ABSTRACT

BREMSER, GREGORY. Analyzing Scheduling Policies and Performance Impacts of a Small Veterinary Practice with Discrete Event Simulation. (Under the direction of Brandon M. McConnell).

Pet ownership has increased in American households year over year since 2016, leading to an increased demand for veterinarian services. Concurrently, the rate of new veterinarians joining the workforce has remained stagnant. With the increased demands, veterinary clinics require great efficiency in planning clinic operations to provide high-quality care, increase profits, and decrease staffing-related stress. Simulation can be used to cheaply and safely experiment with staffing levels and appointment schedules in a virtual environment to assess the impact of potential changes. This research uses data from a veterinary clinic in Ankeny, Iowa, to build a discrete event simulation using data collected both in-person and from the clinic's enterprise software. The model evaluates various appointment schedules at the current and alternative staffing policies. Experimentation provides insight into how the clinic would perform with changes in staffing and scheduled appointments. The results show that with proper adjustments, the clinic can maintain high levels of patient care, and there are alternative scheduling strategies that increase employees' flexible work schedule opportunities to improve employee satisfaction.

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Analyzing Scheduling Policies and Performance Impacts of a Small Veterinary Practice with Discrete Event Simulation

by
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DEDICATION

To my parents.

BIOGRAPHY

Gregory Bremser was born in Elkhorn, Wisconsin, and was raised in a military family. He spent his childhood all over the world. Eventually, the family settled in Kansas. Gregory received his undergraduate degree in industrial engineering at Kansas State University, was commissioned into the Army as an Infantry officer, and continues to serve as such. Upon graduation, Gregory will move to West Point to teach as an instructor in the Department of Mathematical Sciences at the United States Military Academy.

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CHAPTER

1

INTRODUCTION

1.1 Research Background and Motivation

During the COVID-19 pandemic, pet ownership surged, with approximately 23 million people adopting pets (ASPCA 2021). This increase contributes to a growing demand for veterinary care. An American Veterinarian Medical Association (AVMA) study reported that 67 million American households have dogs and 37 million have cats (AVMA 2022). However, the number of qualified doctors and staff at veterinarian clinics is not expanding at a rate that can keep pace with these demand trends (Lloyd 2023). This mismatch has exacerbated the stress levels among veterinary professionals and has led many to retire early or leave the profession entirely due to the high strain on mental health (Garcia 2023). Alternatively, increased demand also comes with the opportunity for higher revenues. In the last four decades, pet owners have been spending more on pets and visiting veterinarians more often to ensure the health and longevity of their pets (Garcia 2023). By strategically planning operations to prioritize staff health and well-being, veterinary clinics have the potential to enhance both profitability and efficiency.

Given these increases in demand, it becomes imperative for veterinary clinics to likely restructure their staffing and appointment policies. One approach that can facilitate this analysis is Discrete Event Simulation (DES). DES is a method that can be used to analyze the clinic's operations to identify changes that can be made quickly and inexpensively without

alternating the existing structure (Jacobson et al. 2013). By simulating various scenarios, DES can help find effective strategies to help schedule efficiently, which will help reduce the turnover of veterinary staff and provide better care for the patients.

Figure 1.1: Ankeny Animal Health Clinic (Google 2013)

1.2 Clinic Overview

Ankeny Animal Health Clinic (AAHC), depicted in Figure 1.1, is a small veterinary clinic that serves as a view into how clinics across America are navigating the challenges described above. Located in Ankeny, Iowa, a growing town of 72,000 people (Census 2022), just north of Des Moines, the clinic specializes in treating dogs and cats. They provide care from routine wellness check-ups to specialized surgeries. This clinic provides a valuable look at how a veterinary business operates and evolves in the new post-pandemic environment.

Ankeny Animal Hospital clinic operates from 7:30 am to 5:30 pm and generally only takes appointments as its business model, but it can handle same-day call-in appointments in limited capacity. The patient will be referred elsewhere if the clinic cannot help with a same-day call-in. Typically, they plan for 8–16 appointments in the morning and 10–17 afternoon appointments, though this varies based on the daily staffing. The clinic has also blended drop-off appointments with the standard appointment model. These appointments led to more flexibility and options for their clientele.

The physical interior of the clinic has a small reception area where only one animal can wait for an appointment. In the event additional patients arrive early and have to wait, owners are directed to wait in their vehicles to prevent any possible altercations and allow mobility space in the reception area.

Once a patient is checked in and an examination room is available, they are guided by a technician through the initial appointment procedures and then brought back to where the appointment will take place. There are four examination rooms. Two examination rooms are primarily used for small dogs and cats, one room is used for large dogs, and the last room can accommodate any animal but doesn't have the same specialized tools as the other rooms. The clinic has a surgery room and a dental surgery room for patients requiring either type of surgery. These kinds of surgeries need different large pieces of equipment, so they call for separate rooms to ensure all the required tools can be properly stored and used when needed. The clinic also has a lab to perform in-house tests and a holding area for patient recovery following surgery. A room is also designated for x-ray requirements. X-rays are generally done during normal appointments or prior to surgeries when needed. Since this time is already accounted for in appointment times, this is not considered a separate appointment. Lastly, the veterinarians have an office to do paperwork and prepare for appointments.

Figure 1.2: Ankeny Animal Health Clinic Reception Area

1.2.1 Appointments

There are many variations of scheduling that a clinic can incorporate. Some clinics may run an all-walk-in appointment clinic. These kinds of clinics need large waiting areas and will have

Figure 1.3: Lab Area to conduct tests in-house. Certain tests that the clinic can't handle need to be outsourced.

highly unpredictable fluctuations from high demand to low demand (Vandenberg 2024). Other clinics will be all scheduled appointments, and others will use a combination of both. The policy at Ankeny Animal Health Clinic is largely appointment-driven, but when able, the clinic will accept emergency same-day appointments. If they cannot handle the emergency appointment due to insufficient capacity or they do not have the proper emergency equipment to sufficiently treat the injured animal, they will refer the patient to a clinic specifically for animal emergencies (Vandenberg 2024). The research will primarily focus on the clinic's standard policy of scheduled appointments and variations of those schedules based on various demands throughout the day.

The clinic separates appointments into four different categories: Wellness, Medical, Technical, and Surgical appointments. Table 1.1 shows the standard time lengths in minutes that the clinic uses to plan schedules for a day for each of these appointment types. Wellness appointments usually take 15 minutes and are completed as a checkup for the patient. Typically, this applies to new patients or a yearly checkup for patients with no significant health concerns. The medical appointment is for specific health issues and concerns and is planned for 30

Figure 1.4: Holding Area for Patient Rehab after surgery.

minutes. The third type of appointment is the technical appointment; technicians can perform the procedure in these appointments without the veterinarian's direct supervision. Some example procedures are nail trims, administering shots, and collecting specific samples for testing in the lab. Lastly, the surgery appointments are the most complicated. The procedures can vary due to the many different types of surgeries and the length of time the patient will remain in the clinic. Further, only a few veterinarians can perform these appointments due to the specialization, training, and certification required to perform the surgeries. Although surgeries require the most scrutiny, training, and care to be performed, they are generally the highest revenue-producing procedures the clinic completes. The main types of surgeries and the percentage of the time they are performed can be seen in Table 1.2.

Table 1.1: Typical Appointment Totals

Appointment Type	Planned Length in minutes
Wellness	15
Medical	30
Surgery	See Table 1.2
Technical	3 – 15

Based on 307 appointment data points collected from the clinic, there are typically eleven wellness appointments, ten medical appointments, three to four surgeries, and six technical appointments daily. All surgery appointments are dropped off at the same time in the morning at 0830 and later picked up in the afternoon.

Table 1.2: Surgery Types and Length in Minutes

Surgery Type	Length of Time in Minutes	Percent of Occurrence
Spays	45 – 60	25
Neuters	30 – 40	19
Dental, Easy	30 – 45	7.3
Dental, Routine	60 – 90	14.6
Dental, Hard	90 – 120	7.3
Mass Removal, Easy	30 – 45	3.5
Mass Removal, Routine	60	7.1
Mass Removal, Hard	120 – 150	3.5
Other	Various	12.2

1.2.2 Staffing

The clinic is typically staffed with two veterinarians and six technicians. There are two technicians to help every veterinarian with medical, wellness, and surgery appointments. Two technicians are also needed to complete technical appointments, typically one to calm and hold the patient while the other administers and completes the procedure. Other tasks that the technicians complete for the clinic are helping run tests, preparing patients for surgery, conducting initial tests and interviews with owners prior to wellness and medical appointments, and conducting general upkeep of the clinic. Only one veterinarian can do surgeries, while the other conducts wellness and medical appointments. Once the doctor completes all the surgeries scheduled in the morning, that doctor can transition to doing wellness and medical appointments in the afternoon.

The owner of AAHC detailed how the staff is utilized during a typical day. He described that during a typical hour, a staff member will dedicate about 30–40 minutes of an hour to appointments. The staffer then completes 10–15 minutes of ancillary tasks in the clinic. For technicians, this may mean cleaning an area or running certain labs. For doctors, this generally means preparing for their next patient by reading previous charts or writing notes on a patient just seen. Finally, he says there usually is 5–10 minutes of idle time (Vandenberg 2024). Table 1.3 describes this breakdown in percentages that can be extrapolated across a whole day.

Also present with staffing is deciding on the optimal staffing configuration. A clinic must assess whether or not it is overstaffed or understaffed and then identify the appropriate level of staff for the clinic and its demands. There are possible negatives on both sides of staffing (Vandenberg 2024). If there is overstaffing, employees may feel undervalued. This can cause employees to not perform as well at work, and they may seek ways to avoid the work they need to

Table 1.3: Observed Utilization of Staff through a day (Vandenberg 2024).

Appointments	50 – 66%
Other Tasks	16.7 –25%
Idle Time	8.3 –16.7%

do because it doesn't feel important, which can lead to a reduction in productivity overall. On the other hand, if the clinic is understaffed, employees may feel burnt out and may feel that they never have enough time to finish all their tasks (Vandenberg 2024). Both of these staffing situations can lead to increased turnover and a turbulent clinic operation.

1.3 Research Questions

Veterinary clinics tend to be seen as recession-resistant during economic downturns because people will still spend money caring for a pet, and new owners will get a pet to provide companionship (Gilmartin and Zirkle 2023). Although resistant to economic hardships and in high demand for services and work, the veterinary medicine profession faces many challenges. These challenges are related to work-life balance, job stress, and a concerning trend where the number of retiring veterinarians outpaces new graduates entering the workforce (Salois 2024).

To try and alleviate the demand with limited resources issues, we will attempt to address the following questions with a simulation model based on the data provided by the Ankeny Animal Health Clinic:

1. How does the current staffing policy react to various appointment demands? Does the current staffing model efficiently and aptly handle differing numbers of appointments day-to-day?

2. How do the appointment demand changes affect staff utilization, and how is utilization affected across different staffing changes? Does the possible lack of technicians affect the doctors' ability to complete appointments?

3. What can future appointment and staffing policies look like to continue operating and growing the clinic effectively?

1.4 Literature Review

1.4.1 Veterinarian Profession

During the COVID-19 pandemic, significant and unexpected changes in consumer spending occurred. This includes money spent on pets and at veterinarian clinics (Salois 2024). This increased revenues for most clinics but added stress to animal care and staff health due to increased demand. In turn, the increased demand and stress have led to a significant turnover in many practices. Forty percent of veterinarians surveyed told the AVMA that they are considering leaving the profession with the cited reason of mental health and work-life balance. Turnover also incurs many hidden costs, including recruitment and training, loss of institutional memory, and damage to the practice brand from well-liked doctors and staff leaving (Salois 2024).

These factors are exacerbated by the size of the incoming generation of veterinarians, which cannot replace the retiring generation; turnover will continue to increase in veterinarian practices unless productivity increases. Clinics can mitigate this challenge by optimizing staff responsibilities and schedules (Salois 2024).

1.4.2 Employee Stress and Turnover in the Service and Health Industries

Occupational stress can come from work overload and role ambiguity (Gautam and Gautam 2024). This hints that both overstaffing and understaffing can be negative on an organization. Occupational stress can not only cause general negative workplace experiences for workers and clients alike, but it can also increase turnover intention in organizations (Gautam and Gautam 2024). An increase in turnover has many negative effects on organizations due to a loss of intangible knowledge and expertise, operational knowledge, customer satisfaction, and service quality (Jian et al. 2022). Turnover can also have a quantitative cost associated with it. For example, in the healthcare industry, hospitals, on average, lose four million dollars each year due to turnover (Jian et al. 2022). Reducing turnovers can help an organization's economics and operational efficiencies.

1.4.3 Discrete Event Simulation (DES)

Discrete event simulation is a simulation method well-suited to planning healthcare services and evaluating the performance impacts of potential changes (Gjerloev et al. 2024). A few examples are scheduling staff and measuring equipment capacity (Katsaliaki and Mustafee 2011). A DES is carried out by increasing simulated time and updating the system state when necessary at discrete intervals (Banks and Carson 1986). A key benefit is the ability to use

probability distributions to account for the variations in the processing time that an entity can experience at stations in the clinic (Seminelli et al. 2016). DES is an inexpensive way to test multiple possible changes quickly and with accurate results without disrupting the real system with time, tests, and unnecessary changes (Banks and Carson 1986).

1.4.4 DES in Veterinarian Practices

There is limited literature on simulation in veterinary practices. Steward and Standridge (1996) demonstrate that veterinary clinic simulation can help make decisions, specifically, resource utilization, personnel, demand, and scheduling. Steward and Standridge (1996) examine scheduling issues and report that most clinics need to do their surgeries in the morning because the clinics do not have the capability to keep patients overnight for longer recovery times. Since a running veterinarian clinic cannot easily switch policies without possible unforeseen consequences, a simulation can quickly evaluate alternative policies without risking the current operation of the clinic. This demonstrates why simulation can be a powerful tool for assessing a clinic.

1.4.5 DES in Healthcare

The narrow range of literature on simulation in veterinarian clinics does not thoroughly explore scheduling and utilization of resources. Conversely, standard healthcare systems have been studied extensively and have a large amount of published literature that can be considered in regard to simulation (Gjerloev et al. 2024; Vázquez-Serrano et al. 2021; Ala et al. 2023; Seminelli et al. 2016; Slocum et al. 2021; Richardson and Cohn 2018). Comparatively, there are many operational similarities between veterinary clinics and human healthcare facilities. In general, both have patients who need to schedule appointments ahead of time, ensuring organized and timely care. Upon arrival, the patient enters the clinic and must check in with the receptionist to ensure patient tracking and smooth patient flow. Then, a healthcare professional—a nurse or a veterinary technician—will escort them to an examination room. Subsequently, a doctor will then conduct the exam depending on the appointment, and, following the exam, the patient will go and check out at the receptionist's desk to finalize their transaction at the facility. Both clinics need to decide how to staff and manage appointment loads according to the staffing while still providing the best and most compassionate care possible to the patients (Ala et al. 2023). Inference from standard healthcare DESs can help identify key themes and ideas to incorporate in modeling a small animal health clinic.

Many studies have used DES to evaluate medical clinics with the intent of helping make staffing decisions, reduce staff overtime, or improve patient experiences (McKinley et al. 2020;

Seminelli et al. 2016; Slocum et al. 2021; Vázquez-Serrano et al. 2021; Jacobson et al. 2013; Hamrock et al. 2013). McKinley et al. (2020) describes the steps to create an effective simulation, while Seminelli et al. (2016) and Slocum et al. (2021) describe different patient scheduling methods that can be implemented in a DES. The interested reader should consult Vázquez-Serrano et al. (2021) for a recent review on the simulation in healthcare literature.

1.4.6 Policies on Scheduling Patients and Staffing

Unsurprisingly, studies often focus on critical elements that clinics can influence and control: staffing policies and demand scheduling strategies (Slocum et al. 2021; DeRienzo et al. 2017; Mondal and Norman 2023).

Slocum et al. (2021) simulates various block scheduling policies at a chemotherapy clinic to find easy-to-implement scheduling policies. The results from the simulation found that there was a 24% reduction in patient wait time and a 66% reduction in nurse overtime. Slocum et al. (2021) achieved this by focusing on a classification system for patients requiring different chemotherapy treatments. Depending on the classification of the patient will determine the amount of time and resources required to allocate and provide for that specific patient. The chemotherapy clinic can then build a schedule based on the classification and maximize the utilization of infusion chairs (Slocum et al. 2021). It is worth considering the possibility of organizing the veterinary clinic's schedule into a similar block pattern based on its four distinct categories.

Using DES to try to optimize staff levels has proven effective in various healthcare applications. For instance, DeRienzo et al. (2017) apply DES to try and improve the staffing of a neonatal intensive care unit (NICU). They find potential improvements to staffing that can positively impact unit performance. Also, Mondal and Norman (2023) employ DES to reduce patient monitoring (PM) time for psychiatric units, reducing staff hours, which, consequently, lowers the risk of burnout while achieving cost savings for the hospital. These examples show that DES is an effective tool in healthcare. They provide a glimpse at how adjustments in staffing can improve patient outcomes and reduce staff stress, enhancing the hospital unit's capabilities and financial stability.

Similarly, exploring different staff levels to find veterinarian clinic improvements merits investigation. This may be key to ensuring the future growth of the Ankeny clinic, and if designed at a larger scale, can be implemented throughout the veterinary profession to ensure continued positive growth in the field.

1.5 Organization of the Document

The rest of the document is organized as follows Chapter 2 presents the simulation model and initial experimentation, Chapter 3 explores alternative appointment schedules, and Chapter 4 provides concluding thoughts and ideas for future consideration.

CHAPTER

2

METHODS

2.1 Data

The data was collected in person at the Ankeny Animal Health Clinic. The clinic uses software to automatically collect all patients' transaction data when they check in and out at the receptionist desk. The raw data collected was the check-in time to the receptionist, the appointment time, the check-out time based on when the payment happened, animal species, and what type of appointment the visit was. Lastly, data was taken if the patient was late, early, or on time. The collected data included a total of 307 separate appointments. Table 2.1 provides a sample of the collected data.

Table 2.1: Sample of data collected. The positive numbers indicate how early a patient was for their appointment.

Appointment Date and Time	Check In	Check Out	Appointment Type	Species	Early/ Late (Min)
3 APR 23, 0800	0759	0820	Wellness	Canine	1
3 APR 23, 0815	0808	0827	Medical	Canine	7
3 APR 23, 0900	No Show	–	Medical	Canine	–
3 APR 23, 0930	0920	0934	Medical	Feline	10
3 APR 23, 1000	0941	0953	Wellness	Canine	19

Collecting accurate information for surgery appointments was more challenging. The method mentioned above did not accurately provide the surgery duration. The recording system records the time a patient was in the clinic. This time in the clinic would include surgery preparation, the surgery, and in-clinic recovery time. All surgeries arrive at 8:30 am and are then conducted sequentially. The patients are then placed in a holding area to observe their immediate recovery. The owners will then come and pick the patients up later that afternoon. The appointment system records when the patient arrived and checked out but does not give the exact length of time that the patient was in surgery. The design of the simulation only requires to have the length of the surgeries. If surgery patient sojourn time is reduced enough through policy changes, it may be possible to add an additional surgery, which is the highest revenue-generating procedure.

For this reason, and following the literature from Kuhl et al. (2010), Slocum et al. (2021), and Seminelli et al. (2016), the veterinarian surgeon was asked how much time is required for the most common surgeries. Since different surgery types varied widely, it was determined to separate the distributions by surgery type instead of attempting to aggregate all the surgeries into one “surgery" category. Refer to Table 1.2 to see all the surgery types considered. The surgeon was asked for the most likely, fastest, and slowest amount of time each specific surgery required to support the construction of a generalized Beta distribution. To view the times that the surgeon provided, Table 1.2 summarizes the data (Vandenberg 2024).

2.1.1 Cleaning Data

There were some inconsistencies in the data that had to be investigated, primarily for the medical, wellness, and technical appointments. Some appointments are registered as zero minutes in length. This is because the owner would pay for the service as soon as the patient checked in; thus, there were zero minutes in the system, according to how the clinic’s proprietary software records the time a patient stays in the system. The data indicates that this generally only happens for quick technical appointments but is observed in rare cases for medical and wellness appointments. Speaking with the clinic owner, he agreed that this happens more often for technical appointments when the pet owner does not need to move with the patient to the technical appointment area, where the short procedure takes place. Examples of a procedure are when it is just a vaccine or nail clippings. The clinic owner specified that, at a minimum, an appointment would take at least three minutes, and those under three minutes should be deemed as inaccurate or as errors (Vandenberg 2024). All appointments under three minutes were removed from the data since any appointment under three minutes was deemed an error and did not accurately reflect the actual appointment data.

Table 2.2: Distributions Used for Appointments

Appointment Type	Distribution Type
Wellness	3 + Gamma(2.43, 6.73)
Medical	3 + Gamma(3.36, 6.37)
Technical	3 + Exponential(7.60)
How Early or Late	Logistic(8.43,5.67)

2.2 Input Modeling

The reason to conduct input modeling is to manage the uncertainty in the data collected and to be able to approximate and represent the services and systems modeled with a reasonable amount of accuracy. To do this, probability distributions are fitted to the data. With this understanding, the data from the clinic was analyzed to find appropriate distributions for the appointments' lengths in minutes. The distributions were selected based on the Pearson Chi-Square goodness of fit test. The proprietary software @Risk was used to compare and find distributions from the data collected. See the data Table 2.2 for the selected distributions. A distribution also had to be found to fit the arrival times of the patients on how early or late they were to an appointment. See Appendix C for specifics on how the distributions were found.

2.2.1 Surgery Duration

As described in Section 2.1, the surgery appointment distributions had to be found in a different manner. Following Kuhl et al. (2010), a generalized Beta distribution best models the surgery distributions by taking the form

$$a + (b - a)\text{Beta}(\alpha_1, \alpha_2), \tag{2.1}$$

with the lower bound a, upper bound b, and two shape parameters, α_1 and α_2.

To create the Beta distribution, the minimum (lower bound), most likely (mode), and maximum (upper bound) amount of time to do surgery was needed in order to find the shape parameters as described in Kuhl et al. (2010).

Equation 2.1 is the generalized Beta form. To find the shape parameters, we calculate the asymmetry ratio, r, using

$$r = \frac{(b - m)}{(m - a)}, \tag{2.2}$$

where m is the most likely surgery duration obtained from the veterinarian surgeon, along with the minimum and maximum durations, a and b, respectively. The shape parameters are

Table 2.3: Surgery Distribution Times

Surgery Types	Distributions	Calculated Mean (Min)
Spays	45 + 15 Beta(1.05, 4.05)	48
Neuters	30 +10 Beta(1.09, 4.08)	32
Dental (Easy)	30 + 15 Beta(1.08, 4.07)	33
Dental (Routine)	60 + 30 Beta(1.03, 4.03)	66
Dental (Hard)	120 + 30 Beta(1.02, 4.02)	126
Mass Removal (Easy)	30 + 15 Beta(1.07, 4.07)	33
Mass Removal (Routine)	60 + 30 Beta(1.03, 4.03)	66
Mass Removal (Hard)	120 + 30 Beta(1.02, 4.02)	126

then

$$\alpha_1 = \frac{(4+3r+4r^2)}{(1+r^2)}, \tag{2.3}$$

and

$$\alpha_2 = \frac{(1+3r+4r^2)}{(1+r^2)}. \tag{2.4}$$

The results found are added to the generalized Beta form and attributed to the surgery appointments in the model. Table 2.3 summarizes the resulting distributions for surgery times found using Equations (2.1–2.4).

