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Industrial engineering analysis to improve phlebotomy lab operations

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Industrial Engineering Analysis to Improve Phlebotomy Lab Operations

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Abstract

Phlebotomy lab inefficiencies commonly produce numerous grievances: 1) from patients and healthcare providers for lengthy wait times; and 2) from healthcare administrators for excessive unnecessary costs. These time and cost issues ordinarily occur due to one or more of the following causes: 1) the lab is understaffed; 2) staff duties are not effectively coordinated, 3) insufficient resources are available, or 4) inefficient flow processes for ordered (and re-ordered additional) tests and specimen collection. These factors can cause increased patient wait time to unacceptable levels. We examine current phlebotomy lab practices at a local facility and propose methodologies to improve quality, productivity, and effectiveness within the lab to ultimately reduce patient wait time and facility costs.

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1 Background/Motivation

The chief purpose of a hospital phlebotomy lab is to collect samples of patients' blood and/or urine and conduct tests on the samples to determine if any problems in the patients' health exist. At the Veterans Health Care System of the Ozarks (VHSO) facility in Fayetteville, AR, when patients schedule an appointment with a physician, they are ordinarily also scheduled to have a specimen collected. Although they are scheduled to specifically arrive at either the upstairs or downstairs phlebotomy lab at a certain time, there is no check-in system within the lab and patients are serviced on a first-come first-served basis (with some exceptions). Therefore, patients often disregard their scheduled lab arrival time and arrive when convenient. For example, patients required to fast before lab work often arrive as soon as the lab opens so they can eat as soon as possible. This causes the queue to swell and waiting times to increase.

Furthermore, phlebotomists are often interrupted throughout the day to attend to emergency patients and inpatients, answer the phone, and add additional tests to previously drawn blood. Recent cuts to the VHSO budget have caused the phlebotomy staff to decrease and thereby heighten the effect of these interruptions on wait time. The VHSO lab has specified an ideal maximum wait time of fifteen minutes; however, numerous patients complain of and report waiting over an hour to have blood drawn. This research aims to simulate the current lab configurations and then modify different parameters of the simulation to ultimately improve the phlebotomy lab flow and reduce patient wait time.

2 Literature Review

Improving efficiency in hospital labs has been a source of numerous studies. Most of these studies have been conducted on improving the turnaround time of tests being conducted.

Durr [6] reports that the Arlington Memorial Hospital near Philadelphia used benchmarking, measuring and identifying best practices, to improve turnaround time for tests and productivity. These studies ultimately lead to deciding to improve technology and implement more automation. For example, the storage and archiving process of specimens was automated to reduce the time technologists wasted looking for specimens in storage. Craig [5] also determined that automating the testing and storage of specimens greatly reduces test turn-around time after studying its implementation at three separate hospitals. The Department of Laboratory Medicine of Geisinger Health Systems in Danville, PA implemented the use of bar code labels to identify specimens. The bar codes sped up the testing process by cutting out the time to hand-write labels and the time to identify the appropriate patient when tests were conducted. However, decreasing turn-around time of labs does not necessarily decrease wait times for patients having specimens collected.

Other studies looked to improve patient wait times. According to Amacher [4], to improve a lab, before adding or improving technology, current processes should be observed and improved; "Otherwise, the end product will be a lab that, despite all the state-of-the-art equipment, is still producing well below its potential." For example, a radiology lab near Boston, MA that had unsatisfactory patient wait times and unpredictable patient traffic implemented Six Sigma to improve these problems. Ultimately, the consultants added resources, such as more workstations, and improved the flow of patients by reducing intermediate processes. Not only was patient satisfaction improved, but also costs were cut significantly. In another study, hiring a phlebotomist to work exclusively in a hospital's Emergency Department reduced the time between a patient's arrival to the ED and the moment the patient first sees a doctor.

Studies more pertinent to the Fayetteville, AR VA Hospital have also been conducted. A VA Hospital in Reno, NV with similar issues actually implemented the use scanners to check patients in with their VA cards. In this system, patients are called to lab based on appointment and scan time, rather than on a first-come, first-served basis. When the patient is called, their information automatically appears on the phlebotomist's computers. According to Tolin [8], a small hospital laboratory began allowing patients requiring fasting to have draws conducted before normal lab hours to not only increase patient satisfaction, but also to reduce wait times later in the day. Finally, Storrow, Zhou, etc. [7] used simulation models to successfully model and increase efficiency in a hospital emergency department and lab by conducting extensive time and current practice studies.

