The Lebanese Red Cross: Improving the Efficiency of Lebanon's Largest Humanitarian Organization

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***Abstract*— This paper aims to analyze and tackle some of the major challenges faced by the main emergency medical services center operating in Lebanon: The Lebanese Red Cross. This non-governmental organization is a major pillar of the Lebanese community as it ensures the safety and well-being of all citizens. Its centers rely on independent volunteers to satisfy daily emergency calls. To ensure the efficient allocation of rescuers to shifts, this paper outlines the methods to develop an interface that prioritizes volunteer schedule preferences while accounting for organizational requirements. To further assist the Lebanese Red Cross, we will work on optimizing the efficiency and cost effectiveness of their main warehouse by categorizing the commodities based on criticality, forecasting their demand and ultimately developing an optimal ordering policy and an improved layout design.**

Keywords—industrial engineering, emergency medical services, shift allocation, warehouse management, optimization

I. Introduction

The Lebanese Red Cross (LRC) responds to 270,000 missions every year, equivalent to over 740 missions per day; illustrating the crucial role it plays in our country. The LRC's 46 first aid centers and 280 ambulances spread over the entire country aim at promoting peace, serving the society, and alleviating human suffering ("EMS Missions Report", 2019). Each center manages its own resources and responds to missions that occur in its neighborhood. For instance, there are four centers covering the Beirut area; located in Gemmayze, Furn El Chebek, Mreijeh and Spears. Lebanon's constant political instability, the numerous regional conflicts it has faced, as well as it's civil war, have been a substantial challenge over the last 70 years that the LRC has responded to by constant and impressive dedication. It is one of the few Non-Governmental Organization that has served the Lebanese people consistently and efficiently with total neutrality and impartiality regarding religious and political beliefs. The LRC has again been in high demand in the last few months, with Lebanon's major economic, financial, and health crisis.

All businesses and organizations, whether for profit or not, strive to control costs and improve efficiency. Industrial Engineering (IE) is the engineering branch that focuses on optimizing operations by reducing the cost of production, increasing efficiency, improving quality, and ensuring health and safety. Since the LRC is a non-profit organization and given the importance and complexity of its operations, we were challenged and compelled to assist Lebanon's largest humanitarian organization with our IE knowledge.

II. Goals and Objectives

A. *Objective 1:* Ensure the efficient allocation of rescuers to shifts at the Gemmayze center

a) Aim 1: Identifiy trends in the arrival of missions

b) Aim 2: Determine the optimal allocation of rescuers to shifts

c) Aim 3: Build a user-friendly interface to be used by the center's management to allocate rescuers to shifts

B. *Objective 2:* Improve the efficiency and cost-effectiveness of the organization's warehouse

a) Aim 1: Categorize the warehouse's items based on criticality and identify demand trends for each product family

b) Aim 2: Determine the ordering policy for different product families

c) Aim 3: Redesign the warehouse's layout

III. Background

a) Optimal use of EMS resources

Emergency Medical Services (EMS) operate in different ways and follow a different structure in different countries but they all provide an essential service in ensuring the well-being and safety of their respective communities. They can be operated by the government, the fire department, private hospitals or a non-governmental organization. The nature of the provider greatly affects EMS effectiveness and access to funds (Al Shaqsi, 2010). Research shows that the quality of pre-hospital care plays an essential role in patient survival and can prevent the occurrence of irreversible damages. The EMS systems of developing and developed countries have been compared, and the quality variation that currently exists emphasizes the need to develop international standards on the quality and performance of EMS (Roudsari et al., 2007).

To make sure EMS can meet these standards, a lot of research has been done around optimizing the use of the organization's limited resources. In order to understand demand trends, studies relied on past data, mainly on the number of incoming emergencies, as well as the EMS's team preparation time and team response time (Andersson et al., 2020). Alternative allocation of rescuers and ambulances to different locations is then proposed. These allocations have been done through the use of the maximal coverage problem (Erdogan, Erkut, Ingolfsson & Laporte, 2008) and the tabu search algorithm (Gendreau, 1997). Based on these studies, EMS can avoid overstaffing of rescuers and idle ambulances.

