Increasing the productivity of health facilities in urban areas in México

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Abstract

In Mexico, pharmacies have the possibility of offering basic health services inside or close to their facilities. The foregoing generates direct competition for non-profit civil associations such as the Mexican Red Cross in Monterrey (MRCM), which currently has nine urban health facilities, known as relief bases. As it is well known, the Red Cross is maintained through donations, and for the services provided, a voluntary fee is asked. Due to the recent financial losses, and looking for increasing the productivity of its health care facilities, the MRCM is considering the closure of some of them with a minimal social impact due to the decrease of the community's access to health services.

The closure's impact of urban health facilities has not been deeply explored. After a bibliographic review, fifteen variables related to social impact were identified, which were grouped into three categories: competition, organization and affected population. Based on these variables, this paper proposes two strategies to increase the productivity of the MRCM: a staff reassignment scheme and an optimization model to determine which relief bases should be closed with the least social impact and significantly increase of the MRCM's average productivity.

Keywords
Healthcare, health facility, facility closure, productivity, DMAIC, optimization model, social impact

1 Introduction

One of the action lines of the Mexican Red Cross (MRC) in Monterrey, Mexico, hereafter MRCM, is to provide medical services in the nine relief bases located in the metropolitan area. The objective of this project is to increase the productivity of the medical services operations of these relief bases. The MRC is a humanitarian institution of private assistance, which is part of the International Red Cross and Red Crescent Movement. It is dedicated to preventing and alleviating human suffering in a timely manner to improve the living conditions of people and communities in situations of emergency or disasters (Mexican Red Cross Delegación Monterrey, 2017).

The MRCM has nine relief bases which are located in the municipalities of Monterrey, Escobedo, Guadalupe, Apodaca, Santa Catarina, García and San Pedro. (see Figure 1). These facilities are intended to provide emergency

medical services and contribute to improving the health of the community. (Mexican Red Cross Delegación Monterrey, 2016).

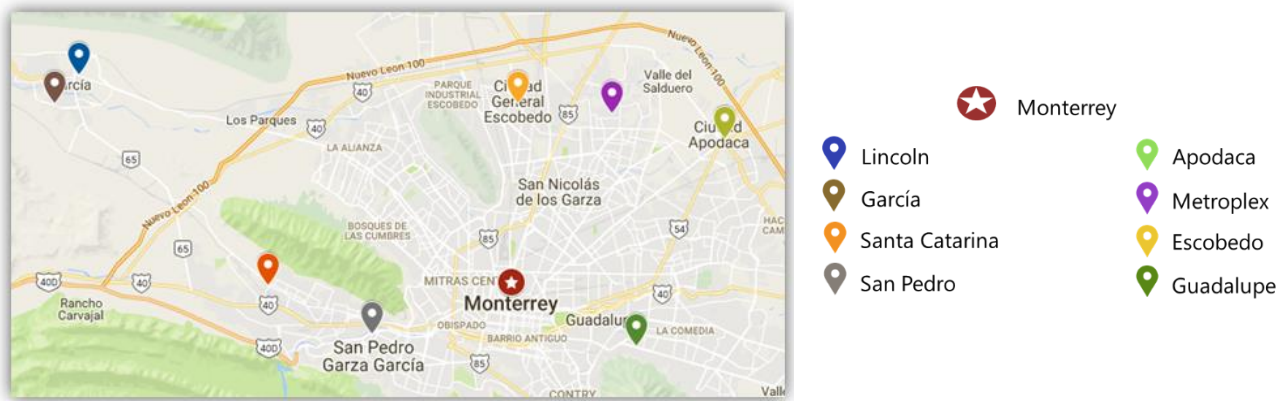

Figure 1: MRCM's relief bases

It is well known that the Red Cross funds its operations through donations and recovery fees. In the case of the recovery fee, the patient can be totally or partially exempted depending on their economic situation. Recently, the MRCM has presented a significant decrease in the influx of patients. Compared to 2015, it has decreased by 31% directly impacting the income of the institution. However, the average amount paid per patient in 2016 was $ 90.96 MXN, while the average cost per patient is $ 138.40 MXN. The above can be translated into an average loss per patient of 34%, which the MRCM must pay for. Therefore, in this paper we apply DMAIC methodology with the aim of increasing the productivity of the relief bases. As a result, two strategies to increase the use of the facilities and at the same time to reduce the operating cost were proposed: a staff reassignment scheme and an optimization model to select the closure of facilities; so that the area of medical services of the MRCM can be more productive.

