Process Improvement with Simulation in the Health Sector

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Abstract. The need for organizations to became everyday more competitive, has made them to engage in the study and re-engineering of their processes trying to improve the form they perform their tasks. However, even though the number of organizations that are doing these kinds of studies is growing, the failing rate reported in the literature is high (Hlupic, 2001). One of the main reasons reported, is the lack of using tools that enable the analysis of the process from two different perspectives: static, by means of process modeling, that permit to obtain a general vision of the process and detect some fundamental problems; dynamic, using simulation techniques, to predict process behavior once this has been redesigned and before its implementation. With the use of the two techniques together, a more complete and accurate approach to the analysis and management of processes is expected. In this work we illustrate how process modeling and simulation can be used together during process analysis. We do this, with a real case study in the Mexican public health sector, in particular, in an emergency room service.

1. Introduction

Nowadays organizations require, every time more, to perform their tasks in a more efficient way. Therefore, they are more concerned with analyzing and improving their processes and engaging in re-engineering efforts. Although the number of organizations doing this is growing, the failure in these projects is over 50%. One of the main problems reported in the literature is the lack of using tools to predict process behavior once it has been redesigned and before implementation [Hlupic, 1998], besides the difficult task of capturing processes in a structured form. Health organizations are not an exception. In addition to the support that IT can provide in needs of clinical information, resources' management, etc. There exist a set of support tools that can be used to address the dynamic aspects of the medical processes such as computer simulation [Wainwright and Waring, 2000]. This provides elements to analyze and evaluate aspects related with times of the daily medical processes. Enabling with the last, the possibility to analyze resources, activities, space distribution, service and queue times, within others. However to successfully use simulation in process improvement, we need to integrate it with a study of the process structure to establish the flow of activities, roles and their responsibilities, information entities, etc. This can be accomplished integrating simulation with process modeling.

In this paper we present some results arising from the development of a case study developed in the public health sector applying process modeling and simulation, in particular, in an emergency room service. We used the steps of a standard process re-engineering methodology, which we will introduce in a later section.

The corresponding process model is very complete and complex. It contains many roles with different types of interactions between them. Some of the interactions produce dependencies between activities. Thus, if there are insufficient resources to carry out all these activities in a given time, some results could be bottlenecks due to lack of resources and bad coordination in timing.

2. Process Modeling and Simulation

Process models are used to capture, study and understand processes in organizations. The five basic uses given by Curtis et. al. [1992] are: (1) Facilitate human understanding and communication, by documenting and supporting procedures in organizations in a consistent and uniform manner. Creating a common ground of communication; (2) Support process improvement, by establishing the basis to define and analyze processes; (3) Support process management, giving the basis for comparing actual processes against those already established; (4) Automate process guidance, establishing an automated guide for the process by means of computerized tools; (5) Automate execution support, facilitating process enactment. Here a process is considered as a group of related tasks, which are performed by people and an IT system interacting together to achieve the goals of an organization. A good process model addresses the three important aspects in processes: Information Technology (IT) support of the process, social issues such as staff training, culture, etc, and the process itself [Warboys et al, 1999].

Static process modeling tools and techniques, such as Role Activity Diagrams (RAD)[Holt et. al. 1983, Ould 1995], Integrated DEFinition Method (IDEF0), etc., are used to capture processes both to help in their understanding and to highlight the important aspects of them, such as organizational goals, analysis of activities, protocols, etc. However, such techniques do not generally capture the dynamic aspects (e.g. time, process instances, etc.) of these processes and therefore cannot fully predict the results of any proposed changes that might be applied to them, whereas simulation models aim to do exactly this [Pegden 1997, Gladwin and Tumay 1994].

Process modeling is growing in importance as an application area for simulation, in particular in the evaluation of the design and redesign of processes (process improvement). Even though simulation alone could be used to capture a process and perform a redesign analysis, a more detailed analysis of different aspects of an organizational process has to be carried out initially. Features such as what activities are being performed (functional view – activities well defined), when and how are being developed (behavioral view - rules of the process), where and whom in the organization are executing them (organizational view - responsibilities), and the entities produced and/or manipulated by the process, their structure and relations (informational view) [Curtis et al, 1992] have to be analyzed to provide a complete process analysis. Some information corresponding to the views is provided by a process model (activities, responsibilities, some entities, interactions between agents, etc.) and is not given by the simulation model. On the other hand, with the simulation model some details such as the behavior rules (times) and entities are very well defined. Therefore, the information provided by both models complements each other providing the details needed for a proper analysis of the process.