Moreover, it can identify whether the size of its workforce or the number of ambulances at certain locations are limiting its call satisfaction rate and response time.

Depending on the demand trends, an EMS can choose to use dynamic team allocation (allocating more rescuers to shifts on days with increased demand) or fixed team allocation (considers that demand is stationary and allocates an equal number of rescuers to every shift). In both cases, rescuer preference should be considered and even prioritized because it is one of the EMS' most valuable resources. (Goldberg, 2004). To achieve this optimal allocation of rescuers, scheduling software based on linear programs is used. These linear programs can be developed to maximize employee preferences subject to specific requirements of any organization (Gordon & Erkut, 2004).

In order to help the LRC, Lebanon's EMS, we aim to develop an interface that automatically allocates rescuers to shifts based on a linear program that aims at maximizing volunteer preferences subject to their specific set of constraints.

b) Warehouse management for EMS

A lot of literature also exists around warehouse management for all kinds of businesses. It is specifically important for the EMS because many of the commodities involved are critical and directly affect its ability to serve the community. The presence of commodities with different criticalities, shelf life and substitutions calls for different ordering policies (Yadavalli & Sundar, 2015). Based on forecasting and analysis of previous product demands, any warehouse can formulate an ordering policy using a linear program.

For the ordering policies to offer real improvement, the physical layout of the warehouse should be restructured based on various product characteristics. Most facilities planning research has been done around manufacturing facilities, office spaces or service facilities but similar tools such as Decision Support System can be used for warehouse design (Arince, Banerjee & Sylla, 1989).

In order to help the LRC, we aim to analyze demand trends for each commodity type. Moreover, we will develop efficient ordering policies and finally suggest an improved layout design for the LRC's central warehouse.

IV. METHODS

A. Allocation of rescuers to shifts

For our analysis, we focused on one of the organization's 46 centers, the Gemmayze center; which is made up of 75 rescuers and responds to around 300 missions per month. At this center, rescuers are assigned to one shift per week; where team 1 covers Monday's shift, team 2 covers Tuesday's shift etc. up to team 5, which covers Friday's shift.

a) Trend analysis

We received data on all missions that the center responded to in the past two years. It contained information about each mission's type, date, time, duration as well as location. It also indicated which of the center's teams responded to the emergency.

First, we looked for inconsistencies in the data and corrected them accordingly. Second, we grouped missions that have similar requirements in terms of team formation into two categories: emergencies and first aid assistances. Emergencies correspond to situations in which the patient requires urgent transportation to the hospital for specialized care and it involves five rescuers and an ambulance. In contrast, first aid assistances correspond to situations in which the patient is in need of basic care at their home and at scheduled times; it requires two rescuers and a regular car. Third and finally, we computed the number of missions that the center satisfied per month and subsequently graphed them in order to identify behaviors (e.g., randomness, seasonality, increasing trend, decreasing trend, etc.).

b) Linear program

We identified all the constraints to abide by when allocating rescuers to teams; which are (1) rescuers cannot be allocated to a team if it is not one of their choices, (2) rescuers should be equally distributed across all teams, (3) males and females should be equally distributed across all teams, (4) rescuers' roles (i.e. driver, mission leader, scout or beginner) should be equally distributed across all teams and (5) siblings or couples cannot be allocated to the same team.

We then defined the decision variables (Table I) and parameters (Table II) used in the linear program.

