinea pigs) to the relevant data we had for the model, 50% for dogs, 40% for cats and 10% for Furries respectively.

To represent this graphically, we used the seaborn package in Python to plot these times across the year period we were looking to simulate. From Simul8, we were able to see that during one simulation there was 16,084 customers entering the vet and used this as our size in the numpy.random.exponential function and provided a scale of 10, representing the average arrival time. To demonstrate the time spent at reception we represented this using a normal distribution with a mean of 3 and a standard deviation of 1 and utilized seaborns sns.histplot function and np.random.normal function from Numpy.

Figure 2.

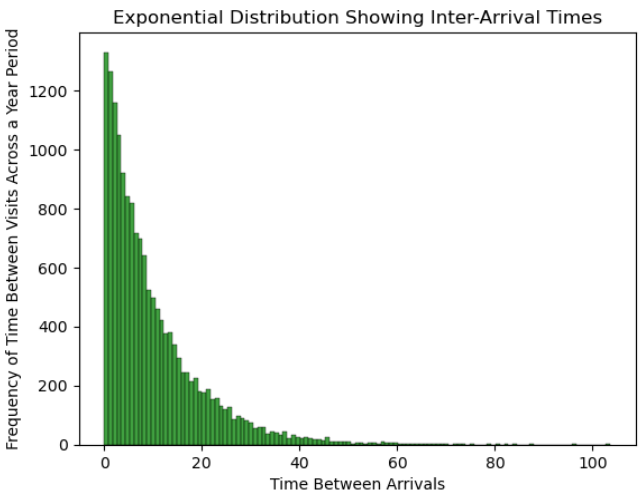
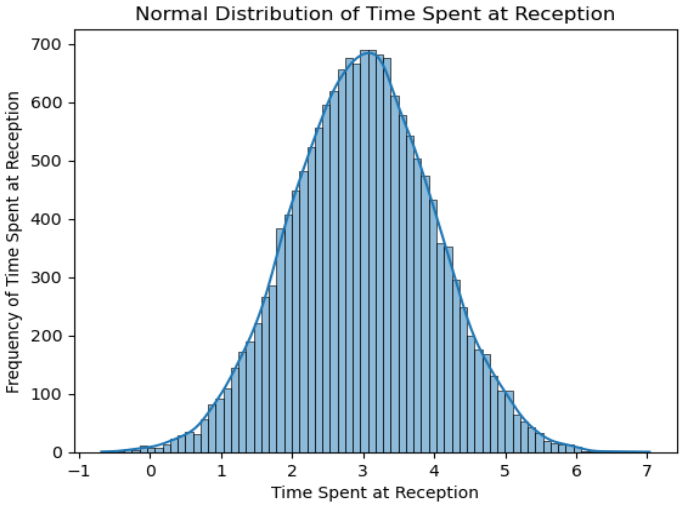


Figure 3.



The model then goes on to demonstrate the treatment times for the respective different customers. From discussions, we were advised that different animals firstly take different times for their respective treatments, and, in addition, the proportion of those treatments differs depending on the animal. Take for example furries, owners will typically only bring them in at the point where emergency treatment is required and dogs whereby, they have increased levels of pain relief treatment due to higher rates of joint issues and muscle and bone injuries. This variation was explained in the model by using the SIMUL8 function 'Routing Out' and using the discipline 'Percent' to provide an accurate representation from the data we had for the relevant treatments.

With respect to treatment times, there were discrepancies across all types of treatment with different animals. To demonstrate this variation, we implemented multiple Simul8 'activities' for each animal and their treatment times and assigned them with the relevant triangular distributions. (as demonstrated below in Figure 3 and graphically in Figure 4 and Figure 5) This type of statistical distribution was implemented due to the uncertainty around the true distribution of the variables and, the relative confidence we had on the range and the central tendency of the information we were provided. In order to generate the visualisation of the example provided of the triangular distribution, we used numpy function np.random.triangular, which takes on the relevant values and seaborn's sns.histplot function as well.

Figure 4.

