MULTIPLE VIEWS OF THE MEDICINE DISTRIBUTION IN A PHARMACY OF A NAVY HOSPITAL

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ABSTRACT

The field of simulation has developed in such a way that is now possible to build a model that approaches reality. Recent technological advances grant our move ahead to see the results of a simulation experiment merging the formal approach with virtual scenarios. A method that allows one to imagine a particular hospital service, formulate a discrete-event model, evaluate and execute a formal simulation experiment producing 3D visual results is used in this paper. Recent upgrades results points to the direction to considering different views of the most important parties involved in the models. The objective of this paper is to describe a simulation carried out by a group of twenty OR post- graduate students at the Federal University of Rio de Janeiro- COPPE. The medicine distribution system of the pharmacy of a Navy Hospital in Rio de Janeiro is evaluated and a simulation model is proposed. The model is based upon the integration, at the same level of importance, of the viewpoint of three of the most important entities involved in the medication distribution process: The patient, the attendants and the medication logistics. It is argued that the synchronization of the life cycle of these important entities could contribute to improve the performance of the models. The principles of the method have been largely used to evaluate aspects of the operation of several Brazilian public hospitals.

KEYWORDS: Visual Simulation. Object oriented. Pharmacy. Public Services.

1. Introduction

Operational Research (OR) is an exciting ground providing tools, perspectives and new ways to structure and think about theory and practice. An examination of the early OR studies in Hospital Admission Systems (HAS) permits a classification of efforts according to problem areas. The first published papers are related to demand for Health Services and utilization of facilities in both the United Kingdom (UK) and the United States of America (USA). Complex problems of probabilistic nature, sometimes dominated by systematic factors such as seasonal variation, scheduling rules and other mathematical features, have earlier attracted the attention of researchers. It is possible to trace by the 1960’s the growing interest in the admission scheduling problem or, at least, in the components of it.

Most of the first studies focused on the census variability, prediction and control. The stochastic models have been used mostly to study census variability and prediction. The optimization models have been used chiefly for designing admission policies and to exercise control over the census. Complex problems which may not be treated analytically have been studied experimentally by simulation. To review such a wealth of new material in a succinct manner and to give credits to everyone would be a very difficult task. The author’s interests in this field started in the 1980´s. Alternative models are proposed to study the flow of emergency and elective patients to the Glasgow Western Infirmary.

The accessibility to public health services in Brazil is a big issue and much remains to be done to improve the quality of the services. The insufficient structure of the public services contributes its overload, transforming them into one of the most problematic areas off the Unified Health System (SUS). Several attempts have been made to improve the emergency service of some public hospitals in the municipality of Rio de Janeiro. The research topics includes: I) Pre-hospital services such as call centers, rescue operations, ambulance services and transfers; II) Hospital services such as the entry door, reception, triage, risk evaluation, medical care, ancillary services and pharmacy operation. Most models focus on the flow of entities, reduction of waiting times and composition of human and material resources in order to achieve an adequate treatment according to the severity of the case. The main entities or agents involved in the hospital admission process are the patient, the medical staff and the administration. Taken into account the patient's complaint, the medical skills and administrative knowledge, it can be argued that in the cause of better functioning of the system the different viewpoints of the parties involved should be taken into account in the drawing up of any modified procedure.

Previous research advocates that most public hospitals in the city have similar problems related to the human and material resources, flow of services, huge demand and long waiting periods to start services. Alternative OR models have been proposed to deal with these problems. A 3D visual simulation method has been proposed to help the implementation of new hospital facilities (De Oliveira, 1998). The method is based upon a real problem that is formulated as a logical model, which is then converted into a computer model. This model is verified and tested to see if it is doing what the analyst wants it to do. The model is used as an operational model to produce some results, or some conclusions, or for implementation after being validated against the real world. The best simulation results are visually presented in a modern virtual environment.

Due to the complexity of the hospital services, formulation is a very difficult task. The construction of the logical model representing the formulation of the problem is, in many instances, the most difficult aspect of the modeling. In fact, understanding what the problem is may be the object of the whole exercise. In many instances, the function that the computer model serves, is to perform a medium of communication for the structuring of the problem for all participants in the decision making process. The interactive virtual fashion of the method contributes to reduce the gap between theory and practice. The visualization of the results of a simulation model is a recent progress that has been applied to the hospital context. It is now possible to "see" the results of a simulated mathematical model instead of numerical reports only. This apparatus should be extensively used in learning and training programmes.