TABLE I. LINEAR PROGRAM DECISION VARIABLES

Decision variables	Definition	Values
T_{ij}	Rescuer i is allocated to team j	$T_{ij} = 1$ if rescuer i is assigned to team j $T_{ij} = 0$ otherwise

TABLE II. LINEAR PROGRAM PARAMETERS

Parameters	Definition	Values
I = [1,...,N]	Identification number	1 = Rescuer 1 2 = Rescuer 2 etc.
G = [M,...,F]	Gender	M = Male F = Female
R = [L,...,D]	Role	D = Driver L = Mission Leader S = Scout B = Beginner
x	Weight of choice 1	To be determined
y	Weight of choice 2	To be determined
z	Weight of choice 3	To be determined
X_{ij}	1st choice of rescuer i	$X_{ij} = 1$ if team j is the first choice of rescuer i $X_{ij} = 0$ otherwise
Y_{ij}	2nd choice of rescuer i	$Y_{ij} = 1$ if team j is the second choice of rescuer i $Y_{ij} = 0$ otherwise
Z_{ij}	3rd choice of rescuer i	$Z_{ij} = 1$ if team j is the third choice of rescuer i $Z_{ij} = 0$ otherwise

Moreover, we formulated the linear program's objective function:

$$Max\ w = \sum_i \sum_j x \times X_{ij} \times T_{ij} + y \times Y_{ij} \times T_{ij} + z \times Z_{ij} \times T_{ij} \quad (1)$$

The objective function (1) aims to maximize the rescuers' satisfaction by allocating them to a team of their choice (i.e. it should correspond to either their first, second or third choice as shown in Table II). Note that the choices' weights (i.e. x, y and z) should be determined by the center's management such that $x > y > z$. Finally, we translated the requirements of the team allocation into constraints; in order to incorporate them into our linear program (Table III).

TABLE III. LINEAR PROGRAM CONSTRAINTS

Constraints	Definition
$T_{ij} \leq X_{ij} + Y_{ij} + Z_{ij}$	Allocate a rescuer to a team of one of his 3 choices
$\sum_j T_{ij} = 1$ for all i	Each rescuer is allocated to one team (and one only)
$\sum_{i \in N} T_{ij} \geq \|N\|/5 - 1$ for all j N = Set of rescuers	Number of rescuers is equally distributed in each team
$\sum_{i \in M} T_{ij} \geq \|M\|/5 - 1$ for all j M = Set of males	Number of male rescuers is equally distributed in each team
$\sum_{i \in F} T_{ij} \geq \|F\|/5 - 1$ for all j F = Set of females	Number of female rescuers is equally distributed in each team
$\sum_{i \in D} T_{ij} \geq \|D\|/5 - 1$ for all j D = Set of drivers	Number of drivers is equally distributed in each team
$\sum_{i \in L} T_{ij} \geq \|L\|/5 - 1$ for all j L = Set of mission leaders	Number of mission leaders is equally distributed in each team
$\sum_{i \in S} T_{ij} \geq \|S\|/5 - 1$ for all j S = Set of scouts	Number of scouts is equally distributed in each team
$\sum_{i \in B} T_{ij} \geq \|B\|/5 - 1$ for all j B = Set of beginners	Number of beginners is equally distributed in each team
$\sum_{i \in S[k]} T_{ij} \leq 1$ for all j, for all k S[k] = Set of siblings/couples	If rescuer 1 and rescuer 2 cannot be in one team together (e.g., they are siblings)

c) Interface development

In order to facilitate the allocation of rescuers to shifts, done manually by the center's management twice per year, we developed an Excel workbook that incorporates our linear program. First, we created a sheet which contains a list of each rescuer's identification number, gender and role as well as their first, second and third choices of shifts. Here, the center's management will manually input the rescuers' choices and personal information. To ensure that all rescuers selected three distinct choices between team 1, team 2 up to team 5, we created a button that generates an error message if the user inputs any number or character other than 1, 2, 3, 4 and 5 or if any rescuer's first choice also corresponds to their second or third. Second, we added a sheet that indicates which rescuers cannot be allocated to the same team (siblings or couples). Third, we created three additional sheets respectively called first choice, second choice and third choice with the purpose of converting the rescuer's choices from numbers (1, 2, 3, 4 and 5) to binary values (0 and 1). Fourth, we added six sheets respectively called males, females, drivers, mission leaders, scouts and beginners; which list all rescuers that fall under each category. This allows us to update our linear program's contraints (e.g., the number of females is equally distributed across teams). Fifth, we inputted all decision variables, objective function and constraints into Excel solver. Finally, we created a button which directs the user to the teams' sheet; where all rescuers allocated to team 1 are listed under team 1, all rescuers allocated to team 2 are listed under team 2, etc.; along with their identification number, name, gender and role.

