RESEARCH

"Hospitales en Red" (Hospitals in a Network): a software to manage health resources during Covid-19 pandemic

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Abstract

In this work, we present our experience in developing software that organizes the resources of a network of public Hospitals from the Province of Buenos Aires, Argentina, in the Covid-19 pandemic context. The system collects, organizes, and visualizes information on the use and availability of beds and patients. The software is totally configurable and open to any other hospital network. Besides optimizing the use of beds, it allowed the collection of useful information to understand the operation of the Network in the particular Covid-19 crisis.

Keywords: public health; covid crisis; software

Introduction

In March 2020, with the pandemic already in Argentina, National and local governments planned to supply the health country's system with new hospital modules and essential supplies.

The Province of Buenos Aires is in the central-east region of Argentina. Four municipalities of the south of the Province make up the Southeast region ((see Fig 1 B) where $1,800,000$ people live according to the 2010 national census. That region includes some vulnerable neighborhoods (see Fig 1 C and D). Eight hospitals in the region, which had already been operating in a network, put on alert to face the pandemic: for example, Oñativia, Iriarte, Mi Pueblo, and the High Complexity Hospital of El Cruce (see Fig 2). Seven new hospital modules would be built in record time to add to the Southeast Network's health resources, besides equipping the network's original hospitals with new beds for critical and general therapy.

The *hospitals in a network* functioning is a common practice that, at critical times, allows optimization of physical and human resources, facilitating the referral of patients of medium and high complexity among the hospitals in the network.

The accelerated dynamics and the complexity of some already known situations (patients with varying levels of clinical and social risk) and other unprecedented and typical of this epidemic (health personnel ill and isolated) made foresee that new tools were needed to sustain networking logistics.

More than ever, each hospital's decision was required to consider the rest of the network's real situation. For example, to decide where to admit a new patient, it was essential to have updated information on the occupancy of beds of different

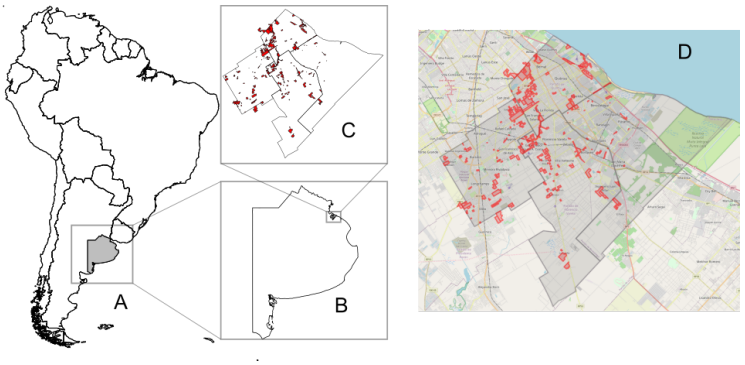

Figure 1 Argentina in the south of America (A), the Province of Buenos Aires in the center-east of the country (B). The Southeast region of the Province of Buenos Aires involves four municipalities: Quilmes, Florencio Varela, Almirante Brown y Berazategui, (C). Polygons in red are the vulnerable neighborhoods of the region (C and D).

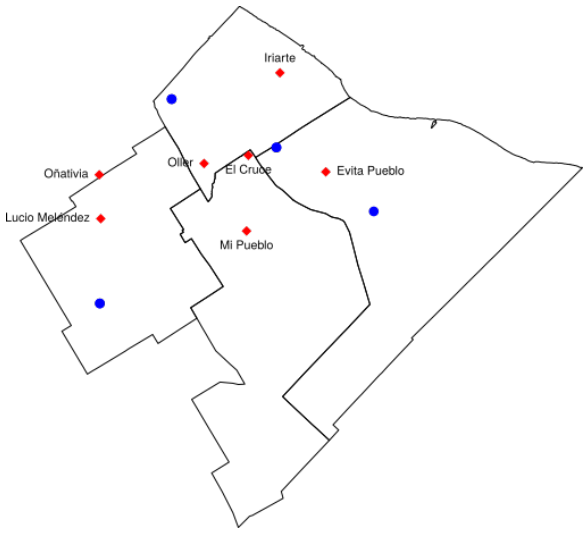

Figure 2 The Southeast region included eight Hospitals at the beginning of the pandemic (red diamonds). The government of the Province built seven new hospital modules during the first two months of the pandemic (blue circles).