The recent advances in the information technology make it possible people in different places access, through the internet, a virtual emergency hospital environment and interact with other real or virtual entities. It can be applied to let user have a sensation of being within a real hospital.
The new approach leads to the direction of study the different viewpoints of the agents involved in the simulation model. It is possible to evaluate the interaction between agents and synchronize their activities in order to improve accessibility and quality of the services. This new advance has theoretical interest and provides useful information to the elaboration of a complex model. An application of the method is presented in this paper. The is focus on the Medicine Distribution Service (SeDiMe) of the Hospital Naval Marcílio Dias (HNMD) that is a major navy hospital in the municipality of Rio de Janeiro, Brazil. The aim is to reduce the unnecessary waiting time to collect medicines at the pharmacy. The costs involved are of social nature and are measured the benefit brought to the clients.

2. The problem

The HNMD is one of the most important institutions of the Brazilian Navy in the city. The hospital has 530 inpatient beds, 80 consulting rooms and 54 clinical services. It provides medical assistance to the Navy Health System, which is called Sistema de Saúde da Marinha (SSM). The system comprises their own Pharmacy Laboratory (LFM) that is responsible to produce and stock medicaments. The production line comprises several pharmaceutical items. They are offered through a lower cost to about 360 thousand SSM members. The beneficiaries are mostly military people and their families. One of the main concerns of the hospital administration is the operation of the medicine distribution service of the SeDiMe. According to the hospital administration, the service presently shows some flow problems that caused long waiting times to deliver the medicine items to the users.

3. The model

A number of visits were necessary to evaluate the service operation. The necessary data to build the model was collected by a group of 20 post graduate students from the OR department of COPPE at the Federal University of Rio de Janeiro. All the steps of the model building are based on discrete-event simulation methods and reflect the author's experience in teaching and experiments in the hospital context. The modeling platform is a suite of modules that provides the basic steps required to execute the experiment. The main modules are the formulation, the simulation, the scenario building and the 3D visual simulation. The formulation of the problem is the first and the most important step of the simulation experiment. To start the formulation one shall define the entities, the activities and the queues.

The entities are the system's components, that is, people or objects that are able to change the state of the system in time. They have an attribute, which identify its state. The physical components have variables, which identify its operational state. The activities are actions which represents functions and services executed within the system where two or more entities are used simultaneously for a certain period of time. They are active states, which involves the cooperation of entities from different classes. The duration of an activity should be estimated from real data. The queues are passive states where the entities should wait until all the necessary conditions for beginning the next activity are achieved. The time spent in the passive state depends on the future state of other entities because a particular activity can only start if all the entities involved are available.

The formulation approach adopted here helps the users create the life cycle of all entities and provides tools to concatenate them in order to check the integrity of the formulation. There are several ways to represent the logical aspects of the model. De Oliveira (1994) shows how a patient-oriented simulation model could be used to reflect about alternative hospital admission policies. It is argued that the orientation of the model should be aligned with the objective of the experiment. The overall objective of the model is to synchronize the performance of the most important entities of the SeDiMe, in order to reduce the excessive waiting time spent by the parties involved to distribute and collect the prescribed medicine. Three independent simulation models are devised for the patient flow, the attendance service and the medicine stock control logistics.

The next step is to synchronize the models in order to attain the necessary improvements. There are many ways to achieve better quality of the service. A common element of all approaches is the need for synchronization in the management of the work flow through the system. A perfectly synchronized system is reached when the most important entities involved in a particular activity are available in the right time, so that there they do not cause delays to activities. The approach adopted here involves the combination of discrete event simulation and the theory of constraints (Sabbadini et. al. 2008).

3.1 The patient flow model

The first model focuses on the patient. Figure 1 shows a flow diagram that describes the path to gather the prescribed medicine. The patients are classified either as normal or priority according with their attributes. Both have to wait for attendance in separate queues. The attendance process includes two important questions: the availability of the prescribed medicine in either of pharmacy and the availability of funds. The former question is necessary because the medicine can be acquired through payment discount, as the patients and the hospital are from the same public segment. Some patients have to make the payment through a Bank.