Treatment	**Triangular Distribution Properties**
Dog Pain Relief Treatment	Lower:5, Mode:11, Upper:15
Dog Preventative Healthcare	Lower:5, Mode:10, Upper:13
Dog Medication Review	Lower:12, Mode:20, Upper:22
Dog Emergency Treatment	Lower:15, Mode:20, Upper:30
Cat Pain Relief Treatment	Lower:4, Mode:6, Upper:10
Cat Preventative Healthcare	Lower:4, Mode:8, Upper:12
Cat Medication Review	Lower:10, Mode:14, Upper:16
Cat Emergency Treatment	Lower:16, Mode:25, Upper:35

Furries Pain Relief Treatment	Lower:4, Mode:7, Upper:9
Furries Preventative Healthcare	Lower:3, Mode:5, Upper:8
Furries Medication Review	Lower:7, Mode:13, Upper:15
Furries Emergency Treatment	Lower:15, Mode:22, Upper:28

Figure 5.

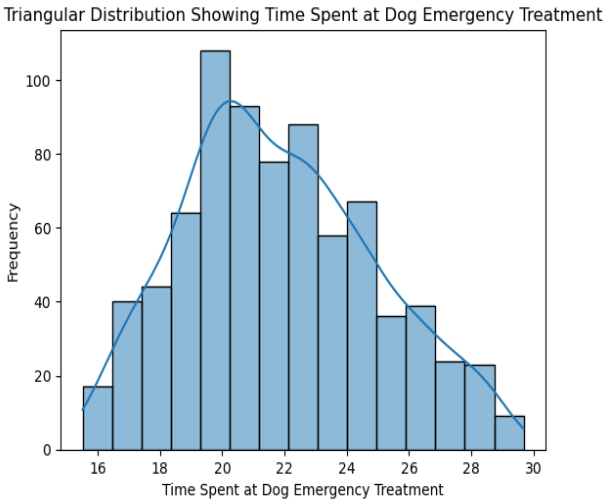
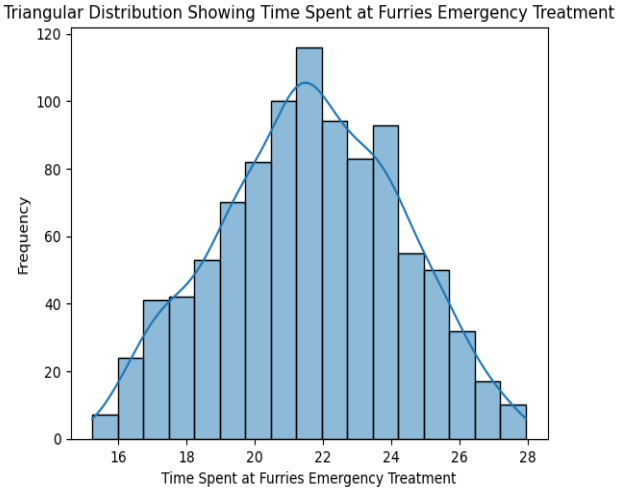


Figure 6.



The model demonstrates the different shift times of the resources available and the priority in which they operate their work. By using the 'Shift Dependent' function we were able to assign resources to the relevant worktimes we were advised about. Between 08:00 – 18:30 there is a veterinarian working continuously and another who undertakes a split shift with work starting between 9:00 – 11:00 and back in again from 14:00 – 18:30. By utilising the resource function we were also able to demonstrate the priority in which the veterinarians were expected to work. In the instance that an emergency treatment enters the facility, the vet is required to prioritise this work over any other. To demonstrate this, we utilised the SIMUL8 function 'Priority Matrix' and placed all emergency treatments with top priority. Furthermore, to account for requirements for lunch breaks and toilet breaks we had assigned a 95% availability to the veterinarians and the receptionists by using the Simul8 function 'Availability' found within the 'Resource' actions.