Process modeling can be used to analyze static aspects of the process such as: duplication of activities and documents, interactions between agents (communication and coordination problems), responsibilities no defined, analysis of the IT which gives support to the process, etc. On the other hand simulation can be used to address questions such as: What is the total process cycle time? How long do customers have to wait before being served? What is the best way to schedule personnel? Bottlenecks analysis (location and timing for processing them), etc., [Gladwin and Tumay, 1994].

Simulation techniques, on the other hand, enable a more dynamic approach to the study of organizational processes. It can be used to model a current, redesigned or not yet existing (for process design) process. In this manner the behavior of the process can be predicted and analyzed. Simulation of such complex systems is a way of promoting the understanding of current processes, and of any proposed changes to improve their performance. Because of its usefulness, simulation is usually considered as an integral part of the decision making process [Tumay, 1996], assisting in the prediction of the behavior of these processes by investigating "what if" questions. Thereby, facilitating the understanding of possible outcomes produced by change and verifying the implementation of the system with a simulation model.

To perform the case study in the health sector, we used the steps of the Process Analysis and Design Methodology (PADM) (Wastell et. al., 1994). PADM has 4 main steps: (1) Process definition, (2) Process capture (elicitation and modeling), Process evaluation (validation and analysis) and (4) Process redesign. The process definition and capture was obtained with interviews with the people (agents) involved in the activities. With this information the process modeling was performed using the Role Activity Diagrams (RAD) (Holt et. al 1983, Ould 1995). RAD is a structured technique that captures most of the main features of a process: roles, agents, objectives, activities, decisions, interactions, etc. (Miers, 1996). During the step of static analysis the process model helped in the understanding and highlighting important aspects of the emergency room processes, such as organizational goals, analysis of activities, protocols; and to detect some problems such as duplication of information, ill defined responsibilities, lack of Information Technology (IT), etc. While this technique does not capture the dynamic aspects (e.g. time, process instances, etc.) of the process and therefore cannot fully predict the results of any proposed changes that might be applied to them, simulation models aim to do exactly this (Pegden 1997, Gladwin and Tumay 1994). Thus, we took the process model captured in RAD and mapped them to a Discrete Event Simulation (DES- entities, queues, servers, resources, etc.), to perform a dynamic analysis (Martinez and Mendez, 2002). The dynamic information that establishes the times that take to perform the different activities of the process were provided by the head of the emergency room, who supervises and monitors the process and the agents involved in its performance. During the process, these agents take the times concerning when they start and finish their activities for the medical attention. Every day, the head of the emergency room collects and concentrates the data to analyze the process behavior. The DES model was implemented with the ProcessModel simulation package. With this we could obtain a more dynamic view of the process and perform "what if" experimentation visualizing queues, waiting times, bottlenecks, resources needed to improve the process, statistics, etc. With the later, being able to predict the process behavior according to the data collected and the parameters of interest. The hope is that this might lead us to a position where a more complete and accurate approach to the analysis and management of processes is possible. In this work we present the development of the process study, from process modeling to simulation and discuss some issues that arise from their analysis.

A key feature of a process re-engineering is based on establishing which aspects of the process need to be improved. Therefore, it is necessary to know the aim of the process, its main inputs and outputs, the areas involved and in general the detail of how the process performs. During the step of capture we establish these aspects concentrating on the flow of information, the agents involved, and the activities that are being performed.

The emergency room process was captured by interviewing the process owners: medical assistants, nurses, physician, the head of the emergency room, social worker and patients that required medical attention. We also analyzed the documents and formats used for each agent involved in the process. These interviews and the analysis of the documents were the based for defining the process description and the simulation model.

2.1 Process Description

The process starts when a *patient* arrives to the emergency room and asks the *medical assistant* for medical attention, the *assistant* registers the *patient*'s arrival on the form for medical attention and visitors. There, the *patient* has to probe that s/he is registered for medical attention at the hospital. In the case when they do not have their documents with them, the *medical assistant* will have to verify their adscription on the computer system or request to the *social worker* to provide her with this information. In the cases when it has not been able to demonstrate the *patient*'s adscription s/he is provided with medical attention giving him or his family certain time to provide the corresponding documents. Otherwise he is translated to another hospital.