This paper is structured as follows: next section summarizes the methodology used, and consistent with it, we present the problem statement which includes a diagnosis of the organization and an analysis of its competence, then we define the objectives and strategies to be followed to develop the solution to the problem. These strategies are divided into 2, the first focused on the creation of efficient staff allocation schemes and the second focuses on an action plan for the most inefficient bases, which includes the rationale, formulation and implementation of the solution model. Subsequently, an analysis of different scenarios that allow improving the productivity of the relief bases is made and the final recommendations for the MRCM are expressed.

2 Methodology

We chose to use the DMAIC methodology. Introduced in Motorola in 1987 it is a strategy for continuous improvement in business that aims to increase the performance of the processes of an organization. It consists of 5 major steps: define, measure, analyze, improve and control. Figure 2 describes how the DMAIC methodology was adapted to this problem according to Ortega, Baeza, & Lizárraga (2017). In the first phase, *Define*, the need is described and the problem is posed, selecting the variables that intervene, as well as the formulation of the hypothesis. In the second phase, *Measure*, the model is formulated, as well as its equations. In the third stage, *Analyze*, the generated scenarios are studied. In the fourth stage, *Improve*, the model is validated. Finally, in the fifth stage, *Control*, operating policies are established.

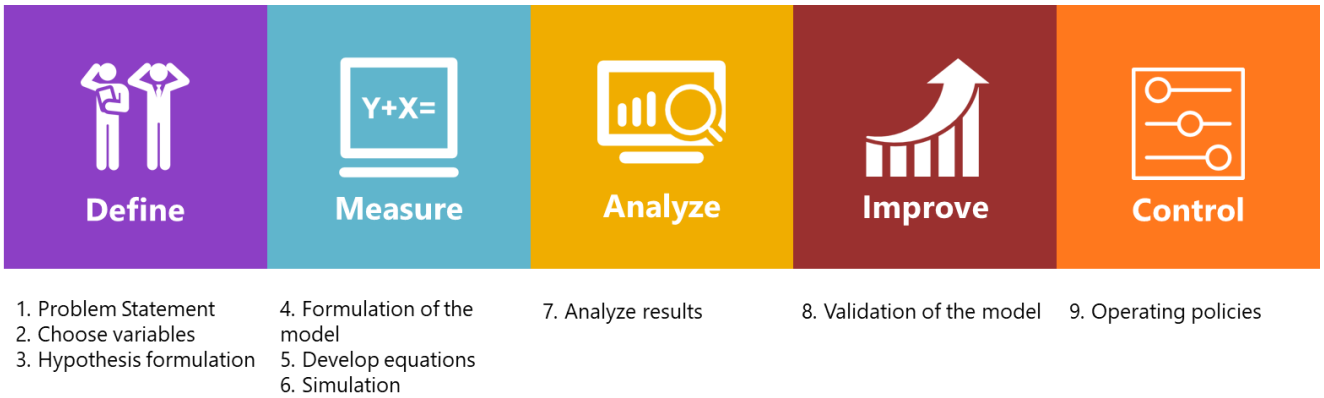

Figure 2: DMAIC Methodology

3 Problem Statement

To help understand the MRCM's social impact and its current situation, an overview of the organization and its competition is presented. Before analyzing the competition, a definition of the influence area of each relief base is determined.

3.1 Organization overview

Based on data collected from the MCRM's records, field studies, and we the support of tools as Google maps, the following aspects give a glance of the MCRM situation.