types in each hospital and the severity of those hospitalized. Any anticipation by doctors required that they have complete and up-to-date information at hand. Until March, information on occupation and availability of beds was collected through telephone calls from the El Cruce Hospital twice a day, in the morning, and the afternoon, to the rest of the hospitals. But the pandemic made it impossible to continue with this way of centralizing information. Reality would change too fast. Loading information needed to become decentralized by many authorized users so that the updated data became reflected in real-time throughout the network. At the same time, the Southeast Network was growing, as were its human resources.

A new system

A new system became necessary. While there was a list of priorities to develop, such as the need to visualize the entire system's situation in real-time, other requirements emerged as the project progressed. Thus, the system should meet a series of initial objectives but later should have the versatility to add new requirements. Furthermore, these new requirements were not clear from the beginning, but rather emerged as the system began to be used by the network and by more and more users, and the needs to cover different functionalities became clear.

Initial Requirements

The first objectives that had to be met, in a very few days, were the following:

- Collect information on the bed occupancy from all the hospitals of the network in a decentralized way.
- Visualize a Dashboard with the occupation and availability of beds throughout the network in real-time.
- Store many users and patients.
- Save information about the traceability of the load data by users, facilitating the evaluation of the system's use, the software's learning, and improving its use by the users.

As the network resources were growing, some conditions were non-fix:

- The total number of beds in each hospital was variable.
- Health personal would define new types of beds during the process, such as intermediate ones.
- Health personal would redefine the patients' possible states, such as the *suspicious* status of Covid-19.

Subsequent Requirements

The following requirements arose later and made the system work with all the functionalities of a hospital network:

- Add new users with different roles and permissions (which would also change during the process).
- Include patients' information, like the level of clinical risk (fair, medium, wrong) and social risk (YES, NO), age, sex, other diseases (a list of categories defined by the medicines).
- Automatically assign an ID for the patients.
- Register the discharge of patients, selecting one of the available options defined by the doctors: home discharge, death, transfer to another hospital in the network, among others.
- Save patient referral information within the network and view it on the Dashboard.
- View the information on different screens: i) initial screen of bed occupancy; ii) patient loading screen; iii) risk level screen with details regarding the clinical and social risk of the hospitalized patients; iv) bed management screen and v) users administration screen.
- Use the system on various devices: computers, cell phones, and tablets.
- Link patient information with visual icons that help clinicians capturing a quick snapshot of the situation at different levels.

Framework

We fulfilled the first objective in a very few days. In addition to the urgency, other essential issues arose, such as building a system within a framework of protecting patients' personal data.

Considering the urgency to reach the system, the availability of scarce economic resources for software development, and the need to protect people's health information (sensitive data), we decided to use the Amazon server to host the system and not load any personal data into the system. In this sense, the system does not allow users to upload names, documents, postal addresses, nor emails. Besides, there is no space for users to upload any free text of any kind (nor numbers). The system had to assemble with the software that already worked in the hospitals containing patient information. The system's ID is used to link each patient with their data stored on secure devices. Although this was more laborious for the system's users, we considered the most appropriate way to reach the urgency, taking advantage of all the facilities that Amazon offers while protecting people's sensitive information.

Furthermore, once the first objectives (detailed in **??**) were covered, the system evolved in a generic way. Thus, any health network could set up its bed occupancy Dashboard, and, in the future, it can be applied for other crises as a public health tool.

