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Models for Incorporating Block Scheduling in Blood Drive Staffing Problems

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Models for Incorporating Block Scheduling in Blood Drive Staffing Problems

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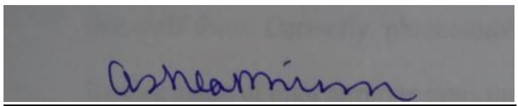

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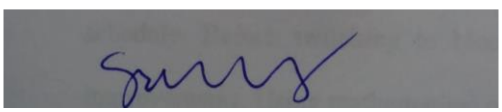

Abstract

The purpose of this research is to develop decision support models that can be used by the American Red Cross (ARC) to schedule blood drives with improved shifts for the phlebotomists that staff them. Currently, phlebotomists work inconsistent hours and the ARC believes this is a leading cause of high turnover rates they are experiencing. For example, phlebotomists sometimes staff a blood drive until 11 PM one night and will have to work another at 8 AM the next morning. Assigning phlebotomists more consistent shifts in blocks of time will definitely improve their work schedule. Before switching to block scheduling, the ARC would like to see the potential improvements. Using mathematical optimization software and heuristics to model the scheduling scenarios, this research has evaluated the effectiveness of block scheduling, which was measured by the number of drives needed to be moved from their originally requested start time, etc. Ultimately, these models and results will help the ARC decide whether to switch to block scheduling for assigning phlebotomists to blood drives.

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I. Background/Motivation

Currently, phlebotomists work inconsistent hours at the American Red Cross (ARC). Administrators wish to evaluate the impact of changing to a block scheduling system that will ensure phlebotomists work blood drives the same days of the week and at the same time slot of day. Blood drives are booked upon request by specific sponsors at their location (e.g., university, company). When sponsors volunteer to host a blood drive, they submit a desired date and time. Currently, phlebotomists are assigned to a drive if they are available and if this additional time range has not exceeded their weekly workload limit. If there are not enough phlebotomists for the required blood drive, the ARC will work with the sponsors to find alternative times. Because sponsorship of drives is a voluntary process, the ARC would like to meet sponsor satisfaction by having to move as few drives as possible.

While minimizing the number of drives needed to be moved from the sponsor's requested time, the ARC would like to consider imposing an additional criterion for assigning a phlebotomist. The new change will only allow a phlebotomist to be assigned to a particular drive if it occurs during their scheduled block of time.

To determine the feasibility of the new method, it is necessary to investigate if this type of block scheduling has a negative impact on the ARC's ability to book drives at their requested times. A series of information were provided by the ARC to help develop a model to evaluate block scheduling. The information consisted of a Word document describing the project requirements and an Excel file containing the blood drive data of October 2011- September 2012 for the Dallas and Tulsa regions. The data from the Tulsa region were used for the case study described in this thesis.

II. Literature Review

In order to better understand the ideology and motivation of this research, it is important to know more about the work style of phlebotomists and how block scheduling could benefit them. The phlebotomy profession is very demanding. According to Hartford Hospital, quality phlebotomists need extensive training. Phlebotomists are required to not only collect blood from patients but also have many other complicated duties, like performing computer operations, implementing quality control procedures, and properly verifying a patient's information prior to collecting blood [7]. In addition, they are required to staff various shifts ranging from 12 hour shifts to working night shifts that run from 7 PM to 7 AM [6]. On top of that, the salary of phlebotomists is low. Based on the Bureau of Labor Statistics, in 2013 the median annual pay of phlebotomists is $29,730 or about $14 per hour [3]. This salary is only about half of that of a registered nurse ($65,470).

When combining the low salary and unfavorable shift times, many phlebotomists will choose to transition to other professions like nursing [5]. This further emphasizes the importance of more suitable shift times for phlebotomists, especially for the ARC because there are budget constraints to limit the organization from raising salaries. The proposed method of assigning phlebotomists more suitable times is block scheduling.

Block scheduling has been successfully executed in many places. Currently, it is a common practice used in nurse staffing scenarios. In order to minimize the number of nurses needed for a hospital, mathematical models can be created to limit the number of hours and intervals that nurses work [2]. Similarly, block scheduling has also been successful in staffing hospital workers more efficiently and bettering the use of the limited resources [4]. Hospitals frequently have difficulties managing operation rooms and this has resulted in many use conflicts. With organized scheduling methods, the operation rooms have become more efficient, solving the hospitals' capacity restraints.

III. Initial AMPL Model Formation

Two mathematical models were created for assigning phlebotomists to blood drives. The first did not include block scheduling constraints and the second did. The objective of both models was to schedule as many drives at their originally requested times as possible. The number of drives needed to be moved from their originally requested times were compared across both models to assess the effectiveness of block scheduling.