Lastly, weighted paths are built in the simulation to decide which surgery appointment is to happen during the day. Based on the percentages given in Table 1.2, the weights are attributed to those surgeries. For example, a surgery patient will arrive through the source block and then be given a 25% chance of being a spay surgery.

2.2.2 Non-Surgery Appointments

Three minutes were subtracted from all non-surgery data points based on the veterinarian saying all appointments were three minutes or longer in length. After subtraction, the data is better able to conveniently fit a distribution with a lower bound of zero. The residual appointment durations then had a distribution fitted according to the data. When the distribution was attributed to the servers in the simulation, three minutes were added back onto the distributions to account for the three minutes subtracted earlier. See Table 2.2 for all the distributions found for all appointments except surgeries.

Table 2.4: Appointment Totals

Appointment Type	Number of Appointments by Model		
	Easy	Base	Hard
Wellness	8	11	13
Medical	8	10	11
Surgery	3	4	4
Technical	2	6	8

2.2.3 No shows and Variations in Arrival Time Distribution

The model attempts to mirror the clinic as closely as possible by also incorporating the data for appointment no-shows and the variability in patient arrival times. From analysis of the data, 15 of the 307 (approximately 5%) appointments were no-shows. On analysis of the arrival time, it was found that the average deviation from zero was approximately nine minutes early, with only about 11% of patients being late.

Patients tend to arrive early to appointments, which can help the clinic with general flow and efficiency. However, in the case of a significantly delayed appointment, the clinic will reschedule the appointment. This ensures that late appointments do not interfere with other patients' wait times and experience at the clinic. The no-show percentage and the distribution from the arrival time were added as attributes to the patient entities in the simulation model (see Table 2.2). With this information implemented, we can ensure that the simulation accurately reflects the operational challenges faced by the clinic on a daily basis.

2.3 Identifying Appointment Schedules

The number of appointments per day was first analyzed to create the initial appointment model. The initial effort was to find the average number of daily appointments. With the average daily appointments, a "Base" schedule was built based on the clinic's current appointment policy (see Appendix B, Table B.1 for the base schedule created).

To test different appointment schedules, we first had to identify what kind of schedules to test and how many of the various appointments to add to the schedules. We decided to test how the staff can handle an "Easy" and a "Hard" schedule, along with an average "Base" schedule, as seen in Table B.1. To create an easy and hard schedule, we used the raw appointment data discussed in Section 2.1 to create box and whisker plots (as in Figure 2.1).

Two schedules were created from the plot. A hard schedule was the number of appointments found in the third quartile of the data, and an easy schedule was the number of appointments

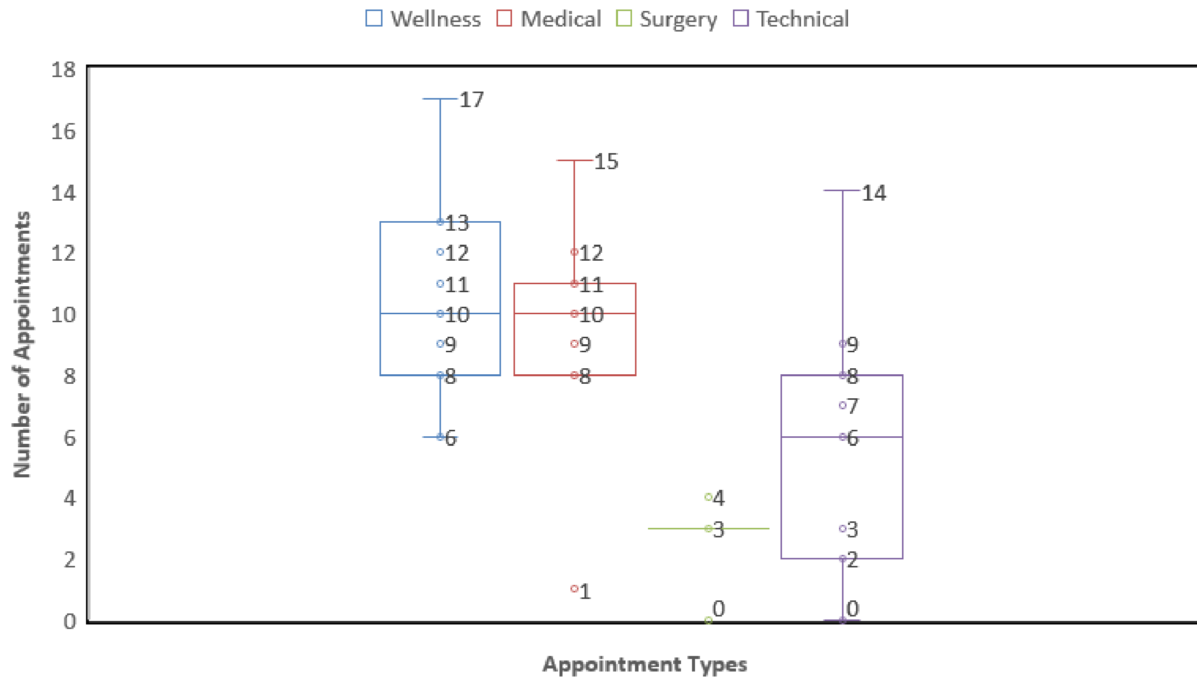

Figure 2.1: (color online) Box and Whisker Plot Showing Number of Appointments by Type

found in the first quartile of the data. This resulted in an easy 21 appointment day and a hard 36 appointment day. In the collected data, we observed both a 35-appointment day and a 19-appointment day as the two extremes. Given the resemblance of the actual schedules observed with the data-driven generated schedules, it was determined that the method was effective in creating easy and hard schedules. Table 2.4 summarizes the appointment totals for an easy, base, and hard day. The interested reader can find the easy and hard appointment schedules in Tables B.2–B.3 in Appendix B. For surgery appointments, only three kinds of appointment totals were observed across all the days of gathered data. There were zero, three, and four surgery appointment days. This rendered the box and whisker plot only to have those three points. A zero appointment day only occurs when the surgeon has taken a day off. Since we only consider days with a surgeon working, the zero appointment day can be ignored. Thus, it was decided that an easy day would have three appointments, and a base and hard day would have four appointments. This makes sense since surgeries are typically the highest revenue appointments (Vandenberg 2024). This gives the clinic incentives to keep a high number of these appointments, even on easy appointment days.

2.4 Simulation Model

The model is created using the Simeo simulation software. Simio can be used to create dynamic simulations and models and can be easily adapted to many systems. Patient movement through the simulation is shown in Figure 2.2. It was determined that the scale of the clinic was negligible, so the model is not built to the exact dimensions but is instead built according to resources needed, capacity of rooms, and appointment times. Patients are modeled as entities in the model and enter the clinic through a Simio source block that has the appointment schedule built into it. The patients are then routed according to their appointment type to be treated in separate areas. Medical and wellness appointments are treated in the same rooms, but surgeries and technical appointments are treated in different clinic areas. Dental and general surgeries are not separated into separate rooms in the simulation. This is because the doctor cannot work on a dental patient and general surgery patient at the same time, so both rooms in the actual clinic will never be used at the same time. All the surgery distributions are attributed to the same server area in the simulation.

To summarize, the appointment schedules are created by the method explained in Section 2.3. Patients are assigned an appointment type and enter the source block at their appointment time based on the appointment schedule. The patients then flow through the model and receive treatment based on the input modeling distributions found according to their appointment type. The clinic's Doctors and technicians are modeled as resources used to complete these appointments. The primary output data that will be analyzed from the results was the staff members' utilization and the total time in the system for each patient by appointment type.

2.4.1 Simulation Model Assumptions

The model makes several assumptions:

1. The travel distance in the clinic is negligible and not modeled.

2. The non-appointment and general clinic administration and upkeep tasks are not accounted for in the model but will be considered during the analysis and interpretation of the results.

3. There are no same-day emergency call-in appointments where an owner calls ahead of time to get their pet seen. This is not a limiting assumption.

4. The model does not consider drop-off appointments. With this type of appointment, a patient is dropped off in the morning and picked up later in the afternoon once the

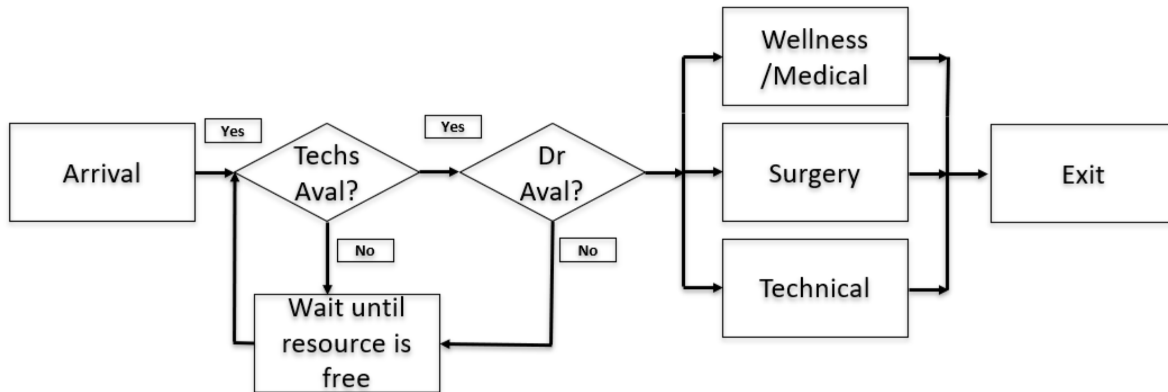

Figure 2.2: Simulation Model

owner is available. In the event one of these appointments is scheduled, the veterinarian will typically complete the examination when they have time throughout the morning or lunch hour. These appointments generally go quicker because the owner can not request additional aid or medical services. Since this and same-day emergency appointments are relatively rare and the objective was to analyze a typical day, they were ignored.

5. Due to the many different types of surgeries, not all could be modeled. These are referred to as "other" in Table 1.2. Since this became very broad and each individual surgery was rare, they were not modeled and not included in the weights for the model. The weight from the "other" category was evenly and proportionally distributed back to the other surgeries.

2.5 Verification and Validation

The model is based on the data collected in the clinic to create what a typical day looks like. Throughout the model's development, processes and statistics were verified through expert input from the veterinarian owner of the clinic and with comparison to the raw data collected. The owner also looked at the flow of the model and agreed it was similar enough to the actual clinic. Incrementally building the model and asking for input reduced model development time and ensured fewer possible errors in the final results.

Two methods were used to validate the final base model: expert validation and comparison testing. The approach to final validation is similar to verification. The expert was again consulted to confirm the results to validate the model.

Table 2.5: Displays the observed means and utilization as reported by the owner versus what was observed from the base simulation results

	Observed Data	Simulation
Utilization		
Doctor 1	50 – 66 %	66%
Doctor 2	50 – 66 %	59%
Technician	50 – 66 %	45%
Sojourn Time Mean (Min)		
Medical	24.4	26.4
Wellness	19.3	19.3
Technical	10.6	11.2
Surgery	NA	NA

The model's output data was also compared to the raw data collected to validate the model. The two key performance indicators that were compared were the patient sojourn time and the staff utilization. When comparing the results with raw data and the anecdotal utilization of the staff, which the owner provided, they match comparatively. Refer to Table 2.5 to see the entire verification.

Following a pilot experiment of 750 replications of the base schedule, the owner also validated that the results resembled the actual operation of the clinic when only considering these four appointment types.

2.6 Experiment Testing Staffing Levels

In addition to testing how the current staffing policy would handle the different appointment schedules, variation in staffing was also tested. Other staffing variations were tested to see how the key performance indicators would react compared to the base model and the two new schedules developed. The number of Doctors remained consistent at two, but the technicians varied from four on a low staffing day, six on a typical staffing day, and eight on a high staffing day. The reason for the even number of technicians is that the clinic policy is to have two technicians per Doctor. The additional technicians are used to complete the technical appointments and other clinic tasks. It is important to note that while staffing will vary, the same schedules of easy, base, and hard appointment schedules will be experimented on over the 750 replications. See appendix

The appointment schedules remained the same when testing the staffing policies. Ideally, we would like to observe the effect the appointment schedules have on the variations in staffing,

specifically with the utilization and sojourn time of the patients.

2.7 Results and Analysis

The bar charts in this section show the results and comparison of the different models with the various staffing levels. The raw model data can be found in Appendix E. We calculate and depict 95% confidence intervals for the means based on default Simio settings (Smith and Sturrock 2023). With 750 replications of each simulation, it was determined that the half-widths became small enough to be reasonably confident in the mean provided.

2.7.1 Utilization

In general and unsurprisingly, the results show that there is lower staff utilization with a higher staff level and fewer appointments. With low staffing and base or high appointment schedule, the utilization can be argued to be too high, especially when considering the other tasks in the clinic that are not modeled. See Figures 2.3, 2.4, and 2.5 for the utilization comparison for the technicians, Doctor 1, and Doctor 2, respectively.

An interesting result is that the number of technicians does not affect the utilization of Doctors. Although utilization rises as the schedule's appointment volume increases, Doctor utilization remains constant through the staffing changes. The original hypothesis was that the Doctors would have to wait for the technicians to complete their technical appointments for the Doctors to complete their appointments. In actuality, the results are interpreted to mean that the Doctors do not typically have to wait for technicians to start appointments, regardless of the model. This makes sense in the actual clinic because Doctors are the highest-paid employees. If a technician's assistance is delayed from an appointment with a Doctor, the costs to the clinic will be much higher than if a technician has to postpone their technical appointment for a few additional minutes.

The technician staff are the most affected by the policy changes. As appointments increase and staffing is reduced, utilization rises dramatically from high to low staffing models. The low staff policy can easily handle an easy appointment day but may struggle with base and hard appointment schedules. In the low staffing models, utilization is at 50%, 70%, and 75% for the easy, base, and hard appointment days. Due to the model only accounting for the work the technicians do in an appointment and not the other ancillary tasks needed to get done in the clinic, the utilization may be too high for the base and high appointment day schedules. When adding in the utilization from the other clinic tasks that need to be performed, technician utilization may be as high as 85% or 90%. If any variability occurs in the system, patient sojourn

time may spike to unacceptable levels, and significant delays could occur.

The clinic could consider prioritizing the ancillary tasks that need to be completed and deciding that specific tasks could be dropped or moved to an easier day if required. The other option would be only to have base staffing for the base and hard appointment days.

Another observation is that Doctors are well utilized regardless of the model. If Doctors were the only staff to be concerned with, I would recommend always scheduling hard days because this would make them the most cost-effective. When considering the technical staff with the Doctors, I suggest having six technicians working if it is a hard day. For a base appointment day, the clinic should do some serious analysis of the ancillary tasks that can be dropped. If they are able to find some efficiencies, I recommend using a low staff level for base days. If they cannot find the efficiencies, then a base staff level will be more than sufficient. For a low appointment day, I recommend using four technicians. The results do not support the need to have eight technicians working in the model under the current tested conditions. It is advisable to remove this option due to being unnecessary.

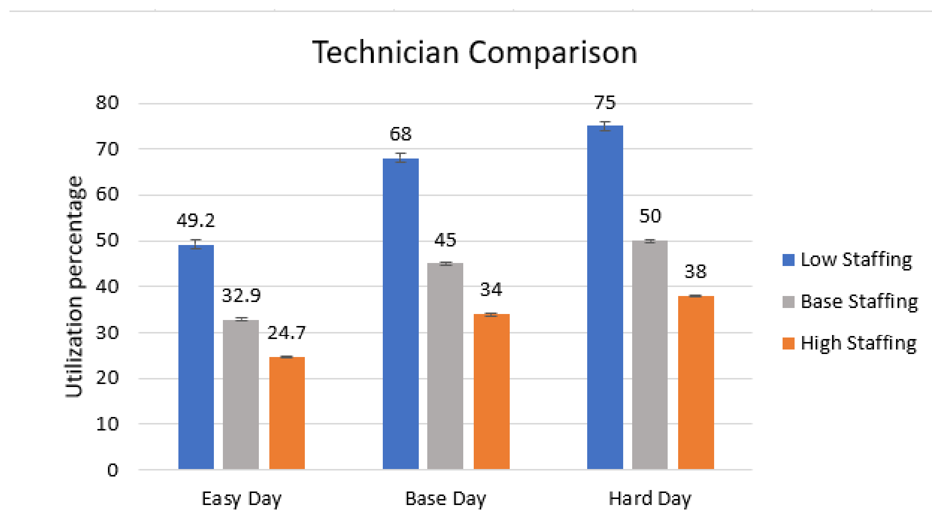

Figure 2.3: (color online) Technician utilization compared by the staffing levels and the three different models

2.7.2 Sojourn Time

Next, we analyze the sojourn time of the various patients with different appointment types. Sojourn time increases for all appointments when there is low staffing on base and hard days, but when staff is at a base or high level, sojourn time remains relatively stagnant. This

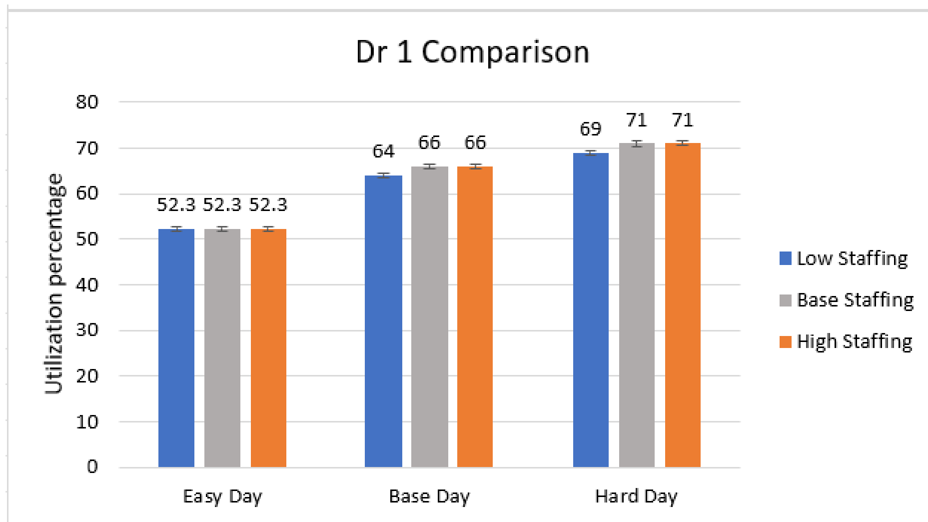

Figure 2.4: (color online) Dr.1 utilization compared by the staffing levels and the three different models

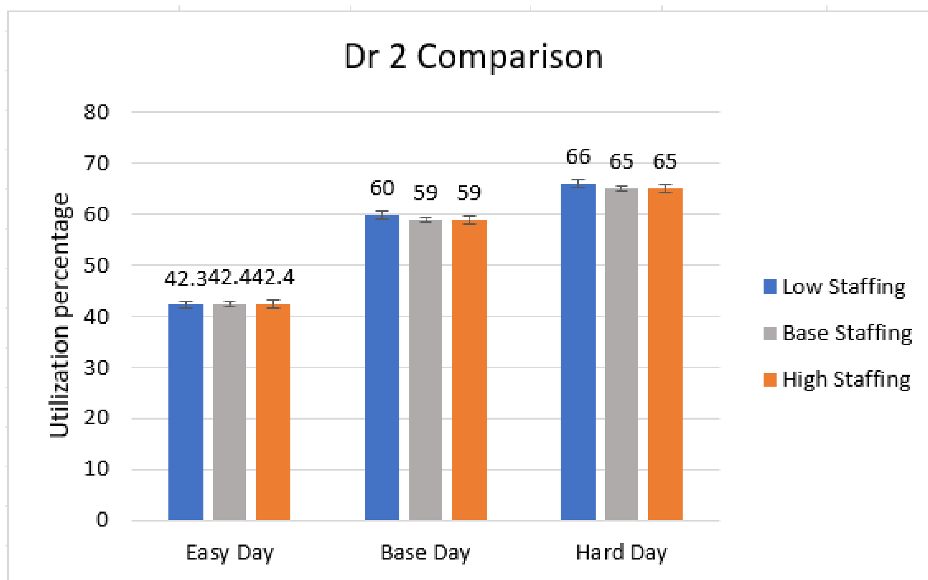

Figure 2.5: (color online) Dr.2 utilization compared by the staffing levels and the three different models

indicates that patients must wait for technicians in the low staffing models. When low staffing is compared to the base and high staffing levels in the base and hard models, there is a time in system increase of 22%, 260%, 14%, and 16% in the wellness, technical, surgery, and medical appointments, respectively. This, along with the rest of the technical appointments compared to the day's demand, can be seen in Figure 2.8. Technical appointments are severely affected by changes in staffing.

On an easy day, there would be only a slight increase in sojourn time across all appointments, as seen in Figure 2.6 and 2.7. I recommend using only four technicians on an easy day. If the goal is to minimize the sojourn time on the base and hard days, I use the base amount of technicians needed. The clinic would need to do a cost-benefit analysis to see if it is worth the additional sojourn time and possibly causing patient dissatisfaction while using a low staff for the base and hard schedule days.

A reminder for the surgery sojourn times, the model categorizes appointment days into three types: easy days, with three surgeries planned, and base and hard days, where four surgeries are scheduled. All surgery patients arrive simultaneously and have to wait one at a time for the Doctor to complete the surgeries ahead of them. Patients are then retrieved later in the afternoon by their owners. The sequential processing results in varying sojourn time between patients in the model, with the first patient typically experiencing shorter times in the system. The first patient in the queue could have a much shorter surgery sojourn time than the average sojourn time reported. This is deemed acceptable for the model. By having a more average duration result from the surgeries, we can assess whether the clinic can benefit from adjusting the number of surgeries scheduled per day, which can create better operational efficiency and patient care. See Figure 2.9 to see the surgery sojourn time across all the models.

2.7.3 Quartile Analysis of the Sojourn Times

Although the means of the appointment times gleaned valuable insight into how staffing levels affect different demand schedules, it is also important to learn what the tails of the replication distribution look like to get a complete understanding of the risks and other possible outcomes of a staff policy change. In this section, only the base appointment schedule will be examined against the three staff levels. This is done because the easy and hard schedules are both similar in distribution to the base schedule. The charts in this section encompass the lower percentile of 5% to the upper percentile of 95%. They also show the minimum and maximum results of the replications along with the mean and median. The mean is represented in the yellow box.