- Analysis of Services: 6 services represent 80% of the revenues of the medical area and the facilities with less affluence are García, Metroplex and Apodaca, in that order. Figure 3 presents a Pareto chart showing the main services.
- Patient flow: The flow of patients shows a stable behavior throughout the working day (8:00 AM-10:00 PM) as shown in Figure 4. Therefore, this aspect is not critical to achieve the objectives.
- Analysis of Exemptions: Exemptions can occur because either the patient cannot or does not want to pay the full fee, or even nothing of all, or because is a beneficiary of a Procurement Program, which consists that employees of benefactors (i.e. donor companies) can use the MCRM services for free. In general, it was observed that all the agreements are justified thanks to the fact that the donations are greater than the exemptions.
- Evaluation of the demand by relief basese: 67% of the bases present a low demand per hour (less than 2 patients) with the exception of Escobedo, Monterrey and Guadalupe. See Figure 5.

3.2 Affected population

Impact area definition

To define the affected population, we used the formula of the impact area developed by the authors Succi, Lee, & Alexander (1997) and published in its article "Effects of market position and competition on rural hospital closures"

$$R_f = \sqrt{{\rho_{max}}^2 \frac{{\rho_{f\,base}}^2 - {\rho_{f\,max}}^2}{{\rho_{f\,min}}^2 - {\rho_{f\,max}}^2}} \tag{1}$$

Where R_f is the influence radius, ρ_f the population density, P_{max} is the maximum distance to a hospital (i.e. 4.85km), and P_{min} is the minimum distance to a hospital (i.e. 3.24km).