3 Current Practices

3.1 Lab Configuration

The VHSO phlebotomy lab consists of two collection (draw) rooms, one upstairs and one downstairs, and a specimen-testing lab upstairs. The downstairs draw room contains four chairs, three computers, and one unisex bathroom. The upstairs lab includes three chairs, two computers, and two bathrooms. Patients are assigned to a specific draw room when they make an appointment with their doctor. However, when the downstairs draw room is exceptionally busy, some patients voluntarily go to the upstairs draw room. The downstairs draw room services outpatients and emergency patients. The upstairs draw room services outpatients, add-ons, inpatients and emergency patients (after the downstairs lab closes). The downstairs draw room is open approximately from 6:30 am to 3:30 pm while the upstairs room is constantly open. Both draw rooms service the sixteen outpatient clinics and see 330 to 400 outpatients combined every day. According to lab authorities at the VA, in an ideal staffing situation there are four phlebotomists and a volunteer downstairs, and five phlebotomists upstairs. Three of the five upstairs phlebotomists are staffing the draw room, one is changing add-ons, and the last is performing "floor runs" to collect from inpatients.

3.2 Outpatient Process

Outpatients are usually scheduled an appointment to have blood drawn approximately two hours prior to their doctor's appointment. When the patient arrives, they walk to either the downstairs or upstairs waiting areas and collect a number. If the lab is fairly idle, a sign will be placed on the number dispenser directing the patients to go directly to the draw room door. Downstairs, the patient waits for their number to appear on the monitor and then walks to the draw room. Upstairs, the patient waits for their number to be called. A phlebotomist directs the patient to a chair and asks for their VA card. The patient is then asked to state their name and the last four digits of their social security number to verify their identity. After labels are printed to identify their blood vials, they are asked to verify that their name and SSN are correct on the labels and to sign the last one. The patient's arm is next cleaned and their blood is drawn. The patient may then be asked for a urine or stool sample. Afterwards, the patient is free to leave. Some patients are required to fast before having their blood tested; these patients typically arrive promptly at 6:30 am when the lab opens, whether or not that is their appointment time.

3.3 Phlebotomist Process

3.3.1 Outpatients

Downstairs, when the draw room is busy and the numbering system is in use, the phlebotomist first increases the number on the monitor in the waiting room. Upstairs, the phlebotomist changes the number card and calls out the number. If a patient does not respond, the phlebotomist has to walk to the waiting room to retrieve the patient. When the patient comes to the door, the phlebotomist calls them in and directs them to a chair. They are then asked for their VA card. Once the phlebotomist has the patient's VA card, they ask the patient to state their full name and last four digits of their SSN. Once confirming what the patient said with the information on the card, they scan the barcode on the back of the card into the computer. This brings up the patient's file and lists their needed tests. The phlebotomist accessions the patient's needed tests and looks ahead and back approximately thirty days to see if the patient missed any tests or has any future tests scheduled (that can be performed early) to reduce the number of times the patient is required to be stuck. Accessioning simply involves looking up the patient's ordered tests in the computer system, entering the current time, and printing out the vial labels.

The phlebotomist then walks to the single label printer in the draw room to retrieve the labels. The phlebotomist compares the name on the labels with the name on the VA card and asks the patient to read and confirm that their name and SSN are correct on the labels and sign the last one. While the patient is reading, the phlebotomist gathers the appropriate supplies and sterilizes their hands with foam sanitizer from a dispenser above their workstation. They then prepare the patient's skin and draw blood into the appropriate vials. Certain tests require certain vials, which are identified by color. The four vials that are used most frequently (red, green, blue and purple) and urine cups are abundantly stocked at each station. Vials for special tests and containers for stool samples are kept in a supply closet.