Medical and wellness appointments had a similar distribution across their base and high staffing levels. Where there was a large distinction with the low staffing replications. As observed in Figure C.2 and Table 2.6 for the medical appointment, low staffing had an upper percentile of 48 minutes, while base and high staffing had an upper quartile of 37 minutes. Similarly, for wellness appointments, the upper percentile was 38 minutes for low staff, whereas the base and high staffing were 28 minutes. This shows how large the distribution varies, not only in the mean value of the appointments but through the percentiles.

The technical appointment distributions show the largest discrepancy between the base

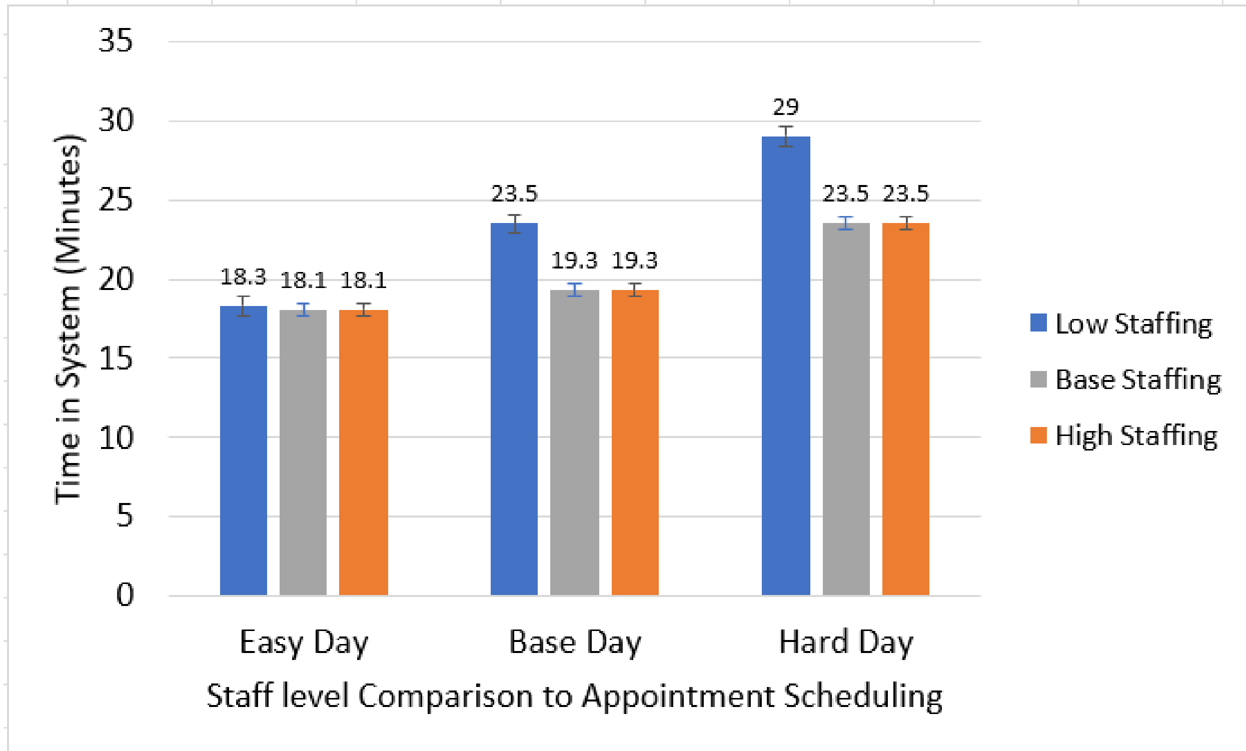

Figure 2.6: (color online) Wellness patient sojourn times. Wellness appointments are typically planned for 15 minutes.

Table 2.6: Medical Distribution Values for a Base Day

	Low Staffing	Base Staffing	High Staffing
Min	13.1	13.1	13.1
Max	96.1	63	63
Lower	18.3	17.3	17.3
Upper	48	37	37
Mean	29.7	25.6	25.6
Median	27.6	24.6	24.6

and high staffing and the low staffing. Observing Figure 2.12 and Table 2.8, the upper percentile of the low staffing is 58 minutes, whereas for the other staffing options, it is at 17 minutes. This could indicate that there are instances where the clinic could not complete the technical appointments because of the staff levels. With such a large variation, it would be useful to look at the utilization quartiles of the technicians as well. Looking at Figure 2.13 and Table 2.9 shows that utilization is elevated at the upper quartile to a point where customer satisfaction may be affected, especially when considering other clinic tasks that need to be completed.

Surgery sojourn times remain relatively consistent across the three staffing levels. Low staff

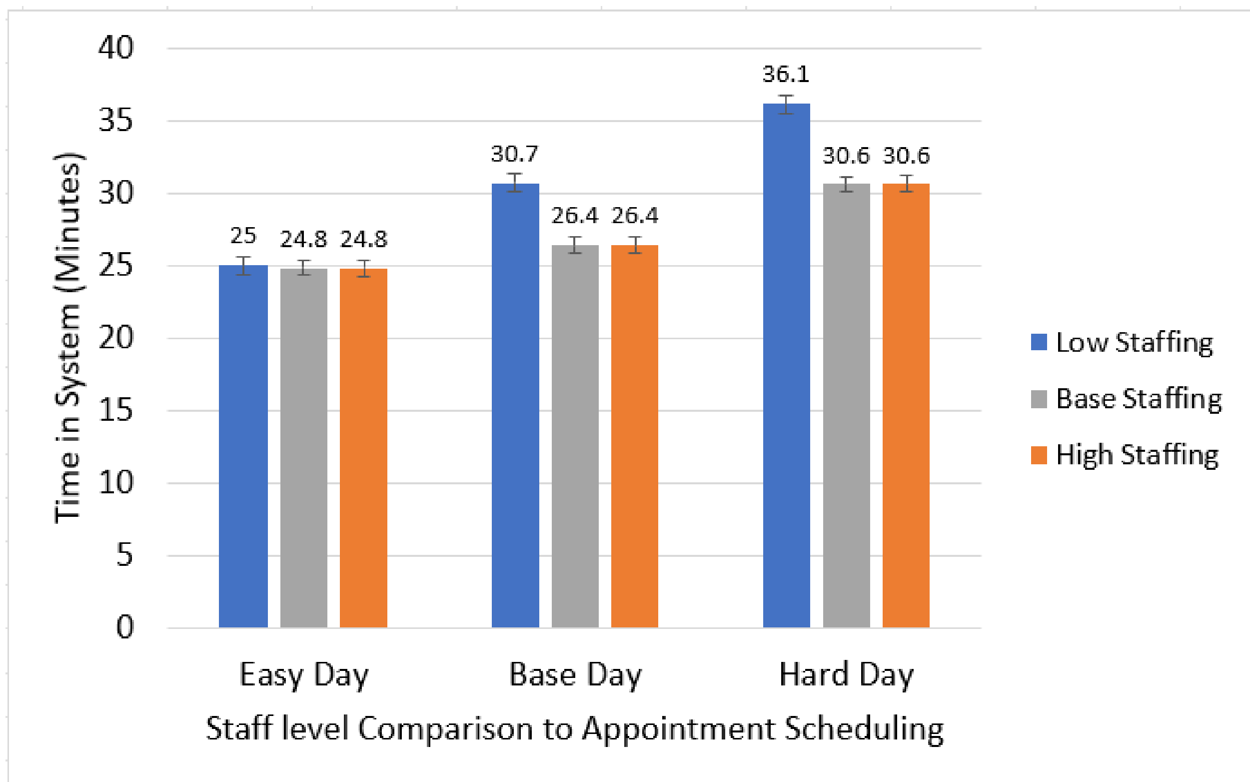

Figure 2.7: (color online) Medical patient sojourn times. Medical appointments are typically allotted 30 minutes.

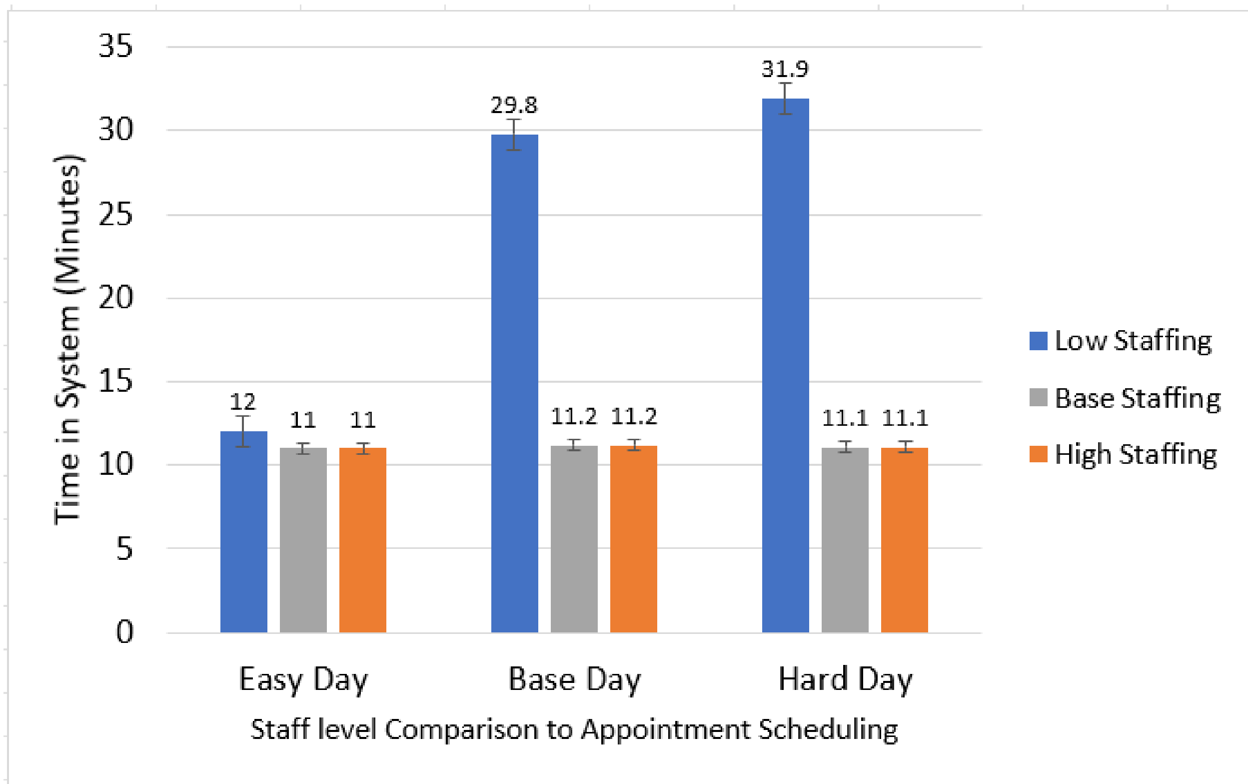

Figure 2.8: (color online) Technical patient sojourn times. Technical appointments are planned for short procedures without the supervision of a veterinarian and planned for 5–15 minutes.

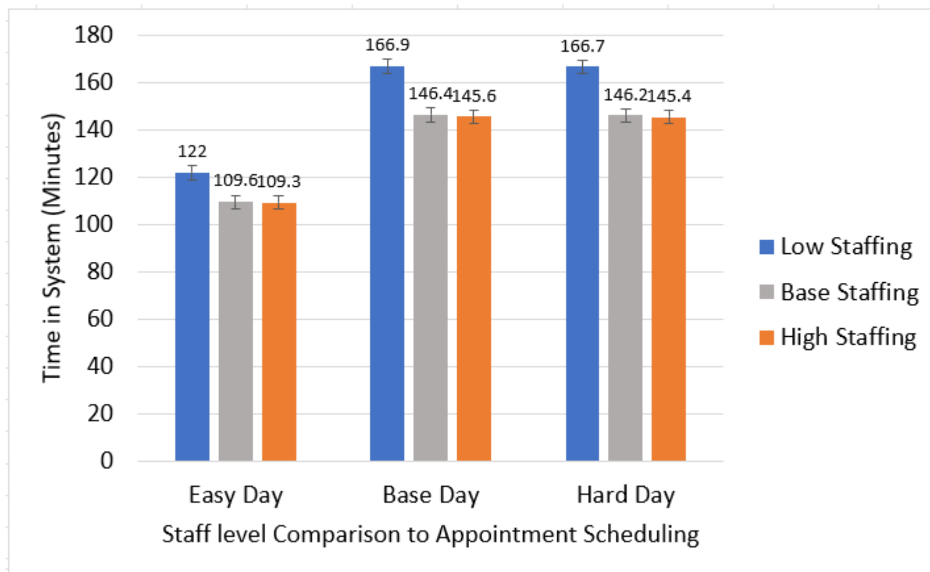

Figure 2.9: Surgery Sojourn: Appointments vary wildly based on the surgery. See Table 1.2 for all surgery times.

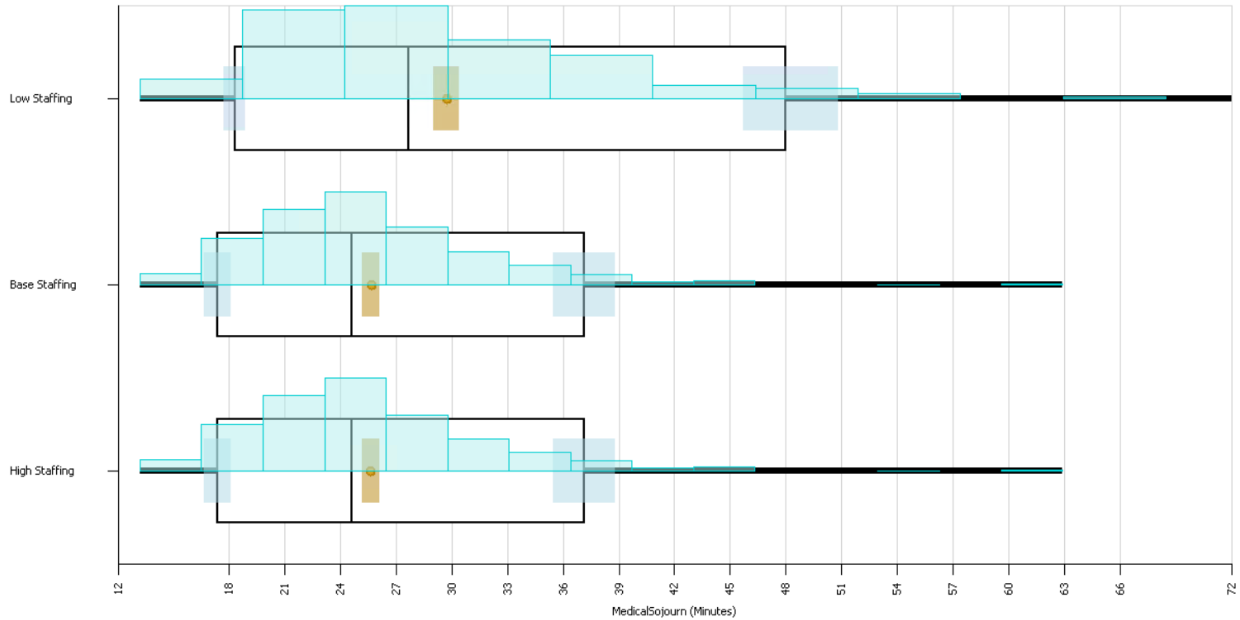

Figure 2.10: (color online) Base Model Medical Sojourn time distributions

Table 2.7: Wellness Distribution Values for a Base Day

	Low Staffing	Base Staffing	High Staffing
Min	10.5	8	8
Max	82.8	52.8	52.8
Lower	13.3	12.1	12.1
Upper	38.6	28.5	28.5
Mean	23	18.9	18.9
Median	21.1	18	18

metrics are longer due to the possibility that there are not enough technicians to immediately begin surgery appointments when the patient is ready. Also, note that the different surgeries vary in time drastically and that the patients wait in the system one at a time to be served. This can help explain the wide range of sojourn times across the replications.

2.7.4 Overall Analysis and Possible Improvements

If the clinic's goal is to maximize utilization without breaking the system, the clinic should only schedule hard days when six technicians are expected to work. Otherwise, for the easy days, I recommend having four technicians work to maximize both utilization and revenue. Although not tested, three technicians may be enough to ensure that the easy appointment schedule will still be comfortably completed. This assumption is based on the observation that

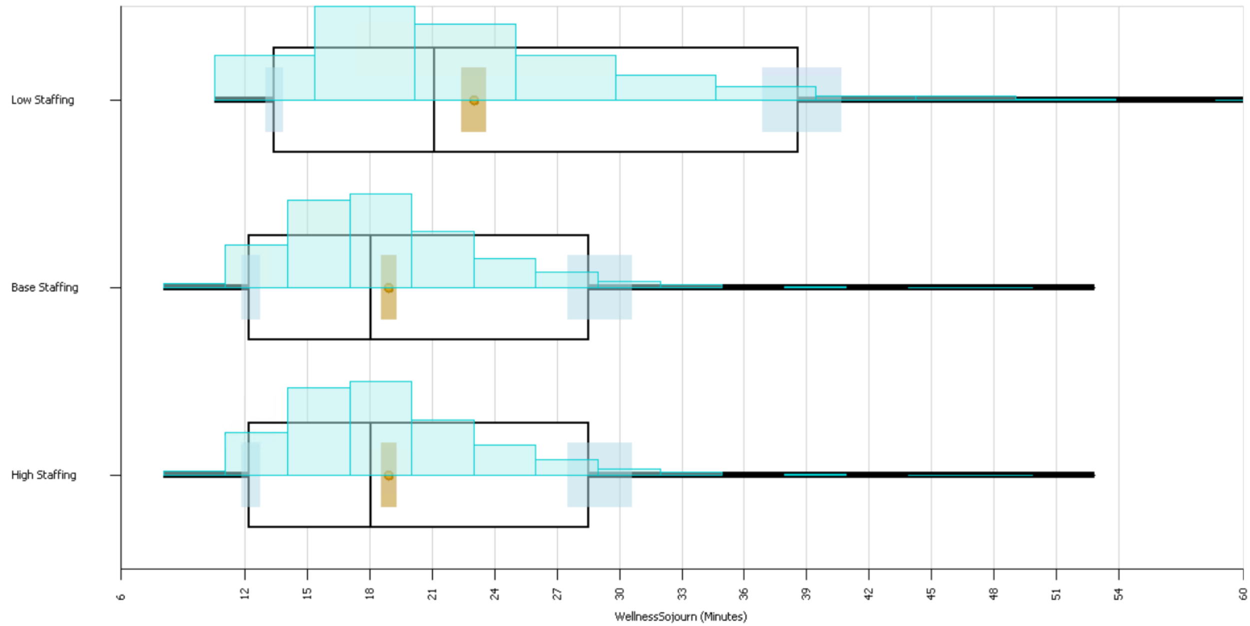

Figure 2.11: Base Model Wellness Sojourn time distributions

Table 2.8: Technical Distribution Values for a Base Day

	Low Staffing	Base Staffing	High Staffing
Min	6	5	5
Max	146	24	24
Lower	11	6.7	6.7
Upper	58	17	17
Mean	28	11	11
Median	24	10.5	10.5

four technicians are only utilized 50% of the time, which falls below an acceptable utilization threshold.

The results suggest using six technicians if the clinic tries to minimize client time in the system. If the clinic is willing to allow additional waiting time, a low technician level could also be manageable, but the clinic would have to possibly handle dissatisfaction more often from patients.

Overall, if the clinic wants to compromise within the existing policies, it is recommended to have six technicians staffed for the base and hard appointment schedules while using the low level of staffing on the easy appointment days.

Possible improvements to the schedule will be explored in Chapter 3 through the analysis of the results. One observation that will be analyzed further is the technical appointments and the technicians. From the results, there is a possibility that the need for base-level staff will

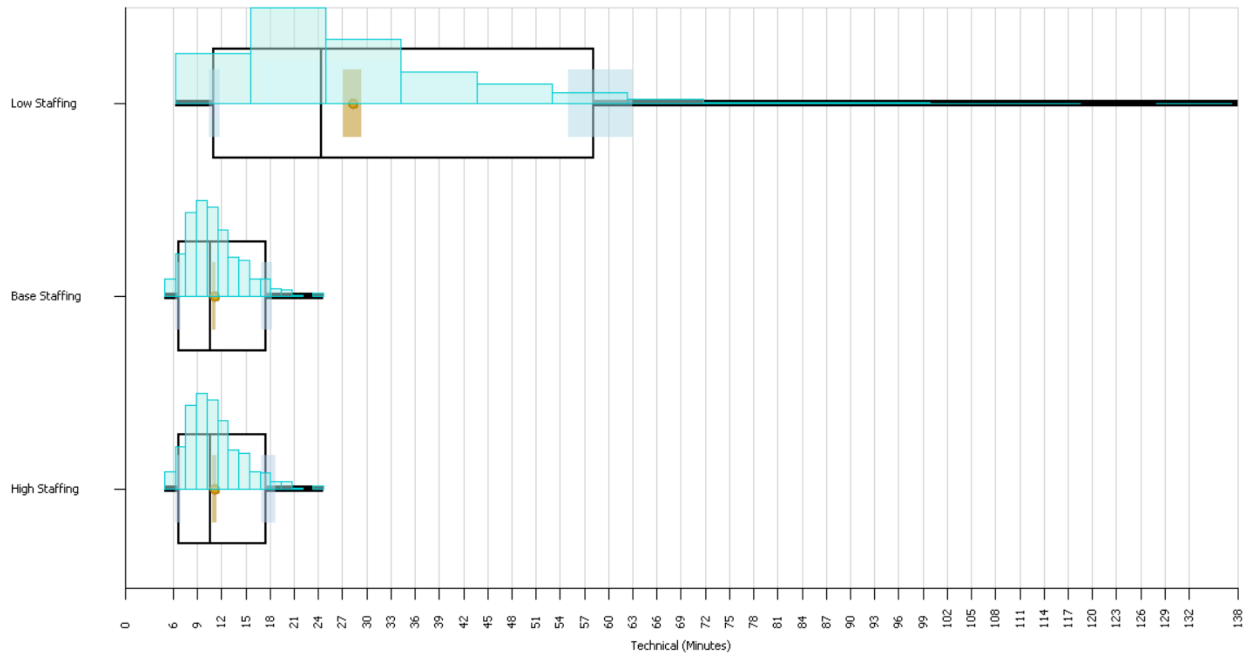

Figure 2.12: Base Model Technical Sojourn time distributions for a Base Day

Table 2.9: Technician Utilization Distribution for a Base Day

	Low Staff	Base Staff	High Staff
Min	40	26	19
Max	90	56	42
Lower	50	33.5	25
Upper	76	50	37
Mean	62	41	31
Median	62	41	31

disappear if some efficiencies can be found. Depending on the significance and implementation feasibility of the efficiencies, all appointment schedules could be managed with four technicians. The idea will be to reduce the utilization of the technicians by grouping technical appointments so they only happen in the afternoon. Currently, technical appointments happen throughout the day. Suppose they are only scheduled to be conducted in the afternoon. Will the resulting scheduling allow technicians to more efficiently complete the surgeries in the morning and then do the same with technical appointments in the afternoon?