Lastly, the project's multidisciplinary and collective framework since its conception was crucial to the achieved results. All of us who are part of the development fulfill well-established roles in which the constant interaction was essential to carry out the work, from its initial stage to the most advanced, while the system was already in use. In summary, we can summarize the following construction instances of the project:

During the pandemic, health personnel, assistants, administrators, and collaborators met periodically in the Hospital El Cruce's Situation Room. There, they discussed the new needs, faults, and improvements required by the system. They expressed requirements almost immediately to the development team coordination, which organized the work in the following way: we studied the feasibility, assembled them with the previous system, and managed priorities. In many cases, mock-ups (on paper first, digital later) helped to review the improvements, and once approved by the health team, the computer developments implemented the issues. Modifications were checked, incorporated into a trial version of the Dashboard, and later into the real version.

This way of working favored the best use of the developers' monetary resources involved in the project (one layout designer, one back end, and one front end developer).

On the other hand, the health users, highly involved in transforming the concrete needs from the hospital situation room into the system tasks, were engaged in the same way of loading data into the system, to have full and updated information, essential for the project.

The System

Dashboard: definition and first steps

To initiate a Hospital Network Dashboard, the new user, whose role is to administer, validates his/her email account [**?**] and can define the characteristics of the new

dashboard. Among the available options, he can: invite new users with the role of *administrator*, *administrator of a hospital or a group of hospitals* and *viewer* (see Fig 3); define the type of beds, for example, *critical*, *intermediate* and *general*, as well as the color associated with each one (see Fig 4); define the possible states of the patients occupying the beds, for example, *Covid*, *Suspicious*, *Other* (see Fig 4); edit information for each hospital in the network: name, geographic location, the total number of beds of each type, and type of editing for data loading (*Basic*, where only bed totals can be loaded or *Advanced*, to edit patient-level information) (see Fig 5). In the case of the advanced edition, as a result of the admissions, modifications, and discharges of the patients, the system calculates the total number of beds of each type at all times.

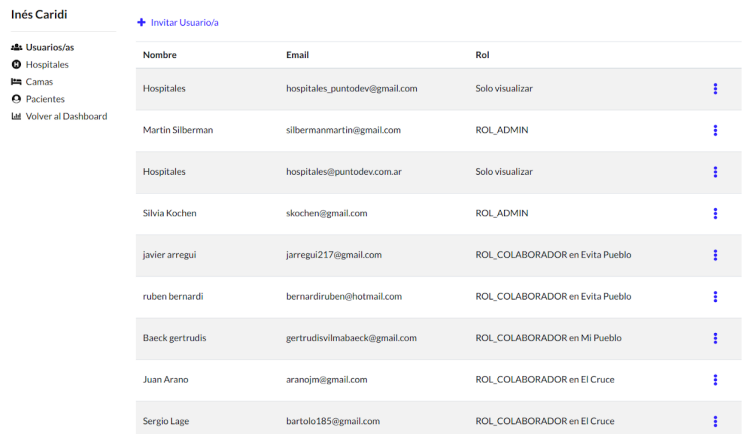

Figure 3 Screen to invite new users.

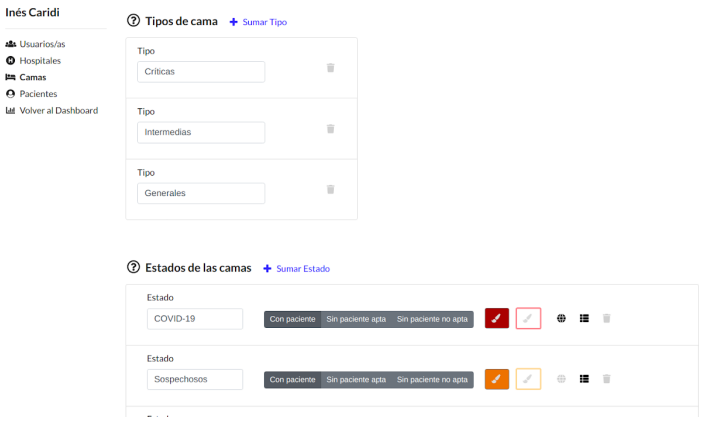

Figure 4 Screen to define the type of beds (critical,intermediate and general) and the possible states of the patients occupying the beds, (for example, Covid, Suspicious, Other).

