Don’t Let Blood Donors’ Efforts be in “Vein”: Blood Donor Scheduling Using Modeling Techniques and Interface Design

Mohammad Ghamloush
MSFEA
AUB
Beirut, Lebanon
mmg22@mail.aub.edu

Nura Afaneh
MSFEA
AUB
Beirut, Lebanon
nsa67@mail.aub.edu

Sara Nasser
MSFEA
AUB
Beirut, Lebanon
smn16@mail.aub.edu

Serge Daou
MSFEA
AUB
Beirut, Lebanon
sjd08@mail.aub.edu

***Abstract*—*This paper outlines the progress taken to improve the amount of fulfilled volunteer-based blood donations by Donner Sang Compter (DSC). The World Health Organization set a goal to turn the global blood supply from a replacement system to a 100% volunteer system by 2025, and Lebanon is behind on this goal. The head of Donner Sang Compter (DSC), Yorgui Teyrouz, estimates that in 2019, the replacement system still constitutes 90% of the blood donations in Lebanon. Our objective is, therefore, to improve the amount of volunteer-based blood donations in Lebanon by improving DSC’s donor rate. The initial phase of our project consisted of forecasting blood demand and its fulfilment by DSC, and simulation of the call center processes. At this stage, the results so far have disclosed the widening gap between the demand DSC receives and the blood requests they fulfill, as well as the lag time between receiving and fulfilling a demand. In the next phase of our project, we plan to utilize predictive donor scheduling and ergonomic interface improvement to increase demand fulfillment.*

***Keywords*—*Forecasting - Predictive Modeling - Blood - Donor - Interface Design - Simulation - NGO - scheduling - Blood Donation - Scheduling - Call center*

I. Introduction

To combat the foreseen shortages in blood supply, the World Health Organization (WHO) launched an initiative in 2010 to turn the global blood supply from a replacement system to a 100% volunteer system by 2020 (Wilson, 2018). This deadline was extended to 2025 for Mediterranean countries (Brennan, 2019). Although local NGOs in the blood donation sector, such as Donner Sang Compter (DSC) or the Lebanese Red Cross, are trying to push for progress on this goal in Lebanon, the country is still behind schedule. Currently, we are unable to estimate the exact percentage of blood donations that are purely donated by volunteers, due to the lack of any national statistics for blood donations. However, the president and founder of DSC, Yorgui Teyrouz, estimated that in 2019 the replacement system made up around 90% of national blood donations.

Donner Sang Compter, which refers to give without asking for anything in return, is an NGO mainly focused on linking blood donors to patients in need of donations, founded in 2006 with a mission to “build communities that promote blood donation as a humanitarian and national cause in Lebanon” (DSC Homepage, 2019)”. To this day, DSC has organized over 1,003 blood drives in partnership with 41 blood banks and collected over 35,900 blood units. DSC has been working relentlessly on bridging the gap between the supply they receive and the demand they fulfill.

Our team opted to work on a project with DSC because we wanted to induce change on an altruistic, societal level in Lebanon, rather than focus on a corporate, profit-driven organization. DSC is a blood donation NGO founded by Mr. Yorgui Teyrouz in 2006. Their mission is to “build communities that promote blood donation as a humanitarian and national cause in Lebanon” (DSC Homepage, 2019). To this day, DSC has organized over 1,003 blood drives in partnership with 41 blood banks and collected over 35,900 blood units. DSC has been working relentlessly on bridging the gap between the supply they receive and the demand they fulfill. And as industrial engineers, we aim to help them manage this through our industrial engineering techniques. We also consider the issue of blood donation in Lebanon to be an overlooked one. By helping an NGO like DSC improve their internal processes and increase their efficiency using tools such as forecasting and simulation, it would bring us one step towards a Lebanon that is 100% reliant on volunteer-based blood donations.

II. Goals and Objectives

A. *Objective 1: Optimize the efficiency of the call center.*

Aim 1: Forecast the demand for blood donation.

Aim 2: Simulate the blood donation call center.

Aim 3: Create a predetermined scheduling system for donors.

B. *Objective 2: Improve the usability of DSC’s interfaces.*

Aim 1: Improve the blood distribution visualization interface for employees to increase service efficiency.