Even though the labels are printed with the phlebotomist's identification, the phlebotomist still initials each of the labels to further ascertain that they were the person to draw that patient's blood, in case issues arise or the phlebotomist accessioned the patient while another phlebotomist was logged into the computer. The phlebotomist attaches the labels to the appropriate vials and places the vials on a rack in the back of the room. The patient is then free to leave. The phlebotomist next attaches the last label, the one the patient signed, to their patient workload sheet and sterilizes their hands once more. Patient workload sheets keep a record of how the phlebotomist spends their time and how many patients they see in a day. They also are used to further confirm which phlebotomist saw which patient to prevent one phlebotomist from being blamed for another's mistake. The phlebotomy supervisor enters the information into a computer database every three weeks to determine the number of patients each phlebotomist sees on average. The workflow sheets are then kept for a certain period of time in case problems arise or are reported by a patient.

The downstairs draw room usually has a volunteer to transport the blood upstairs to the lab. If the draw room is busy, the volunteer waits until the vial rack is full and carries it upstairs in a biohazard box. An empty rack is always in the biohazard box to replace the used one. If the lab is relatively slow, the phlebotomists usually fill biohazard bags every thirty minutes with the blood vials and the volunteer carries it up. If a collection must be tested immediately, it is placed in a red "Stat" bag and taken to the lab immediately. Upstairs, lab specimens are taken to the nearby lab every fifteen minutes, unless the specimen is stat.

3.3.2 Inpatients

When a doctor orders an inpatient to have blood work, an order prints at the upstairs lab. A phlebotomist takes the printout, writes the patient's room number or location and the required draw time on the back, and then pins it to a bulletin board in the draw room. Patients with the same draw times are stacked under the same pin and are placed chronologically across the board. Every hour an "hourly" prints, listing all scheduled inpatient draws. The phlebotomist checks the hourly with the board to make sure nothing has been missed or cancelled. In each draw room, there are several trays stocked with all specimen collection supplies, including special vials, for draws that occur outside of the draw room. When it is close to the draw time, a phlebotomist takes one of the portable lab trays, checks that it is fully stocked with their needed supplies, takes a pager and walks to the appropriate area of the hospital (inpatient rooms, ICU, or ER). If the patient is in the ICU or ER, the phlebotomist attempts to draw blood as close to the scheduled time as possible for accurate testing results.

Once the phlebotomist arrives at the appropriate room, they announce to the patient what they are there for, asks for the patient's full name and full social security number, and then also verifies the information on the printout with the patient's armband. The phlebotomist then follows standard draw procedure, but writes the patient's full name and full social on each vial. The draw time is recorded on the printout, and the phlebotomist either moves on to the next patient or returns to the draw room. After returning to the draw room, the phlebotomist accessions the inpatients they visited using the order number on the printout and places the printed labels under the handwritten ones on the vials. The vials are then taken to the lab for processing.

3.3.3 Emergency Patients

If a patient admitted to the emergency room requires blood work, the ER clerk will call the downstairs draw room if it is open, the upstairs room otherwise, or page a phlebotomist on duty. The phlebotomist takes a portable lab tray and walks to the ER. When the phlebotomist reaches the ER (located downstairs), a paper with the patient's information and ordered tests will be laying face down in a tray on the counter. The clerk writes the patient's room number on the back of the paper and circles it so the phlebotomist knows immediately where to go. Since the phlebotomist is being hurried and is away from their computer, they must have a thorough knowledge of which tubes are required for the ordered tests.

After reviewing the printout and determining the appropriate tests and vials to use, the phlebotomist walks to the patient's room, asks the patient to state their name and last four to verify their identity with the information on the printout. They then confirm this with the patient's wristband. The specimen is collected into the proper vials, and the phlebotomist hand-writes the patient's information on each of the tubes. Once this is complete, they record the current time on the printout because Emergency Room draws are considered time-sensitive. Once the phlebotomist returns to the draw room, they accession the patient and tests there, initial the printed labels, and place the labels below the handwritten one on the vials. The blood vials and the printout are then placed in a stat bag and sent upstairs to the lab. The phlebotomist then adds the emergency run to their workflow sheet.