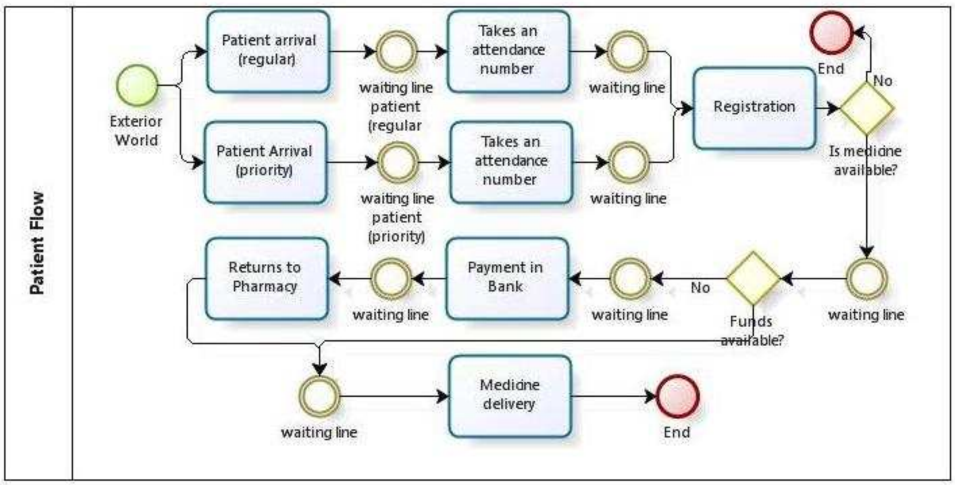

***Figure 1** – Patient flow*

There are two classes of patients named normal and priority. Both have to use a ticket machine located at the entry door to receive a number that give them their position in a first in first out queuing mechanism. After collecting the ticked the costumer should wait to be called. There are two service stations. The attendance activity involves the registration, the verification of funds and the availability of the medicine in two different places (stocks 1 and 2). If one of the conditions is not fulfilled the patient have to return though a different flow.

Data are collect from interviews with the servers and from information offered by the service administration. They include all the details of the patient flow. The duration of the activities are estimated from statistical procedures. The goal is to verify possible ways to improve the patient flow. The simulation experiment includes the method to search for medicine in the stock, change in the number of attendants and the configuration of the service. The impact of changes is measured by the reduction of waiting times, the increase in the number of services and the adequate number of attendants to attain quality as the demand changes.

3.2 The attendance service model

The second model focuses on the attendance process. This process is divided in two phases. The first includes the patient call, the registration and the fund check. The second phase is regarded to the availability of items in the pharmacy stock and the delivery of the medicine prescribed. Figure 2 shows a simplified attendance flow.

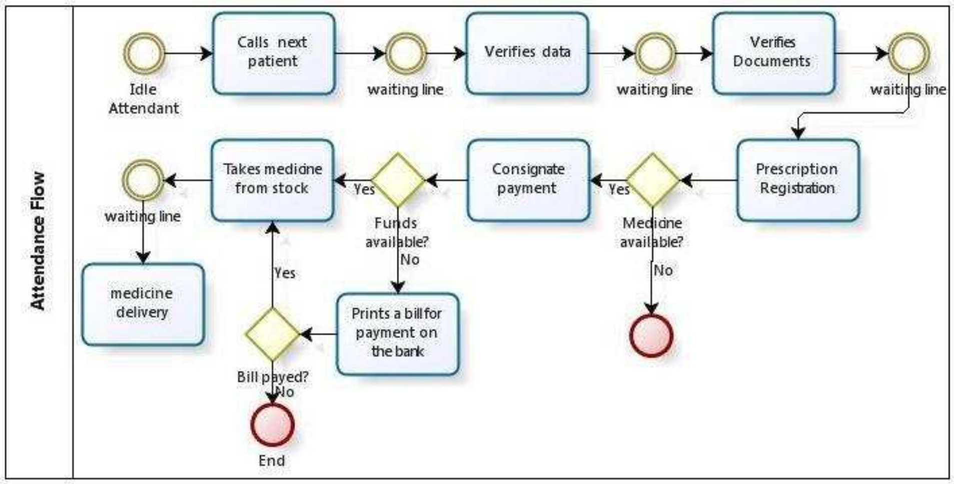

Figure 2– Attendance flow

There are two different places where the medicine is stored. The stock 1 is located near to the balcony. It usually stores the most prescribed medicine. The stock 2 is located in other floor of the hospital building. This demands more time to collect the items.