The model is then completed for some of the customers as 'End Points' have been placed to undertake relevant analysis for how long it takes for emergency treatments to take place and other treatments. This was important to evaluate our research objectives which we had set out. For instance, does the vet comply with attending to emergency appointments and completing them all within 60 minutes? And is the 15-minute appointment time suitable for the practise? The model then continues for those pets that require referrals to be undertaken to specialist veterinary practises to combat their issue. During our information gathering, we were advised that Dogs were more likely to go through specialist referrals than cats and furries. To represent this, the model uses the 'Routing Out' function and the percent discipline to demonstrate the number of pets that go through the relevant referrals or are just treated at the veterinary practise. Those being referred were 15% for dogs, 5% for cats and 5% for furries respectively.

For those pets that go through specialist referrals they must return to reception and await confirmation of the time and location for their appointment by the receptionist. Due to the differing demands amongst specialist centres, it was advised that it takes longer for receptionists to confirm appointments for dogs than it does for cats or furries. To

demonstrate this, the model implements ‘Label Based Distributions’ which assigns each object with different distributions to demonstrate the differences in time taken for the activity. For dogs, we assigned a normal distribution with a mean of 4 and a standard deviation of 1. For both furries and cats, we assigned a normal distribution of 3 and a standard deviation of 1.

Model Verification & Validation

To ensure that the model was representative, we made use of our source to maintain discussions during the construction process. This was done to ensure that the model demonstrated real-life applicability to the process. As we will later discuss, the bottlenecks were representative of their experience working at the organisation with an accepted degree of accuracy. This helped us to accept that the simulated results were somewhat representative of the real-life output.

We further provided extreme values for some of the distributions of the activities and removed the resources in our model to see if this had the expected impact. By removing resources, it validated their importance to the performance of the model, with zero veterinarians we had no entity reaching their end point, as expected. Further, with large increases in the distribution values we had a significant increase in the queues present for all of the activities.

This verification and validation ensured that our model was representative and fit for purpose for our later simulations.

Simulation Experiments & Results

Referring to our Research Objectives, we wanted to evaluate the model in its current format, and then look to make alterations to see if we can provide remarks that could help improve efficiency. We therefore ran the model over the course of one year to provide a large enough sample size to make statistically significant inferences of the results.

What we found was the vets handled their target of ensuring that emergency appointments were met within 60 minutes very well. In all types of customer treatment the business had at least 96.33% of all appointments met within the targetted time. The vet also manages to produce an average time of 35.54 minutes in dealing with emergency appointments with a standard deviation of 9.79.

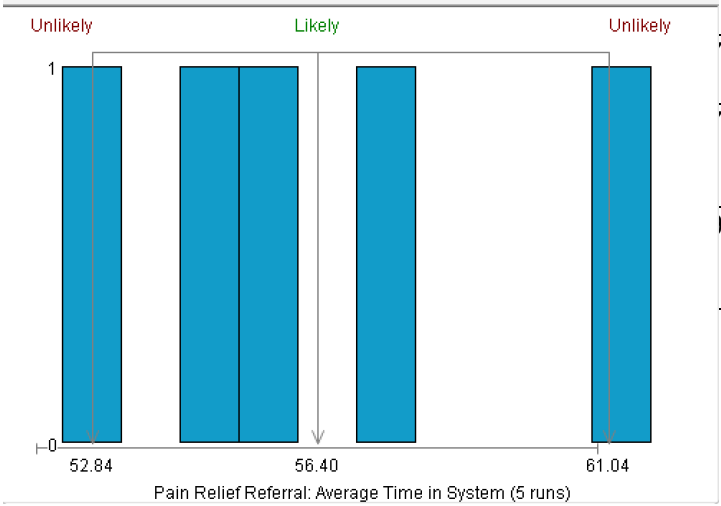
Types of Emergency Treatment	Minimum	Average	Maximum	Standard Deviation	Percentage of Time within 60 minutes
Furries Emergency Treatment	19.79	33.89	105.17	10.02	97%
Cat Emergency Treatment	22.32	38.08	102.99	9.49	96%
Dog Emergency Treatment	20.92	34.65	87.93	9.86	96%

Average of Emergency Treatment	21.01	35.54	98.69	9.79	96.33%

To review the results for the 15-minute appointments, we took the expected amount of time from arrival and reception and then added this to the appointment time. (reception time spent at around 5 minutes + appointment time) We can therefore make relatively accurate analysis over how many appointments are treated at this activity within 20 minutes. The results were disappointing, and we find that the business struggles to be able to meet these on time consistently as detailed below. The average time in the system was far greater than what we would have expected given the appointments, and we observe large standard

deviation figures implying that many of the results largely exceed this average. The customer would expect to enter the business, undertake the appointment, and be finished within 20 minutes only 35.33% of the time. We further experience some very high maximum values and high levels of deviation from around the mean.