The system allows the visualization of the information at different levels, with varying degrees of detail. The screens that exist so far, some allowing doing tasks, as mentioned above, are:

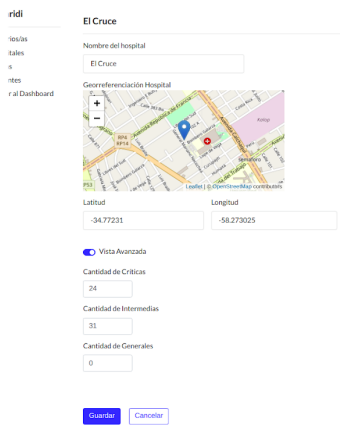

Figure 5 Screen to edit information for each hospital in the network.

Initial display screen of beds:

The hospital network's main screen shows the status of beds (occupied by Covid confirmed, Covid suspects, by other pathologies, free and disabled) of all the hospitals in the network. We can see an example of this screen for a fictitious hospital network in Fig 6. Doctors at the hospital El Cruce proposed this screen's design because they needed to overview the situation at first glance. Rectangles represent the beds ordered by color to quickly see the availability of free (green) and disabled beds (gray) in each hospital, which has a lot of variation in crisis contexts.

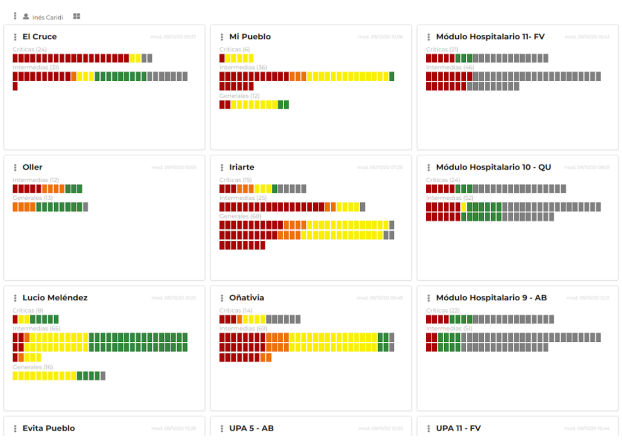

Figure 6 Example of Initial display screen of beds for a fictitious hospital network. Total of beds of each type (occupied by Covid, by Covid suspects, by other pathologies, free and disabled) are shown of all the hospitals in the network.

Administrators can change the hospitals' distribution on the screen, for example, organizing them by geographical areas to facilitate their visualization, as in the Southeast Network. The same screen also shows a navigable map with the hospitals' geographic location with information on bed occupancy. Finally, two graphs show the percentages of bed occupancy and detailed by each category (see Fig 6b with the same fictitious example).

This screen adapts to the device's size to make the most of its extension and locate as many hospitals in columns as possible. This functionality was useful for the big monitor of the situation room that works in Hospital El Cruce, other smaller monitors in hospitals, and the computers, tablets, and cell phones used to view it.

Patient risk level screen:

After the first initial screen of beds (screen 1) with the availability of free beds, doctors required seeing some patients' indicators, which could help to anticipate the use of beds (clinical and social risk, age, gender, length of stay). Thus, this risk screen includes only hospitalized patients with Covid or suspected of Covid status and information on free beds.

This screen helps plan transfers of patients between hospitals (for example, a high clinical risk level patient from one hospital without critical bed available to another one with availability). The idea is to plan the transfer before the patients' most urgent situation, which implies fewer risks. Fig 7 shows an example of this screen for the same fictitious example. It was essential to incorporate risk icons and colors (yellow, green, and red for low, medium, and high clinical risk levels) to help doctors capture relevant information on this screen.