AMPL (a software that enables solving math models) was used to obtain solutions to the model without blocking. The initial formation of the mathematical model was derived from a vehicle routing problem with time windows and multiple vehicles [1]. This was possible because of the similarity of the two problems, as blood drives with time windows are analogous to customers that must be visited in vehicle routing. The derived model 1 is shown as:

Model 1: Scheduling without Blocking

Sets

- V, Set of drives
- *K*, Set of phlebotomists
- *A*, Set of times
- V^+, Drives union 0

Variables

- $X_{i,j,k}$ $X_{i,j,k} = 0, 1$, binary variable indicating if a drive j is assigned immediately after drive i by phlebotomist k
- $Y_{i,k}$ $Y_{i,k} = 0, 1$, binary variable indicating if drive i is performed by phlebotomist k
- T_i, scheduled start time of drive i
- $Z_{i,a}$, binary variable indicating new start time of drive

- D_i, variable indicating if start time of drive i needs to be scheduled at time other than that requested

Parameters

- S_i, requested start time of each drive in hours
- Ga, possible times for each drive to be moved
- L_i, length in hours of each drive
- R_i, number of phlebotomists required for each drive
- H_k, hours worked for each phlebotomist for the week (currently 40 hours a week)
- U, large constant

Objective Function

Min $\sum_i^V D_i$ Minimize the sum of drive times that need to be scheduled at times other than those requested (1)

Constraints

$\sum_j^{V+(j<>i)} x_{i,j,k} = Y_{i,k} \;\; \forall\, i \; in \; V \,, k \; in \; K$ (2)

$\sum_k^K Y_{i,k} = R_i, \;\; \forall\, i \; in \; V$ (3)

$\sum_i^{V+} X_{i,h,k} - \sum_J^{V+} X_{h,j,k} = 0 \; \forall\, h \; in \; V \; and \; K \; in \; K$ (4)

$\sum_i^{V+} X_{0,i,k} = 1 \; \forall\, k \; in \; K$ (5)
$\sum_i^{V+} X_{i,n+1,k} = 1 \; \forall\, k \; in \; K$ (6)
$\sum_i^V Y_{i,k} * L_i \le H_k \; \forall\, k \; in \; K$ (7)
$\sum_a^A Z_{i,a} = 1 \; \forall\, i \; in \; V$ (8)
$T_i = \sum_a^A Z_{i,a} * G_a \; \forall\, i \; in \; V$ (9)
$(T_{i,k} + L_i) - U\big(1 - X_{i,j,k}\big) \le T_j \forall k \; in \; K \; i \; in \; V, j \; in \; V$ (10)
$T_i - S_i \le D_i \forall\, i \; in \; V, k \; in$ (11)
$D_i \ge 0 \; \forall\, i \; in \; V$ (12)

This model was used to schedule drives and determine the number of drives that must be scheduled at times other than those requested each week, based on the information given by the ARC. The sets include the drives during the week, the phlebotomists for the week, and the possible start times for the scheduling of drives. The set V^+, which is used in the constraints to make sure each phlebotomist starts at a drive or ends at a drive, includes an additional home node with the set of drives. The binary variables in this model include: X, which indicates if a drive is scheduled after another assigned to the same phlebotomist; Y, which indicates if a drive is performed by a phlebotomist; Z, which indicates what the start time of the drive is; and D, which determines if a drive start time must be scheduled at a time other than that requested. The last variable T is the assigned start time of the drive, which may be different from the time requested. For each week, the parameters that the user needs to provide are defined in model 1 above.

The objective function of model 1 is to minimize the number of drives that must be scheduled at times other than those requested, allowing the ARC to evaluate whether drives can be scheduled at their requested time and how block scheduling will impact this. Constraints 2 and 3 enforce that each drive has the required number of phlebotomists and the phlebotomists can only serve one drive at a time. Constraints 4-6 are flow conservation constraints. Constraint 7 restricts the amount of hours each phlebotomist works to at most 40 hours per week. Constraints 8 and 9 determine the values of the Z variables which in turn set the start times for each drive. Constraint 10 restrains phlebotomists from staffing multiple drives that occur during the same time period. Constraints 11-12 set the values of the decision variables that are summed in the objective.

After formulating the model 1, a number of instances were solved using AMPL on a server with 24GB of RAM. The dataset provided by the ARC contained 52 weeks of drive data from the Tulsa region. For each week, there was an average of 34 drives, approximately 5 staff members were needed per drive, and each drive lasted an average of 4 hours and 46 minutes. Unfortunately, achieving optimal solutions for the problem instances was challenging. AMPL required at least six hours of runtime in order to find a feasible solution for each instance. In many of the instances, AMPL could not find a feasible solution because the server would run out of memory. Even when AMPL found a feasible solution, the optimality gap (how close the solution is to the best known lower bound on the optimal solution) would stay above 80%. The scenarios, for which AMPL identified feasible solutions, were limited to weeks where less than 25 drives were required.