III. Background

In the realm of blood supply chain and collection studies, researchers tend to focus on the efficiency of inventory management. Simulation is a powerful way to accomplish this management, as well as other problems faced in blood donation, such as production planning (Osorio et al., 2017). However, we found an insufficient amount of papers citing any simulation analysis on blood donation organizations and the demands they receive. Since DSC runs a call center to receive blood demand, we investigated the general use of simulation in call centers. Much research has been done regarding optimizing call centers using ARENA simulation models. One of these studies includes Takakuwa & Okada's (2005) paper, delving into calculating the expense of call centers through ARENA, direct search methods, and linear programming. We want to use a derivation of their method to simulate DSC's call center and propose an optimized scenario that can benefit DSC. In comparison to literature on blood supply chains, Blake (2019) notes in his recent paper that literature on blood donor clinics is also incomplete.

We found in our research that literature on the forecasting on the day to day supply and demand of blood is even more limited. Blake & Shimla (2014) studied and optimized the staffing requirements of blood donor clinics in Canada and only mentioned the existence of an arrival rate for donors. De Angelis, Impelluso, & Felici (2003) go further in their paper, finding the specific arrival rate of donors at a clinic in Rome. Prastacos (1984) notes that daily blood demand follows a Poisson distribution. However, he fails to mention how the parameters for the distribution relate to any other measure. Research is concerned with forecasting the supply and demand of blood usually bases the forecast on the population. Currie, Patel, McEwan, & Dixon (2004) forecasted an upcoming shortage in blood supply, with the increasing elderly population above 70 years old requiring 46% of all blood transfusions and no significant forecasted change in donations. Similar foreseen shortages were found in Ontario (Drackley, Newbold, Paez, & Heddle 2012), Switzerland (Volken et al., 2015), and Japan (Akita et al., 2016).

Volken et al.'s (2015) research on Swiss blood supply used general additive regression models and time-series models with exponential smoothing to forecast donations. Akita et al.'s (2016) paper on Japan's supply forecasted donations through a Markov model, which is commonly used in the medical field, based on multiple criteria such as donor's past donations, age, and gender. We plan on following a Markov model once we compile the correct data and begin with forecasting using regression analysis on the data DSC has already provided.

The next objective we plan to work on is concerned with improving the productivity of DSC's interfaces. Bolstad's (2005) book provides an apparent reference on geographic information systems that we plan on using to create an interactive map of the blood distribution in Lebanon. Ouhbi et al.'s (2015) provide multiple recommendations to designers of blood donation apps, such as considering different languages in addition to English for the interface and including notifications for urgent requests for blood. We will use these recommendations for the app DSC currently has in development for blood donation.

IV. Methods

In order to improve the scheduling of donations, we devised an action plan:

A. *Forecasting:*

To understand the current trend of blood donation we needed to forecast the current demand. To forecast the blood demand diverted to DSC's call center, we collected data from the organization on the incoming calls, including information such as date and time, type of blood requested, and whether DSC fulfilled the patient's demand for blood.

Using Excel, we then compiled this data into a set of daily received demands for blood and used this rearrangement to forecast the future incoming requests for blood to DSC through regression analysis. To do this, we first used linear regression to find the trend line of the data for the present dates, as in (1), as well as how the trend line progressed in the future for our forecast.

TREND (known_y's, [known_x's], [new_x's], [const]) (1)

We then calculated the ratio of each day's demand to the trend line on that day. To find the seasonality, or the pattern within the weekly demand in our case, we averaged the ratios by the day of the week, as in (2). (for example, averaging all ratios for Mondays together).

$$\text{Seasonality}_{\text{monday}} = \sum_{1}^{n} \frac{\text{ratio}_{\text{monday}}}{N} \tag{2}$$

N=number of weeks we have as data

Finally, we computed the forecasted demand by multiplying the seasonality ratio by the trend value, as in (3).

$$\text{Forecasted demand}_{\text{day}} = \text{seasonality}_{\text{weekday}} \times \text{trend}_{\text{day}} \tag{3}$$

B. *Simulation:*

To further investigate the problems in the call center processes (Fig.1), we opted to use simulation. Using the forecast, we simulated the current processes happening at DSC's call center using ARENA Software in order to find any possible bottlenecks that affect the efficiency of the process, check the utilization and the efficiency of the workforce, and obtain a base point for any improved scenarios that we will