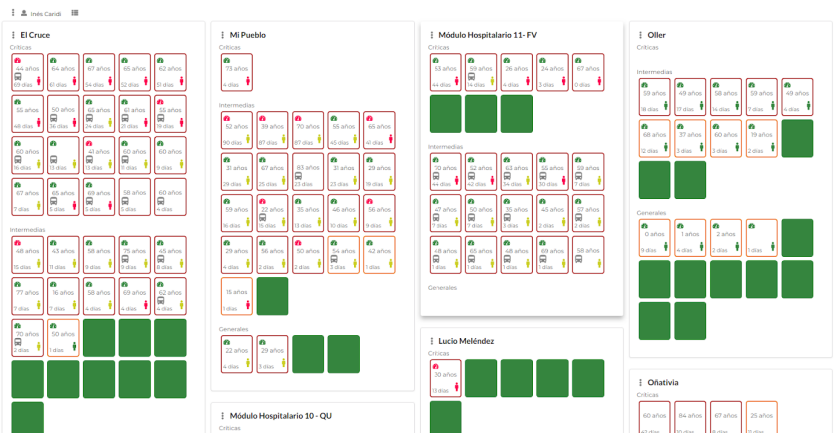

Figure 7 Patient risk level screen.

Patient screen:

This screen displays patients' information for a particular hospital. It also allows the entry of patients to the system, moves them from beds within the same hospital (for example, a patient in a general bed can go through a critical condition), and records their home discharge, death, or transfer to another hospital in the network. Fig. 8 shows an example of this screen for a hospital from the same fictitious case.

Hospital general screen:

This screen allows for editing the hospital's name, geographic location, the total number of beds of each type (critical, intermediate, and general), and the kind of data load editing of the beds (basic or advanced mode). Fig. 5 shows this screen for one of the hospitals in the same fictitious example.

User administration screen:

This screen displays the hospital network users, including their name, email, and role (administrator, collaborator of one or more hospitals, and viewer). This screen

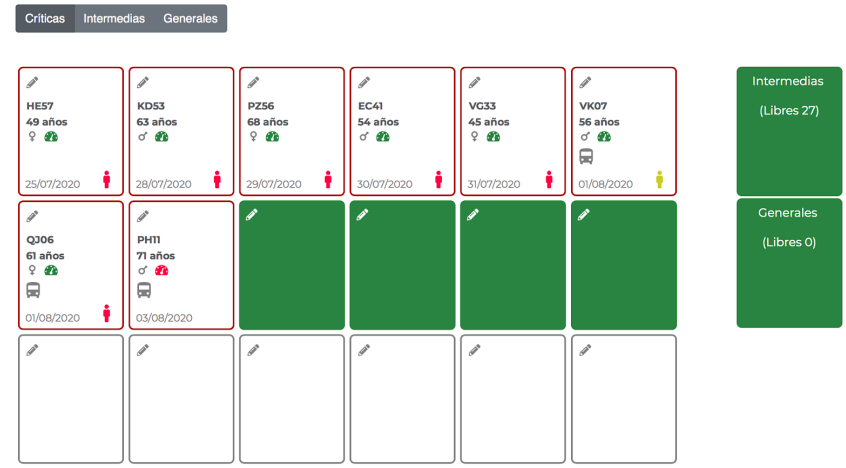

Figure 8 Patient screen of a particular Hospital (example).

is accessible only to users who have the administrator role, who can also invite other users, uploading their email, and eventually delete them. The new user will receive an email to their mailbox and must enable their account to enter the system. Also, the collaborators of a hospital/s can invite other collaborating users from the same set of hospitals and viewers.

The different users' roles are detailed below:

- *Administrator*: Can edit in all screens, invite new users, as well as delete them.
- *Contributor*: Has the administrator role only for a particular hospital or a group of hospitals. Thus, he can edit only the information related to the hospital (s) assigned to collaborate. He can invite other users as collaborators of the same hospital and viewers and delete them. He can see the risk level screen, although he will only see details of the patients of those hospitals assigned to collaborate. He has access to the edit screen of patients and the general screen of those hospitals he collaborates with.
- *Viewer*: He can see only the main screen of the hospital network.

Some results

Here we show some results from data collected by the system during the pandemic until writing this paper.

The Southeast Network system began operating on April 2020, with five users. Today, six months later, it has 69 users. From the original eight hospitals, there are seven new hospital modules in the health network.

Fig. 9 shows the type of discharge from the total number of patients in the network, distinguishing the subgroups by the value of clinical and social risk.