Due to the limitations of obtaining solutions using AMPL, a heuristic solution approach was designed to solve the drive scheduling problem without blocks. Because a model that considers block schedules would be more computationally challenging to solve in AMPL, another heuristic approach was pursued to solve the drive scheduling problem with blocks as well. These heuristic methods are described in the next section.

IV. Alternative Approach: Heuristics

The heuristics designed employ a sequence of decision logic to choose phlebotomists to staff blood drives and assign the start times for the drives. With the heuristics a user is able to create two schedules for the same week, one with block scheduling and one without. The heuristics for the two scheduling models are very similar except that the blocking heuristic imposes a blocking constraint while the non-blocking heuristic does not. Heuristic A is detailed below and is used to solve the drive scheduling problem with block schedules. The heuristic for scheduling without blocks can be formed by simply deleting the italicized portions of Heuristic A.

Heuristic A: Heuristic with Blocking

Calculating Blocks:

1. Calculate the minimum number of phlebotomists needed for the week by summing the total hours needed for all of the drives and times by 120%.
2. *The first shift starts during the start time of the earliest drive and ends 10 hours after.*
3. *The second shift starts during the highest volume time period.*
4. *The last shift ends with the last drives end time and the start time is 10 hours before.*
5. *The number of phlebotomists assigned for the first shift is the maximum number of phlebotomists needed for that drive that exclusively starts only in the first shift's range.*
6. *The number of phlebotomists assigned for the last shift is the maximum number of phlebotomists needed for that drive that exclusively ends only in the last shift's range.*
7. *The remainder of the phlebotomists left over is allocated to the third shift time interval.*

Scheduling:

0. Sort the drives each day by the earliest start time of each drive, then pick the drive with the most phlebotomists; if there are more than one drive with the same number of phlebotomists required, then pick the drive with the earlier start time.
1. Find phlebotomists to assign to the drive such that:

a. The first available phlebotomist is assigned to that drive.
b. Phlebotomists will not violate their workweek duration constraints:
    i. Each phlebotomist only works 40 hours a week;
    ii. Phlebotomists cannot work more than 1 drive during the same time period.
c. Phlebotomists will only work the block period they are assigned.

If no phlebotomists exist, then

1. Skip this drive and come back later on,
2. Find a new time for this drive:
    a. Find the next available time period where a phlebotomist is available to take the drive:
        i. The new time needs to have enough phlebotomists to staff this time slot.
3. If no time slot is available, then take drive out of the week and move to another week.

In order to use the heuristics, a user needs to pull a week's worth of drive data from the ARC database. The data include information about each drive like the date scheduled, start time, shift length, and staff requested. The user can then use software like Microsoft Excel to set up a table to schedule phlebotomists according to the heuristics. Table 1 (attached in the Appendix) is an example of a template developed to find the schedule for each phlebotomist.

As seen in this table, information about each of the drive, namely the length, start time, and number of phlebotomists, is included to make it easier to follow the heuristic. At the very end of each row, the total number of hours for each phlebotomist can be calculated to make sure the 40 hour-weekly workload limit is not exceeded. When calculating the schedules of phlebotomists with block shifts, the user needs to take caution to ensure that phlebotomists only work the shift they are assigned to.

Choosing the shifts in the original heuristics was performed based on initial theories regarding what may comprise "good" shift times. The heuristics would rank drives based on a sequence, in this case, earliest start time. Then phlebotomists would be assigned to drives based on whoever is on the top of the list. Phlebotomists are numbered for easy identification and their numbers will serve as a priority system for serving drives. For example, if both phlebotomists 2 and 12 are available to staff a drive, phlebotomist 2 will be chosen. When assigning a phlebotomist, the user must make sure that the phlebotomist does not work more than 40 hours a week or more than one drive at a time. If there are not enough phlebotomists to assign to a drive, then the drive start time will have to be moved. Generally, the preferred new start time is the next available time period with enough phlebotomists. By following the steps of this heuristic, the drive start times for a week will be scheduled.

For the block scheduling heuristic, the key is in determining times for three shifts. The beginning shift will have the earliest start time of the week of drives and will last 10 hours. The final shift will be the time interval with the latest ending time of the week and will start 10 hours before that. The middle shift will occur during the highest volume time period, which is decided by the user. 10 hours are used instead of the typical 8 hours for a shift period because most drives last more than 4 hours and if a phlebotomist is to staff two drives in one day a regular 8 hour shift will not be enough.

To determine if the above heuristic can be improved, another heuristic was developed for comparison. The bolded steps below show the differences from Heuristic A.