B. Improvement of the warehouse's efficiency

The organization's warehouse supplies all 46 centers with the supplies, accessories and equipment necessary for their day-to-day operations. Thus, it is critical to avoid shortages while taking into consideration financial constraints.

a) Trend analysis

We received the list of all products that the main warehouse supplies to each center. It consists of around 300 items, their prices and their suppliers. The LRC also gave us access to all orders issued by each center over the past two years. To facilitate the trend analysis, we used Python to group the products into product families based on size, supplier and criticality. First, we assigned criticality levels to each product (i.e. low, high). Second, we combined the orders issued for each item by all centers in order to determine the total quantity requested from the warehouse per month. Third, in order to obtain our product families, we combined products that vary solely in terms of size together (e.g. jackets of sizes XS, S, M, L and XL into the general category jackets). We also combined products purchased from the same suppliers only when they have similar criticality level. Finally, for each product family, we computed the number of orders issued per month (by all centers) and subsequently graphed them in order to identify behaviors (randomness, seasonality, increasing trend, decreasing trend, etc.).

b) Aggregate planning

We will use aggregate planning to determine the optimal ordering policy per product family (i.e. when and how much to order) and then we will de-aggregate in order to determine the optimal ordering policy per product (i.e. for all 300 items).

c) Facilities planning

We will develop an alternative layout for the organization's warehouse by studying which products should be placed next to one another and how much space each product should occupy given consumption patterns and criticality levels.

V. RESULTS

A. Allocation of rescuers to shifts

We decided to focus on emergencies rather than first aid assistances because they represent 90% of all missions satisfied by the center. The number of emergencies satisfied shows a stationary trend. However, it is characterized by minor seasonality; with, for example, January, February and March having more missions than June, July and August for 2018 as well as 2019 (Fig. 1).

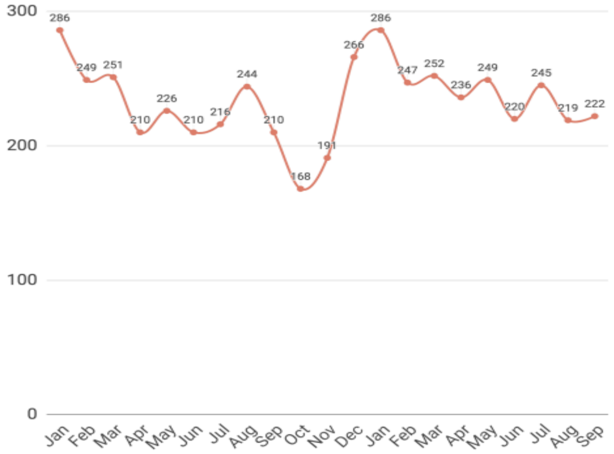

Fig. 1. Number of emergency missions answered by month from 2018 to 2019

Moreover, the number of emergencies answered is equally distributed across teams, with each team satisfying around 20% of the missions (Table IV).

TABLE IV. NUMBER OF EMERGENCIES SATISFIED BY EACH TEAM

Team	Number of emergencies	Percentage of emergencies
1	616	20%
2	620	20%
3	567	19%
4	632	21%
5	617	20%
Total	3052	100%

The workbook contains an instruction manual with information about its purpose, required inputs and generated outputs written down in a step by step fashion; so that it can be used by the center at any point in time without assistance.

Fig. 2 shows a sample of the suggested optimal team allocation generated by the linear program.

Team 3		
Rescuer ID	**Gender**	**Role**
2	M	Driver
5	M	Mission leader
8	F	Mission Leader
13	F	Eclaireur
19	M	Eclaireur
22	F	Beginner
25	M	Beginner
32	F	Beginner

Fig. 2. Identification numbers, gender and roles of rescuers allocated to team 3

The linear program successfully improved rescuer's satisfaction as the number of rescuers allocated to their first choice increased from 23% to 84% (Table V).