Fig 10 shows the evolution of each type's percentage of beds (occupied by patients with Covid, suspects, other pathologies, and free beds) throughout the pandemic. It can be seen that at the beginning, approximately 10 percent of the beds were occupied by Covid patients, and approx at middle of August, 45 percent. It is important to note that the hospital network increased the total number of beds

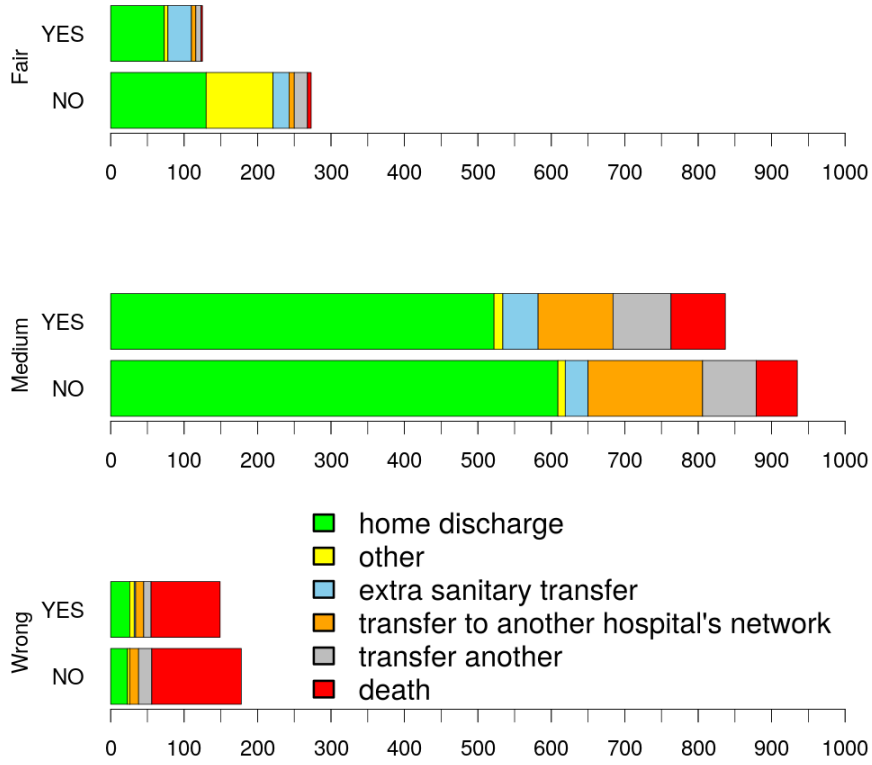

Figure 9 Type of discharge of patients according to their level of clinical risk (good, intermediate, severe) and social (YES, NO).

during the same period. The minimum number of free beds and the maximum number of beds occupied by cases of Covid, already passing. These days, the total number of beds occupied by patients with other pathologies is increasing.

We formalized the hospitals' functioning as a network, based on the information on the transfers of patients among the system's hospitals. Nodes represent the Hospitals and links, the number of transfers of patients between a pair of Hospitals. The obtained network showed in Figure 11. Only one Hospital (of the new ones) didin't use transfer of hospitals. The El Cruce Hospital is the central Hospital of the Region, and in the network it plays a central role too.

Conclusions, Lessons learned and next steps

One of the most significant challenges of this project was transforming doctors and health personnel's specific needs and "what they imagined" that could be useful into a new tool that would contribute to the work of hospitals' network to face the pandemic. But at the same time, trying that the system developed could be used by other hospital networks and, in the future, for different situations. Thus, we needed to balance development times to first advance in the most urgent, and only then to plan the generic format that implied a delay in time but was worth it and then move in a generic system.