Heuristic B: Alternative Heuristic

Calculating Blocks:

1. Calculate the minimum number of phlebotomists needed for the week by summing the total hours needed for all of the drives and times by 120 %.
2. *The first shift starts during the start time of the earliest drive and ends 10 hours after.*
3. *The second shift starts during the highest volume time period.*
4. *The last shift ends with the last drives end time and the start time is 10 hours before.*
5. *The number of phlebotomists assigned for the first shift is the maximum number of phlebotomists needed for that drive that exclusively starts only in the first shifts range.*
6. *The number of phlebotomists assigned for the last shift is the maximum number of phlebotomists needed for that drive that exclusively ends only in the last shift's range.*
7. *The remainder of the phlebotomists left over is allocated to the third shift time interval.*

Scheduling:

0. **Sort the drives each day with the most phlebotomists required; if there is more than one drive with the same number of phlebotomists required, then pick the drive with the earlier start time.**
1. Find phlebotomists to assign to the drive such that:
    a. The first available phlebotomist is assigned to that drive;
    b. Phlebotomists will not violate their workweek duration constraint;
    c. Each phlebotomist only works 40 hours a week;
    d. Phlebotomist cannot work more than 1 drive during the same time period; and
    e. *Phlebotomists will only work the block period they are assigned*.

If no phlebotomists exist, then

1. Skip this drive and come back later on,
    a. Find a new time for this drive.
    b. See if the drive can be moved to a different day with the same time period:
        i. Find the next available time period where a phlebotomist is available to take the drive.
    c. Phlebotomists will not violate their workweek duration constraints:
        i. Each phlebotomist only works 40 hours a week;
        ii. Phlebotomist cannot work more than 1 drive during the same time period.
    d. Phlebotomists will only work the block period they are assigned.

2. If no time slot is available, then
    a. Start from the beginning to see if one of the drives that were not moved could be changed the least time to fit the un-movable drive into the time slot.
    b. Phlebotomists will not violate their workweek duration constraints:
        i. Each phlebotomist only works 40 hours a week;
        ii. Phlebotomist cannot work more than 1 drive during the same time period.
    c. Phlebotomists will only work the block period they are assigned.

This heuristic has some differences from heuristic A, like the order in which phlebotomists are scheduled and the procedure for moving drives if no time slots are available. The number of drives needed to be moved using the alternative heuristic can be compared to the original heuristic A to determine a better recommendation for the ARC.

V. Results

The alternative heuristic allows the user to determine if there is a better way to schedule drives. Every step of the original heuristic can be changed and compared to find the optimal way that suits the ARC's scheduling standards and goals. The following scenarios are the comparisons made between the original and new heuristics.

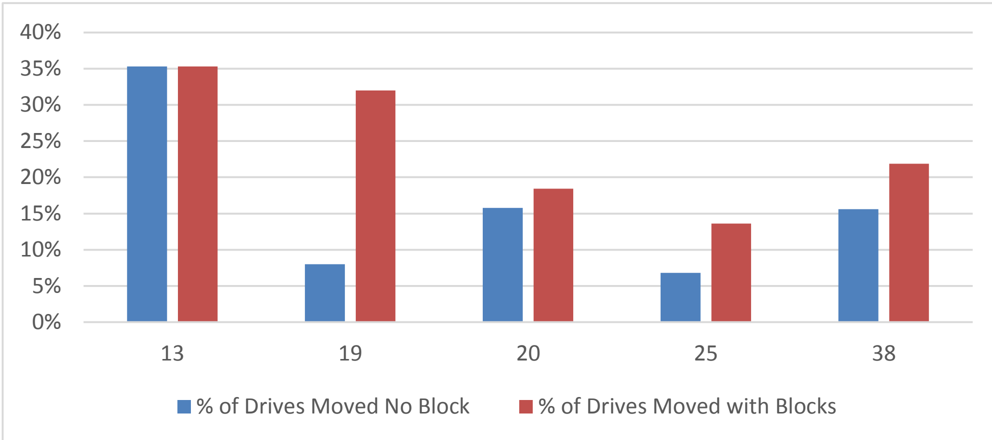
For testing purposes, five weeks of drives from the Tulsa region were used. They represent a variety of drives that may occur at the ARC, from busy weeks to relaxed weeks. The information regarding the five weeks of drives are shown in Table 2.