Three alternatives are independently evaluated:

1- Rate of unavailability of stock 1, which represents percentage of time that the attendant has to go to stock 2.
2- Changes in the number of attendants.
3- Changes in the attendance configuration, which considers the use of extra personnel only to perform the second phase of the attendance.

The simulation results suggest positive measures to improve the performance of the system. For example, the frequent replenishment would imply in lower rates of unavailability in stock 1. Furthermore, there are expressive improvements in attendance quality if the number of servers is raised. The increase of attendants, for the whole process, produces better results when compared to the changes in attendance configuration, for the same number of people.

3.3 The medicine distribution logistic model

The third model focus in the pharmacy logistic with regards to items included in this particular study. The daily attendance is about 450 prescriptions which correspond to 14000 items. The medicine flow is showed in Figure 3.

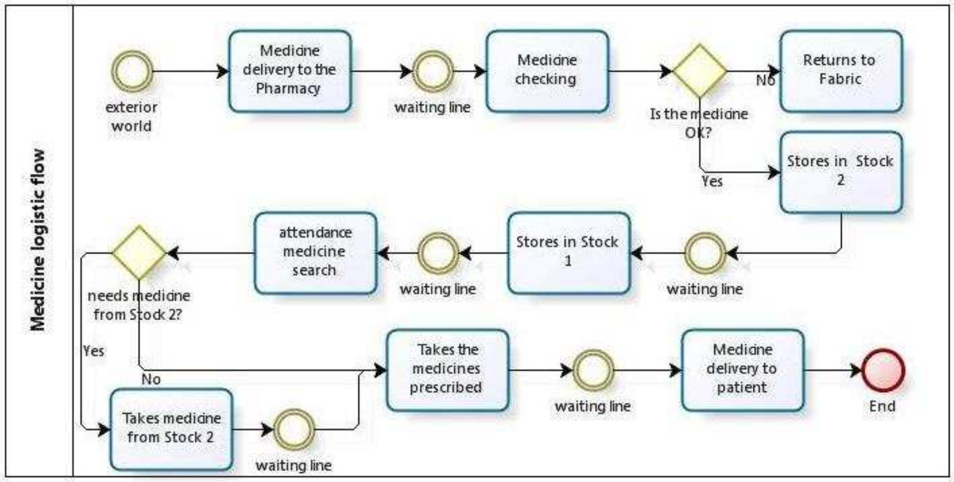

Figure 3 – Medicine Flow

The original model includes only two attendants that have contact with the patients and carry out the search in either stock 1 or 2. They also refill stock 1 that happens every three days. There are eight different medicine classes in sock 1. The stock 2 is bigger and has a capacity for 1 month. The replenishment of stock 2 happens once a month. The modelling process for the medicine logistic involves a link with the patient flow model, the transfer between stock 1 and 2, link with attendance model, stock 2 refill lead time, and scheduled transfer time between stocks 1 and 2 and delivery. The logic of the model includes the availability of medicine, and includes a score relative to time to transfer items from stocks to delivery. It also verifies the time of delivery time, searching for quality improvement measures. The results show the stock management has a direct influence in the patient attendance time. This time could be reduced as the reorder level of stock 1 and 2 is increased and the replenishment is carried out more frequently. The reduction of the number of attendants is unacceptable

4. The Synchronization

The medicine delivery process requires the joint participation of the three entities. Therefore, the next step is to carry out a synchronization process to ensure the simultaneous availability of these entities. The objective of the synchronization mechanism is to reduce the waiting time to start the delivery activity. Therefore, it is necessary to calibrate the model so that individual flows are optimized in order to guarantee that this activity will be executed as soon as possible. This procedure necessarily comes under a constraint reduction. A constraint is anything that limits the system's performance. The identification of constraints is an opportunity to evaluate and improve the system concerned. Figure 4 shows, in a schematic form, this reasoning. Each entity has its own activity cycle. At some point, the three entities will be jointly participating of a common activity. Synchronization is one of the requirements for the proper functioning of the delivery process.