The other observation that will be tested is the surgery appointments. The current model has all the patients arriving at the same time in the morning, causing the patients to wait one at a time for the surgeon, which results in long sojourn time. In the second scenario, what will be explored is what happens if we build two surgery blocks. One block of two appointments is

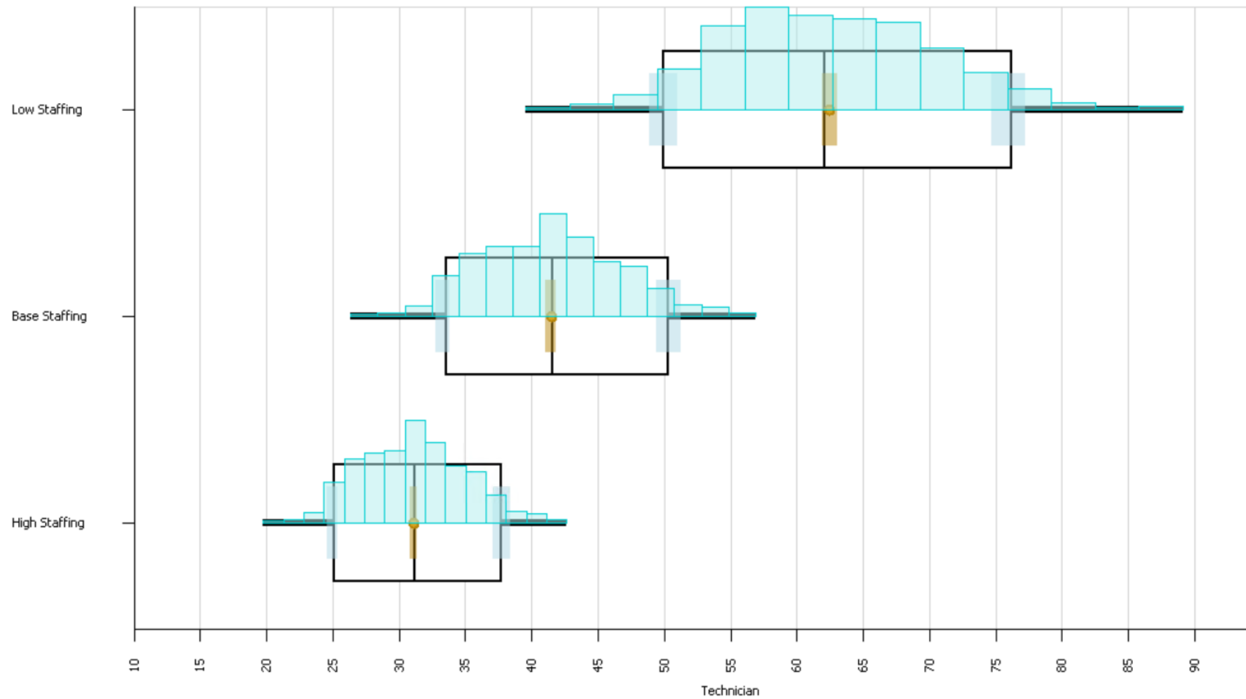

Figure 2.13: Technician Utilization Distribution for a Base Day

Table 2.10: Surgery Sojourn Values for a Base Day

	Low Staffing	Base Staffing	High Staffing
Min	48	46	46
Max	307	275	275
Lower	98	90.5	90.5
Upper	242	222	222
Mean	159	143	143
Median	151	134	134

scheduled in the morning, and one is scheduled in the afternoon.

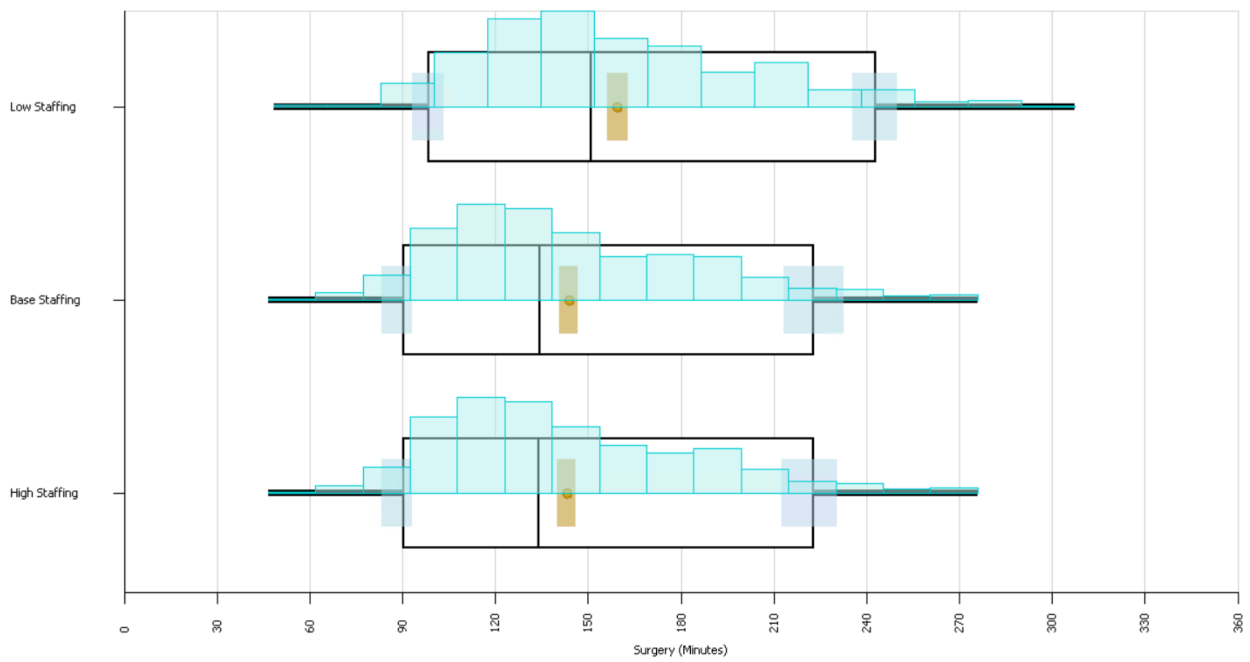

Figure 2.14: Base Model Surgery Sojourn time distributions

CHAPTER

3

ALTERNATIVE SCHEDULING STRATEGIES

In this chapter, two alternative scheduling strategies are examined in detail. Another staffing option of five technicians was also considered. The discussion will begin by outlining the design principles behind each strategy, focusing on the specific objectives and considerations that went into their development. Following this, we will analyze the results obtained from implementing each schedule. Specifically, this will encompass the quantitative outcomes of changes in sojourn time and staff utilization. Through this approach, the chapter aims to provide a nuanced understanding of how different scheduling strategies can impact clinic operations and identify potential avenues to improve overall clinic performance.

In general, the questions to be explored through schedule manipulation and then answered will be:

1. Will shifting technical appointments to only being in the afternoon improve the utilization of technicians to the point where low staffing would be feasible for other scheduled demands?

2. Could the implementation of a block surgery policy where the surgeries are separated into a morning and afternoon block improve not only surgery but other appointments sojourn time? Will utilization also decrease for the technician staff due to the morning stress being distributed throughout the day?

3.1 Alternative Scheduling Design

An attempt to improve operational efficiency was made by finding better scheduling strategies, specifically with regard to staff utilization and patient sojourn time. The proposed approach involves blocking appointments at different times throughout the day to address two main objectives.

The first goal is to attempt to reduce staff utilization to possibly reduce the needed staff while maintaining the same level of appointments and customer service. This goal seeks to cut operational costs and boost profits by maintaining the service level with an improved staffing model.

The second goal is to reduce the patients' sojourn time. Through strategic appointment blocking inspired by Slocum et al. (2021), the intention is to allocate sufficient time for complex or unpredictable appointments, thereby ensuring smoother transitions between patients and reducing wait times.

The general rules for these new schedules are to maintain the same number of appointments and staffing tested in Chapter 2 but shift when certain appointments happen to try to reduce staff utilization and sojourn time. The following strategies were developed in conjunction with the goals and rules described above.

3.1.1 Strategy One Overview

To try to address some inefficiencies in scheduling, strategy one looks specifically at when the technical appointments occur during the day. The current policy allows technical appointments to be scheduled throughout the day, including the mornings when technicians work on surgeries. This can cause conflicts for the technicians, as they will have to manage both surgery and technical appointments simultaneously. Due to the complexities of surgery, unforeseen issues may arise, lengthening the surgery time. This can cause issues if there is a technical appointment patient is waiting for a technician.

Strategy one moves all technical appointments to the afternoon. If all the technical appointments are moved to later in the day, the conflict between surgeries and technical appointments should not occur. The anticipated results of implementing this strategy are a reduction in the technicians' workload in the morning, which can improve efficiency elsewhere in the clinic, and then, in the afternoon, technicians can focus on technical appointments. Patient satisfaction should also increase due to a more predictable appointment flow.

Recall that technicians also still need to assist with wellness and medical appointments. Although strategy one is looking to reduce technician utilization and improve technical appointments, this approach may also introduce trade-offs by potentially increasing the sojourn

times of the other appointments. This shows the complexities of schedule planning and fully understanding the risks and trade-offs that a strategy may provide.

Note that strategy one will not be testing the easy appointment schedule as all the technical appointments are already scheduled in the afternoon for the base model easy appointment day.

3.1.2 Strategy Two Overview

Strategy two attempts to rearrange the surgery appointments to reduce the stress of busy mornings. The idea is to divide the surgery times into two separate blocks: one at the existing 8:30 am time slot and another at a new 12:30 pm time slot. The surgeries will be redistributed evenly across these two blocks, with two surgeries scheduled for the morning and two in the afternoon for the base and hard scheduled days. For an easy day, there will be two in the morning and one surgery in the afternoon.

The redistribution of the surgeries should "smooth" the workload from the busy mornings to throughout the entire day. The expected outcome is to see a reduction in sojourn time for surgeries and technical appointments because the resources are more balanced for the entire day.

A few assumptions and potential impacts need to be considered for strategy two. If pets need additional observation for rehab after surgery in the afternoon, they can stay overnight at the practice in the holding area of the clinic. Another assumption is that the animals have completed all pre-surgery preparation prior to the surgery, although acknowledging that it may be more difficult. For example, many procedures require the animals not to eat for 24 hours before surgery. This can be done more easily if the patient is taken to the clinic first thing in the morning. Lastly, further analysis of the impacts would need to be done to see if this is economical for the clinic or if there is a demand for owners to drop off pets in the afternoon. However, simulation results should demonstrate if this approach at least alleviates the staff stress and patient time in the clinic and warrants further consideration of other factors.

3.1.3 Alternate Schedule Construction

To see the morning and afternoon appointment blocks, see Table 3.1 for strategy one and Table 3.2 for strategy two. To see the full appointment schedule for these new strategies, see Appendix B, for all the appointment schedule scenarios.

Lastly, we introduced a new staffing level of five technicians to test these strategies. The reason for this choice is that through the testing and analysis in Chapter 2, there was a large variation in the results between the low and base staffing levels. Four technicians failed to

provide the operational stability needed for them to run the clinic, but six technicians seemed to exceed the capacity needed. It is worth investigating to see if five technicians create a potential ideal zone for the clinic, offering a balance for staff use. The five technicians are included in the following results, along with the low (4), base (6), and high (8) staffing levels from Chapter 2.

Table 3.1: Strategy One: Number of Appointments in Morning and Afternoon Appointment Blocks

	Easy Day		Base Day		Hard Day	
	AM	PM	AM	PM	AM	PM
Wellness	5	4	6	5	6	7
Medical	3	2	5	5	5	6
Technical	0	4	0	6	0	8
Surgery	3	0	4	0	4	0

Table 3.2: Strategy Two: Number of Appointments in Morning and Afternoon Appointment Blocks

	Easy Day		Base Day		Hard Day	
	AM	PM	AM	PM	AM	PM
Wellness	5	4	6	5	6	7
Medical	3	2	5	5	5	6
Technical	1	3	4	2	4	4
Surgery	2	1	2	2	2	2

3.2 Results and Analysis

The strategies will be compared individually to the base results to assess the impacts and effectiveness of the new staffing and scheduling policies. This comparison aims to identify each strategy's strengths and weaknesses and provide insights into potential benefits over the base model.

The evaluation process will use statistical analysis tools and the simulation results. The error bars depicting 95% confidence intervals for the mean provided in the bar charts will permit visualization of t-tests to tell if there is a statistically significant change. A change is

deemed statistically significant if the bars do not overlap with the base model, which in this case would overlap with the horizontal axis on the bar chart.

3.2.1 Strategy One Results versus the Base

The results from strategy one provided intriguing results. Contrary to the initial assumption, utilization remained relatively unchanged across all the model runs, including the technical staff. Upon reflection, this makes sense. The overall volume of scheduled work remains the same between the schedules did not change, so the result is consistent with what has been observed in the previous simulation. The original premise was that the technician's busyness caused doctors delays in appointments where both technicians and doctors are required to complete the procedure. This suggests that the clinic is either running at an efficient level or there are other factors causing inefficiencies. See Appendix E, Table E.4 for details on the staff utilization percentage change from the base model.

What changed was the sojourn time for some of the appointments. This suggests that the reorganization of tasks does have an effect on the patient experience. The largest reduction in sojourn time came from the technical appointments, showing that a restructured appointment strategy can improve patient flow for certain tasks. Figure 3.1 shows the reduction in the sojourn time from strategy one from the base model, illustrating the impacts of schedule changes.

3.2.2 Strategy Two Results Versus the Base

Strategy Two provided results that were partially consistent with those of Strategy One. The utilization, again, did not change significantly. However, a change can be observed in the sojourn time for some appointments, specifically the surgery and technical appointments. The surgery sojourn time was lowered in all the Strategy Two models, and the technical appointments reduced time in the four and the five technician staffing levels. See Figure 3.2 for all the sojourn time changes.

The change in surgery times can be attributed to the even surgery split in the mornings and afternoons. This reduces the waiting time for treatment, and patient care is enhanced by minimizing waiting for the procedure. In the base model, the doctor can only work on one patient at a time, so the patients in line build up a long sojourn time.

This strategy change appears to create a smoother operation in the clinic and can also be viewed as scheduling flexibility for pet owners. This strategy allows owners to decide when to pick up their pets based on their schedule. This will also reduce boarding maintenance time, where technicians typically have to spend time providing primary care—such as bathroom breaks, cleaning, and providing food and water—and instead spend time on other critical tasks.

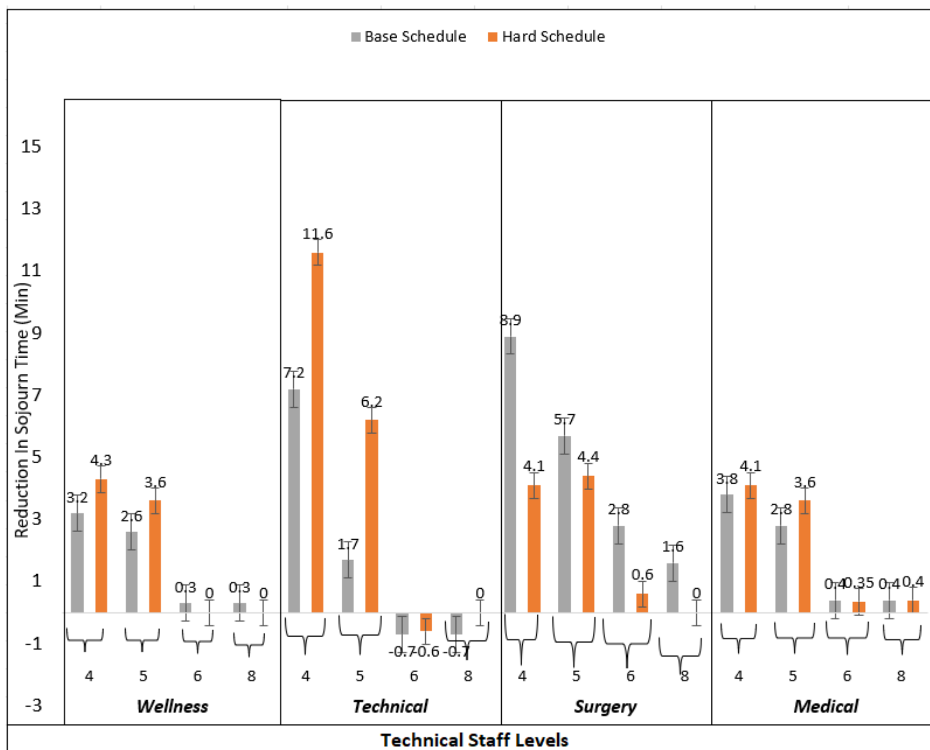

Figure 3.1: (color online) Scenario One: Reduction in Sojourn Time. The positive value is the reduction in appointment times in minutes. The technical staffing is depicted in the horizontal axis.

Lastly, the redistribution of surgery times allows the clinic to better cater its service offerings to the patients. For example, if patients need a longer observation time, the clinic can decide to observe afternoon patients overnight. This option could allow the clinic to do more complicated and expensive surgeries. However, some considerations about overnight staffing and associated costs would have to be made.

Similarly, suppose the clinic does not want to do overnight observations of patients. In that case, the clinic can choose to do surgeries that generally are faster in the afternoon and can be completed and rehabilitated before the end of the day. For example, neuters and spays are relatively quick and with a lower risk of complications because they are some of the most completed surgeries. These could be good options for afternoon procedures.

Technical appointments also see a positive impact from this strategy, particularly under a four-technician staffing day. From the analysis, the clinic would benefit from exploring the potential of these schedule changes. The clinic would need to do some additional analysis to see if this strategy would be feasible and align with the goals of the business, but there are many possible upsides. The model shows the possibility of improving sojourn time, improving patient flexibility and care, and offering more enhanced healthcare options. Exploring this strategy could enhance the clinic's competitiveness and economic standing in the local area.

3.2.3 Five-Technician Staffing

Lastly, the five-technician staffing variation did not produce results as anticipated. Utilization was reduced from the low staff variation, but sojourn did not reduce across the appointments. This can be attributed to the requirement that all appointments require at least two technicians to complete. While four technicians are occupied with appointments, the fifth technician remains cannot begin an appointment until one of the other appointments is complete. This operational constraint results in sojourn times similar to the four-technician staffing level. With these findings, it is not advisable to use this staffing level unless there are clinic policy adjustments regarding the minimum number of technicians who can work on certain appointments.

3.2.4 Summary of Results

The results found in these strategies allowed us to answer the questions from the beginning of the chapter. Through experimentation, it was found that strategy one did not reduce utilization in any significant way, but it did improve sojourn time, especially when considering technical appointments. Strategy two also did not reduce utilization but reduced sojourn time in all appointments. The results were comparable to strategy one, except for surgery appointments.

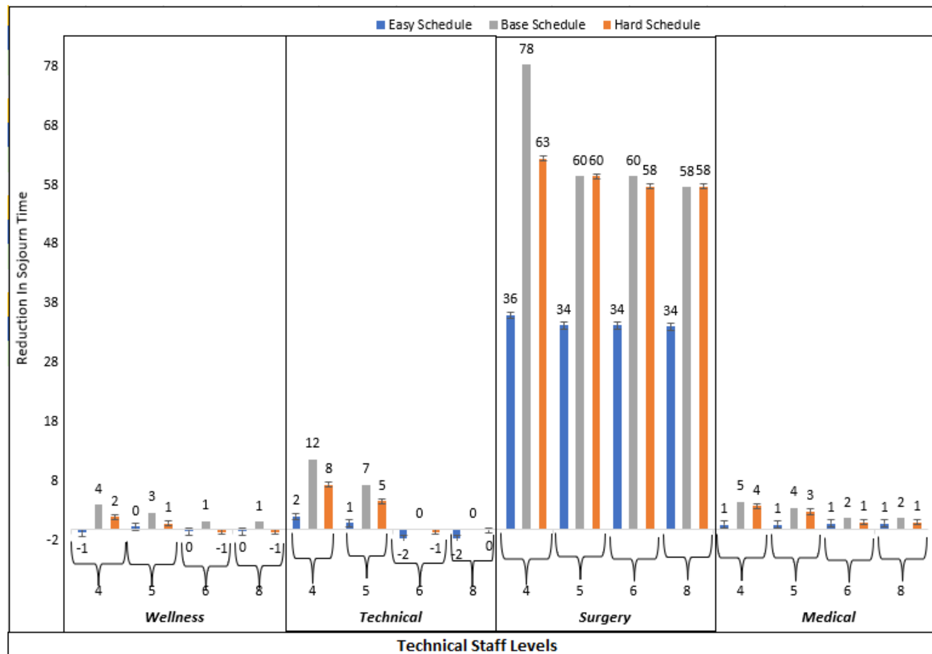

Figure 3.2: Scenario Two: Reduction in Sojourn Time. The positive values are the reduction in appointment times in minutes. The technical staffing is depicted in the horizontal axis.

Surgery appointments had large reductions in sojourn time due to patients only having to wait behind one other appointment instead of three. Strategy two would require additional business analysis and a deeper observation of customer satisfaction metrics due to the large changes in operations required to implement this strategy effectively.

CHAPTER

4 CONCLUSION AND FUTURE WORK

4.1 Conclusions

The experimentation in this research observed the effects of strategic appointment scheduling and staffing on a veterinarian clinic's operations. By observing a mixture of differently planned strategies and staffing, the research shows that operations can be improved. First, the paper looked at how the model handles the schedule across three separate days: an easy, base, and hard appointment day. This is then also compared against different technician staffing totals of low, base, and high staffing, which translates to four, six, and eight technicians, respectively. A staffing level of five technicians was added when simulating the additional scenarios to try and find an ideal zone for staffing. This research shows that clinics have the opportunity to improve their policies to still meet their business goals while supporting the well-being of the staff and the patients.

Staffing Recommendations The analysis of the results would recommend using low staffing for an easy appointment day. With the low staffing, utilization for technicians is at 49% while for the doctors is at 52% and 42%. Even when considering the additional tasks needed throughout the day, there is enough unused time to feel confident it will all get completed. There may be the opportunity to change the policy to two technicians per doctor and use only three

technicians for the easy day. The utilization should still be low enough to feel comfortable, but some procedures may need to change to account for a doctor only having one technician helping with appointments. The low appointment schedule could be viewed as a "break" day, providing an opportunity for clinic staff to complete other accumulating tasks after a sequence of hard days. The trade-off of this schedule with a low staff is that fewer appointments translate to less revenue and possibly a more considerable backlog as new customers continue to call in for appointments.