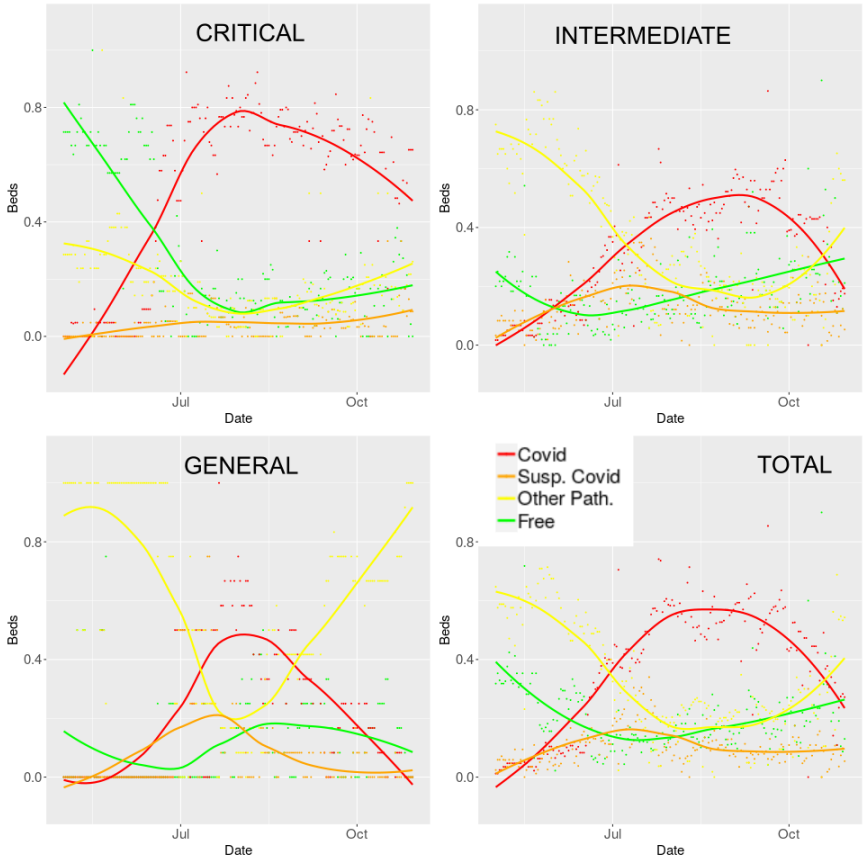

Figure 10 Evolution of the percentage of bed occupancy according to the status of patients and free beds.

One of the characteristics of this project was the multidisciplinary and also collective framework. It was a teamwork in which all of us who belong to the network's health system and those who joined in this system's collaboration was part of the project's creation. This framework helped the system become a tool for real use, and the data load, essential for the system to be used to make decisions, has been possible.

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References
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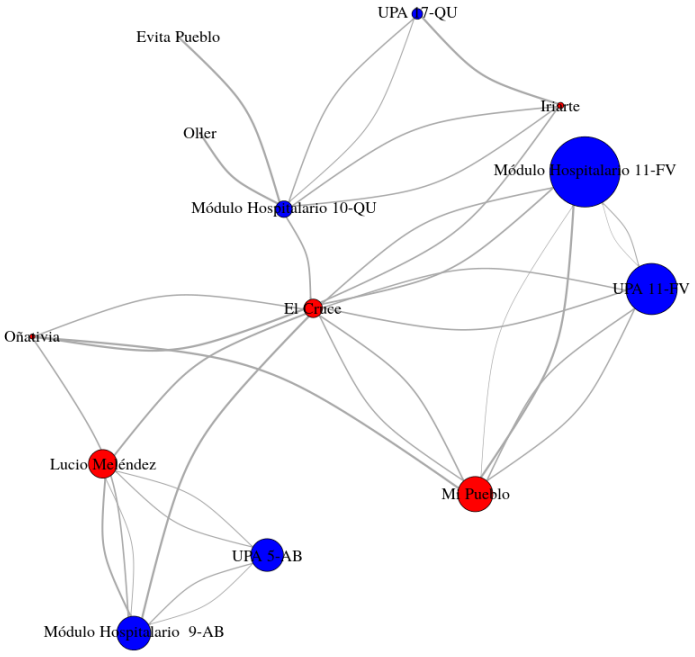

Figure 11 The network of Hospitals based on the transfer of patients. The node's size represents the total number of transfers (received + emitted) and the edges' width, the number of transfers between hospitals. Red circles represent original Hospitals, and blue ones, the new modules.