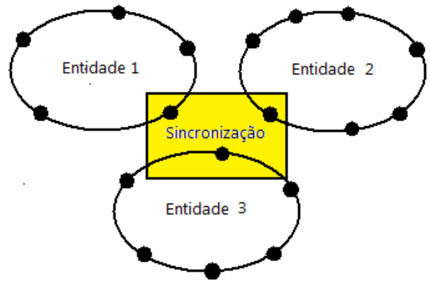

Figure 4 – The synchronization process

The Theory of Constraints (TOC) concepts have been originally designed to investigate productivity improvements in the manufacturing area (Goldratt, 1992). The fist premise is the existence of a managerial constraint. The argument is that the administrative scheme is a process or a series of processes, in which inputs are turned into desired outputs, like a chain. The capacity of the system is limited by its constraints. A comprehensive review of the visibly benefits resulting from implementation of the TOC philosophy and practice can be seen elsewhere (Watson et al, 2006). A survey of viewpoints and applications is carried out to identify journal articles and conference proceedings between 1980 and 1995 (Rahman, 1998). It is noticed that most of the applications are concentrated on accounting, production, purchase, quality, administration and education. The author suggests further investigation in the services sector. The applications are usually focused on operational performance together with reduction in order-to-delivery lead time (70%), reduction in manufacturing cycle time (65%), increase in throughput/revenue (63%) and data performance (44%) to uphold gains for several organizations (Mabin and Balderstone, 2000). An interesting study demonstrates the benefits of TOC and its impact on the NHS waiting lists and patient throughput (Lubitsh et al., 2005). The theory holds that the only way to create ongoing improvements is to release the weakest links of the chain. It can be summarized in the five steps bellow (Goldratt, 1990; Knight, 2000; Burton and Aron, 2002):

1. Identify the system's constraint(s);
2. Decide how to exploit the system's constraint(s);
3. Subordinate/synchronize everything else to the above decisions;
4. Elevate the system's constraint(s);
5. If in the above steps the constraint has shifted, go back to step 1

This theory views the organization as a chain of interdependent processes. The performance of each process is dependent upon the previous one. The capacity of the system is determined by the capacity of the parts or -more precisely, by the capacity of the bottleneck. The expansion of the process is limited by this constraint. Improvements can be obtained by simply managing and synchronizing the activities that need to be accomplished before the bottleneck – the scarcest resource – to make sure that there is no 'starvation' of the bottleneck (Knight, 2000). Figure 5, shows an example of the constraint identification in a sequence of processes related to the delivery of medicine.

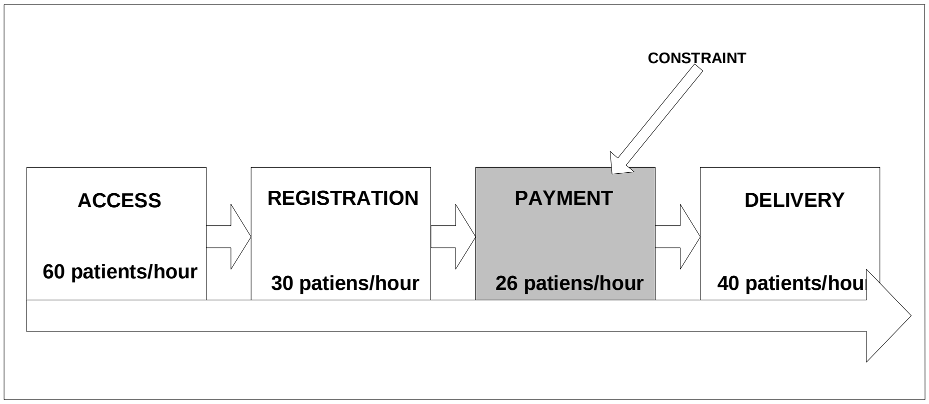

Figure 5 - Constraint identification in the patient flow

The approach consists of developing three different models of the system under investigation, incorporating a method of animating the model and offering an interaction with the model in order to investigate alternative decision strategies. This work developed models that represent visually and interactively the role played by the most important entities. The aim is to explore three different synchronization approaches in order to explore the joint effect of improvements. There are several possible outcomes from the simulation models, which could be used to strain the characteristics of each synchronization approach. In order to focus the attention on the main objectives of this paper the measures used are the total time to deliver the items, the average waiting time for each entity, the average time that each item spends in the system.