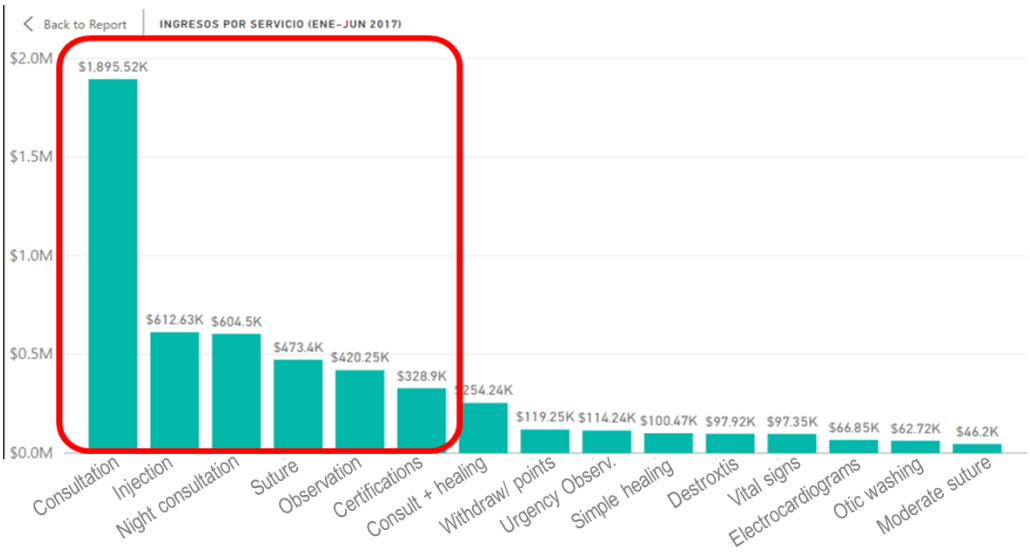

Figure 3. MCRM services ordered by income

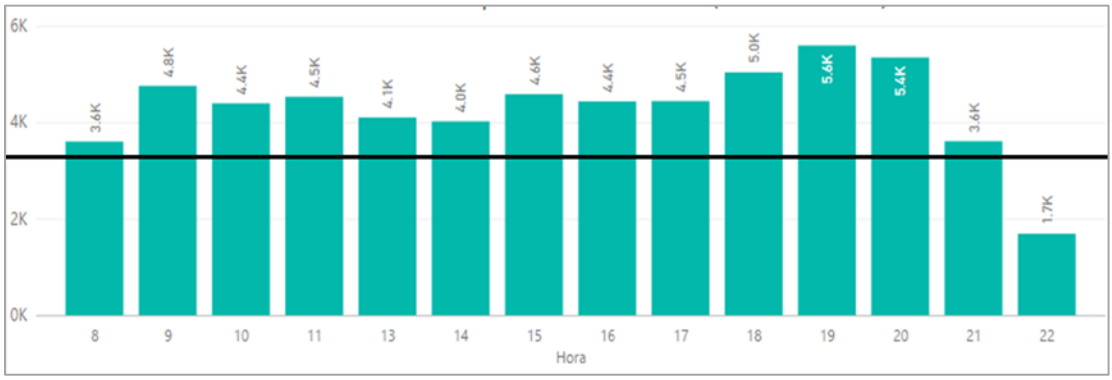

Figure 4: Patients served per hour in all bases (January – June 2017).

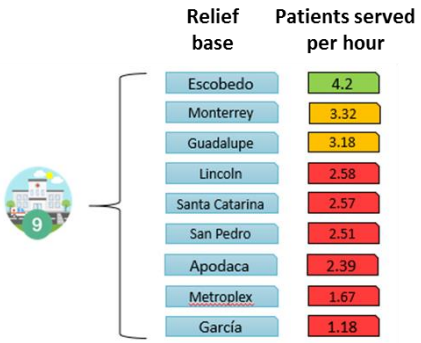

Figure 5. Demand served analysis per relief base.

The influence radius obtained for each of the relief base are showed in Table 1, and the influence areas are represented in Figure 6. They are also delimited by the actual urban zone at considers topographical limits.

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Table 1. Bases' influence radios

Health facility	Influence radio (km)
García	4.85 km
Santa Catarina	4.85 km
San Pedro	4.63 km
Metroplex	4.32 km
Apodaca	4.32 km
Escobedo	4.23 km
Monterrey	3.93 km
Lincoln	3.93 km
Guadalupe	3.24 km

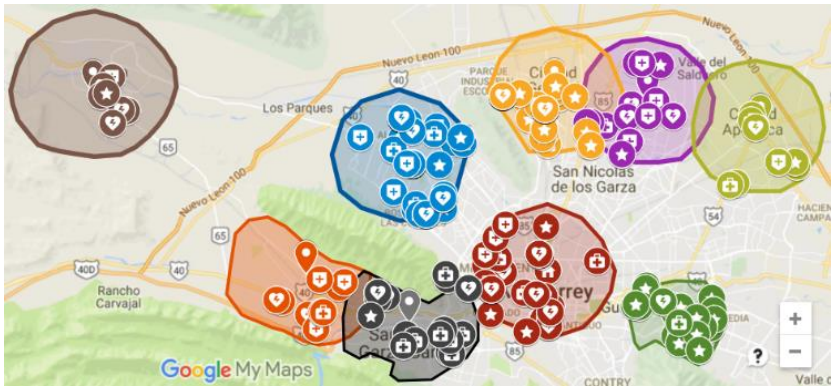

Figure 5. Influence areas of each health facility.

3.3 Competition overview

Wilson (1994), states that the competitors of a company are those companies focused on the same market as ours, that offer a similar product or service, that use similar technology, as well as competitors where the client can exercise the same power of purchase that with our product. Therefore, three pharmacies were defined as principal competitors, because they offer medical guidance services at an economical price. Likewise, all those health centers, clinics or independent clinics were considered within the "Other" category.

Comparison of services and prices

The prices that each of the competitors offer against those of the MRCM were evaluated, obtaining that the MRCM is more expensive than the rest of the competitors, but it also has a portfolio of services much wider than the competition. The competitor Farmacias del Ahorro only has 2 basic services, while the Farmacias Benavides and Farmacias Similares offer 10 basic and intermediate services. Now, the MRCM offers 16 basic and intermediate services and 43 specialized services that are classified as laboratory tests, which are not offered by any competitor.