Low staffing can still be used for a typical "base" day if only looking at the utilization, which approaches 70% for technicians. Assuming the general clinic upkeep remains around 10–15% of the technician's day, operations are expected to continue smoothly. However, issues arise when looking at sojourn time for technical appointments. Analyzing the low staffing base model results, the technical appointment time jumps to 30 minutes, which is over a 200% increase. The significant jump in time would require the clinic to evaluate the trade-offs between reduced staffing and the impact of technical sojourn time. If extended sojourn times are deemed unacceptable, base staffing would be ideal, but the utilization may be lower than ideal. Sojourn time remains consistent once base staffing is used, regardless of the appointment schedule.

Lastly, for a hard day, the utilization of technicians if there is low staffing is at 75%. This may be too high to be reliably used when considering other clinic tasks. It is advisable that the clinic looks at what non-essential tasks could be reduced or removed for a hard appointment day if they want to use a low staffing level. Otherwise, the base staffing becomes the best choice to ensure the completion of all tasks without straining the staff resources too high. The base staff provides a more manageable workload and ensures that the sojourn time for the technical appointments remains close to ten minutes. While the low staffing option is not unfeasible for a hard schedule day, the clinic needs to analyze how to prioritize tasks and what additional responsibilities need to be deferred if the technicians get overwhelmed with their appointments. It is advisable to keep the base staffing if the clinic cannot create strategies and policies to alleviate these possible stressors and reduce turnover in the long run for the clinic.

Appointment Scheduling Next, this paper experimented with blocking different appointments into different time periods during the day. The purpose was to see if utilization and sojourn time could be improved to the point that either staff could be reduced or that sojourn time could be reduced enough to add another appointment and possibly increase revenue. The appointment volume remained the same as the models tested in Chapter 2, with the primary adjustment being the movement of certain appointments to different periods of the day. Also added to the test is having a five-technician staffing option.

All technical appointments were scheduled exclusively in the afternoon in the first alternative strategy tested. This schedule attempts to alleviate the technicians' stress in the morning. In the base model, technicians must help with all appointments, whereas in this strategy, technicians can focus on surgeries in the morning and technical appointments in the afternoon. Despite these changes, the utilization remained relatively unchanged from the base model. A notable change in sojourn time is observed, with a reduced technical time of nearly 8 and 12 minutes in the models using low staffing for both the base and hard appointment days. This may suggest a solution that the clinic can implement if they want to schedule a low staff regularly for hard appointment days.

The second strategy explored redistributing the surgery appointments from only being in the morning to having a morning and afternoon block. The change was aimed at finding a balance of the workload throughout the day. The results showed that the utilization remained generally the same, but the most significant difference was the surgery appointment sojourn time. Surgery patient sojourn time was reduced in all models and staffing levels by over 30 minutes.

On the surface, this initially seems advantageous, and this approach should be implemented. However, when considering the base model where all the surgery patients arrive at the same time in the morning, a realization occurs that there will always be longer sojourn time due to the sequential patient processing. This is because the doctor can only work on one patient at a time, causing the following patients to wait and extending the average sojourn time. By distributing surgeries, the sojourn time is reduced because there is only one patient in the queue awaiting treatment at any time. This method can give the clinic flexibility if they want to explore other options to make this strategy more feasible.

Implementing this block strategy for surgeries offers the clinic and owners flexibility in scheduling. The clinic can potentially explore the addition of more complex surgeries that require longer recovery times by using the afternoon time slot for those procedures. Similarly, owners can better plan when to have these surgeries completed according to their schedules. Clinics will need to do some feasibility analysis and consider if the associated costs are worth the possible improvements.

Lastly, the additional testing of five technician staff levels resulted in some mixed results. Some results actually returned worse than the low technician level. After some contemplation, the results are most likely due to the policy that every procedure requires at least two technicians to be completed. Utilization will still be relatively high with five technicians because, in the model, the fifth technician is seized and being utilized even though the appointment cannot be completed. That technician has to wait for one of the other technicians to be released to complete the appointment. This problem extends then to sojourn time as well. Similar to

the three-technician discussion earlier in this chapter, the clinic would need to reevaluate its appointment policy to possibly make this option more viable.

If clinics can reduce daily staffing but maintain appointment throughput, they will retain revenue, reduce costs, and allow better flexibility for staff scheduling. For example, the clinic could employ six technicians but be able to rotate them and provide hours that may be better for their work-life balance. The same could be said for doctors. Suppose the clinic can generate more revenue from implementing this policy. In that case, it may be able to hire a part-time veterinarian to help take the workload off of the other doctors. Using this DES method shows that clinics can test the complexities of scheduling and staffing to improve worker retention while still maintaining their service to meet the growing demand of the veterinarian business.

4.2 Future Work

This research examines one small clinic in the suburban setting of Des Moines, Iowa. The results could be used in similar-sized clinics and demands to make generalized assumptions. The direct applicability of these results to other veterinary practices may not translate. Practices whose size, location, or services available, such as a large city clinic or a 24-hour emergency clinic, will need a more tailored model with those unique characteristics considered.

Although this research presents some business considerations for the implementation of the alternate schedules, a more in-depth analysis should be completed to truly get a sense of the scope of changes the clinic may encounter. The clinic should look at both the qualitative and quantitative side of these possible changes.

A variable that would be worth considering is how the clinic would handle emergency appointments. Although rare in the Ankeny clinic's current operations, emergencies do come in, and the clinic treats the patients if it is equipped for the emergency. An analysis would need to be done on how frequently emergencies occur and then how to queue emergencies in the system. This could be done with a prioritization method where the emergency appointment will be treated once the next doctor is available and the other appointments are moved back in the queue. The rate of emergencies could be increased or decreased to better understand how the clinic could currently handle emergencies, and then policies could be developed around those results to better handle emergencies.

Investigating the long-term effects of certain schedules presents a promising area for future research. A more robust DES that can simulate the clinic dynamics and schedules over a period of multiple days could offer better insights into the sustainability and operational effectiveness of the various scheduling configurations. A way to consider doing this is by inserting an easy appointment day among a period of hard appointment days to see the long-term benefits or

issues that can arise. Additional metrics would also be worth consideration. For example, the percentage of time a patient is still in the system when the clinic is supposed to close. With this information, the clinic can better anticipate the possible amount of overtime needed over a period of time. Also, it may be valuable to employ conditional value at risk (CVAR) styled metrics at the tails of the sojourn results, which could provide better insights into the expected worst-case scenarios the clinic can see.

To build these multi-day schedules, either a similar schedule could be built based on the methods described in this research, or the schedules could be automatically generated based on the distributions of the appointments seen through the collected data. This can allow a more dynamic look at the varying demands the clinic can see and can provide a better way to understand how different days can affect staff utilization and patient care.

Furthermore, variable staffing would be a topic of interest to investigate further. The ability to adjust staffing based on the time of day or to the planned demand could offer the clinic other ways to improve operational efficiencies. An example of this is having more staff in the mornings to handle the high morning demand and then reducing the staff in the afternoon when demand tends to decrease. This approach could reduce the clinic's costs and provide more flexible scheduling for the staff.

Lastly, a more detailed look at the clinic's staffing policies for appointments could be made. This refers to how the current clinic policy has two technicians assigned to every appointment. The simulation could show how the system reacts to a different amount of technicians assigned to appointments. A more detailed investigation into the data of different appointments would need to be done. For example, maybe technical appointments with only a shot being administered could be completed with one technician. This could be possible to model but may be harder to identify through the current data collected.

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APPENDICES

APPENDIX

A

ACRONYMS

A summary of all acronyms is documented in Table A.1.

Table A.1: A summary of acronyms used in alphabetical order.

Acronym	Abbreviation
Ankeny Animal Health Clinic	AAHC
American Society for the Prevention of Cruelty to Animals	ASPCA
American Veterinarian Medical Association	AVMA
Conditional Value at Risk	CVAR
Discrete Event Simulation	DES
Key Performance Item	KPI
Subject Matter Expert	SME

APPENDIX

B

APPOINTMENT SCHEDULES

This appendix contains the typical appointment schedule (Table B.1) along with the Easy (Table B.2) and Hard (Table B.3) schedules taken from clinic data. Also included in this appendix are the alternate scenarios tested. Scenario one's base and hard schedule can be found in Tables B.4 and B.5. Scenario two's easy, base, and hard schedules can be found in Table's B.6, B.7, and B.8 respectively.

Table B.1: Typical Appointment Schedule

Appointment Times	Appointment Types	Entities
8:00 am	Wellness	1
8:15 am	Medical	1
8:30 am	Surgery	4
8:45 am	Wellness	1
9:00 am	Medical	1
9:15 am	Technical	1
9:30 am	Wellness	1
9:45 am	Medical	1
10:00 am	Technical	1
10:15 am	Wellness	1
10:30 am	Medical	1
10:45 am	Technical	1
11:00 am	Wellness	1
11:15 am	Medical	1
11:30 am	Technical	1
11:45 am	Wellness	1
12:00 pm	Medical	1
12:15 pm	Technical	1
12:30 pm	Wellness	1
12:45 pm	Medical	1
1:00 pm	Technical	1
1:15 pm	Wellness	1
1:30 pm	Medical	1
2:00 pm	Wellness	1
2:15 pm	Medical	1
2:45 pm	Wellness	1
3:00 pm	Medical	1
3:30 pm	Wellness	1
3:45 pm	Medical	1

Table B.2: Easy Appointment Schedule

Appointment Times	Appointment Types	Entities
8:00 am	Wellness	1
8:30 am	Surgery	3
9:00 am	Wellness	1
9:15am	Medical	1
9:45 am	Wellness	1
10:00 am	Medical	1
10:30 am	Wellness	1
10:45 am	Medical	1
11:15 am	Wellness	1
11:30 am	Medical	1
12:00 pm	Wellness	1
12:15 pm	Technical	1
12:30 pm	Technical	1
12:45 pm	Wellness	1
1:00 pm	Medical	1
1:15 pm	Wellness	1
1:45 pm	Medical	1
2:15 pm	Medical	1
2:45 pm	Medical	1

Table B.3: Hard Appointment Schedule

Appointment Times	Appointment Types	Entities
8:00 am	Wellness	1
8:15 am	Medical	1
8:30 am	Surgery	4
8:45 am	Wellness	1
9:00am	Medical	1
9:15 am	Technical	1
9:30 am	Wellness	1
9:45 am	Medical	1
10:00 am	Technical	1
10:15 am	Wellness	1
10:30 am	Medical	1
10:45 am	Technical	1
11:00 am	Wellness	1
11:15 am	Medical	1
11:30 am	Technical	1
11:45 am	Wellness	1
12:00 pm	Medical	1
12:15 pm	Technical	1
12:30 pm	Wellness	1
12:45 pm	Medical	1
1:00 pm	Technical	1
1:15 pm	Wellness	1
1:30 pm	Medical	1
1:45 pm	Wellness	1
1:50 pm	Technical	1
2:00 pm	Wellness	1
2:15 pm	Medical	1
2:45 pm	Wellness	1
3:00 pm	Medical	1
3:15 pm	Wellness	1
3:20 pm	Technical	1
3:30 pm	Wellness	1
3:45 pm	Medical	1

Table B.4: Scenario 1 Base Schedule: Moving technical appointments to the afternoon

Appointment Times	Appointment Types	Entities
8:00 am	Wellness	1
8:15 am	Medical	1
8:30 am	Surgery	4
8:45 am	Wellness	1
9:00 am	Medical	1
9:30 am	Wellness	1
9:45 am	Medical	1
10:15 am	Wellness	1
10:30 am	Medical	1
11:00 am	Wellness	1
11:15 am	Medical	1
11:45 am	Wellness	1
12:00 pm	Medical	1
12:05 pm	Technical	1
12:15 pm	Technical	1
12:30 pm	Wellness	1
12:40 pm	Technical	1
12:45 pm	Medical	1
1:00 pm	Technical	1
1:15 pm	Wellness	1
1:25 pm	Technical	1
1:30 pm	Medical	1
2:00 pm	Wellness	1
2:10 pm	Technical	1
2:15 pm	Medical	1
2:45 pm	Wellness	1
3:00 pm	Medical	1
3:30 pm	Wellness	1
3:45 pm	Medical	1

Table B.5: Scenario 1 Hard Schedule: Moving technical appointments to the afternoon

Appointment Times	Appointment Types	Entities
8:00 am	Wellness	1
8:15 am	Medical	1
8:30 am	Surgery	4
8:45 am	Wellness	1
9:00am	Medical	1
9:30 am	Wellness	1
9:45 am	Medical	1
10:15 am	Wellness	1
10:30 am	Medical	1
11:00 am	Wellness	1
11:15 am	Medical	1
11:45 am	Wellness	1
12:00 pm	Medical	1
12:15 pm	Technical	1
12:30 pm	Wellness	1
12:45 pm	Medical	1
1:00 pm	Technical	1
1:15 pm	Wellness	1
1:20 pm	Technical	1
1:30 pm	Medical	1
1:45 pm	Wellness	1
1:50 pm	Technical	1
2:00 pm	Wellness	1
2:05 pm	Technical	1
2:15 pm	Medical	1
2:40 pm	Technical	1
2:45 pm	Wellness	1
3:00 pm	Medical	1
3:15 pm	Wellness	1
3:20 pm	Technical	1
3:30 pm	Wellness	1
3:40 pm	Technical	1
3:45 pm	Medical	1

Table B.6: Scenario 2 Easy Schedule: Creating two surgery blocks, a morning block, and an afternoon block.

Appointment Times	Appointment Types	Entities
8:00 am	Wellness	1
8:30 am	Surgery	2
9:00 am	Medical	1
9:15am	Wellness	1
9:45 am	Medical	1
10:00 am	Wellness	1
10:30 am	Technical	1
10:45 am	Wellness	1
11:15 am	Medical	1
11:30 am	Wellness	1
12:00 pm	Technical	1
12:15 pm	Wellness	1
12:30 pm	Medical	1
12:30 pm	Surgery	1
12:45 pm	Wellness	1
1:00 pm	Technical	1
1:15 pm	Medical	1
1:45 pm	Technical	1
2:15 pm	Wellness	1
2:45 pm	Wellness	1

Table B.7: Scenario 2 Base Schedule: Creating two surgery blocks, a morning block, and an afternoon block.

Appointment Times	Appointment Types	Entities
8:00 am	Wellness	1
8:15 am	Medical	1
8:30 am	Surgery	2
8:45 am	Wellness	1
9:00 am	Medical	1
9:15 am	Technical	1
9:30 am	Wellness	1
9:45 am	Medical	1
10:00 am	Technical	1
10:15 am	Wellness	1
10:30 am	Medical	1
10:45 am	Technical	1
11:00 am	Wellness	1
11:15 am	Medical	1
11:30 am	Technical	1
11:45 am	Wellness	1
12:00 pm	Medical	1
12:15 pm	Technical	1
12:30 pm	Wellness	1
12:30 pm	Surgery	2
12:45 pm	Medical	1
1:00 pm	Technical	1
1:15 pm	Wellness	1
1:30 pm	Medical	1
2:00 pm	Wellness	1
2:15 pm	Medical	1
2:45 pm	Wellness	1
3:00 pm	Medical	1
3:30 pm	Wellness	1
3:45 pm	Medical	1

Table B.8: Scenario 2 Hard Schedule: Creating two surgery blocks, a morning block, and an afternoon block.

Appointment Times	Appointment Types	Entities
8:00 am	Wellness	1
8:15 am	Medical	1
8:30 am	Surgery	2
8:45 am	Wellness	1
9:00am	Medical	1
9:15 am	Technical	1
9:30 am	Wellness	1
9:45 am	Medical	1
10:00 am	Technical	1
10:15 am	Wellness	1
10:30 am	Medical	1
10:45 am	Technical	1
11:00 am	Wellness	1
11:15 am	Medical	1
11:30 am	Technical	1
11:45 am	Wellness	1
12:00 pm	Medical	1
12:15 pm	Technical	1
12:30 pm	Wellness	1
12:30 pm	Surgery	2
12:45 pm	Medical	1
1:00 pm	Technical	1
1:15 pm	Wellness	1
1:30 pm	Medical	1
1:45 pm	Wellness	1
1:50 pm	Technical	1
2:00 pm	Wellness	1
2:15 pm	Medical	1
2:45 pm	Wellness	1
3:00 pm	Medical	1
3:15 pm	Wellness	1
3:20 pm	Technical	1
3:30 pm	Wellness	1
3:45 pm	Medical	1

APPENDIX

C

DISTRIBUTION ANALYSIS

C.1 Wellness Appointment Distribution selection

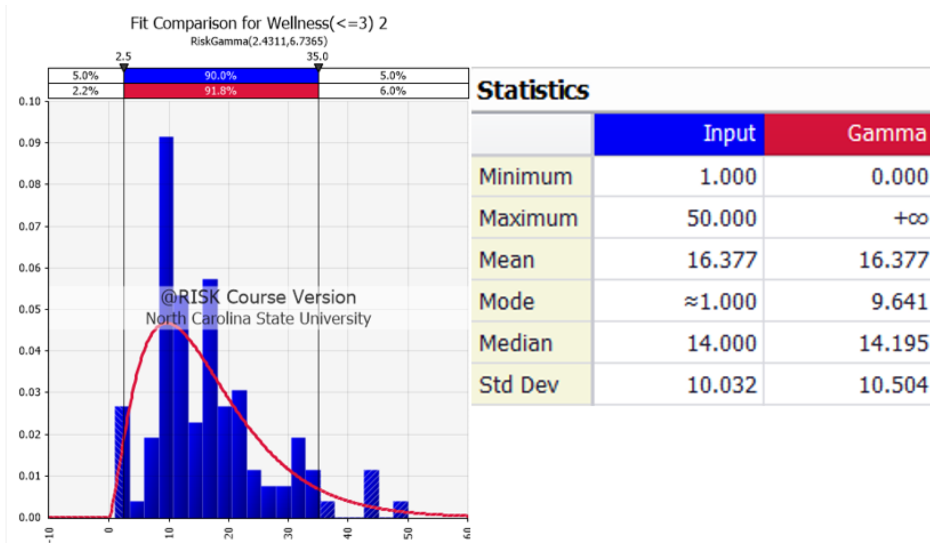
Figure C.1 is based on 111 data points after appointments that are less than three minutes removed. The Pearson Chi-square test returned good values and had a P-value of 0.268.

C.2 Medical Appointment Distribution selection

Figure C.2 shows the distribution for medical appointments. The selection is based on 81 data points. It ranked the highest in the @Risk distribution of fit tests with a P-value of 0.451 for the Pearson Chi-square test.

C.3 Technical Appointment Distribution selection

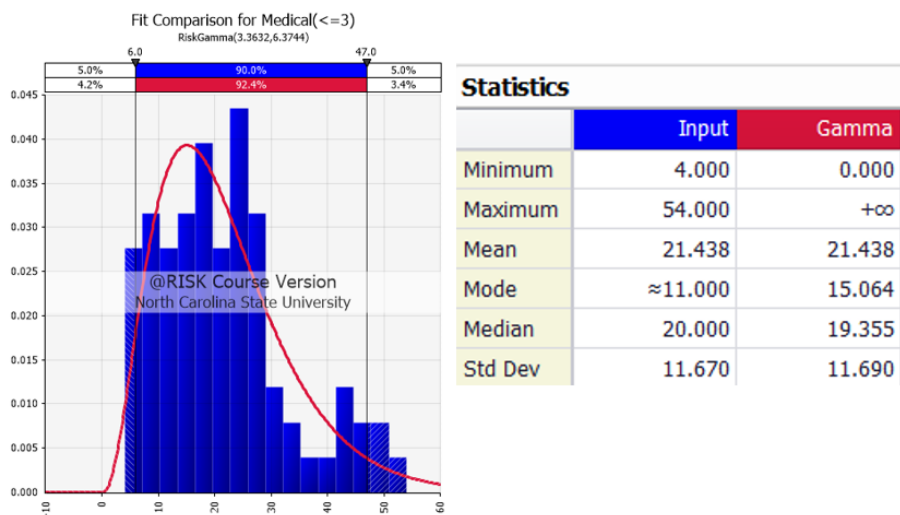
Figure C.3 shows the distribution for technical appointments. The selection is based on 52 data points and a high ranking on the goodness of fit tests run on @Risk. The data presents an exponential fit with many short appointments—zero to ten minutes in length—and a few longer appointments that exceed 10 minutes.



Statistics

	Input	Gamma
Minimum	1.000	0.000
Maximum	50.000	+∞
Mean	16.377	16.377
Mode	≈1.000	9.641
Median	14.000	14.195
Std Dev	10.032	10.504

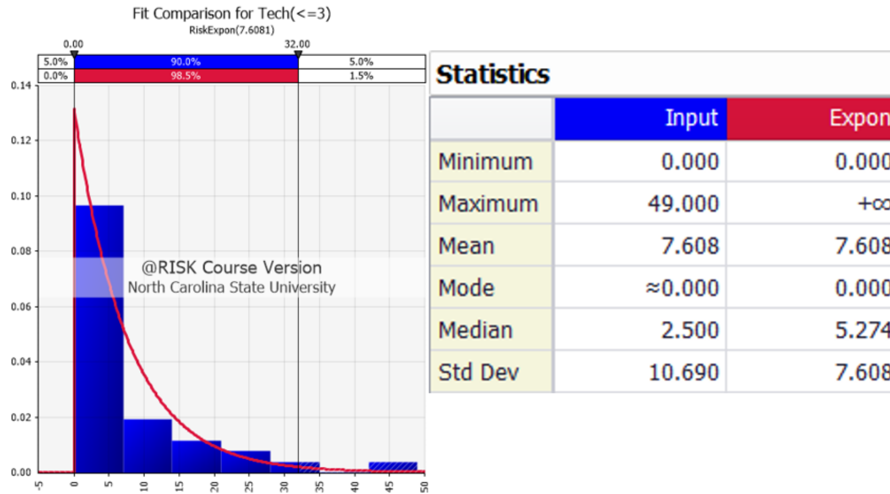
Figure C.1: Wellness Appointment Time Distribution



Statistics

	Input	Gamma
Minimum	4.000	0.000
Maximum	54.000	+∞
Mean	21.438	21.438
Mode	≈11.000	15.064
Median	20.000	19.355
Std Dev	11.670	11.690

Figure C.2: Medical Appointment Time Distribution



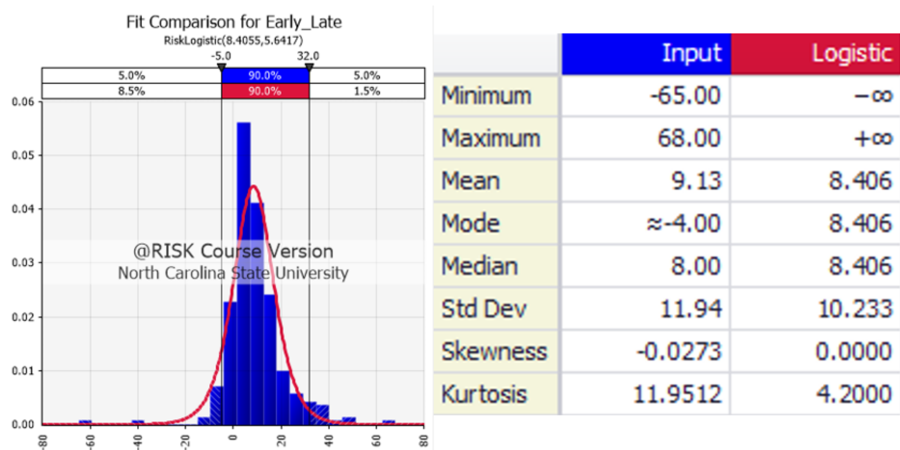
Statistics

	Input	Expon
Minimum	0.000	0.000
Maximum	49.000	+∞
Mean	7.608	7.608
Mode	≈0.000	0.000
Median	2.500	5.274
Std Dev	10.690	7.608

Figure C.3: Technical Appointment Time Distribution

C.4 Distribution of Patient Arrivals

Lastly, Figure C.3 shows the distribution for technical appointments. The selection is based on 260 patients' arrival times, based on minutes away from being on time. Negative minutes represent how many minutes late a patient was and positive minutes show how many minutes early a patient was. Again, appointments under three minutes were deemed an administrative error and removed from this data set. The logistic distribution generally fits the data well with long tails to account for some appointments that were very late or early. It ranks high on the Pearson Chi-square test. The p-value was $p < 0.05$, but the distribution was still the best fit that worked in Simio.