TABLE V. PERCENTAGE OF RESCUERS ALLOCATED TO THEIR CHOICES

Choices	Current situation	Linear program's output
1st Choice	23%	84%
2nd Choice	58%	16%
3rd Choice	19%	0%

B. *Improvement of the warehouse's efficiency*

Grouping the products by size and supplier, we obtained 43 product families; of which 13 are characterized by high criticality and 30 by low criticality. Each product family showed a specific trend; which will be taken as input when formulating its ordering policy. For example, product family 15 shows an increasing trend with minor seasonality (Fig. 3).

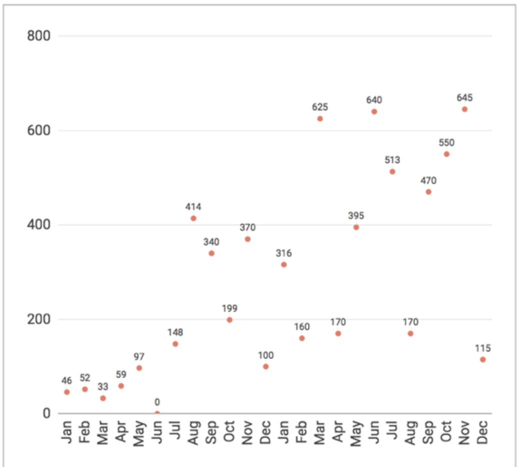

Fig. 3. Product family 15 - Number of orders issued per month from 2018 to 2019

Using aggregate planning, we expect to generate an optimal ordering policy for each product family based on several factors (i.e. criticality, demand trends, expiry date, lead time, etc.).

We will then generate an improved layout for the warehouse considering the following characteristics: product entry and exit frequency, weight and criticality of each product. The improved layout will need to consider two processes: receiving supplies to the warehouse and dispatching supplies to all centers. This will ultimately lead to a decrease in the cycle time; which is the time products spend in motion at the warehouse.

VI. DISCUSSION AND CONCLUSION

A. *Allocation of rescuers to shifts*

a) *Trend analysis*

Through the analysis of past data, the stationary trend of the number of emergency calls observed (Fig. 1) was expected as it is unlikely that the population would significantly decrease or increase in the course of two years. We do however observe minor differences between the winter months and the summer months but our analysis requires data from additional years to confirm any seasonal pattern. This sheds light on one of our study's limitations: for us to achieve a more sensitive analysis that captures the minor demand changes we would need data that covers a larger number of years.

Table IV clearly shows that the number of emergencies answered by the center are equally distributed amongst all teams (each team satisfies the same amount of calls). This result motivated us to move away from dynamic team allocation. Dynamic team allocation is used by many countries to optimally allocate ambulances and rescuers to different locations at different times to satisfy demand changes (Andersson et al., 2020).

b) Linear program

We thus decided to improve the LRC's current allocation mechanism as an optimal use of resources also includes acknowledging the importance of human resources and ensuring their satisfaction. We built a linear program to allocate rescuers to shifts with the aim of maximizing volunteer satisfaction subject to many organizational specific constraints. Linear programs have been used in scheduling studies such as the case study on Edmonton Folk Festival that is similar to our work as it also deals with maximizing volunteer satisfaction rate and ultimately retention rate (Gordon & Erkut, 2004). Our analysis is bound by the organizations' previous decisions regarding the constitution of their teams as we did not analyze the pre-determined constraints.

c) Interface development

We coded the linear program on Excel and then developed an interactive workbook to be used by the LRC administration. The workbook improves the team assignment process, which was both time consuming and manual. Our interface offers an intuitive navigation through an instruction manual, different worksheets and tables. It is however essential to mention that the user friendliness of the workbook is bound by the software's computational power and design options.