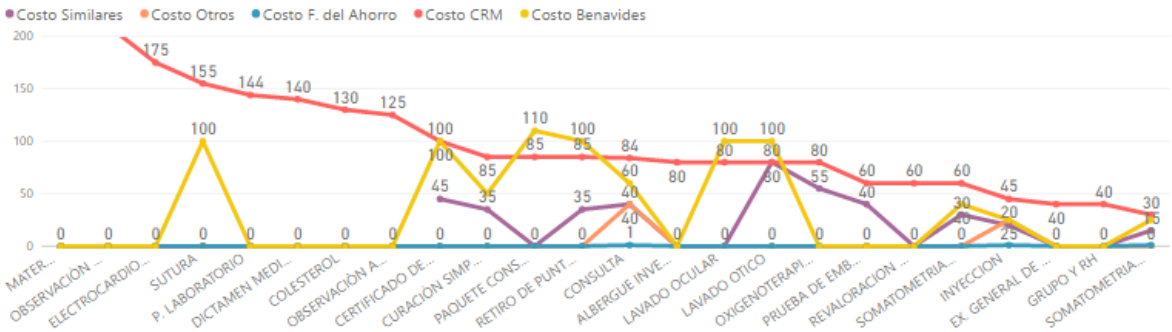

Figure 6: Market prices

Evaluation of work schedules
A field study was conducted to know the hours of service offered by the competition. It was possible to identify that the MRCM has a competitive advantage over its competence in the aspect of hours of service, since it is the only organization that works 7 days per week (392 hours per month), while its competence works 6 days per week. In addition, in one day, the MRCM provides its services 2 hours more than the rest of the competitors. In the same way, it was identified that the competitor Farmacias del Ahorro offers the least hours of service (224 hours per month) compared to any competitor. The rest of the competitors work 264 hours per month.

Participation study by relief base
To finish the study of the competition, the market share of the MRCM's competitors that are within the radius of influence of each facility was analyzed. In a summarized manner it was possible to say that, following a chronological order, the base of Apodaca has 9 competitors, Escobedo 20, Garcia 8, Guadalupe 23, Lincoln 21, Metroplex 13, Monterrey 24, San Pedro 16 and Santa Catarina 10.

On the other hand, in general, the 9 relief bases of the MRCM compete against 29 Farmacias del Ahorro, 25 Farmacias Benavides, 41 Farmacias Similares and 49 "Others", having in total 144 competitors. With this information it was observed that the main competitor as a commercial chain of pharmacies is Farmacias Similares, because even though the "Other" category is the largest, it must be remembered that all those health centers, clinics or independent clinics were considered as if the 49 do not correspond to the same competitor, but to many different ones.

3.4 Objectives
Given the previous information, the objective pursued is to increase the productivity in the relief bases by 10% on average, without deteriorating the provision of services to the community and adhering to the mission of the MRCM. For purposes of calculating the objective, it was decided to calculate productivity in the following way:

$$Productivity = \frac{\#\ of\ patients\ in\ a\ year}{Operating\ cost\ of\ health\ facilities} \tag{2}$$

In order to achieve the objective and according to the analysis made to the organization, the following specific objectives were determined: (a) to reduce the average operating cost per health facility by 10%, and (b) To select the most inefficient facilities.

3.5 Strategies
After having established the specific objectives, it was decided by the team to define two strategies: In order to reduce the average operating cost per health facility, we propose to generate more efficient staff allocation schemes without affecting the satisfaction of demand; and to select the most inefficient facilities to suggest their closure.

4 Staff assignment schemes

As part of the development of the strategy of "Generation of more efficient staff allocation schemes without affecting the satisfaction of demand", a field study was carried out, the job description of the people currently working in a relief base was investigated, the medical service process of the most common service was analyzed and finally different proposals for an ideal staffing template were elaborated.