	Input	Logistic
Minimum	-65.00	−∞
Maximum	68.00	+∞
Mean	9.13	8.406
Mode	≈-4.00	8.406
Median	8.00	8.406
Std Dev	11.94	10.233
Skewness	-0.0273	0.0000
Kurtosis	11.9512	4.2000

Figure C.4: Variation in Arrival Times Distribution (negative times indicate late arrivals).

APPENDIX

D

EXPERIMENTS

In this section, the experiments will be shown in figures. Each experiment was run for 750 replications.

Appointment Schedule	Staff Level
Easy	Low
Easy	Base
Easy	High
Base	Low
Base	Base
Base	High
Hard	Low
Hard	Base
Hard	High

Total Replications	Approximate Runtime (Min)
6750	22.5

Figure D.1: The original schedules experiments run

Strategy One	
Appointment Demand	Staff Level
Base	4
Base	5
Base	6
Base	8
Hard	4
Hard	5
Hard	6
Hard	8

Total Replications	Approximate Runtime (Min)
6000	20

Strategy Two	
Appointment Demand	Staff Level
Easy	4
Easy	5
Easy	6
Easy	8
Base	4
Base	5
Base	6
Base	8
Hard	4
Hard	5
Hard	6
Hard	8

Total Replications	Approximate Runtime (Min)
9000	30

Figure D.2: The experiments run with the alternative schedules developed

APPENDIX

E

RESULTS

This appendix will show the raw results and differences between the other models. In general, the results will be laid out as follows:

1. Easy Model Results
2. Base Model Results
3. Hard Model Results
4. Scenario one results
5. Scenario two results

E.1 Easy Model Results

Table E.1: Easy Model Results

Name		Values				Mean Confidence			Lower Percentile			Upper Percentile		
Scenario Na...	Response N...	Mean	Median	Minimum	Maximum	Half Width	Mean CI Be...	Mean CI End	Lower Value	Lower CI St...	Lower CI End	Upper Value	Upper CI St...	Upper CI End
Low Staffing	Surgery	1.95519315...	1.84583942...	0.86881678...	3.37689990...	0.11180094...	1.84339221...	2.06699410...	1.57266672...	1.47892388...	1.64111773...	2.21911560...	2.09995536...	2.55988487...
Low Staffing	Technical	0.19835860...	0.15368390...	0.06240994...	0.82732186...	0.02662523...	0.17173337...	0.22498383...	0.11824407...	0.10673839...	0.12416442...	0.21851848...	0.18153872...	0.29271689...
Low Staffing	Medical	0.41682257...	0.40278548...	0.22882902...	0.72434751...	0.02029589...	0.39652667...	0.43711846...	0.34717432...	0.32543239...	0.36966598...	0.48709020...	0.44467035...	0.52689728...
Low Staffing	Wellness	0.30594188...	0.28564278...	0.16884023...	0.59307928...	0.01695594...	0.28898593...	0.32289783...	0.24340065...	0.22544445...	0.26183275...	0.36862607...	0.33227256...	0.40391402...
Low Staffing	Technician	44.4604673...	43.8966270...	30.1794793...	61.0355026...	1.24430751...	43.2161598...	45.7047748...	40.7948821...	38.3878834...	41.6787935...	48.8757397...	46.5415077...	50.0716006...
Low Staffing	Dr2	38.3885445...	38.0142938...	15.4821056...	59.1434745...	1.59337842...	36.7951661...	39.9819230...	33.3792263...	31.5788928...	34.5784026...	43.9178407...	40.4269468...	47.4981842...
Low Staffing	Dr1	46.9486760...	46.9125615...	29.7158233...	64.2518564...	1.41502375...	45.5336522...	48.3636997...	42.4630187...	40.2629496...	43.8075342...	51.4761471...	49.6405630...	54.6100139...
Base Staffing	Surgery	1.79423463...	1.71340994...	0.80322500...	3.17677561...	0.10724254...	1.68699209...	1.90147717...	1.45212463...	1.36141806...	1.51106154...	1.97878611...	1.86803757...	2.33368957...
Base Staffing	Technical	0.18464215...	0.15186247...	0.06240994...	0.76858886...	0.02452704...	0.16011510...	0.20916919...	0.11493347...	0.09898845...	0.12155806...	0.19731781...	0.17320497...	0.26140140...
Base Staffing	Medical	0.41398208...	0.40186066...	0.24092175...	0.72391093...	0.02001000...	0.39397207...	0.43399209...	0.34389794...	0.32479477...	0.36436466...	0.48063509...	0.45361805...	0.51988171...
Base Staffing	Wellness	0.30240958...	0.28494409...	0.16884023...	0.59030365...	0.01633784...	0.28607174...	0.31874742...	0.24260700...	0.22544445...	0.26130832...	0.36312946...	0.33199556...	0.38729147...
Base Staffing	Technician	29.6649193...	29.4135438...	20.1196529...	39.8687203...	0.80879767...	28.8561216...	30.4737170...	27.3818418...	25.6774929...	27.9331953...	32.6048290...	31.1529745...	33.4987399...
Base Staffing	Dr2	38.4908156...	38.1503455...	15.4821056...	55.8431116...	1.58650667...	36.9043090...	40.0773223...	33.3792263...	31.1755132...	34.8005592...	44.0416666...	41.7407116...	47.4981842...
Base Staffing	Dr1	46.9889808...	46.5878110...	29.7158233...	64.1132804...	1.39048193...	45.5984988...	48.3794627...	42.5518784...	40.5440290...	43.5327893...	51.4761471...	49.6405630...	54.4199346...
High Staffing	Surgery	1.79423463...	1.71340994...	0.80322500...	3.17677561...	0.10724254...	1.68699209...	1.90147717...	1.45212463...	1.36141806...	1.51106154...	1.97878611...	1.86803757...	2.33368957...
High Staffing	Technical	0.18464215...	0.15186247...	0.06240994...	0.76858886...	0.02452704...	0.16011510...	0.20916919...	0.11493347...	0.09898845...	0.12155806...	0.19731781...	0.17320497...	0.26140140...
High Staffing	Medical	0.41398208...	0.40186066...	0.24092175...	0.72391093...	0.02001000...	0.39397207...	0.43399209...	0.34389794...	0.32479477...	0.36436466...	0.48063509...	0.45361805...	0.51988171...
High Staffing	Wellness	0.30240958...	0.28494409...	0.16884023...	0.59030365...	0.01633784...	0.28607174...	0.31874742...	0.24260700...	0.22544445...	0.26130832...	0.36312946...	0.33199556...	0.38729147...
High Staffing	Technician	22.2486894...	22.0601578...	15.0897396...	29.9015402...	0.60659825...	21.6420912...	22.8552877...	20.5363814...	19.2581197...	20.9498964...	24.4536217...	23.3647309...	25.1240549...
High Staffing	Dr2	38.4908156...	38.1503455...	15.4821056...	55.8431116...	1.58650667...	36.9043090...	40.0773223...	33.3792263...	31.1755132...	34.8005592...	44.0416666...	41.7407116...	47.4981842...
High Staffing	Dr1	46.9889808...	46.5878110...	29.7158233...	64.1132804...	1.39048193...	45.5984988...	48.3794627...	42.5518784...	40.5440290...	43.5327893...	51.4761471...	49.6405630...	54.4199346...
Alternative ...	Surgery	1.79423463...	1.71340994...	0.80322500...	3.17677561...	0.10724254...	1.68699209...	1.90147717...	1.45212463...	1.36141806...	1.51106154...	1.97878611...	1.86803757...	2.33368957...
Alternative ...	Technical	0.19740800...	0.15283721...	0.06240994...	0.92398998...	0.02726682...	0.17014118...	0.22467483...	0.11824407...	0.10570963...	0.12416442...	0.21851848...	0.18153872...	0.28954203...
Alternative ...	Medical	0.41429225...	0.40248786...	0.24092175...	0.72391093...	0.01998008...	0.39431216...	0.43427233...	0.34422457...	0.32479477...	0.36436466...	0.48063509...	0.45361805...	0.51988171...
Alternative ...	Wellness	0.30289756...	0.28494409...	0.16884023...	0.59181932...	0.01640564...	0.28649191...	0.31930320...	0.24260700...	0.22544445...	0.26130832...	0.36312946...	0.33199556...	0.39420307...
Alternative ...	Technician	35.6242946...	35.2962526...	24.1435834...	48.8284021...	0.98192474...	34.6423699...	36.6062194...	32.8582102...	30.8129915...	33.5198343...	39.1257948...	37.3835694...	40.1984879...
Alternative ...	Dr2	38.4948874...	38.1503455...	15.4821056...	55.8431116...	1.59692482...	36.8979626...	40.0918122...	33.3792263...	31.1755132...	34.5784026...	44.0416666...	41.7407116...	47.4981842...
Alternative ...	Dr1	46.9987740...	46.5878110...	29.7158233...	64.2518564...	1.38396097...	45.6148130...	48.3827350...	42.5518784...	40.5440290...	43.8075342...	51.4761471...	49.6405630...	54.4199346...

E.2 Base Model Results

Table E.2: Base Model Results

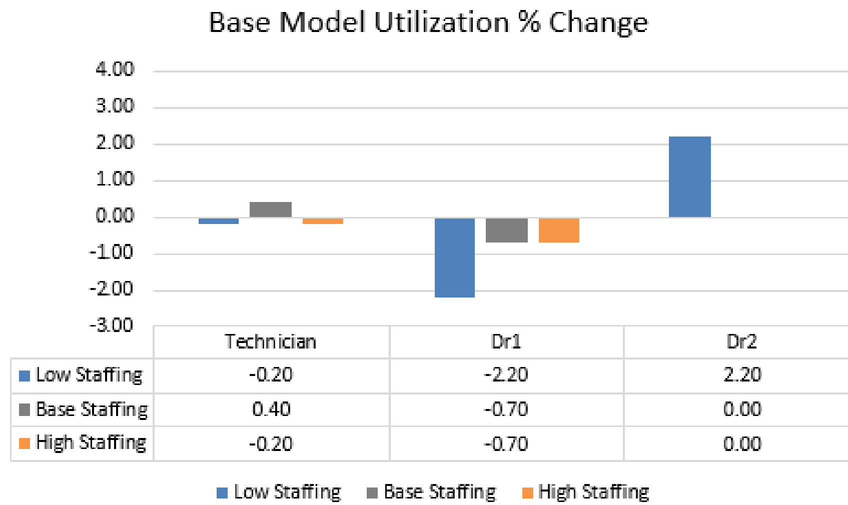
Name		Values				Mean Confidence			Lower Percentile			Upper Percentile		
Scenario Na...	Response N...	Mean	Median	Minimum	Maximum	Half Width	Mean CI Be...	Mean CI End	Lower Value	Lower CI St...	Lower CI End	Upper Value	Upper CI St...	Upper CI End
Low Staffing	Surgery	2.65945877...	2.51709158...	0.80992061...	5.12310808...	0.05287776...	2.60658101...	2.71233654...	1.63858847...	1.55229354...	1.72544518...	4.04749460...	3.92747851...	4.16336775...
Low Staffing	Technical	0.47144970...	0.40642052...	0.10352740...	2.44361957...	0.01910353...	0.45234616...	0.49055324...	0.18434085...	0.17329463...	0.19801887...	0.96801326...	0.91804270...	1.04904343...
Low Staffing	MedicalSojo...	0.49499892...	0.46126284...	0.21957607...	1.60172305...	0.01159293...	0.48340598...	0.50659186...	0.30510185...	0.29464501...	0.31458448...	0.80015593...	0.76175848...	0.84688347...
Low Staffing	WellnessSoj...	0.38368188...	0.35187963...	0.17577806...	1.37935322...	0.01007465...	0.37360723...	0.39375653...	0.22314230...	0.21641790...	0.23049370...	0.64326796...	0.61460737...	0.67776007...
Low Staffing	Technician	62.4518149...	62.1200086...	39.5455046...	89.0897728...	0.57724838...	61.8745665...	63.0290633...	49.9498373...	48.9133703...	50.9801430...	76.1591477...	74.6624697...	77.2766369...
Low Staffing	Dr2	54.4719324...	53.4123835...	20.1809740...	90.1794034...	0.82852636...	53.6434061...	55.3004588...	36.7121257...	35.6747372...	38.0647592...	74.9322198...	73.4981954...	76.5429662...
Low Staffing	Dr1	58.6594641...	58.6990390...	38.7385934...	80.3590143...	0.51601466...	58.1434494...	59.1754787...	46.4438019...	44.9179771...	47.6583154...	70.3616933...	68.9335748...	71.5120751...
Base Staffing	Surgery	2.39592490...	2.24195378...	0.77747727...	4.59856496...	0.04947004...	2.34645485...	2.44539494...	1.50880008...	1.38739783...	1.55333485...	3.71151844...	3.55296845...	3.87511795...
Base Staffing	Technical	0.18499884...	0.17569818...	0.08217603...	0.41062817...	0.00401670...	0.18098213...	0.18901555...	0.11140079...	0.10352740...	0.11495725...	0.29067877...	0.28136723...	0.30391357...
Base Staffing	MedicalSojo...	0.42727390...	0.40995922...	0.21989037...	1.04836942...	0.00770594...	0.41956796...	0.43497984...	0.28966161...	0.27775160...	0.30163363...	0.61870623...	0.59118992...	0.64712424...
Base Staffing	WellnessSoj...	0.31515102...	0.30101277...	0.13444649...	0.88084048...	0.00617862...	0.30897240...	0.32132964...	0.20287610...	0.19708225...	0.21219027...	0.47541738...	0.45873423...	0.51063654...
Base Staffing	Technician	41.4643366...	41.5553463...	26.3636697...	56.8751092...	0.37863075...	41.0857058...	41.8429673...	33.5151084...	32.7537898...	33.8236880...	50.2461549...	49.4436759...	51.2369994...
Base Staffing	Dr2	53.4704915...	52.8618345...	20.1809740...	89.9133645...	0.77075815...	52.6997333...	54.2412496...	37.1937976...	35.0965994...	37.8514927...	71.7485065...	70.0971018...	74.0340523...
Base Staffing	Dr1	59.4979916...	59.3600733...	38.7385934...	84.1145675...	0.55308588...	58.9449057...	60.0510775...	46.4438019...	45.7170494...	47.5196285...	72.4839528...	71.5202681...	73.8771809...
High Staffing	Surgery	2.38571780...	2.23541380...	0.77747727...	4.59856496...	0.04939494...	2.33632286...	2.43511274...	1.50543118...	1.38739783...	1.55001096...	3.71151844...	3.54269262...	3.84443797...
High Staffing	Technical	0.18505082...	0.17569818...	0.08217603...	0.41062817...	0.00402675...	0.18102407...	0.18907757...	0.11140079...	0.10352740...	0.11495725...	0.29067877...	0.28136723...	0.31229103...
High Staffing	MedicalSojo...	0.42715640...	0.40979975...	0.21989037...	1.04836942...	0.00770777...	0.41944862...	0.43486418...	0.28966161...	0.27775160...	0.30160742...	0.61870623...	0.59118992...	0.64712424...
High Staffing	WellnessSoj...	0.31519578...	0.30090720...	0.13444649...	0.88084048...	0.00617490...	0.30902087...	0.32137069...	0.20287610...	0.19708225...	0.21219027...	0.47541738...	0.45873423...	0.51063654...
High Staffing	Technician	31.1027160...	31.1608202...	19.7727523...	42.6563319...	0.28400526...	30.8187108...	31.3867213...	25.1363313...	24.5653424...	25.3677660...	37.6846162...	37.0827569...	38.4277496...
High Staffing	Dr2	53.5023957...	52.8766639...	20.1809740...	89.9133645...	0.76953382...	52.7328619...	54.2719295...	37.1937976...	35.1001581...	37.8514927...	71.7485065...	70.0971018...	74.0340523...
High Staffing	Dr1	59.4854545...	59.3492840...	38.7385934...	84.1145675...	0.55364493...	58.9318096...	60.0390994...	46.4438019...	45.7170494...	47.5196285...	72.4839528...	71.5301404...	73.9934313...
Alternative ...	Surgery	2.44206516...	2.28039004...	0.77747727...	4.70064016...	0.05022810...	2.39183705...	2.49229326...	1.51406044...	1.40258197...	1.58360834...	3.72827874...	3.61064010...	3.90355223...
Alternative ...	Technical	0.36994347...	0.32394334...	0.08360441...	1.58584519...	0.01335910...	0.35658437...	0.38330257...	0.16437822...	0.15346243...	0.17687210...	0.73176074...	0.68656910...	0.81496210...
Alternative ...	MedicalSojo...	0.47237795...	0.44462768...	0.21989037...	1.26915713...	0.01016263...	0.46221531...	0.48254058...	0.30203136...	0.28756148...	0.30753136...	0.76211139...	0.72737175...	0.80416095...
Alternative ...	WellnessSoj...	0.36555242...	0.33532640...	0.13495430...	1.07349614...	0.00851819...	0.35703423...	0.37407062...	0.22508462...	0.21624582...	0.23283783...	0.60559629...	0.56791196...	0.64511016...
Alternative ...	Technician	49.6890501...	49.4570174...	31.6364036...	67.9767361...	0.45013582...	49.2389142...	50.1391859...	40.2124467...	39.3045478...	40.6922537...	60.7704662...	59.2186029...	61.7317436...
Alternative ...	Dr2	53.7076887...	53.3029122...	20.1809740...	87.7156813...	0.78381501...	52.9238737...	54.4915038...	36.2454628...	34.7428546...	37.8846164...	72.6424460...	70.7321771...	74.3749708...
Alternative ...	Dr1	59.1497182...	59.0651277...	38.7385934...	79.5327625...	0.54199080...	58.6077274...	59.6917090...	46.3899989...	44.9278782...	47.1734191...	71.6124536...	70.9120171...	73.0053890...