If a heart attack is suspected or the patient is experiencing chest pains, a troponin test is required to assess if a heart attack occurred. In the case of a troponin, the phlebotomist sends the blood vials upstairs immediately without accessioning. The machine technician stamps the printout with the time, begins the troponin test and then accessions the rest. Emergency procedures require that the time be recorded at each step because the night supervisor assesses each of them. If the total time exceeds one hour the reason for the delay must be determined. If the phlebotomist incurs a delay during the process, they write the reason and the time on the printout for this reason and to avoid being punished. Delays include machine errors, waiting on nurses, etc.

Sometimes during emergency procedures, if the nurse starts an IV before the phlebotomist arrives, they will draw blood into a syringe. Once the phlebotomist arrives, they simply dispense the blood into the appropriate vials to avoid sticking the patient again. All emergency patients require a “rainbow” of vials, which consists of red, green, blue and lavender vials to ensure that most tests can be conducted and time is not wasted by having a phlebotomist return to the patient.

3.3.4 Add-ons

After reviewing the patient’s initial blood tests, a doctor may (and generally does) order add-ons, additional tests on the patient’s blood. When this occurs, the add-on request is immediately printed at the upstairs draw room. A phlebotomist retrieves the printout with the patient’s identification number, looks up the additional tests on a computer with the accession number, and pulls the blood from the refrigerator to see if the tests can be added. If the test can be added depends on the time the blood was drawn, whether or not the test requires the blood to be kept on ice, or if the blood was drawn into the correct vial type for that particular test. If the test can be added, the phlebotomist writes the new test on the existing label and returns it to the lab. If the new test is impossible to add-on, the phlebotomist calls the clinic and the patient must return to have blood drawn again.

4 Problem Statement

Inefficiencies in practices and resources within phlebotomy labs, and at the VHSO phlebotomy lab in particular, cause patient wait times to increase to unacceptable levels. This study aims to discover the source of these inefficiencies and possible solutions through simulation modeling in Arena®. The upstairs and downstairs labs will be simulated with all different possible situations to first confirm the current practices. Then varying configurations and resource availability will be introduced to discover possible improvements to lab function. Finally, the heads of staff of the VA phlebotomy lab specifically requested that the results of closing the downstairs lab be investigated; therefore, this situation will be modeled as well.

5 Model Formulation

Extensive time studies were performed at the VA to collect data to fit distributions and use in the model. The time data collected includes patient interarrival, service, and wait times for both the upstairs and downstairs labs, and the length of time taken for the phlebotomists to use the computer. The length and frequency of phlebotomist's emergency runs, add-ons, and inpatient runs were also recorded. This data was then used to create statistical distributions to use in the models.

Initially both the upstairs and downstairs models considered just the process of patients arriving, having blood drawn, and then leaving the system. The models were then extended to consider emergency runs for the downstairs model and inpatient and add-ons for the upstairs model. Since lengthy wait times are generally only an issue during a four-hour window every morning between 7:00 - 11:00 am and emergency runs are performed exclusively by the downstairs lab during this time, emergency runs are not modeled in the upstairs model. Finally, the use of computers during normal and special processes was implemented in both models.

Using the data collected from observing the VA Phlebotomy Lab, the downstairs and upstairs models create patient arrivals following an exponential distribution with parameters 1.86 and 2.69 minutes, respectively. The entities (patients) are then duplicated and separated. The original entities are sent through the normal process of having blood drawn. Arrival time is first assigned to the entity before it waits in the queue for a chair and phlebotomist to become available and the number entering the system is incremented. Once both are accessible, both are seized by the entity. Wait time is then recorded by subtracting the current time from arrive time. A computer is next seized, with service time following a normal distribution with mean 34.4 seconds and standard deviation 15.4 seconds, and then released. The actual process of collecting blood is then modeled, where service time follows a normal distribution with a mean and standard deviation of 5.12 and 2.68 minutes respectively. The phlebotomist and chair are then released, the number serviced is incremented, the total time in the system is recorded by subtracting the current time from arrive time, and the entities are disposed (aka the patient leaves the system). The collection of urine specimens is not modeled in either model because this does not generally add or subtract from any resource nor does it prohibit a phlebotomist from proceeding to collect from another patient.