4.1 Field study: Focus group
In order to know in depth how the operations are carried out within each of the relief bases, a focus group was carried out with the nursing interns (students who are doing their social service and they operate in the facilities). In a health facility works: doctors, nurses, social workers and nursing interns. It was decided that the nursing interns were the most suitable to participate in the focus group because they receive only 600.00 pesos per month for their services, so it was considered that since the interns are the least economically dependent of the MRCM, they would be the most objective ones when sharing the information about the operations within the relief base. Two focus group sessions were held, the first session was held at the Escobedo facility and the second session took place at the Monterrey facility. The call for participants was made through the Medical Area Coordination of the

MRCM. Currently, the MRCM has 36 interns, of which 14 interns attended to our two focus group sessions that were held (equivalent to 39% of the population).

4.2 Job profile

The positions that have direct contact with the patients in the different operations carried out in the relief bases are: the doctor (a), the nurse (a), the social worker (a) and the nursing intern. Therefore, each of the positions was defined, including their profile, responsibilities and activities to be carried out. The information was obtained from the Coordination of the Medical Area of the CRM-DM and at the same time it was validated in the focus groups that were carried out.

4.3 Medical care process

The consultation is the most used service of the MRCM, which is described in Figure 7. During the focus group sessions, the process of medical attention to a patient requiring such service was analyzed. According to the information obtained in these sessions, the approximate average times in which each of the activities are carried out were determined (i.e. 27 minutes). It was possible to identify that the doctor and the intern are the ones who have a longer time of participation in the medical care process. On the contrary, the social worker is the one who participates least during the process, and the nurse offers support and supervision to the activities of the interns.

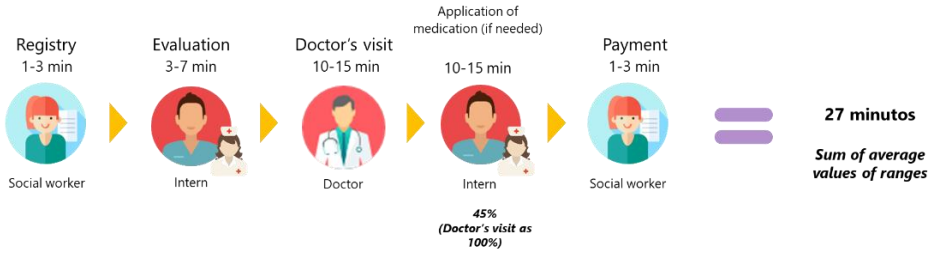

Figure 7. Diagram of doctor's visit

4.4 Ideal work force

However, in order to elaborate the staff allocation proposals, the focus group sessions inquired about the duration of one shift of each one of the positions that operate in a relief base and the perception that the interns have about the average effective hours of each position in that shift.

Table 2. Effectiveness of each job

Job	Hours of shift	Effective hours	% of effectiveness
Doctor	7	3.5	50%
Nurse	7	2	28%
Social worker	7	4	57%
Intern	6	5.5	91%

Following the information gathered and taking as a reference that the previously analyzed competitors such as Farmacias del Ahorro, Farmacias Benavides and Farmacias Similares carry out all their medical care operations with only one doctor in each branch and still manage to satisfy the demand, different scenarios of staff templates were explored to reduce operating expenses.

Table 3 describes the different feasible scenarios of staff reduction. It was suggested to the client the scenario number 7, which consists on to maintain the current staff of doctors and interns, but reduce in each relief base to half the staff of nurses and social workers. This decision arose because it was known that a high percentage of nursing activities are carried out by interns, and although it is known that interns must be supervised by a professional, it is suggested that this responsibility be passed on to the doctors. On the other hand, although the social workers are in charge of carrying out the administrative activities of the relief bases, evaluating their effective work time and remembering that the competition only works with doctors, it is suggested that the administrative tasks be passed on to the rest of the

workers of the base according to its availability at each given moment. The current salary expense is $ 732,000.00 pesos per month, therefore, if the client follows this improvement proposal for all the bases, it would reduce his salary expense by 19%, equivalent to a savings of $ 137,500.00 pesos per month.