The *medical assistant* assesses the symptoms- according to his acquired experience - and asks the patient to wait or points him to get immediate medical attention. At this time she fills in the medical note form with the general information of the *patient*. Once the *patient* is inside the medical attention room, he is stabilized if needed and get medicines and laboratory analysis if required. If the patient is very ill, then the physician assess if he requires to be hospitalized or even to have a surgical intervention. If the *patient* is hospitalized in the emergency room area another *physician* together with a *medicine student* check the medical note, the prescription and the diagnostic to verify the patient's health and continue with his medical care. When an emergency room *physician* arrives he starts his activities checking the hospitalized *patients* to decide if they go to a specialist or home. The *medical* assistant and the *physician* have to fill in several forms according to the activities that are performing. In these forms they record the service times to be analyzed later for the head of the emergency room.

If some medicine is required this is obtained with a medical prescription from an area called CENDIX. A nurse is in charge of the CENDIX and she controls the medicine and inventory. The *social worker* activities are to provide support to the *patients* and his family. She looks for the family of the *patient* in case that they arrived alone or need something, helps them with administrative forms, follow up urgent lab analysis, etc. *Nurses* provide support to the *physicians* in the *patient*'s medical care. They supply the medicine to the hospitalized *patients* and monitor the patient's health.

The *head of the emergency room* is in charge of supervising the activities of each of the agents involved in the process. In order to do that, every day he checks all the formats filled the day before and from them obtains statistics concerning the efficiency of the process.

Once obtained the process description we developed the static process models using the RAD diagrammatic technique.

2.2 Static Process Model Representation

The process models were captured with the RAD's graphical notation. RAD is a structured technique that captures most of the main features of a process (roles, agents, objectives, activities, decisions, interactions, etc.) [Miers, 1996]. In Figure 1 we present the basic elements of RADs highlighting the roles, which group activities performed by an agent to reach an aim. Roles are represented by a rectangle with a label at the top, specifying the role's name and the agent responsible to perform it. Inside the role the activities are drawn as small open squares with its description at the right, the interactions between roles are represented by bold lines, which connect from the role's activity that started the interaction to the activity of the role to which it is communicating. The vertical lines that connect the RAD elements are called state lines, which show the transition (states) between the elements. The decisions are small circles, where each one represents a particular condition or alternative path in the process. There exist also parallel or concurrent threads of activities, where the main characteristic is that they can be executed at the same time, and the activity that follows the set of paths can only be performed when all the threads of activities have finished. These are represented by small rectangles.

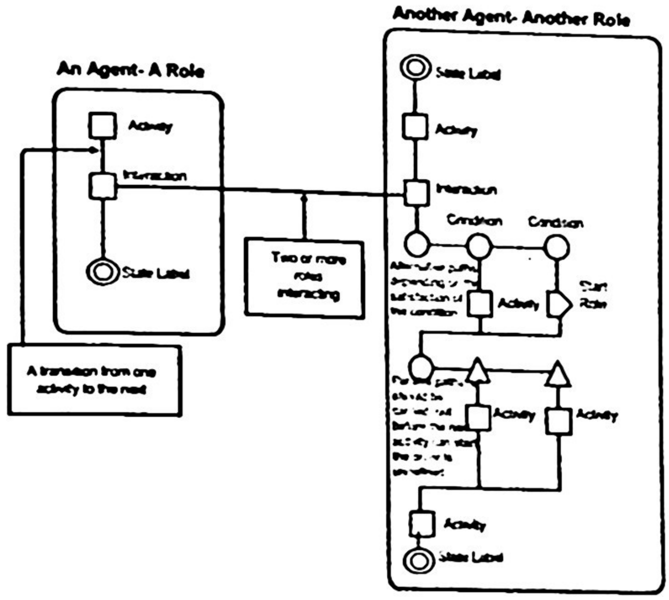

Figure 1. Graphical Notation for the RADs where it shows roles, activities, interactions, decisions, etc.

Figure 2 presents part of the process model of the medical attention at the emergency room. It illustrates the activities performed for the medical assistant and the patient at the time of first arrival, as described before in the process description. The process model was validated with the process owners. At the beginning some changes were done to finally obtain a process model that captures the real process.

3. Process Analysis

The step of process analysis is a key step in process re-engineering. Here we focused in finding points of improvement in order to propose a process redesign and support if necessary. We can perform two kinds of analysis: static, using process modeling, and dynamic with simulation models.