Type of Customer	Minimum	Average	Maximum	Standard Deviation	Percentage of Time within 20 minutes
Dog General	9.12	47.67	346.36	38.90	23%
			76	41.74	33%
			73	24.71	50%
			05	35.12	35.33%



We also ran a trial to show the average time taken to be seen as part of a pain relief referral. The graph demonstrates the 95% confidence intervals, with an upper bound of 61.04, a lower bound of 52.84 and an average of 56.40. We were not provided with specific business objectives at the time of the survey for this, however this could be considered a relatively lengthy time given the value for the distributions which cover each stage of this process.

Stress Testing

From the results we obtained it was clear appointment scheduling was a concern. We therefore conducted different simulations with alterations to various components to try and increase the businesses compliance with this measure.

The organisation can alter staffs shift patterns to improve its efficiency. Running a simulation whereby they enforce a policy removing the split shift taken by one member of their staff and replace it with a full-time shift, greatly improves compliance as demonstrated below. We record an increase from 35.33% compliance across an average of all treatments to 56.33%.

Removal of Split Shifts

Type of Customer	Minimum	Average	Maximum	Standard Deviation	Percentage of Time within 20 minutes
Dog General Treatments	9.39	25.07	116.49	12.08	42%
Cat General Treatments	8.22	21.67	148.22	11.67	59%
Furries General Treatments	7.12	19.51	81.40	8.96	68%
Average for General Treatments	8.24	22.08	115.37	10.90	56.33%

Building on this notion, we ran a simulation implementing a new veterinarian who also operates on the full shift pattern during the business operating hours and found marked improvements in compliance, with an increase from 56.33% to 75.33% and on average with 99% compliance to emergency treatments within 60 minutes.

Employment of Additional Veterinarian & Removal of Split Shifts

Type of Customer	Minimum	Average	Maximum	Standard Deviation	Percentage of Time within 20 minutes
Dog General Treatments	9.34	20.57	86.99	6.61	58%
Cat General Treatments	8.23	16.75	57.97	4.51	80%
Furries General Treatments	8.57	15.16	29.05	3.61	88%
Average for General Treatments	8.71	17.49	58	4.91	75.33%

A further consideration was to investigate the appointment times and reduce the number of appointments that it undertakes to increase its compliance. To evaluate a change to a 20-minute appointment schedule, we would also need to alter the exponential distribution of the start point to 15 and then evaluate the % of individuals seen within 25 minutes instead. (spend around 5 minutes at reception and then a 20-minute appointment) Using this information, we observe a significant increase in the number of patients that can be seen within 25 minutes at an average of 71.67%, compared to the 35.33% we obtained previously. In addition to this, there is a marginal improvement in the % of emergency treatments that comply to the 60-minute target from 96.33% to 99.33%. We observe compliant averages but with large deviations around the mean demonstrating issues with compliance for a lot of appointments.

Change in Appointment Duration

Type of Customer	Minimum	Average	Maximum	Standard Deviation	Percentage of Time within 25 minutes

Dog General Treatments	9.66	27.00	174.79	17.25	63%
Cat General Treatments	8.20	23.99	138.62	16.88	74%
Furries General Treatments	8.62	20.95	84.13	11.80	78%
Average for General Treatments	8.83	23.98	132.51	15.31	71.67%

Given the results we obtained from the change in split shifts to full shifts and the improvements we experienced from changing the appointment times, we ran a simulation to test for the compliance for appointments given changes to both these factors. The results detailed below demonstrate a significant improvement from 71.67% compliance to an average of 86%. We also observe a decrease in the average times from 23.98 to 18.02 alongside a significant reduction in the standard deviation from 15.31 to 5.99 representing a much more consistent and compliant service offering.