Table 3. Scenarios of staff reduction

Scenario	Doctor	Nurse	Social worker	Intern	Cost reduction	Comments
1	2	0	0	4	57%	As competitors
2	2	0	0	4	60%	Decreased service quality
3	2	0	1	4	57%	Not suitable for administrative issues
4	2	1	0	4	70%	Decreased service quality
5	2	0	2	4	71%	Not suitable for administrative issues
6	2	2	0	4	79%	Decreased service quality
7	**2**	**1**	**1**	**4**	81%	Selected
8	2	1	2	4	90%	
9	2	2	1	4	91%	
10	2	2	2	4	100%	Current

5 Relief bases' closure decisions

In order to identify the most inefficient bases and measure the possible effect that their closure would have on the community, a bibliographic research was carried out to select the variables that would form part of our optimization model to determine the closure of relief bases. In total, 14 articles were analyzed that address the issue of closure of health centers and hospitals in rural and urban areas. At the end of the analysis, 35 variables were counted and grouped into three large groups: competence, population and organization.

One of the variables identified in the competition group was the HHI index, which according to the Department of Justice of the United States (2017) is a commonly accepted measure of market concentration. The HHI is calculated by squaring each competitor's market share (%) and then adding the resulting numbers.
Subsequently, limitations on the scope of the identified variables were established and those that were not related to the project were eliminated. The established limits were:

- Hospitals: variables applicable only to hospitals and not appropriate for clinics, clinics and / or health centers were discarded.
- Discrimination against people: Variables that characterize people by age, color or economic level were not considered.
- Juridical form or subject of the organization: Variables that classify organizations and apply government quotas are not considered.
- Subjective information: Variables that include perceptions or opinions wew not considered.
- Non-discriminating: Non-discriminating variables (i.e. variables with unchanged values, variables that not affect at all productivity, etc) were not considered.
- Relevance: Variables that include factors of little relevance were excluded.

Finally, a total of 13 variables were considered. However, two more variables were added, they were not observed in the literature review but they are considered relevant for the study; they are the price of services of the competition and the working hours. Later, some variables used in the influence areas definition, and others in the operating cost of the organization. Therefore, in total 10 variables were selected to be part of the model.

We developed an integer optimization problem to maximize the productivity, *PR*, where the most important binary decision variable X_i takes the value of 1 if the base covering the zone *i* is closed and 0 otherwise. In addition, an integer variable *Y* represents the number of ambulances that could be operated with the resources released by the closure of the bases; and the integer variable *m* is the number of health and prevention campaigns that could be carried out with the same resources.

Remaining notation
i: zone of influence; *a* and *b* represents the zones that belongs to the same municipality.
E_i: monthly demand in zone *i*
Cb_i: monthly operation cost of base *i*
CA: monthly operation cost of an ambulance
CA: operation cost of a health prevention campaign
AC_j: capacity of competitor *j*
$C_{i,j}$: number of "bases" of competitor *j* in zone *i* (number of patients in a month)
A_i: capacity of base *i* (number of patients in a month)
$D_{i,j}$: demand (number of patients) of competitor *j* in zone *i*

The model

$$\max \quad PR = 1000 * \frac{\sum_i E_i * (1 - X_i)}{\sum_i Cb_i * (1 - X_i)} \tag{3}$$

Subject to:

$$Y \leq \sum_i \frac{Cb_i}{CA} X_i \tag{4}$$

$$m \leq \sum_i \frac{Cb_i}{CP} X_i \tag{5}$$

$$\left[\sum_j AC_j * C_{i,j}\right] + [A_i * (1 - X_i)] \geq \left[\sum_j D_{i,j} * C_{i,j}\right] + E_i \quad \forall i \tag{6}$$

$$X_a + X_b \geq 1 \tag{7}$$

$$HHI \leq 2{,}500 \tag{8}$$

$$X_i \in \{0,1\}\ \forall i; Y, m \geq 0, integer$$

The objective function (3) is maximize productivity defined as the total demand of the open facilities, between the sum of the operating cost of the open facilities, and all this is multiplied by 1000. Equation (4) translates the resources available due to closure of the relief bases into the number of extra ambulances that could operate with the release resources. Equation (5) computes the number of health preventive brigades in similar way. Equation (6) guarantee the satisfaction of demand in each zone of influence *i*. That is, the competition and the bases that remain open must be able to meet the current demand that is currently met by the nine open bases.