E.3 Hard Model Results

Table E.3: Hard Model Results

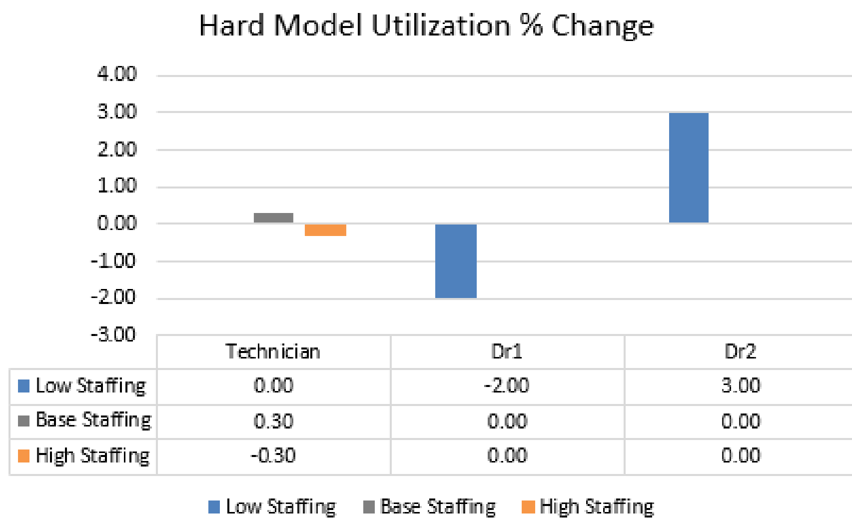
Name		Values				Mean Confidence			Lower Percentile			Upper Percentile		
Scenario Na...	Response N...	Mean	Median	Minimum	Maximum	Half Width	Mean CI Be...	Mean CI End	Lower Value	Lower CI St...	Lower CI End	Upper Value	Upper CI St...	Upper CI End
Low Staffing	Surgery	2.77897857...	2.69257428...	1.26073700...	5.01320980...	0.05198471...	2.72699386...	2.83096328...	2.24526535...	2.20127751...	2.28899736...	3.25073621...	3.19690523...	3.35806151...
Low Staffing	Technical	0.53204515...	0.46245394...	0.13649040...	2.85156679...	0.02034057...	0.51170458...	0.55238573...	0.33251308...	0.31295096...	0.35179961...	0.65337073...	0.62219251...	0.69196235...
Low Staffing	MedicalSOjo...	0.60246699...	0.55001546...	0.29854983...	1.74604526...	0.01441128...	0.58805571...	0.61687827...	0.46158697...	0.45403838...	0.46840961...	0.69455050...	0.66972112...	0.71636092...
Low Staffing	WellnessSoj...	0.48443848...	0.43966664...	0.20420625...	1.67525385...	0.01270092...	0.47173755...	0.49713940...	0.36510461...	0.35551519...	0.37490253...	0.55256630...	0.53454324...	0.57495718...
Low Staffing	Technician	74.9817706...	74.7755366...	52.3774788...	91.2797945...	0.54308118...	74.4386895...	75.5248518...	69.6383155...	68.8572904...	70.4522780...	80.7014942...	79.7468491...	81.3692653...
Low Staffing	Dr2	65.8347699...	66.2236893...	35.8519108...	90.3437901...	0.79256467...	65.0422052...	66.6273346...	58.0823508...	57.0749341...	58.9803537...	73.8691259...	72.5845364...	74.7583825...
Low Staffing	Dr1	68.7531914...	68.8429609...	46.6692821...	86.0920515...	0.46444401...	68.2887474...	69.2176354...	64.5426033...	64.0286889...	65.2662989...	73.1774571...	72.4733897...	73.7563174...
Base Staffing	Surgery	2.43792187...	2.33776264...	0.95284641...	4.71835553...	0.04858200...	2.38933987...	2.48650387...	1.92383649...	1.87180667...	1.98708536...	2.88376157...	2.80982923...	2.95410470...
Base Staffing	Technical	0.18536415...	0.17798151...	0.08442337...	0.48644505...	0.00355505...	0.18180909...	0.18891920...	0.14894629...	0.14591034...	0.15372085...	0.20923492...	0.20492628...	0.21663278...
Base Staffing	MedicalSOjo...	0.51100815...	0.48315544...	0.28386257...	1.43594849...	0.00986349...	0.50114465...	0.52087164...	0.42383846...	0.41530327...	0.43027892...	0.56533411...	0.54865321...	0.58199348...
Base Staffing	WellnessSoj...	0.39192932...	0.36938546...	0.19123871...	1.21310057...	0.00797321...	0.38395610...	0.39990253...	0.32174701...	0.31433495...	0.32790822...	0.43269616...	0.42392045...	0.44137580...
Base Staffing	Technician	50.2706959...	50.1181805...	34.9183192...	65.4941895...	0.38583404...	49.8848619...	50.6565300...	46.5245348...	45.9533633...	46.9352693...	54.0149179...	53.4415348...	54.6729243...
Base Staffing	Dr2	64.6955463...	65.3648642...	32.6113498...	90.5633406...	0.77247697...	63.9230694...	65.4680233...	56.8647019...	55.5956560...	57.7644156...	72.1803182...	71.1098366...	72.9390588...
Base Staffing	Dr1	70.8104335...	70.4317981...	50.0051497...	90.5691490...	0.50817154...	70.3022620...	71.3186050...	65.8501763...	65.2170728...	66.6438053...	75.9779640...	75.1195338...	76.5764395...
High Staffing	Surgery	2.42290694...	2.32072791...	0.95284641...	4.59058979...	0.04844456...	2.37446237...	2.47135151...	1.91499297...	1.85393998...	1.96399789...	2.86296092...	2.79179461...	2.95151356...
High Staffing	Technical	0.18539841...	0.17813774...	0.08442337...	0.48580914...	0.00354584...	0.18185257...	0.18894425...	0.14894629...	0.14591034...	0.15372085...	0.20924840...	0.20527952...	0.21700881...
High Staffing	MedicalSOjo...	0.51047488...	0.48268659...	0.28386257...	1.43594849...	0.00984175...	0.50063313...	0.52031664...	0.42383846...	0.41397085...	0.43027892...	0.56533411...	0.54764552...	0.58199348...
High Staffing	WellnessSoj...	0.39146268...	0.36888849...	0.19123871...	1.21310057...	0.00796661...	0.38349606...	0.39942929...	0.32174701...	0.31434933...	0.32790822...	0.43169935...	0.42265852...	0.44107448...
High Staffing	Technician	37.6947190...	37.5737975...	26.1887394...	49.1206421...	0.28946617...	37.4052528...	37.9841852...	34.8934011...	34.4650225...	35.2014520...	40.4103034...	40.0789212...	40.9643060...
High Staffing	Dr2	64.6671054...	65.1690433...	32.6113498...	90.5633406...	0.77307826...	63.8940272...	65.4401837...	56.8647019...	55.5956560...	57.7206882...	72.1803182...	71.1207184...	72.9390588...
High Staffing	Dr1	70.8081438...	70.3441855...	50.0051497...	90.5691490...	0.50912786...	70.2990159...	71.3172716...	65.8909153...	65.2170728...	66.6493645...	75.9779640...	75.1195338...	76.5558836...
Alternative ...	Surgery	2.49851446...	2.41199914...	0.95284641...	4.56095141...	0.04952881...	2.44898565...	2.54804327...	1.97765468...	1.93423198...	2.04516789...	2.95296934...	2.85876756...	3.03191820...
Alternative ...	Technical	0.43440646...	0.36957069...	0.13762010...	1.65169991...	0.01610386...	0.41830259...	0.45051033...	0.28089949...	0.27185562...	0.29159721...	0.51717310...	0.49515354...	0.54965284...
Alternative ...	MedicalSOjo...	0.58935716...	0.53471839...	0.29858469...	1.58749176...	0.01410976...	0.57524739...	0.60346693...	0.45426335...	0.44533453...	0.46390237...	0.66681317...	0.64400218...	0.70514623...
Alternative ...	WellnessSoj...	0.47355906...	0.43122152...	0.23905459...	1.40576174...	0.01203287...	0.46152618...	0.48559193...	0.36270145...	0.35612318...	0.37085207...	0.53997838...	0.51709490...	0.56209153...
Alternative ...	Technician	60.0375360...	59.8896789...	41.9019831...	73.3105688...	0.44356984...	59.5939662...	60.4811059...	55.6331423...	55.0799621...	56.3045007...	64.7671963...	64.0605403...	65.3961522...
Alternative ...	Dr2	64.4662892...	64.7162291...	36.6822242...	88.6181317...	0.77561358...	63.6906756...	65.2419028...	56.7083230...	55.7083272...	57.8904196...	72.3031511...	71.2055414...	73.2830125...
Alternative ...	Dr1	70.2624718...	69.9443053...	50.0051497...	90.0847656...	0.49010247...	69.7723693...	70.7525743...	65.6501794...	64.8224921...	66.2931501...	74.9662132...	74.3247253...	75.6043258...

E.4 Strategy One Results



	Technician	Dr1	Dr2
Low Staffing	-0.20	-2.20	2.20
Base Staffing	0.40	-0.70	0.00
High Staffing	-0.20	-0.70	0.00

Figure E.1: (color online) Scenario 1: Change in Utilization from the base model



	Technician	Dr1	Dr2
Low Staffing	0.00	-2.00	3.00
Base Staffing	0.30	0.00	0.00
High Staffing	-0.30	0.00	0.00

Figure E.2: (color online) Scenario 1: Change in Utilization from the hard model

Table E.4: Scenario 1: Base Model

Name		Values				Mean Confidence			Lower Percentile			Upper Percentile		
Scenario Na...	Response N...	Mean	Median	Minimum	Maximum	Half Width	Mean CI Be...	Mean CI End	Lower Value	Lower CI St...	Lower CI End	Upper Value	Upper CI St...	Upper CI End
Low Staffing	Technical	0.43816194...	0.30665179...	0.10104369...	2.43360921...	0.02480536...	0.41335657...	0.46296730...	0.20707646...	0.19768584...	0.21600547...	0.55771950...	0.50227593...	0.60433081...
Low Staffing	Surgery	2.75287747...	2.61716008...	1.02716380...	4.91759970...	0.05423803...	2.69863943...	2.80711550...	2.16773719...	2.12126275...	2.22086375...	3.28285863...	3.16251071...	3.36470351...
Low Staffing	Medical	0.53995184...	0.50135384...	0.28451140...	1.52962612...	0.01161988...	0.52833195...	0.55157173...	0.43742324...	0.43034057...	0.44413836...	0.58975241...	0.57495278...	0.60943027...
Low Staffing	Wellness	0.41777468...	0.38520917...	0.21305171...	1.28667108...	0.00964729...	0.40812738...	0.42742197...	0.33076858...	0.32338098...	0.33668670...	0.47395715...	0.46042957...	0.48850877...
Low Staffing	Technician	69.7419030...	69.4942050...	48.3542438...	89.9988310...	0.56088417...	69.1810188...	70.3027872...	64.0139152...	63.3693343...	64.6211533...	75.4000515...	74.1410137...	76.1782682...
Low Staffing	Dr2	59.4258404...	58.8127263...	30.4681688...	88.9566976...	0.82562650...	58.6002139...	60.2514669...	51.6506443...	50.4809256...	52.6305376...	66.7700300...	65.6956234...	68.1840223...
Low Staffing	Dr1	68.6762180...	68.8937789...	48.8862530...	89.7753556...	0.49297006...	68.1832479...	69.1691881...	63.9578475...	63.3156619...	64.4807010...	73.4616588...	72.6334400...	74.2906071...
Base Staffing	Technical	0.20199453...	0.18580274...	0.07384085...	0.79876023...	0.00561909...	0.19637543...	0.20761363...	0.15015032...	0.14653370...	0.15456781...	0.23182056...	0.22463804...	0.24174368...
Base Staffing	Surgery	2.44278107...	2.32085670...	0.84950765...	4.73333223...	0.05020019...	2.39258087...	2.49298126...	1.91039319...	1.87215051...	1.95586362...	2.92255721...	2.84814611...	3.01091755...
Base Staffing	Medical	0.50798823...	0.47919742...	0.28412345...	1.31297854...	0.00962060...	0.49836762...	0.51760883...	0.42286226...	0.41573908...	0.43240604...	0.55418034...	0.53927842...	0.56605156...
Base Staffing	Wellness	0.39195473...	0.36970262...	0.21044329...	1.08876163...	0.00792823...	0.38402650...	0.39988296...	0.32077748...	0.31471834...	0.32656344...	0.43375359...	0.42268069...	0.44336585...
Base Staffing	Technician	46.5534001...	46.1697376...	31.5633293...	63.8231619...	0.38141897...	46.1719811...	46.9348191...	42.6517381...	42.2772799...	43.1420806...	50.1556358...	49.6321140...	50.8073852...
Base Staffing	Dr2	60.4275021...	59.8956749...	22.1455286...	90.1486875...	0.77390217...	59.6535999...	61.2014042...	53.5009956...	52.4902913...	54.2374002...	67.5603111...	66.6038007...	68.6561817...
Base Staffing	Dr1	67.6891406...	67.9891093...	47.1390144...	90.1648888...	0.53579194...	67.1533486...	68.2249325...	62.5326920...	61.8035598...	63.4796057...	72.5331425...	71.8752935...	73.1692818...
High Staffing	Technical	0.20204217...	0.18618391...	0.07384085...	0.79876023...	0.00562177...	0.19642039...	0.20766394...	0.15080777...	0.14649009...	0.15458087...	0.23139662...	0.22463804...	0.24132238...
High Staffing	Surgery	2.43679109...	2.31474129...	0.84950765...	4.73333223...	0.04983261...	2.38695847...	2.48662370...	1.90602349...	1.87211440...	1.95586362...	2.91277513...	2.83096509...	2.99965481...
High Staffing	Medical	0.50801871...	0.47919742...	0.28412345...	1.31297854...	0.00961291...	0.49840580...	0.51763162...	0.42286226...	0.41573908...	0.43240604...	0.55418034...	0.53927842...	0.56605156...
High Staffing	Wellness	0.39206574...	0.36970262...	0.21044329...	1.08876163...	0.00791999...	0.38414574...	0.39998573...	0.32093092...	0.31493309...	0.32678731...	0.43377460...	0.42268069...	0.44435373...
High Staffing	Technician	34.9213324...	34.6983602...	23.6724969...	47.8673714...	0.28625771...	34.6350747...	35.2075901...	31.9888036...	31.7079599...	32.3565604...	37.6167269...	37.2240855...	38.1055389...
High Staffing	Dr2	60.4533919...	59.8956749...	22.1455286...	90.1486875...	0.77441912...	59.6789728...	61.2278110...	53.5957079...	52.4902913...	54.2660095...	67.6072997...	66.6260398...	68.6860181...
High Staffing	Dr1	67.6850006...	67.9891093...	47.1390144...	90.1648888...	0.53585183...	67.1491487...	68.2208524...	62.5194991...	61.8035598...	63.4013263...	72.5331425...	71.8752935...	73.1692818...
Alternative ...	Technical	0.44795882...	0.29155044...	0.10138693...	1.99964015...	0.02598303...	0.42197578...	0.47394185...	0.19931202...	0.19154154...	0.20612907...	0.57231880...	0.51821567...	0.62341258...
Alternative ...	Surgery	2.44299135...	2.31474129...	0.84950765...	4.77473810...	0.05050195...	2.39248940...	2.49349331...	1.90602349...	1.87211440...	1.95586362...	2.92255721...	2.83096509...	3.02382367...
Alternative ...	Medical	0.53405599...	0.50394498...	0.28429495...	1.50091935...	0.01047081...	0.52358517...	0.54452681...	0.43890758...	0.43256071...	0.44709594...	0.59406845...	0.57765593...	0.60870431...
Alternative ...	Wellness	0.41149934...	0.38684844...	0.21630966...	1.18173405...	0.00885138...	0.40264796...	0.42035073...	0.33160536...	0.32408728...	0.33837098...	0.46308051...	0.45049455...	0.47654855...
Alternative ...	Technician	55.7938818...	55.4389418...	37.3650456...	71.5778098...	0.44570220...	55.3481796...	56.2395840...	51.1820857...	50.7327359...	51.7281183...	60.0535872...	59.3580292...	60.5262019...
Alternative ...	Dr2	59.0383623...	57.9464766...	22.1455286...	88.7850430...	0.82179626...	58.2165660...	59.8601585...	51.3482319...	50.3441964...	52.4902913...	66.6260398...	65.5833346...	67.7502786...
Alternative ...	Dr1	69.0242164...	69.2837274...	48.8862530...	88.9157217...	0.49954650...	68.5246699...	69.5237629...	64.3781295...	63.7559319...	65.1676342...	73.8211391...	73.1767919...	74.3279144...

Table E.5: Scenario 1: Hard Model

Name		Values				Mean Confidence			Lower Percentile			Upper Percentile		
Scenario Na...	Response N...	Mean	Median	Minimum	Maximum	Half Width	Mean CI Be...	Mean CI End	Lower Value	Lower CI St...	Lower CI End	Upper Value	Upper CI St...	Upper CI End
Low Staffing	Technical	0.33891441...	0.27933280...	0.09944791...	1.82082724...	0.01541157...	0.32350284...	0.35432598...	0.21535290...	0.20667663...	0.22390883...	0.38124269...	0.35993012...	0.40126227...
Low Staffing	Surgery	2.71511867...	2.64249602...	1.12606138...	4.87198189...	0.05312880...	2.66198987...	2.76824748...	2.12951628...	2.07118222...	2.19183458...	3.20181373...	3.13956633...	3.30226345...
Low Staffing	Medical	0.53208528...	0.50408937...	0.28925837...	1.37470056...	0.01033886...	0.52174641...	0.54242414...	0.43640360...	0.42277194...	0.44316958...	0.58958509...	0.57346208...	0.60628711...
Low Staffing	Wellness	0.41292384...	0.38479261...	0.19935424...	1.07474528...	0.00878767...	0.40413616...	0.42171152...	0.33677135...	0.33002882...	0.34019284...	0.45439104...	0.44549338...	0.46734265...
Low Staffing	Technician	74.6604961...	74.7522080...	54.5442422...	91.2797945...	0.52743108...	74.1330650...	75.1879272...	69.5730358...	68.8161159...	70.3495875...	79.8077617...	79.2340956...	80.5470123...
Low Staffing	Dr2	63.0861027...	62.8840890...	35.9740995...	88.8195165...	0.75317149...	62.3329312...	63.8392742...	55.8086213...	54.7149249...	56.7696783...	69.9724024...	68.9180993...	70.9939150...
Low Staffing	Dr1	71.3019951...	71.3687452...	47.9332272...	90.8807835...	0.48145296...	70.8205422...	71.7834481...	66.7086283...	65.9084658...	67.3485133...	75.8613044...	75.2163356...	76.5018252...
Base Staffing	Technical	0.19440366...	0.18390466...	0.09610858...	0.65629004...	0.00448311...	0.18992055...	0.19888677...	0.15347947...	0.14841804...	0.15747402...	0.22001528...	0.21535524...	0.22731765...
Base Staffing	Surgery	2.42707380...	2.34567701...	0.95284641...	4.73037853...	0.04892640...	2.37814740...	2.47600021...	1.91941097...	1.85428193...	1.96808674...	2.86026356...	2.79207088...	2.95728315...
Base Staffing	Medical	0.50410075...	0.48046885...	0.28062545...	1.20894353...	0.00882182...	0.49527893...	0.51292257...	0.41812442...	0.40870039...	0.42622481...	0.56418860...	0.55308437...	0.57839475...
Base Staffing	Wellness	0.39223533...	0.37246489...	0.19346153...	0.85270725...	0.00702566...	0.38520966...	0.39926100...	0.32881593...	0.32204609...	0.33199459...	0.43733073...	0.42806121...	0.44404576...
Base Staffing	Technician	50.3402987...	50.3276983...	30.2012771...	65.1830142...	0.39292804...	49.9473706...	50.7332267...	46.4587675...	45.9378933...	47.0414894...	53.7948895...	53.4138251...	54.4212629...
Base Staffing	Dr2	64.6682725...	64.6127678...	28.7497746...	90.5408186...	0.77368239...	63.8945901...	65.4419549...	57.1778695...	56.2323475...	58.2921351...	71.7511829...	70.9732876...	72.6147047...
Base Staffing	Dr1	70.8144581...	70.6385066...	45.1101308...	91.6188271...	0.53428946...	70.2801686...	71.3487476...	65.6511002...	64.7455528...	66.2331285...	76.0418124...	75.4265394...	76.8220240...
High Staffing	Technical	0.19448158...	0.18429531...	0.09610858...	0.65629004...	0.00448685...	0.18999473...	0.19896844...	0.15347947...	0.14841804...	0.15747402...	0.22042284...	0.21531997...	0.22821070...
High Staffing	Surgery	2.42382078...	2.34567701...	0.95284641...	4.72462476...	0.04860505...	2.37521573...	2.47242584...	1.91941097...	1.85428193...	1.96808674...	2.85406403...	2.78729711...	2.95446141...
High Staffing	Medical	0.50409058...	0.48046885...	0.28062545...	1.20894353...	0.00882177...	0.49526880...	0.51291235...	0.41794941...	0.40870039...	0.42622481...	0.56418860...	0.55321641...	0.57839475...
High Staffing	Wellness	0.39231652...	0.37229390...	0.19346153...	0.85250884...	0.00702953...	0.38528699...	0.39934605...	0.32867197...	0.32202968...	0.33199459...	0.43771593...	0.42830993...	0.44420656...
High Staffing	Technician	37.7612122...	37.7457737...	22.6509578...	48.8940634...	0.29547420...	37.4657380...	38.0566864...	34.8440756...	34.4534200...	35.2811170...	40.3461671...	40.0603688...	40.8159472...
High Staffing	Dr2	64.6881023...	64.6127678...	28.7497746...	90.5544703...	0.77509223...	63.9130101...	65.4631946...	57.1778695...	56.2323475...	58.3782647...	71.7712643...	70.9892644...	72.6147047...
High Staffing	Dr1	70.8092044...	70.6210715...	45.1101308...	91.6188271...	0.53423835...	70.2749661...	71.3434428...	65.6032402...	64.7336227...	66.2047049...	76.0465071...	75.4265394...	76.8288977...
Alternative ...	Technical	0.33225550...	0.26487662...	0.10623822...	1.56836272...	0.01605612...	0.31619937...	0.34831162...	0.20953804...	0.20274147...	0.21610099...	0.36251226...	0.34098150...	0.38148195...
Alternative ...	Surgery	2.42738405...	2.34567701...	0.95284641...	4.77170212...	0.04901938...	2.37836467...	2.47640344...	1.91941097...	1.85428193...	1.96808674...	2.85792788...	2.78729711...	2.95728315...
Alternative ...	Medical	0.52997853...	0.50319592...	0.27924643...	1.13493621...	0.00985185...	0.52012667...	0.53983038...	0.43032759...	0.42240069...	0.43823516...	0.59581028...	0.58139833...	0.60920141...
Alternative ...	Wellness	0.41356322...	0.39112725...	0.19875900...	0.93431274...	0.00800543...	0.40555778...	0.42156865...	0.33548304...	0.33125474...	0.34073787...	0.45885378...	0.44767101...	0.47687804...
Alternative ...	Technician	59.8511185...	60.0526621...	36.0463752...	73.2436875...	0.42939443...	59.4217240...	60.2805129...	55.6043804...	55.0017802...	56.0310535...	64.0864548...	63.5581647...	64.7965188...
Alternative ...	Dr2	63.0579644...	63.1486361...	28.2618815...	86.6295912...	0.74273771...	62.3152267...	63.8007021...	55.9528015...	54.7215462...	56.9302889...	69.9556680...	69.0077464...	70.7636995...
Alternative ...	Dr1	71.4694617...	71.5092237...	45.6283184...	90.2120589...	0.51160381...	70.9578578...	71.9810655...	66.5764297...	65.9440195...	67.2190445...	76.9690082...	76.2588333...	77.6686964...