Table 2: Drive Information

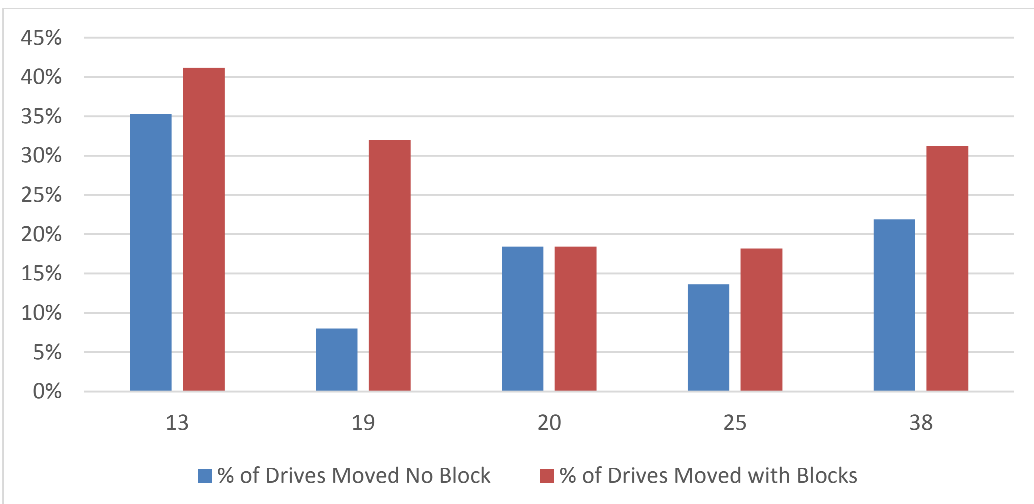
Drive Week	Date Range	Number of Drives	Number of Phlebotomists
13	12/26/2011 to 12/30/2011	17	10
19	02/6/2012 to 02/12/2012	25	25
20	02/13/2012 to 02/19/2012	38	26
25	03/19/2012 to 03/25/2012	44	26
38	05/28/2012 to 06/3/2012	32	23

One of the differences between heuristic A and B is step 0. Heuristic A schedules drives based on the earliest start time during the day, while Heuristic B ranks the drives during the day based on the number of phlebotomists requested for that day. It makes more sense for the ARC to try and schedule drives that need more phlebotomists because these drives will have more donors and therefore more blood collected. The percent of drives that cannot be scheduled on the requested time for the 5 weeks of drives are shown below in Graphs 1 and 2.

Graph 1- % of Drives Each Week Moved Using Heuristic A



Graph 2- % of Drives Moved Each Week Using Heuristic B



Graph 1 shows a comparison between drives that were scheduled without blocking and with blocking using Heuristic A. Graph 2 shows the same comparison but using the new heuristic B that takes preference for drives having more phlebotomists required. When comparing the two graphs, it can be seen that the heuristic change was not able to decrease the percentage of drives needed to be moved. On average 20% of drives times were changed using the original heuristic and 26% of drives were changed using the new heuristic. Because these percentages do not have a major difference, it is reasonable to assume that the ARC would accept and prefer to have drives with more phlebotomists assigned first.

When comparing the two scheduling methods (blocks and no blocks), the percentage of drives needed to be moved was lower on average for drives that were scheduled with no blocks. For the 5 weeks of drives, an average of 20% of the drive times had to be moved without block scheduling while about 27% needed to be changed using block scheduling. Of the 27%, about 10% (1 or 2 drives) could not fit within the available times during the week. Using Heuristic A, the drive that cannot be staffed would mostly likely have to be moved to another week, which may result in scheduling conflicts for that week.

One of the main reasons that certain drives are unable to be scheduled is because some of them occur during the middle of a shift; this will cause the phlebotomists that are assigned to that drive not be able to work another drive for the day. If one of those drives is moved to an earlier or later time period the drives that are originally un-schedulable would fit in the week. Table 3 is shown below comparing the number of drives needed to be changed from the original time using heuristic B.

Table 3: Final Number of Drives changed

Drive Week	Number of Drives Changed	Number of Drives Not Scheduled	Final Number of Drives Changed
13	7	2	9
19	8	1	9
20	7	0	7
25	8	0	8
38	10	0	10

According to Table 3, the average number of drives changed with block scheduling increased to 30% from 27%. Only 2 out of the 5 weeks required scheduled drives to be moved, thus this decision logic is an acceptable change. The drive that can be changed the least amount of time and will allow the un-movable drive to fit in a time slot will be used.

The main objective of this research was to assess whether block scheduling of phlebotomists has a negative impact on the scheduling of drives. From the previous discussion, it seems like scheduling without blocks is better in terms of the number of drives needed to be changed. But, when putting into account the actual work schedules of phlebotomists, the ARC may need to weigh the stakes. Gantt Charts 1 and 2 in the Appendix illustrates the difference of phlebotomists' schedules for the week 19.

The schedules of each phlebotomist are displayed in rows of Gantt Charts 1 and 2. These charts represent the schedules after some of the drive times are scheduled at times other than times requested using heuristic B. As seen in Chart 2, the phlebotomists are able to work more consistent hours and will only staff drives that are within their given blocks of time. For example, Phlebotomist 1 only has to work drives that end before 5 pm and he or she does not need to work more than 10 hours for any given day of the week. Relating back to Graph 2, the number of drives needed to be moved for week 19 without block scheduling is 2 while that with block scheduling is 9.

The phlebotomists with blocked schedules will have consistent times during the day that they work for and will have free time when they are not working; as a result they won't be so stressed or tired at work. For the no blocking results, an example of fatigue or stress can be: 10 phlebotomists will have to work 9 hours until midnight on Monday and will need to report to work on Tuesday at 9 am to 2 pm, and will still have another shift at 8 pm the same day. Whereas for the models with blocking, phlebotomists will only work during their assigned time period and will not have to worry about the drives that occur before or after their shift.