Regarding constraint (7), it is about preserving the image of the organization. That is to say, in those municipalities where there is more than one base, the presence of the institution should not be completely eliminated in order to prevent its image from being affected. Constraint (8) is about maintaining the structure of the market (HHI Index). That is, despite the closure, the market should not be highly concentrated or monopolized. Therefore, the HHI index should be less than 2,500. Finally, domain in variables is given in equation (9).

6 Implementación

Once the model was formulated, it was implemented using the organization's data. In the case of the restriction on the image of the organization, it seeks that in those municipalities where there is more than one base, such as the Monterrey and Lincoln base in the municipality of Monterrey and the Apodaca and Metroplex base in the municipality of Apodaca, the presence of the institution should not be completely eliminated in order to prevent the image of the MRCM from being affected. It is important to note that the restriction on the structure of the market. The calculation of the current HHI index was made and a total of 1,400 points was obtained, that is, it is a competitive market. Then

the exercise of calculating the HHI was done taking into account that all the bases of the MRCM were closed and an index of 1,541 was obtained, that is, a moderately concentrated market. Because the market does not fall into a monopoly even though the MRCM completely eliminates its presence, the restriction of the HHI index was eliminated to avoid being redundant.

The mathematical model and the sensitivity analysis was performed in GAMS. A standard laptop was used, so the model is not very complex and had an average computation time of 0.072 seconds. Also, the productivity equation is non-linear, so the MINLP solver was used.

7 Results

Without any other restrictions, the optimal solution found was to close 6 out of the 9 relief bases, as observed in Table 4. Given that the project research was to achieve a 10% productivity increase, the closest solution is to close only three bases. With this solution, the equivalent to 1.63 ambulances could be operated monthly or a total of extra 43 health campaigns could be performed with the resources released by the three closed bases. The market will be able to absorb the demand of the closed base. It is important to note the robustness of the solution, since the increasing number of closures only add a new base but not change the previous decisions.

Table 4. Sensitivity analysis varying the number of relief bases to be closed.

# Base	# to close	Productivity	Relative increase	*A*	*m*	
	0	7.046	0%	0		
3	1	7.284	3.38%	0.42	11.17	
3,7	2	7.486	6.24%	1.2	32.26	
3,7,6	3	7.687	9.10%	1.63	43.80	Selected
3,7,6,9	4	7.887	11.94%	2.2	59.22	
3,7,6,9,2	5	8.28	17.46%	3.63	97.49	
3,7,6,9,2,8	**6**	**8.47**	**20.18%**	**4.1**	**110.28**	**Best**
3,7,6,9,2,8,4	7	8.088	14.79%	4.61	123.89	

8 Conclusions

Regarding the first strategy, the proposal 7 in Table 3 was suggested to the client, which consists of maintaining the current staff of doctors and interns, but reducing in each relief base to half the staff of nurses and social workers. If the client follows this proposal for improvement for all the bases, it would reduce his salary expense by 19%, (this is MXN$137,500.00 savings per month, which could be used for any other purpose of the organization, according to his priorities In one year, savings of MXN$ 1,650,000.00 would be generated only in salaries. With respect to the second strategy, according to the needs of the organization and its scope, it was decided that closing three relief bases was within the possibilities of the MRCM: García, Monterrey and Metroplex. With this strategy, a relative increase in productivity of 9.10% is generated. In addition, by combining the suggestions proposed in both strategies it will be possible to achieve a relative increase in productivity by 21.04%, which is greater than the proposed as the general objective that was 10%.

On other hand, results reveal that in an urban context, as the one analyzed in this project, the closure of bases does not affect the capacity of the market to provide the current (basic) health services.

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