Meanwhile, the duplicated entities are assigned a number, that determines whether an entity goes through the emergency process downstairs and whether an entity goes through the add-on or inpatient process upstairs. Downstairs, fifteen percent of the duplicated entities go through the emergency process to model the phlebotomists being called away from the lab. If the appropriate number is assigned to the duplicate, the duplicate will seize and delay a phlebotomist for a length of time as determined by a triangular distribution with a minimum, most likely, and maximum time of five, seven, and twenty minutes respectively. With the phlebotomist still seized, a computer is seized and used for the same amount of time as in a normal blood draw to simulate a phlebotomist accessioning an emergency run. The phlebotomist is then released and the duplicate is disposed. If the duplicate does not have the appropriate number, it is immediately disposed.

The same basic process is used for the upstairs model; however, in this model, seven percent of the duplicates are assigned a one to be used as a floor run, fifteen percent are assigned a two to be used for an add-on process, and the rest are assigned a three and disposed of immediately. During the floor (inpatient) run, the same process is used as in an emergency run downstairs; however, the triangular distribution that determines the length of time for which the phlebotomist is seized in this case has a minimum, most likely, and maximum time of seven, sixteen, and forty minutes respectively. If a two is assigned to the duplicate for an add-on process, the duplicate seizes and delays a phlebotomist for a time as determined by a triangular distribution with times of two, four, and six minutes. A computer is then seized, delayed and released over a period in this case determined by a triangular distribution of one, two, and five minutes instead of the normal distributions used previously. This is because add-ons are usually performed in groups and require more computer time. After the computer is used, the phlebotomist is released and the duplicate is disposed.

6 Model Verification

After creating the first two models, one replication of each was ran with the current number of computers, chairs and phlebotomists. The results where then used to adjust the approximated details of the models until the results closely matched the current situation. Due to the nature of the model, the percentage of duplicated entities that were assigned to represent emergencies, add-ons or in-patient runs had to be heavily approximated. These numbers were adjusted until satisfactory results were obtained. Afterwards, the required number of replications for a confidence interval of plus or minus two minutes was found by running ten replications, collecting the half-width information, and using both numbers in equation 1. In this equation, n is the required number of replications for the desired half-width h (or confidence interval), h_0 is the current half-width, and n_0 is the current number of replications.

$$n = n_0\left(\frac{h_0^{\,2}}{h^2}\right) \tag{1}$$

After finding that 100 replications were required for the downstairs model and 60 were required for the upstairs model, the percentages in the model were slightly adjusted again until the desired results were obtained once more.

The models were then run several times, adding one and two to the number of computers and phlebotomists. However, after obtaining the results, not only were times increasing after resources were added, but also the number of patients entering the system was varying. Neither of these results was plausible. After consultation, it was discovered that each number generated by a distribution needed to be assigned an individual random number stream. This assignment guarantees that the random number streams are used by the same distribution during each replication so that results of changes made to the models reflect only those changes and not different random numbers. After these changes were made to each model, the assignment percentages of both were adjusted once again until appropriate results were obtained. Finally, the models could be considered accurate. The approximate real waiting times at the VA are shown in

Table 1 below where “Total” stands for the total time the patient spends in the system, and the initial results from the fully adjusted model are displayed in Table 2.

Table 1. Current Wait and System Times in Minutes

Lab	Average Wait	Max Wait	Average Total	Max Total
Downstairs	14.87	36.00	16.49	40.00
Upstairs	6.24	42.00	10.47	44.00

Table 2. Initial Model Results

Lab	Average Wait	Max Wait	Average Total	Max Total
Downstairs	13.0 ± 1.8	69.0 ± 1.8	18.5 ± 1.7	75.9 ± 1.7
Upstairs	7.6 ± 1.8	92.0 ± 1.8	11.8 ± 1.8	92.0 ± 1.8

The average times for both models are not exact, but are the closest approximations obtained from model alterations. The maximum times are much higher; however, this is justified by the fact that these are close to actual maximum times reported to authorities at the VA, just not times observed during the study.