6. The 3D Visual Simulation.

The visual simulation environment (VSE) has been studied for over two decades and enables discrete- event, picture-based, visual simulation model development and execution for solving complex models (Hurrion and Secker,1978). Guided by the fundamental requirements identified by Balci (1986), incremental development and some prototyping approaches have been used to develop a simulation model development environment (SMDE). The VSE technology has led to the creation of a 2D platform. A simulation platform, devised and developed by De Oliveira (1999) is used here. The platform provides a patient-oriented modelling process and allows one to formulate a particular problem, to conduct a discrete event simulation experiment showing the possible outcomes within a 3D virtual scenario.

The visual simulation is the final step of the modeling process proposed here. One needs to create the 3D scenario and all the entities (objects) involved. The best results of the simulation are then transferred into the virtual scenario. The conveyance process requires a data worksheet with the simulation results and the production of an interface with existing graphic libraries. The results of the model initially formulated are then presented as animation. The method enables one to actually "see" the results. The first step is to build the scenario where the animation is going to happen. The next step is to create and define the position of all objects, which will compose the scenes. After that, one is able to produce the animation. The animation is basically the exhibition, in a certain speed, of a series of frames, where objects change their position in the scene. The results are used to help the work group to understand the dynamic of the flow of patients. An example of the results of the experiment is shown in Figure 6


(a) medicine


(b) patient


(c) attendance

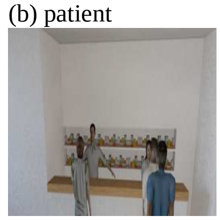
(c) attendance

Figure 6 - ***(a) Medicine logistic view***
(b) Patient view
(c) Attendance view

The example is basically a selection of frames of an animation that shows a typical flow of the most important entities involved in the medicine distribution. The objective is to let the user have a sensation to be in the pharmacy. The 3D visual simulation combines meaningful pictures and easy interactions to stimulate creativity and insight about the nature of the problem. It offers an opportunity to see aspects of the real problem that are virtually impossible to consider in a traditional simulation output. In fact it is intended to promote a mental process that facilitates a rapid cycle of learning about different aspects of the service.

7. Conclusion

The method of simulation modeling proposed is suitable for the complex problem studied here. The formulation of three models provides a mean to understand well the role played by the parties involved in the pharmacy service problem, providing an easy tool to structure the working group's perception of the existing problems leading to the construction of good logical models representing the existing problems. The models do offer support to identify the major constraints, analyze alternative policies and investigate different ways to exploit the system's constraints. The final step is to synchronize the performance of the system according to goals. The synchronization of activities should be made according to key aspects that are related to the interests of the service administration. For example, the increase in the number of employees and the number of items in stock do influence the patient's waiting time. If something is highly desirable for the three entities involved, the implementation depends on the cost impact of the new configuration of services.

The 3D visual simulation platform proposed here is a powerful tool to ease the improvement plan of the pharmacy. It provides means to think about several points of importance in the planning. The physical layout, the admission system, the flow of patients, the human and material resources and the flow of information are examples of some points that can be analyzed through the platform. The outcome of the exercise produces results that could be used to support other decisions. One's experiences in the hospital context show that patients, staff and the administrators accept well this approach because they are able to "see" the results of the simulation and reflect about their role in the process. The good point out of this experience is that, while the simulation program was running, one had time and opportunity to reflect about the ‘reality’ represented by the model. Four standard animations are used to demonstrate the flow of patients within the virtual scenario. This is a new contribution and it is considered that the gap between theory and practice has been narrowed in this area.

There are interesting outcomes from the models. The experiments produce a better understanding of the delivery system providing tools to evaluate the impacts of changes. The study suggests that the attendance process should be modified to reduce the delivery time for the prescribed items. They should be promptly available at all times. The replacement of the stock level is another important issue. There are alternatives to reduce this time. It would be advisable to perform a periodical replenishment of stock 1 and 2. However, the best solution would be to schedule the delivery and introduce an appointment system. A change in the number and configuration of the staff would increase the performance of this service. The flow of service should be modified to accommodate the necessary changes. The experiments are based upon full availability of the staff within working hours, specifically to perform these functions. Therefore the setting of the necessary staff should take into account the stops, shifts, holidays and other military activities to enable the full mounted stations. The construction of the model from different perspectives is an important resource for examining the improvement process, according to the vision of each organization, serving as a useful tool for further analysis. For future studies, it is suggested to integrate the view point of of customers, attendants and medicine logistics.

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