Changes in both Appointment Duration & Shift Patterns

Type of Customer	Minimum	Average	Maximum	Standard Deviation	Percentage of Time within 25 minutes
Dog General Treatments	9.76	20.74	78.38	7.09	78%
Cat General Treatments	8.34	17.32	73.87	5.82	92%
Furries General Treatments	8.55	16.01	38.98	5.05	94%
Average for General Treatments	8.88	18.02	63.74	5.99	88%

The last simulation we wanted to observe was the improvements the business could expect when moving to 20-minute appointments with an additional veterinarian and change to shift patterns. What we observe are additional gains in compliance with an increase from 88% to 94.33% and a 100% success rate in treating emergencies.

Employment of Additional Staff, Change to Shift Patterns & Appointment Duration

Type of Customer	Minimum	Average	Maximum	Standard Deviation	Percentage of Time within 25 minutes
Dog General Treatments	9.57	19.38	57.67	5.44	85%
Cat General Treatments	8.59	15.83	38.88	3.57	99%
Furries General Treatments	8.01	14.67	29.67	3.42	99%
Average for General Treatments	8.72	16.63	42.07	4.14	94.33%

Research Recommendations

Given our observations, we saw the compliance averages suffer due to the businesses usage of split shifts. By operating all members of staff across the full work hours, we experienced an increase of compliance from 35.33% to 56.33%. Still, these results could be considered unsatisfactory, once we simulated the employment of an additional veterinarian alongside the removal of split shifts, we saw compliance rates raised to 75.33%. We also changed the appointment times that the business was proposing to help stem demand and increase compliance. Just through changing appointment times we experienced a marked increase in compliance from 35.33% initially to 71.67%. Extending this further, we also removed the use of split shifts, and this led to a significant increase to 88% compliance. Finally, we implemented all these provisions including the employment of an additional veterinarian and we observed a 94.33% rate of compliance. It is however important to note that the change in appointment duration led to a 33.79% drop in the volume of customers that the organisation treated a fall from 16,041 customers/year to 10,641 customers/year.

We therefore recommend the business drops the usage of splits shifts, operates only one receptionist (utilisation levels were very low at 10% throughout the simulations with two receptionists and only 15% when with one receptionist) and employs an additional veterinarian. When altering the duration of the appointments, this ultimately comes down to a cost-benefit analysis comparing the impact of non-compliant appointments with the volume of customers the business requires to maintain revenue expectations. We would lastly recommend additional research to combat the lengthier times required for dog treatments, as repeatedly throughout the analysis this impacted on the overall averages for compliance. This may involve priority provided to these treatments by a single veterinarian to raise rates of compliance.

Appendix

Figure 2.

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
```

```
exp_values = np.random.exponential(scale=10, size=16084)
ax = sns.histplot(exp_values, color='green', label="Exponential Distribution of Customer Arrivals")
ax.set(xlabel='Time Between Arrivals', ylabel='Frequency of Visits across a Year Period')
ax.set_title('Exponential Distribution Showing Inter-Arrival Times')
```

Figure 3.

```
ax = sns.histplot(np.random.normal(3,1,16084), kde=True)
ax.set(xlabel='Time Spent at Reception', ylabel='Frequency of Time Spent at Reception')
ax.set_title('Normal Distribution of Time Spent at Reception')
```

Figure 5.

```
ax = sns.histplot(np.random.triangular(15, 20, 30, 788), kde=True)
ax.set(xlabel='Time Spent at Dog Emergency Treatment', ylabel='Frequency of Time Spent at Emergency Treatment')
ax.set_title('Triangular Distribution Showing Time spent at Dog Emergency Treatment')
```

Figure 6.

```
ax = sns.histplot(np.random.triangular(15, 22, 28, 969), kde=True)
ax.set(xlabel='Time Spent at Furries Emergency Treatment', ylabel='Frequency')
ax.set_title('Triangular Distribution Showing Time Spent at Furries Emergency Treatment')
```