7 Experimental Results

After verifying the two models, nine scenarios were run for each model. In each scenario, either the number of phlebotomists or number of computers was increased. Increasing the number of phlebotomists is the obvious solution to the problem; however, it is not the desirable solution due to budget cuts and financial constraints at the VA. Increasing the number of computers was suggested by one of the lead phlebotomists and is a plausible solution because chairs and phlebotomists outnumber computers. Increasing the number of chairs was not considered because the current size of the two draw rooms does not allow for additional chairs. The average and maximum wait and total system time results for the downstairs model are listed in Tables 3 - 6 and in Tables 7 - 10 for the upstairs model. The number of patients entering the downstairs system in every scenario was 150, and the number serviced increased from 140 to 147 when the number of phlebotomists was increased. In the upstairs model, the number of patients entering the system in all scenarios was 109 and the number of patients serviced stayed at 105 until the number of phlebotomists was increased to five; however, even then the number serviced only increased to 106.

Table 3. Downstairs Average Wait Time

	# Phlebotomists		
# Computers	**4**	**5**	**6**
3	13.0 ± 1.8	4.0 ± 0.6	2.2 ± 0.3
4	13.0 ± 1.8	4.0 ± 0.6	2.2 ± 0.3
5	13.0 ± 1.8	4.0 ± 0.6	2.2 ± 0.3

Table 4. Downstairs Maximum Wait Time

	# Phlebotomists		
# Computers	**4**	**5**	**6**
3	68.9 ± 1.8	34.7 ± 0.6	21.1 ± 0.3
4	68.9 ± 1.8	34.7 ± 0.6	21.1 ± 0.3
5	68.9 ± 1.8	34.7 ± 0.6	21.1 ± 0.3

Table 5. Downstairs Average Time in System

	# Phlebotomists		
# Computers	**4**	**5**	**6**
3	18.5 ± 1.7	9.7 ± 0.7	7.8 ± 0.3
4	18.5 ± 1.7	9.7 ± 0.7	7.8 ± 0.3
5	18.5 ± 1.7	9.7 ± 0.7	7.8 ± 0.3

Table 6. Downstairs Maximum Time in System

	# Phlebotomists		
# Computers	**4**	**5**	**6**
3	75.9 ± 1.7	41.1 ± 0.7	28.4 ± 0.3
4	75.9 ± 1.7	41.1 ± 0.7	28.4 ± 0.3
5	75.9 ± 1.7	41.1 ± 0.7	28.4 ± 0.3

Table 7. Upstairs Average Wait Time

	# Phlebotomists		
# Computers	**3**	**4**	**5**
2	7.6 ± 1.8	1.8 ± 0.6	0.7 ± 0.2
3	7.5 ± 1.8	1.8 ± 0.6	0.7 ± 0.2
4	7.5 ± 1.8	1.8 ± 0.6	0.7 ± 0.2

Table 8. Upstairs Maximum Wait Time

	# Phlebotomists		
# Computers	**3**	**4**	**5**
2	91.6 ± 1.8	35.9 ± 0.6	20.0 ± 0.2
3	91.6 ± 1.8	34.7 ± 0.6	19.8 ± 0.2
4	91.6 ± 1.8	34.7 ± 0.6	19.8 ± 0.2

Table 9. Upstairs Average Time in System

	# Phlebotomists		
# Computers	**3**	**4**	**5**
2	11.8 ± 1.8	6.1 ± 0.6	5.9 ± 0.2
3	11.8 ± 1.8	6.0 ± 0.6	4.9 ± 0.2
4	11.8 ± 1.8	6.0 ± 0.6	4.9 ± 0.2

Table 10. Upstairs Maximum Time in System

	# Phlebotomists		
# Computers	**3**	**4**	**5**
2	92.0 ± 1.8	41.3 ± 0.6	22.9 ± 0.2
3	92.0 ± 1.8	41.1 ± 0.6	22.7 ± 0.2
4	92.0 ± 1.8	41.1 ± 0.6	22.7 ± 0.2

In all cases, increasing the number of computers did not create the desired effect because not only do the times decrease minimally when a computer is added, but the confidence intervals also overlap in all cases. Therefore, adding a computer has no significant effect on the system. Although increasing the number of phlebotomists was not the desired solution, it is obviously the best as it considerably reduces the wait and system times in all cases. Adding one phlebotomist cuts these times nearly in half in most cases.