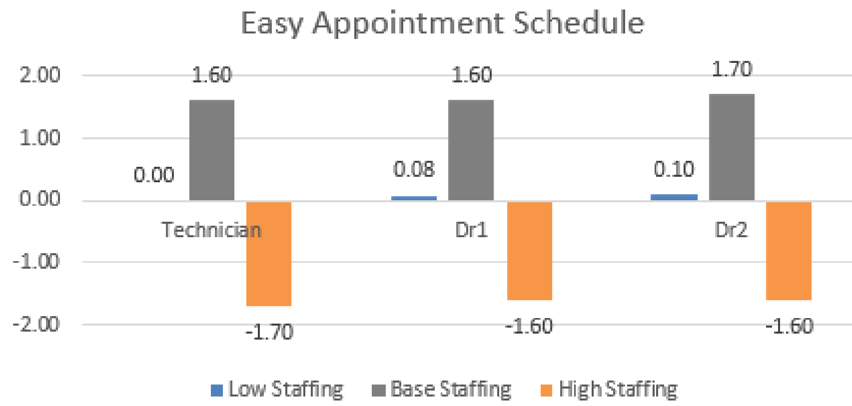


Figure E.3: (color online) Scenario 2: Change in Utilization from the easy model

E.5 Strategy Two Results

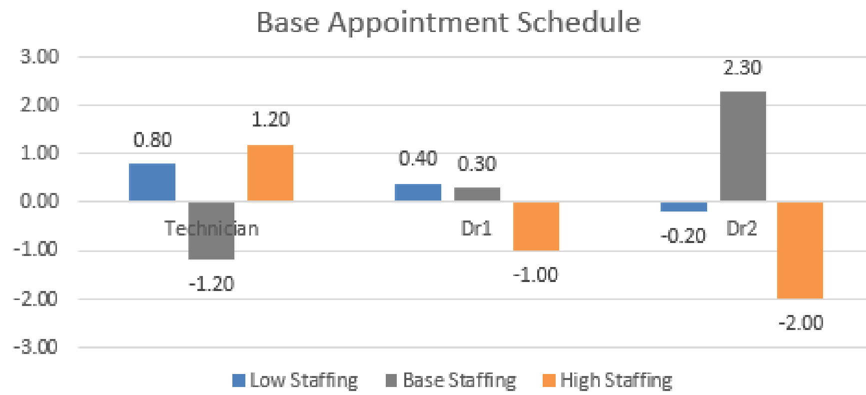


Figure E.4: (color online) Scenario 2: Change in Utilization from the base model

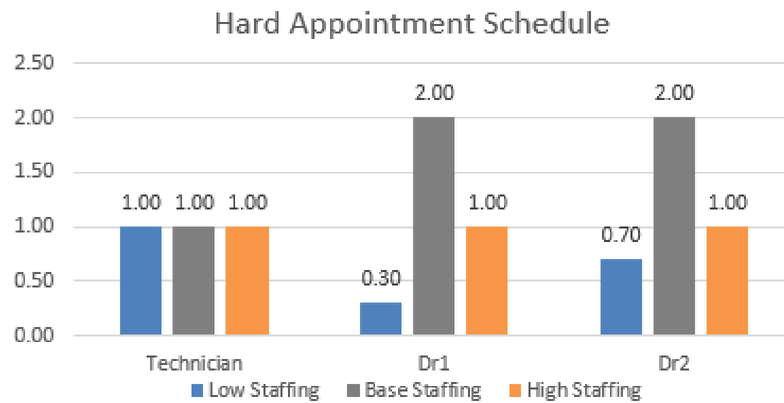


Figure E.5: (color online) Scenario 2: Change in Utilization from the hard model

Table E.6: Scenario Two: Easy Model

Name		Values				Mean Confidence			Lower Percentile			Upper Percentile		
Scenario Na...	Response N...	Mean	Median	Minimum	Maximum	Half Width	Mean CI Be...	Mean CI End	Lower Value	Lower CI St...	Lower CI End	Upper Value	Upper CI St...	Upper CI End
Low Staffing	Technical	NaN	0.17783338...	0.06080505...	1.27538270...	NaN	NaN	NaN	0.12445275...	0.11572592...	0.13117135...	0.26290466...	0.25036809...	0.27978143...
Low Staffing	Surgery	NaN	1.28323763...	0.54065097...	3.36551428...	NaN	NaN	NaN	1.06419194...	1.03820466...	1.09185073...	1.57068487...	1.52101431...	1.63958740...
Low Staffing	Medical	0.46840014...	0.45220155...	0.24776187...	1.00792514...	0.00697810...	0.46142203...	0.47537824...	0.39865642...	0.39240784...	0.40559262...	0.52586366...	0.51892994...	0.53590397...
Low Staffing	Wellness	0.36835062...	0.36075534...	0.14369919...	0.91565662...	0.00633659...	0.36201403...	0.37468722...	0.30755766...	0.30125683...	0.31315287...	0.41062549...	0.40262844...	0.42307014...
Low Staffing	Technician	49.2457305...	49.0099830...	29.6069367...	69.8659407...	0.48367186...	48.7620587...	49.7294024...	44.0821126...	43.5220346...	45.0117809...	53.9167457...	52.9277528...	54.7268344...
Low Staffing	Dr2	43.8994185...	43.6855756...	15.2710961...	78.2232261...	0.68868727...	43.2107313...	44.5881058...	36.4971639...	35.6918457...	37.5262268...	50.4315408...	49.3660936...	51.4690647...
Low Staffing	Dr1	50.6474956...	50.4210269...	33.9756076...	70.5810424...	0.45818338...	50.1893122...	51.1056790...	46.0691456...	45.6227471...	46.6850066...	55.2517394...	54.5366704...	55.8313569...
Base Staffing	Technical	NaN	0.16823794...	0.06080505...	1.13764398...	NaN	NaN	NaN	0.11873827...	0.11356943...	0.12728293...	0.25498421...	0.23537594...	0.26778817...
Base Staffing	Surgery	NaN	1.17728130...	0.52374281...	3.23396058...	NaN	NaN	NaN	0.94789957...	0.92366522...	0.97250216...	1.43276516...	1.40574317...	1.47030518...
Base Staffing	Medical	0.46231769...	0.44658084...	0.24742174...	0.91901398...	0.00691586...	0.45540182...	0.46923355...	0.39648833...	0.38840026...	0.40240472...	0.51823316...	0.50814131...	0.52605000...
Base Staffing	Wellness	0.36065659...	0.35112500...	0.14369919...	0.93768969...	0.00611528...	0.35454131...	0.36677187...	0.30292468...	0.29570494...	0.30833808...	0.40150189...	0.39634393...	0.40981565...
Base Staffing	Technician	32.8629526...	32.6290254...	19.7379578...	48.4453834...	0.32934418...	32.5336084...	33.1922968...	29.4317184...	29.0046871...	30.0741986...	35.7380871...	35.2479012...	36.3595477...
Base Staffing	Dr2	43.9100888...	43.5319404...	15.2710961...	79.3144842...	0.70265430...	43.2074345...	44.6127431...	36.4971639...	35.9813152...	37.3621843...	50.2335310...	49.2894309...	51.1595626...
Base Staffing	Dr1	50.7011307...	50.4808289...	33.9756076...	73.1021032...	0.45750508...	50.2436256...	51.1586358...	46.1060909...	45.5807606...	46.7000077...	55.1387352...	54.5905949...	55.7705987...
High Staffing	Technical	NaN	0.16823794...	0.06080505...	1.13764398...	NaN	NaN	NaN	0.11873827...	0.11356943...	0.12728293...	0.25484994...	0.23488552...	0.26773154...
High Staffing	Surgery	NaN	1.17659819...	0.52374281...	3.23396058...	NaN	NaN	NaN	0.94789957...	0.92366522...	0.96947252...	1.43276516...	1.40574317...	1.47030518...
High Staffing	Medical	0.46228610...	0.44658084...	0.24742174...	0.91901398...	0.00691381...	0.45537228...	0.46919991...	0.39648833...	0.38840026...	0.40240472...	0.51823316...	0.50814131...	0.52605000...
High Staffing	Wellness	0.36052567...	0.35096733...	0.14369919...	0.93768969...	0.00610377...	0.35442190...	0.36662944...	0.30292468...	0.29570494...	0.30833808...	0.40150189...	0.39625641...	0.40981565...
High Staffing	Technician	24.6419554...	24.4717690...	14.8034683...	36.3340376...	0.24618252...	24.3957729...	24.8881380...	22.0737888...	21.7535153...	22.5556490...	26.8035653...	26.4359259...	27.2696607...
High Staffing	Dr2	43.8995427...	43.5319404...	15.2710961...	79.3144842...	0.70106972...	43.1984730...	44.6006124...	36.4971639...	35.9813152...	37.3621843...	50.2335310...	49.2894309...	51.1595626...
High Staffing	Dr1	50.6920380...	50.4808289...	33.9756076...	73.1021032...	0.45652103...	50.2355170...	51.1485591...	46.1060909...	45.5807606...	46.7000077...	55.1030836...	54.5905949...	55.7460791...
Alternative ...	Technical	NaN	0.17736357...	0.06080505...	1.31680449...	NaN	NaN	NaN	0.12430159...	0.11570762...	0.13046207...	0.26455635...	0.25169119...	0.28158141...
Alternative ...	Surgery	NaN	1.17728130...	0.52374281...	3.24020152...	NaN	NaN	NaN	0.94633999...	0.92391566...	0.97427035...	1.43238958...	1.40574317...	1.48220805...
Alternative ...	Medical	0.46728422...	0.44890199...	0.24742174...	1.08816350...	0.00727887...	0.46000534...	0.47456310...	0.39721176...	0.39043843...	0.40311985...	0.52426926...	0.51589114...	0.53445864...
Alternative ...	Wellness	0.36798945...	0.35977091...	0.14369919...	1.07410657...	0.00647954...	0.36150990...	0.37446899...	0.30774740...	0.30081713...	0.31270622...	0.41108073...	0.40262844...	0.42146746...
Alternative ...	Technician	39.4245240...	39.1590406...	23.6855493...	60.3346052...	0.39451736...	39.0300067...	39.8190414...	35.3064452...	34.8306525...	36.0094247...	43.0175717...	42.3150576...	43.7814675...
Alternative ...	Dr2	44.1025993...	43.7366155...	15.2710961...	78.5435495...	0.70425750...	43.3983418...	44.8068569...	37.0220320...	36.0876566...	37.9187496...	50.5590600...	49.4840764...	51.6874052...
Alternative ...	Dr1	50.4918714...	50.2108971...	33.9756076...	71.2217435...	0.45906939...	50.0328020...	50.9509408...	45.8973867...	45.3584701...	46.5079153...	54.9531480...	54.2627611...	55.6913866...

Table E.7: Scenario Two: Base Model

Name		Values				Mean Confidence			Lower Percentile			Upper Percentile		
Scenario Na...	Response N...	Mean	Median	Minimum	Maximum	Half Width	Mean CI Be...	Mean CI End	Lower Value	Lower CI St...	Lower CI End	Upper Value	Upper CI St...	Upper CI End
Low Staffing	Technical	0.39243952...	0.35696824...	0.12746801...	1.24648547...	0.01296215...	0.37947736...	0.40540167...	0.26938186...	0.26043837...	0.27716416...	0.44765193...	0.43050791...	0.48127691...
Low Staffing	Surgery	1.70582256...	1.60044488...	0.82330520...	3.65372232...	0.03265473...	1.67316783...	1.73847729...	1.37893485...	1.35240270...	1.40130073...	2.01278398...	1.93635203...	2.05986512...
Low Staffing	Medical	0.52811903...	0.50665046...	0.25487645...	1.11609668...	0.00930546...	0.51881357...	0.53742449...	0.43982906...	0.43133689...	0.44841232...	0.59300658...	0.57800712...	0.60677671...
Low Staffing	Wellness	0.41537584...	0.39657276...	0.18615750...	1.01311621...	0.00799071...	0.40738513...	0.42336655...	0.33845135...	0.32966039...	0.34560068...	0.46874427...	0.45614238...	0.48440013...
Low Staffing	Technician	69.2971239...	68.9409187...	49.2573355...	88.6299621...	0.54273400...	68.7543899...	69.8398579...	64.1459934...	63.1512180...	64.8061465...	74.7841275...	74.0576767...	75.3195583...
Low Staffing	Dr2	61.5414238...	60.9984896...	23.7895816...	87.5726774...	0.77357649...	60.7678473...	62.3150003...	54.2127716...	53.3618423...	55.0545155...	69.2764092...	68.2123105...	70.0602074...
Low Staffing	Dr1	65.4519523...	65.2910920...	42.7512059...	82.7842970...	0.48611253...	64.9658397...	65.9380648...	60.7516354...	60.2159861...	61.4024306...	70.2846437...	69.6843169...	70.8040228...
Base Staffing	Technical	0.18693413...	0.17789952...	0.08327157...	0.48577849...	0.00393220...	0.18300192...	0.19086634...	0.14657979...	0.14308815...	0.15216564...	0.21660144...	0.21066657...	0.22086761...
Base Staffing	Surgery	1.47892754...	1.40038967...	0.71036689...	3.10179137...	0.02833057...	1.45059696...	1.50725812...	1.18176938...	1.15654495...	1.20696746...	1.74459879...	1.69871765...	1.78507156...
Base Staffing	Medical	0.48436590...	0.47216774...	0.25434735...	0.94485432...	0.00686021...	0.47750568...	0.49122611...	0.41751764...	0.40988024...	0.42561407...	0.54176497...	0.53026680...	0.54917871...
Base Staffing	Wellness	0.37150403...	0.35934931...	0.19694794...	0.70593735...	0.00577362...	0.36573040...	0.37727766...	0.31956126...	0.31242760...	0.32456632...	0.41506889...	0.40697446...	0.42126796...
Base Staffing	Technician	46.2647314...	46.1637367...	32.1398883...	63.3759454...	0.36422174...	45.9005097...	46.6289531...	42.6110776...	42.2154756...	43.0633138...	49.8925958...	49.3987044...	50.3822864...
Base Staffing	Dr2	60.6589883...	60.2272053...	26.4071426...	90.3043984...	0.73875805...	59.9202302...	61.3977463...	53.7622069...	52.7007033...	54.4607114...	67.9471754...	66.9099369...	69.0884465...
Base Staffing	Dr1	66.5276906...	66.1954814...	45.9114233...	89.6746438...	0.51108218...	66.0166084...	67.0387728...	61.6356066...	60.6862532...	62.0592004...	71.9915033...	71.1067333...	72.6215212...
High Staffing	Technical	0.18685792...	0.17789952...	0.08327157...	0.48577849...	0.00392684...	0.18293108...	0.19078476...	0.14657979...	0.14308815...	0.15216564...	0.21653514...	0.20993573...	0.22053929...
High Staffing	Surgery	1.46792119...	1.39358861...	0.71036689...	3.08337820...	0.02813293...	1.43978826...	1.49605413...	1.17438568...	1.14394648...	1.20123813...	1.74288225...	1.69382714...	1.77334910...
High Staffing	Medical	0.48451110...	0.47232274...	0.25434735...	0.92114303...	0.00686273...	0.47764837...	0.49137384...	0.41751764...	0.40988024...	0.42607372...	0.54185212...	0.53026680...	0.54930977...
High Staffing	Wellness	0.37206856...	0.36028973...	0.19694794...	0.70593735...	0.00581621...	0.36625234...	0.37788477...	0.31921362...	0.31242760...	0.32451301...	0.41640576...	0.40784134...	0.42293012...
High Staffing	Technician	34.7214663...	34.6667806...	24.1049162...	46.2204671...	0.27304491...	34.4484214...	34.9945112...	31.9583082...	31.6687085...	32.3105749...	37.4354459...	37.0805974...	37.8263924...
High Staffing	Dr2	60.7147650...	60.3413466...	26.4071426...	90.3043984...	0.73762289...	59.9771421...	61.4523879...	53.8263132...	52.7164383...	54.6476968...	67.9654937...	66.9475104...	69.0885426...
High Staffing	Dr1	66.5686945...	66.2462144...	45.9114233...	88.7104477...	0.51058911...	66.0581054...	67.0792836...	61.6523499...	60.6986044...	62.1335643...	72.1026991...	71.2457509...	72.6373575...
Alternative ...	Technical	0.33848913...	0.29822102...	0.11503159...	1.62793512...	0.01135124...	0.32713789...	0.34984038...	0.23935300...	0.23102014...	0.24642508...	0.39143630...	0.37536371...	0.40819474...
Alternative ...	Surgery	1.50939151...	1.42191722...	0.71036689...	3.46370656...	0.03059581...	1.47879569...	1.53998733...	1.19537606...	1.17438568...	1.22179414...	1.75593555...	1.71027432...	1.83236111...
Alternative ...	Medical	0.52372406...	0.50358182...	0.25434735...	1.14441431...	0.00928152...	0.51444254...	0.53300559...	0.43391675...	0.42538684...	0.44128826...	0.58675911...	0.57668752...	0.60274910...
Alternative ...	Wellness	0.41645751...	0.39990054...	0.18585988...	0.94325650...	0.00787676...	0.40858075...	0.42433427...	0.34001397...	0.33469904...	0.34927943...	0.46719656...	0.45492911...	0.47793702...
Alternative ...	Technician	55.6122302...	55.3302656...	37.6621136...	71.9181199...	0.44096712...	55.1712630...	56.0531973...	51.3174604...	50.7812930...	51.9724840...	59.8924323...	59.1657767...	60.5649037...
Alternative ...	Dr2	60.9966336...	60.1529173...	26.4071426...	89.0712800...	0.74576895...	60.2508647...	61.7424026...	53.8746733...	53.1454720...	54.6037512...	68.2454619...	67.4181021...	69.6796809...
Alternative ...	Dr1	66.4851267...	65.9571879...	42.7512059...	87.5545376...	0.52638077...	65.9587459...	67.0115074...	61.3332966...	60.6570192...	61.9607460...	71.8175222...	71.0874978...	72.4932394...

Table E.8: Scenario 2: Hard Model

Name		Values				Mean Confidence			Lower Percentile			Upper Percentile		
Scenario Na...	Response N...	Mean	Median	Minimum	Maximum	Half Width	Mean CI Be...	Mean CI End	Lower Value	Lower CI St...	Lower CI End	Upper Value	Upper CI St...	Upper CI End
Low Staffing	Technical	0.53204515...	0.46245394...	0.13649040...	2.85156679...	0.02034057...	0.51170458...	0.55238573...	0.33251308...	0.31295096...	0.35179961...	0.65337073...	0.62219251...	0.69196235...
Low Staffing	Surgery	2.77897857...	2.69257428...	1.26073700...	5.01320980...	0.05198471...	2.72699386...	2.83096328...	2.24526535...	2.20127751...	2.28899736...	3.25073621...	3.19690523...	3.35806151...
Low Staffing	Medical	0.60246699...	0.55001546...	0.29854983...	1.74604526...	0.01441128...	0.58805571...	0.61687827...	0.46158697...	0.45403838...	0.46840961...	0.69455050...	0.66972112...	0.71636092...
Low Staffing	Wellness	0.48443848...	0.43966664...	0.20420625...	1.67525385...	0.01270092...	0.47173755...	0.49713940...	0.36510461...	0.35551519...	0.37490253...	0.55256630...	0.53454324...	0.57495718...
Low Staffing	Technician	74.9817706...	74.7755366...	52.3774788...	91.2797945...	0.54308118...	74.4386895...	75.5248518...	69.6383155...	68.8572904...	70.4522780...	80.7014942...	79.7468491...	81.3692653...
Low Staffing	Dr2	65.8347699...	66.2236893...	35.8519108...	90.3437901...	0.79256467...	65.0422052...	66.6273346...	58.0823508...	57.0749341...	58.9803537...	73.8691259...	72.5845364...	74.7583825...
Low Staffing	Dr1	68.7531914...	68.8429609...	46.6692821...	86.0920515...	0.46444401...	68.2887474...	69.2176354...	64.5426033...	64.0286889...	65.2662989...	73.1774571...	72.4733897...	73.7563174...
Base Staffing	Technical	0.18536415...	0.17798151...	0.08442337...	0.48644505...	0.00355505...	0.18180909...	0.18891920...	0.14894629...	0.14591034...	0.15372085...	0.20923492...	0.20492628...	0.21663278...
Base Staffing	Surgery	2.43792187...	2.33776264...	0.95284641...	4.71835553...	0.04858200...	2.38933987...	2.48650387...	1.92383649...	1.87180667...	1.98708536...	2.88376157...	2.80982923...	2.95410470...
Base Staffing	Medical	0.51100815...	0.48315544...	0.28386257...	1.43594849...	0.00986349...	0.50114465...	0.52087164...	0.42383846...	0.41530327...	0.43027892...	0.56533411...	0.54865321...	0.58199348...
Base Staffing	Wellness	0.39192932...	0.36938546...	0.19123871...	1.21310057...	0.00797321...	0.38395610...	0.39990253...	0.32174701...	0.31433495...	0.32790822...	0.43269616...	0.42392045...	0.44137580...
Base Staffing	Technician	50.2706959...	50.1181805...	34.9183192...	65.4941895...	0.38583404...	49.8848619...	50.6565300...	46.5245348...	45.9533633...	46.9352693...	54.0149179...	53.4415348...	54.6729243...
Base Staffing	Dr2	64.6955463...	65.3648642...	32.6113498...	90.5633406...	0.77247697...	63.9230694...	65.4680233...	56.8647019...	55.5956560...	57.7644156...	72.1803182...	71.1098366...	72.9390588...
Base Staffing	Dr1	70.8104335...	70.4317981...	50.0051497...	90.5691490...	0.50817154...	70.3022620...	71.3186050...	65.8501763...	65.2170728...	66.6438053...	75.9779640...	75.1195338...	76.5764395...
High Staffing	Technical	0.18539841...	0.17813774...	0.08442337...	0.48580914...	0.00354584...	0.18185257...	0.18894425...	0.14894629...	0.14591034...	0.15372085...	0.20924840...	0.20527952...	0.21700881...
High Staffing	Surgery	2.42290694...	2.32072791...	0.95284641...	4.59058979...	0.04844456...	2.37446237...	2.47135151...	1.91499297...	1.85393998...	1.96399789...	2.86296092...	2.79179461...	2.95151356...
High Staffing	Medical	0.51047488...	0.48268659...	0.28386257...	1.43594849...	0.00984175...	0.50063313...	0.52031664...	0.42383846...	0.41397085...	0.43027892...	0.56533411...	0.54764552...	0.58199348...
High Staffing	Wellness	0.39146268...	0.36888849...	0.19123871...	1.21310057...	0.00796661...	0.38349606...	0.39942929...	0.32174701...	0.31434933...	0.32790822...	0.43169935...	0.42265852...	0.44107448...
High Staffing	Technician	37.6947190...	37.5737975...	26.1887394...	49.1206421...	0.28946617...	37.4052528...	37.9841852...	34.8934011...	34.4650225...	35.2014520...	40.4103034...	40.0789212...	40.9643060...
High Staffing	Dr2	64.6671054...	65.1690433...	32.6113498...	90.5633406...	0.77307826...	63.8940272...	65.4401837...	56.8647019...	55.5956560...	57.7206882...	72.1803182...	71.1207184...	72.9390588...
High Staffing	Dr1	70.8081438...	70.3441855...	50.0051497...	90.5691490...	0.50912786...	70.2990159...	71.3172716...	65.8909153...	65.2170728...	66.6493645...	75.9779640...	75.1195338...	76.5558836...
Alternative ...	Technical	0.43440646...	0.36957069...	0.13762010...	1.65169991...	0.01610386...	0.41830259...	0.45051033...	0.28089949...	0.27185562...	0.29159721...	0.51717310...	0.49515354...	0.54965284...
Alternative ...	Surgery	2.49851446...	2.41199914...	0.95284641...	4.56095141...	0.04952881...	2.44898565...	2.54804327...	1.97765468...	1.93423198...	2.04516789...	2.95296934...	2.85876756...	3.03191820...
Alternative ...	Medical	0.58935716...	0.53471839...	0.29858469...	1.58749176...	0.01410976...	0.57524739...	0.60346693...	0.45426335...	0.44533453...	0.46390237...	0.66681317...	0.64400218...	0.70514623...
Alternative ...	Wellness	0.47355906...	0.43122152...	0.23905459...	1.40576174...	0.01203287...	0.46152618...	0.48559193...	0.36270145...	0.35612318...	0.37085207...	0.53997838...	0.51709490...	0.56209153...
Alternative ...	Technician	60.0375360...	59.8896789...	41.9019831...	73.3105688...	0.44356984...	59.5939662...	60.4811059...	55.6331423...	55.0799621...	56.3045007...	64.7671963...	64.0605403...	65.3961522...
Alternative ...	Dr2	64.4662892...	64.7162291...	36.6822242...	88.6181317...	0.77561358...	63.6906756...	65.2419028...	56.7083230...	55.7083272...	57.8904196...	72.3031511...	71.2055414...	73.2830125...
Alternative ...	Dr1	70.2624718...	69.9443053...	50.0051497...	90.0847656...	0.49010247...	69.7723693...	70.7525743...	65.6501794...	64.8224921...	66.2931501...	74.9662132...	74.3247253...	75.6043258...