The improvement displayed in Table V indicates that a large number of volunteers are now assigned to their preferred choice and will experience higher organizational appreciation and satisfaction. This advances the ultimate goal of maintaining high volunteer retention rates and positive work environment.

B. *Improvement of the warehouse's efficiency*

a) Trend analysis

The demand trends will be taken into account when formulating the product families' ordering policies. For example, to be able to compute the optimal ordering quantity for product family 15, we will need to forecast its demand for the upcoming years given that it shows an increasing trend with minor seasonality. Moreover, product families that are characterized by high criticality will be analyzed in greater details given that they are indispensable to the organization. This analysis will allow the LRC to gain a better understanding of its entire supply chain.

b) Aggregate planning

The ordering policy we will suggest aims to avoid shortages and surplus. The reduction of shortages is critical as it impacts the Lebanese community as a whole and ensures that all LRC centers have the adequate equipment to attend to community needs. As for reducing the surplus, the LRC would be allocating its budget more efficiently by avoiding unnecessary expenses. It would also be reducing its carbon footprint through only necessary product received and delivered. Finally, it can also reduce its generated waste by minimizing the disposal of expired products.

c) Facilities planning

Through the improved layout, the warehouse will be designed based on the products it stores. Commodities will be strategically placed, and the shelves rearranged to achieve lower cycle time and ensure a comfortable and neat work environment. One of the characteristics taken into consideration to determine product location is product weight and so through our improved layout, the LRC can alleviate any physical strain that comes from transporting the products in and out of the warehouse. This will then ensure greater safety and wellbeing of the warehouse employees.

REFERENCES

[1] Andersson, H., Granberg, T. A., Christiansen, M., Aartun, E., & Leknes, H. (n.d.). Using optimization to provide decision support for strategic emergency T medical service planning – Three case studies. *International Journal of Medical Informatics* , *133* (January 2020). doi: https://doi.org/10.1016/j.ijmedinf.2019.103975

[2] Arinze, B., Banerjee, S., & Sylla, C. (1989). A methodology for knowledge based decision support for facilities layout planning. *Computers & Industrial Engineering*, *17*(1-4), 31–36. doi: 10.1016/0360-8352(89)90032-6

[3] Al-Shaqsi, S. (2010). Models of International Emergency Medical Service (EMS) Systems. *Oman Medical Journal*. doi: 10.5001/omj.2010.92

[4] EMS Missions . (n.d.). Retrieved from http://www.redcross.org.lb/index.aspx?pageid=907 .

[5] Erdoğan, G., Erkut, E., Ingolfsson, A., & Laporte, G. (2010). Scheduling ambulance crews for maximum coverage. *Journal of the Operational Research Society* , *61* (4), 543–550. doi: 10.1057/jors.2008.163

[6] Gendreau, M., Laporte, G., & Semet, F. (1997). Solving an ambulance location model by tabu search. *Location Science*, *5*(2), 75–88. doi: 10.1016/s0966-8349(97)00015-6

[7] Goldberg, J. B. (2004). Operations Research Models for the Deployment of Emergency Services Vehicles. *EMS Management Journal* , *1* .

[8] Gordon, L., & Erkut, E. (2004). Improving Volunteer Scheduling for the Edmonton Folk Festival. *Interfaces* , *34* (5), 367–376. doi: 10.1287/inte.1040.0097

[9] Response Times: Myths, Measurement and Management. Retrieved from https://www.jems.com/2005/08/31/response-times-myths44-measure/.

[10] Roudsari, B. S., Nathens, A. B., Arreola-Risa, C., Cameron, P., Civil, I., Grigoriou, G., ... Rivara, F. P. (2007). Emergency Medical Service (EMS) systems in developed and developing countries. Injury, 38(9), 1001–1013. doi: 10.1016/j.injury.2007.04.008

[11] Yadavalli, V. S. S., Sundar, D. K., & Udayabaskaran, S. (2015). Two substitutable perishable productdisasterinventorysystems. *AnnalsofOperationsResearch*, *233*(1),517–534.doi: 10.1007/s10479-014-178