Since a desirable solution was not truly obtained, closing the downstairs lab was next considered. To model closing the downstairs lab, the upstairs model was used, but the assign module was modified to include emergency runs and the emergency run modules were added. Also, to accommodate all patients, the time between arrivals was approximated as an exponential distribution with a mean of 1.2 minutes. Initially, the mean was set to 1.5 minutes; however, the number of patients entering the system was too low. After changing the mean to 1.2 minutes, the number of arrivals increased to 230, as compared to the downstairs and upstairs total of 259 patients in. The original configuration assumes that no chairs or computers are added upstairs and seven phlebotomists are working. The model is then tested assuming that one chair can be added (which is not ideal, but possible), that a computer can be added, and that phlebotomists can be added. These results are displayed in Tables 11 and 12 below.

Table 11. Average Times of Combined Lab with Three Chairs

Avg Wait Time	**# Phlebotomists**		
# Computers	**7**	**8**	**9**
2	32.4 ± 2.0	26.8 ± 1.6	24.4 ± 1.5
3	31.0 ± 2.0	25.2 ± 1.6	22.7 ± 1.4

Avg Sys Time	**# Phlebotomists**		
# Computers	**7**	**8**	**9**
2	36.2 ± 2.0	30.7 ± 1.6	28.4 ± 1.5
3	34.8 ± 1.9	29.0 ± 1.6	26.6 ± 1.4

Table 12. Average Times of Combined Lab with Four Chairs

Avg Wait Time	**# Phlebotomists**		
# Computers	**7**	**8**	**9**
3	18.0 ± 1.9	9.5 ± 1.2	5.6 ± 0.7
4	17.9 ± 1.9	9.3 ± 1.1	5.5 ± 0.7

Avg Sys Time	**# Phlebotomists**		
# Computers	**7**	**8**	**9**
3	22.1 ± 1.9	13.7 ± 1.2	9.8 ± 0.7
4	21.9 ± 1.9	13.5 ± 1.1	9.7 ± 0.7

If a chair is not added upstairs, the results do not meet the fifteen-minute desired wait time. However, once a chair is added, the results come closer to that desired window and are furthermore under fifteen minutes when eight phlebotomists are working.

Finally, the VA is currently undergoing construction on an additional wing, which will include a single, larger phlebotomy lab. Therefore, the last model was tested assuming all current resources are moved to this lab (seven chairs, five computers). These results are in Table 13. Even though seven chairs are available, if only seven phlebotomists are available, the chairs will never fully be utilized because at least one phlebotomist will always be performing an emergency run, inpatient draw, or add-on. In fact, the chair utilization in this scenario was only 45.6%, whereas when only four chairs are available the utilization is 76.6%.

Table 13. Average Times of Combined Lab with Seven Chairs

Avg Wait Time	**# Phlebotomists**		
# Computers	**7**	**8**	**9**
5	14.1656 ± 1.70	5.0177 ± 0.70	1.8628 ± 0.27

Avg Sys Time	**# Phlebotomists**		
# Computers	**7**	**8**	**9**
5	18.2681 ± 1.69	9.2543 ± 0.71	6.1117 ± 0.27

Furthermore, this scenario meets the fifteen-minute desired wait time.

8 Conclusions and Future Work

The goal of this study was to explore different possible opportunities for wait time improvement within the VA Hospital Phlebotomy Lab. These possibilities were explored through simulation modeling by creating the current situation and then changing input parameters to find points of improvement. Ultimately the best recommendation for the VA Lab was found to be to increase the number of scheduled phlebotomists. However, it was also discovered that closing the downstairs lab is a feasible solution if enough phlebotomists are hired and working during the four-hour peak. Furthermore, this research further endorsed the opening a single, larger lab, which the VA is planning to do within the next five years.

In the meantime, however, while hiring additional phlebotomists may not be financially feasible, making improvements to managerial aspects of the current lab is a source of future work to improve functionality. During the study it was noticed that, as in most real-world work environments, some phlebotomists worked more than others while others took frequent breaks or saw less patients. Further studies on the phlebotomist's workload sheets and recommendations for using those to improve lab efficiency could possibly create another solution to immediately decrease patient wait time.

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