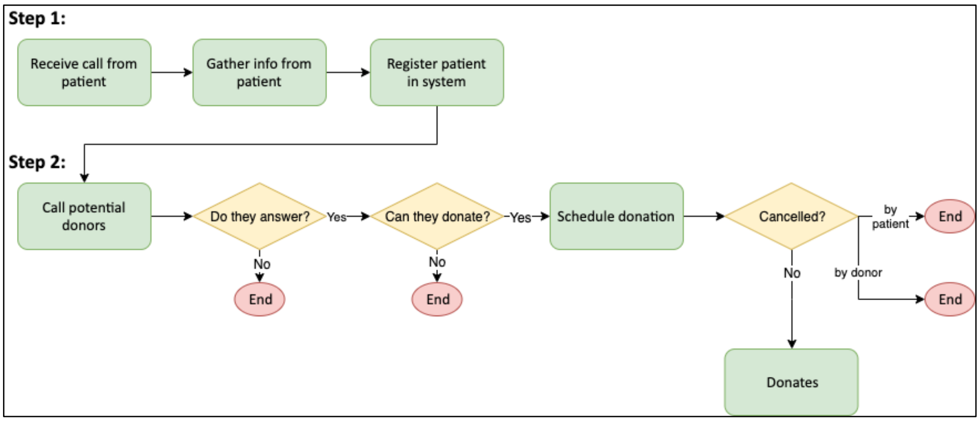

Fig. 1 *Process Flow of DSC's Call Center*

work on. We collected data from the call center by monitoring the calls, requests, service time, and response time.

C. Predictive Modeling:

By integrating the results from the simulation and the forecasting, we will be using multiple predictive modeling techniques to create a donation schedule for the volunteers. We received the blood demand data from DSC regarding the blood types, the hospitals, the week of the demand, and the year. By using this data as features and the blood types as the labels. Currently, we are going through many techniques to figure out which is the correct one to use to predict blood demand.

D. Interactive Interface:

We will use the data from DSC to extrapolate the blood distribution of Lebanon and visualize it on a map. We will then layer on top the demand fulfillment of DSC to provide an interactive interface to better visualize the current blood demand in the country by applying the human-computer interaction (HCI) principles. Our attention is currently focused on finding a program that will allow us to visualize our data properly.

E. Feasibility Study:

As a final step, we will perform an economic feasibility analysis to check whether these improvements in the design of the process will have positive economic returns.

V. Results

A. Forecasting:

With our initial forecast, we found a decreasing trend in incoming calls that opposed the apparent growth in the organization and our predictions (Fig. 2). However, the blood demand fulfilled by DSC was consistent throughout the year, comprising an average of 29% of the incoming demand. Our group and Myra Khalife, Executive Committee Secretary of DSC, hypothesized that environmental factors could be at play. Other blood donation organizations, such as Red Cross, could be getting more calls due to increased marketing or a decrease in the trust in DSC, or there could be an internal inefficiency in DSC's operations. There is also a possibility that January has the highest blood demand and that, therefore, there is an additional monthly seasonality at hand.

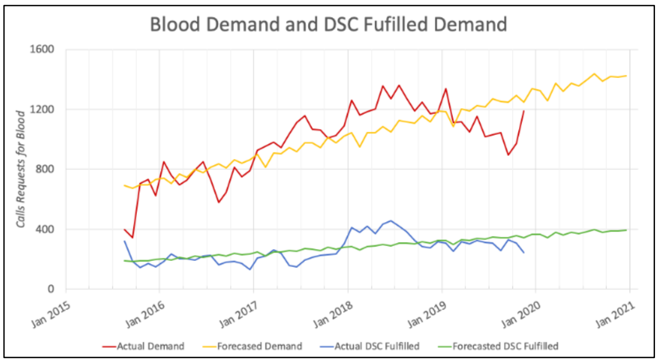

Fig. 2 *Blood Demand Diverted to DSC*

We found that in 2019, DSC had a significantly lower demand compared to the clear upward trend of incoming calls for blood since 2015. On the other hand, we found that DSC's fulfillment of blood has been steadily increasing over the past couple of years, with an upward trend predicted in the future.

B. Simulation:

In our simulation, we noticed that the operators receiving the calls are idle most of the time, which leads to inefficiency in the process. There was virtually no queue in the incoming calls in our simulation, and the utilization of the operators ranged between 10% to 20% (Fig. 3). Moreover, the time it took to find a donor and assign them to a demand ranged between 2-3 days.

For call arrivals, we calculated the mean interarrival times of demand from the number of call arrivals per day in the provided data. Using Input Analyzer and ExpertFit, we found that the distribution was Lognormal with a mean 0.36 and a standard deviation of 0.12. We then calculated the probability of a particular blood type being the requested demand and integrated both of our results in the simulation. We used the same process to find service times for receiving and making calls. However, no accurate or enough data about the time to fulfill a donation request exists within DSC's database, so we estimated the average time a regular person takes to donate as 2-3 days. We also took into consideration the proportion of donors that cancel themselves last minute and donors that get canceled by patients. Finally, we integrated the staff schedule supplied by DSC into our ARENA model to get an accurate representation of workforce utilization based on our assumptions.