When looking at the other four weeks, the number of drives needed to be changed only increased by one or two drives. For all 5 weeks of drives, a final schedule was generated with a preferable assignment for the phlebotomists. Because the number of drives changed for block scheduling was only about a 7% increase on average, it is recommended that the ARC consider block scheduling for testing.

Additionally, statistical information about the utilization of phlebotomists that were scheduled using blocks for the five weeks is summarized in Table 4.

Table 4: Phlebotomist Utilization Based on Week Using Heuristic B

Week	Average Utilization	Min Utilization	Max Utilization	Utilization Standard Deviation
13	78.75%	32.50%	97.50%	21.61%
19	82.80%	37.50%	100.00%	15.36%
20	86.44%	10.00%	100.00%	18.43%
25	81.15%	10.00%	97.50%	21.25%
38	81.68%	37.50%	100.00%	16.62%

The average utilization for the phlebotomists each week is consistent with each other with an overall average of 82% utilization rate. The minimum utilization for two of the weeks is at 10% because not many drives were required during that time period.

With block scheduling, the reason why so many of the drives have to be moved is because there was a limit set on the number of phlebotomists available to work the shifts. The heuristic only allowed a 20% increase in the number of phlebotomists available from the absolute minimum number required (all the phlebotomists work 40 hours a week). If this number is increased slightly, the number of drives needed to be moved would significantly decrease. The recommended final heuristic is attached in the appendix. This heuristic is very similar to Heuristic B. The ARC can change any part of the heuristic to better fit their expectations and can test any additional heuristics to test for new scheduling methods.

VI. Recommendations for Future Work

Something that can be considered in the future is a more detailed case study of the Tulsa Region. Understanding more in terms of how many resources are available and how sponsors schedule blood drives will be beneficial in developing new models. It will also be beneficial to look at the way sponsors pick to choose drive times and days. One of the main reasons for the high percentage of drives that have to be moved for the block heuristic is because there are some drives that are scheduled during the middle of a shift and take many resources. This will cause other drives to have to be rescheduled.

Coming out with possibilities of limiting the options available to sponsors, like if a certain amount of drive has been scheduled for a certain day then that times slot will not be available for sponsors to choose, can be something that will impact the ability to schedule drives greatly. Giving sponsors a list of available times that their drive can be scheduled and having them choose a few of the options will open up more opportunities to develop preferable schedules for both sponsors and ARC. After all of the drive data are received for a certain time period, a proposed schedule can be generated based on the feedbacks of the sponsor. Statistics and conclusions on the effectiveness of generating a schedule can then be gathered to see if this would be feasible.

Additionally, looking at how block scheduling will affect the turnover rate of phlebotomists will be something that will be impactful in the decision of whether to implement block scheduling.

Being able to retain workers is something that is really important especially for a nonprofit organization given the fact that training costs and fixed costs of hiring a new worker is expensive.

Lastly but not least, it is also important to understand how much impact part-time phlebotomists play in the ARC. If there are part-time workers available then certain drives won't have to be moved if they are just missing one or two phlebotomists.

Appendix:

Chart 1: Week 19 Schedule, No Block

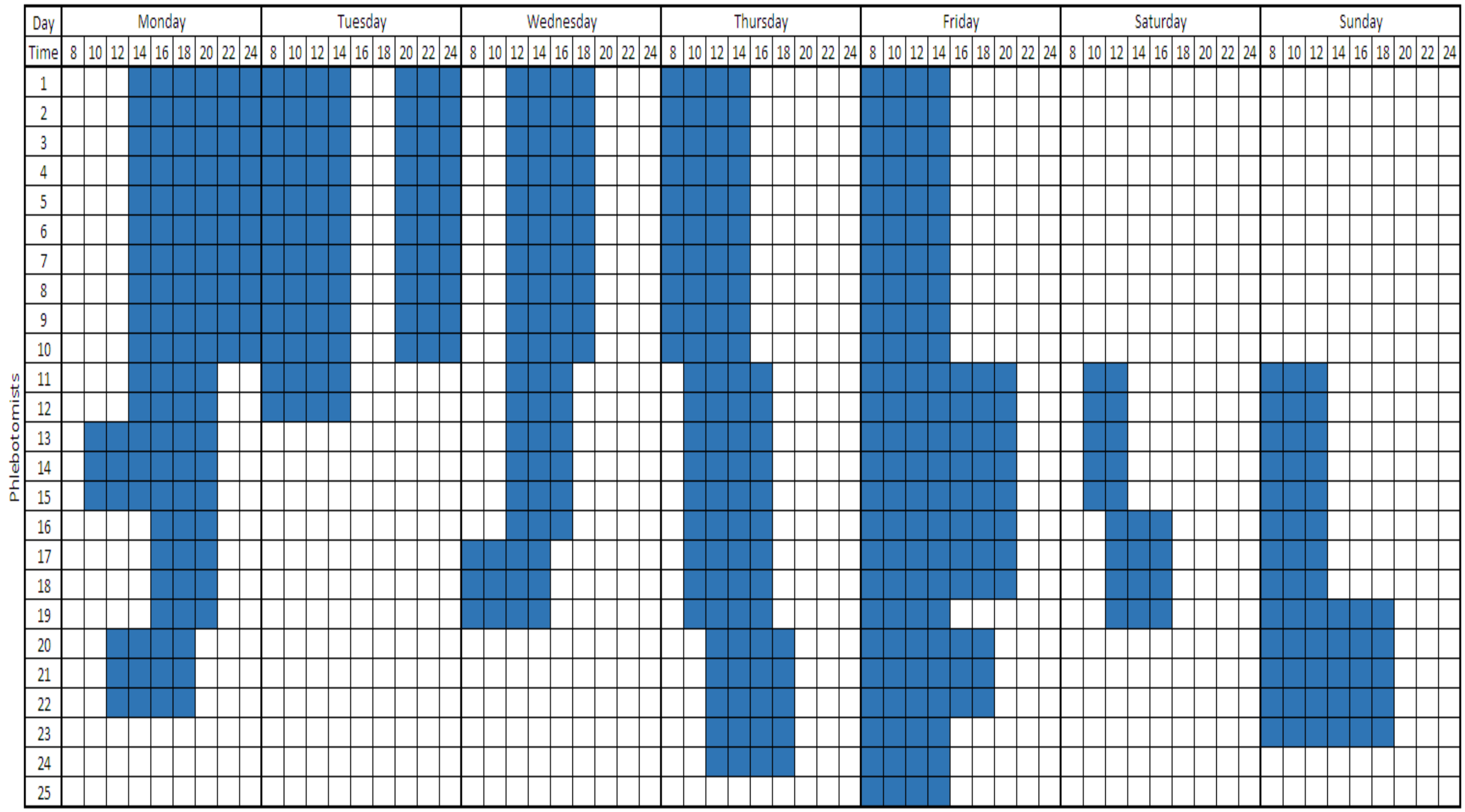


Chart 2: Week 19 Schedule, with Blocks

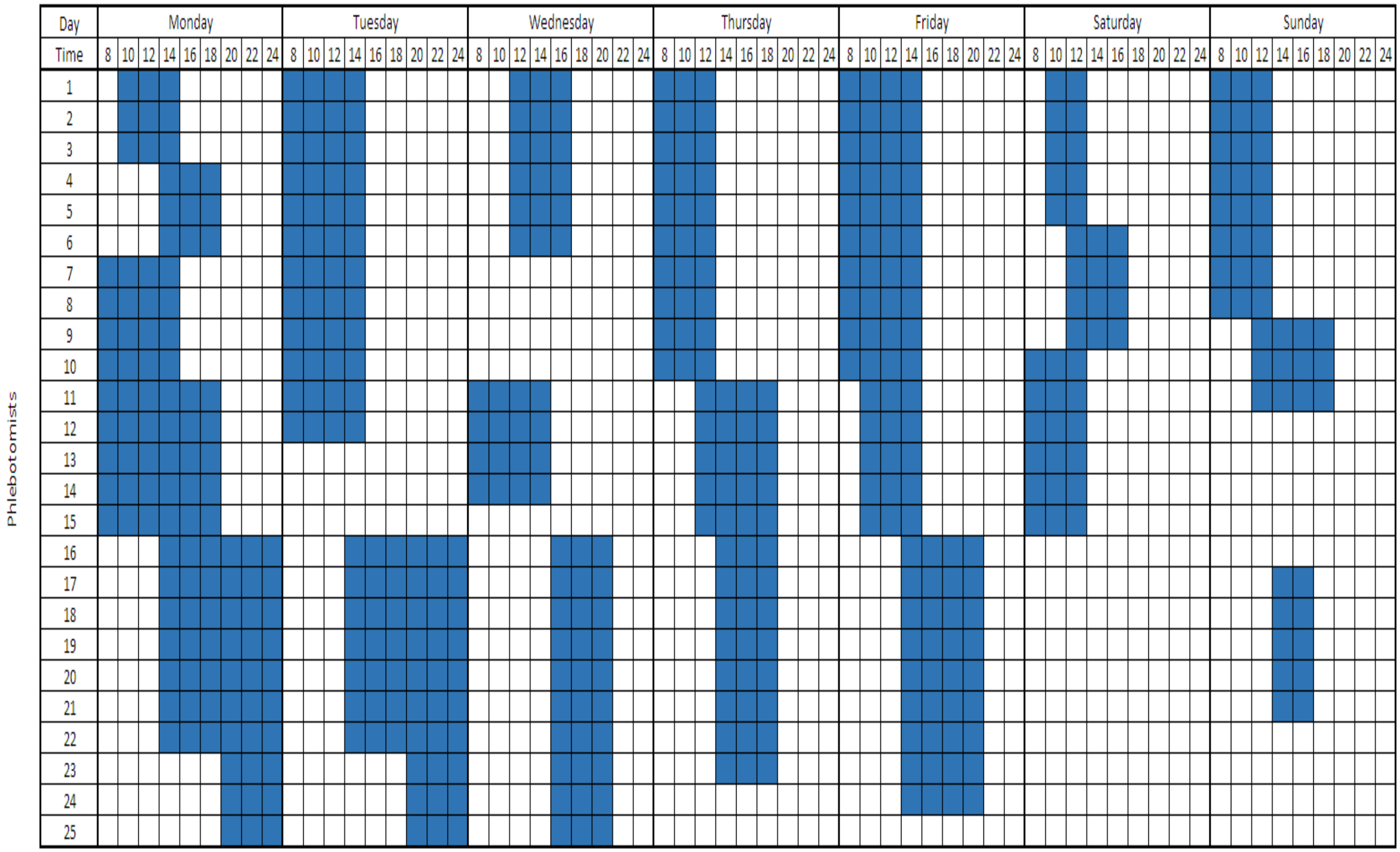


Table 1: Heuristic Template

	Hours	5	4	5	5	4	5.5	4	5	4	7	6	6	5.5	6	5.5	5.5	4	4.5	3.5	4	5	3	5		
		Monday					Tuesday		Wednesday			Thursday			Friday					Saturday		Sunday				
	Start Time	10	14	14	15	20	9	20	9.5	12	12	8	11.5	13	8	9.5	15	9.5	13.5	10	12	8	8.5	11.5		
Phlebotomists	End Time	15	18	19	20	24	14.5	24	14.5	16	19	14	17.5	18.5	14	15	20.5	13.5	18	13.5	16	13	11.5	16.5	Total Hours	Utilization
1		1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	35%
2		1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	35%
3		1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	35%
4		0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	20%
5		0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	20%
6		0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	20%
7		0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	23%
8		0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	23%
9		0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	23%
10		0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	23%
11		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13%
12		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13%
13		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13%
14		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13%
15		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13%
16		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13%
17		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13%
18		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13%
19		0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13%
20		0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13%
21		0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13%
22		0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13%
23		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
24		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
25		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
	Actual Number	3	3	12	7	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	# Required	3	3	12	7	10	12	10	4	6	10	10	9	5	10	9	8	6	3	5	4	8	5	5		

Heuristic C: Final Heuristic with Blocks

Calculating Blocks:

0. Calculate the minimum number of phlebotomists needed for the week by summing the total hours needed for all of the drives and times by the allowed %.