3.1 Static Analysis

During the static analysis of the process we have observed that the process satisfies its main objective. That is to provide medical attention to those patients that request it. However, we detected some problems in the process, where the technical aspects could be solved with the use of IT and the social with the creation of new roles and defining responsibilities in a more convenient way. With the use of IT we want to improve the performance of the process avoiding problems such as duplication of activities. On the other hand, the human aspect should be considered to have a better work environment and facilitate the communication between agents of the process.

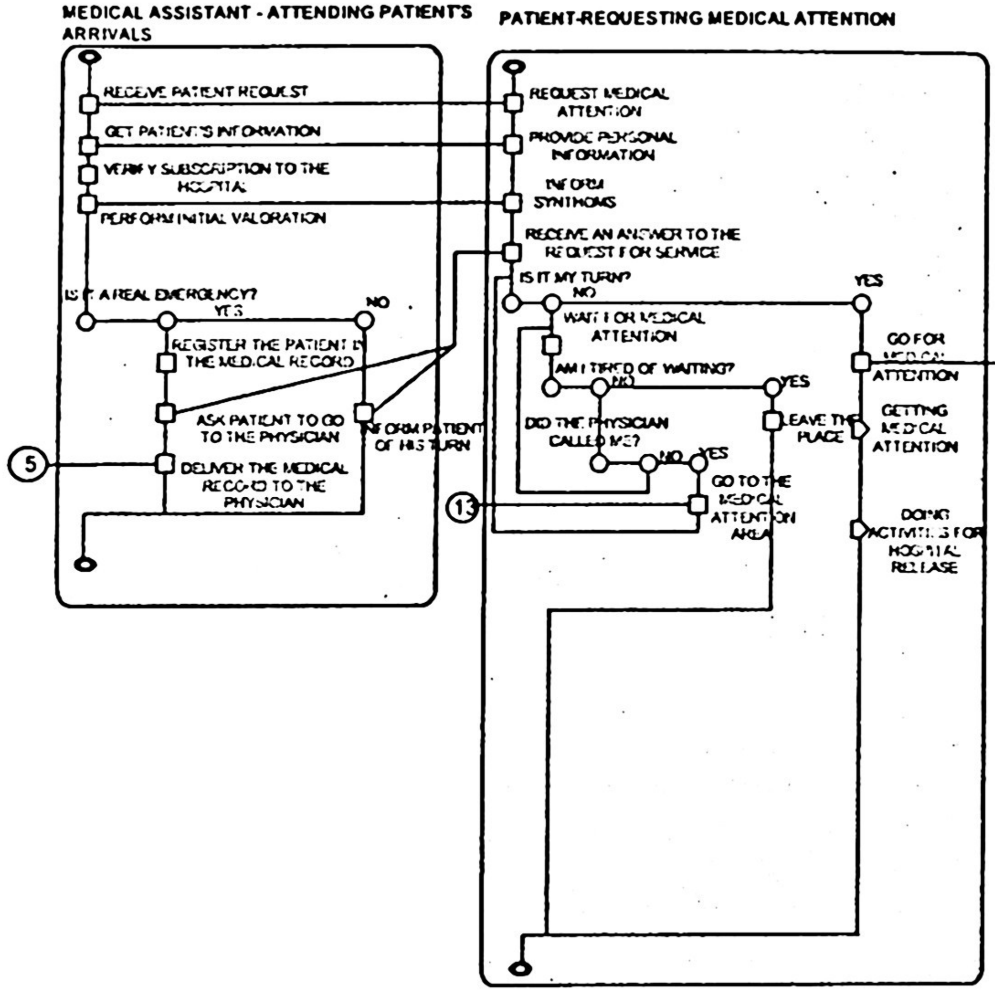

Figure 2. RAD diagram that shows: the activities that the medical assistant performs when a patient arrives, a patient requesting medical attention and the interaction with the system that verifies subscription to the hospital.

Some of the socio-technical points found during the static analysis of the process, based on the analysis of the process model are presented next.

- It is necessary to have a medical trained person, such as a physician, in the emergency reception area. A bad judge of a patients' case could be of deadly consequences. That is, there should be a new role in this area, eliminating the responsibility of classifying the emergencies from the medical assistant.
- There are some disagreements between some physicians about the use of new medicines. Some have the opinion that what the hospital offers is quite good and useful for many diseases, while others think that more and new medicine should be introduced.