To validate, we compared the inter-arrival means per day between the actual and the ARENA output, which were very close: 0.0296 and 0.0274 interarrival times per day respectively. Nevertheless, it is important to note that no affirmation can be taken regarding validation yet since we have yet to consider the most recent data collected. Therefore, we will continuously improve our model as part of our next phase's scope as it is an iterative process.

C. Predictive Modeling:

For predictive modeling, we expect to get a pattern for each blood type in reference to the week and year. With these results, we will be able to create a schedule for DSC for each week in each year and validate our findings simultaneously.

D. Interactive Interface:

For our interface, we expect to create a map visualizing the blood distribution of Lebanon and the current demand for blood. Users will have the ability to select and zoom in on the individual cases displayed on the map.

VI. Discussion and Conclusion

We have surmised with the results obtained from the forecasting that if DSC does not make significant and sustainable improvements to their fulfillment rate, even with their current growth, the actual gap between the supply and demand will continually increase. This concurs with the findings of multiple studies, including a study conducted by Currie, Patel, McEwan, & Dixon (2004), that foresee upcoming shortages in blood supply around the globe.

Regarding the simulation, there was an excess in the number of operators receiving calls, so we should reduce the number of operators or assign them additional tasks in our improved scenario. In addition, we also found that there was a significant waste of resources in the lack of donor reallocation when scheduled donations are cancelled by the patient. Most importantly, we found the process of finding a donor and waiting for the donor to donate is a significant bottleneck, due

Scheduled Utilization	Average	Half Width	Minimum Average	Maximum Average
Worker 1	0.0758	0.00	0.0687	0.0811
Worker 2	0.0746	0.00	0.0697	0.0802
Worker 3	0.0900	0.00	0.0845	0.0955
Worker 4	0.0866	0.00	0.0828	0.0903
Worker 5	0.0709	0.00	0.0636	0.0790
Operators	0.2221	0.00	0.2101	0.2336
Worker 6	0.0785	0.00	0.0717	0.0855
Worker 7	0.0707	0.00	0.0566	0.0834
Worker 8	0.0821	0.00	0.0791	0.0853
Worker 9	0.0649	0.00	0.0552	0.0737

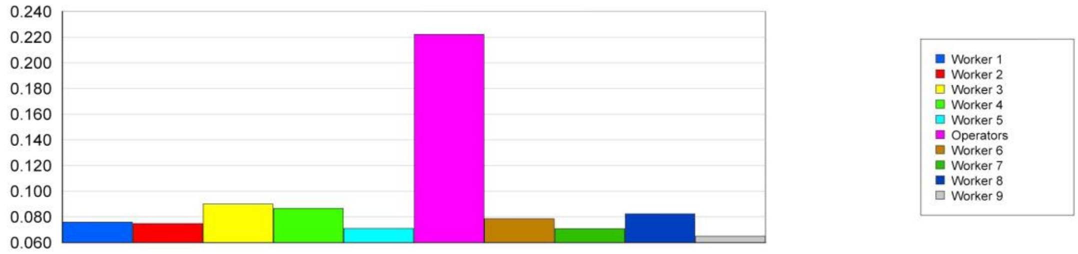

Fig. 3 *Utilization Percentage of the Workers (receive calls) and Operators (make calls)*

to the large amount of time that it requires compared to the length of the overall process.

Ultimately, using the results obtained from the forecasting, we are prepared to initiate our predictive model and integrate the results with the optimized simulation scenario. As opposed to Volken et al.'s (2015) use of exponential smoothing and Akita et al.'s (2016) use of a Markov model, we are leaning towards implementing a multivariate regression model to find the expected demand in terms of blood types and areas. This would, in the ideal case, significantly decrease the lead time on demand fulfillment. In tandem, we hope the improvement of DSC's interfaces using the blood distribution map and HCI will improve the lead time on fulfillment and the conversion of demands to fulfillments.

If our work proves successful, our model can be implemented in other non-profit organizations dealing with blood donors. In particular, the model for finding a more detailed expected demand for call centers can be generalized and used for the improvement of various non-profit activities.

Unfortunately, our progress was hindered by several limitations we faced. Uncertainty in the region in late 2019 caused significant effects on DSC's operations and hindered us from getting the data we required. In addition, the pandemic in early 2020 prevented us from physically visiting DSC's operations and our university, further inhibiting our project.

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