1. The first shift starts during the start time of the earliest drive and ends 10 hours after.
2. The second shift starts during the highest volume time period.
3. The last shift ends with the last drives end time and the start time is 10 hours before.
4. The number of phlebotomists assigned for the first shift is the maximum number of phlebotomists needed for that drive that exclusively starts only in the first shifts range.
5. The number of phlebotomists assigned for the last shift is the maximum number of phlebotomists needed for that drive that exclusively ends only in the last shift's range.
6. The remainder of the phlebotomists left over is allocated to the third shift time interval.

Scheduling:

Sort the drives each day by the earliest start time of each drive, then

7. Pick the drive during the day with the most phlebotomists required. If there is more than one drive with the same number of phlebotomists required, then pick the drive with the earlier start time.
8. Find phlebotomists to assign to the drive such that:
    a. The first available phlebotomist is assigned to that drive;
    b. Phlebotomists will not violate their workweek duration constraint;
    c. Each phlebotomist only works 40 hours a week;
    d. Phlebotomist cannot work more than 1 drive during the same time period; and
    e. Phlebotomists will only work the block period they are assigned.

If no phlebotomists exist, then

3. Skip this drive and come back later on,
    a. Find a new time for this drive.
    b. See if the drive can be moved to a different day with the same time period:
        i. Find the next available time period where a phlebotomist is available to take the drive.
    c. Phlebotomists will not violate their workweek duration constraints:
        i. Each phlebotomist only works 40 hours a week;
        ii. Phlebotomist cannot work more than 1 drive during the same time period.
    d. Phlebotomists will only work the block period they are assigned.

4. If no time slot is available, then
    a. Start from the beginning to see if one of the drives that were not moved could be changed the least time to fit the un-movable drive into the time slot.
    b. Phlebotomists will not violate their workweek duration constraints:
        i. Each phlebotomist only works 40 hours a week;
        ii. Phlebotomist cannot work more than 1 drive during the same time period.
    c. Phlebotomists will only work the block period they are assigned.

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