- All the process information is captured manually in formats and the transcribed with a typing machine. This causes duplication of activities and may cause errors when transcribing the information.
- Sometimes there are many patients that have to be hospitalized and there are not enough hospital beds in the emergency area to do that. Neither enough space in the halls to put some extra beds.
- When there are not forms to capture certain information, this is written in a blank piece of paper that can be lost easily with other papers.
- There is only one computer in this area and is only used to verify the subscription to the hospital.

3.2 Dynamic Analysis

The dynamic analysis can be performed using simulation techniques that permit to determine the current and future behavior of the process. In this work we use Discrete Event Simulation (DES). The main elements necessary to build a DES model are illustrated in Figure 3. An entity is something (a person, a thing, etc) that is manipulated in the system (i.e. patients arriving at the emergency room, child or adult). The entities can have attributes (i.e. grade of illness). A queue is a collection of entities waiting for a service provided for a server (activities such as to evaluate a patient's health). A resource is a person or machine necessary to provide a service (a physician, a nurse) [Law and Kelton, 1991].

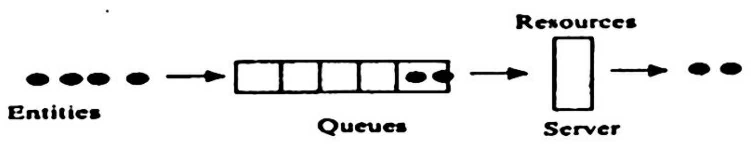

Figure 3. Basic elements of a Discrete Event Simulation model.

From the static process model in RADs we developed the DES models to perform a dynamic analysis of the process as it is. In particular we concentrated in the *subprocess of patient's emergency medical attention and reception.*

With the process models in RAD we obtained some information for the simulation model such as: the agents involved in the process, the activities performed, and the flow of entities. That is, the RAD provided the information to establish the DES model static structure. However RAD does not have information to determine the process behavior. Therefore we had to define the dynamic attributes of the process, such as inter-arrival times, service time, etc for each entity, to have a complete simulation model definition. This information was obtained from interviews with the head of the emergency room, where he provided us with a data concentrate of the timing of the process performance that they collect daily. From the model of figure 2 we defined the patients that required medical attention as entities of the process. Their inter-arrival time was established introducing the monitoring data of the process activities (of June, July and august) to the model. We represented the activities carried out in the process as servers in the DES model and the agents that perform them as resources. Again we used times captured and processed from the real environment.

Analyzing the data provided for the head of the emergency room, we could observe that there was not timing information for all the process activities. Therefore, when building and simulating some of those activities in model we used times provided by the process owners according to their experience. The simulation model statistical data was not validated, thus the analysis of the model was more qualitative than quantitative, although we will show some numerical results from the experiments for reference.

Also from the data obtained we determined some parameters for the process flow and simulation such as: a probability of 56% for a patient to be hospitalized in the emergency room (observation area) and of 44% for those requiring other kinds of service among others. We established as well the number of human resources and their time schedule. There are three shifts: the first in the morning (7:00 to 14:00), the second in the afternoon (14:00 to 21:00) and the third at night (21:00 to 7:00). In the first and second shifts there is only 1 medical assistant, 4 physician (3 for the second) and 10 nurses. In the last shift is the same as the second but with 6 nurses. Other resources are the beds available at the hospital in the emergency room: there are 9 beds for adults, 8 in the children area and 10 in cubicles.

To determine the average times of the process, such as average inter-arrival, average service time per patient (in the different areas), with the data obtained from the clinic, we used the module *Stat::Fit* of *ProcessModel* [ProcessModel]. We obtained *a Poisson(14.5)* probability distribution for the inter-arrival, *Binomial(22,0.541)* for the service in the adults' observation area and *Poisson(11)* in the children's observation area (the observation areas are zones of hospitalization from hours to a couple of days). With the information gathered from the RADs and the head of the emergency room, we defined and implemented the dynamic simulation model of the *patient's emergency medical attention and reception subprocess* in the visual simulation tool ***ProcessModel***. The model is presented in Figure 4.

In *ProcessModel* the simulation models are built using visual objects that represent the organizational elements such as entities, activities (servers), waiting lines, resources, etc. The simulation model of figure 4 was presented to the head of the emergency room to validate its structure; this is the flow of entities, activities and agents involved in the process. During this meeting the head of the emergency room requested some specific experiments during the dynamic analysis of the process such as: total of patients attended in a given time, how many were sent to the area of adults or children observation, and how many to the hospital or other areas.

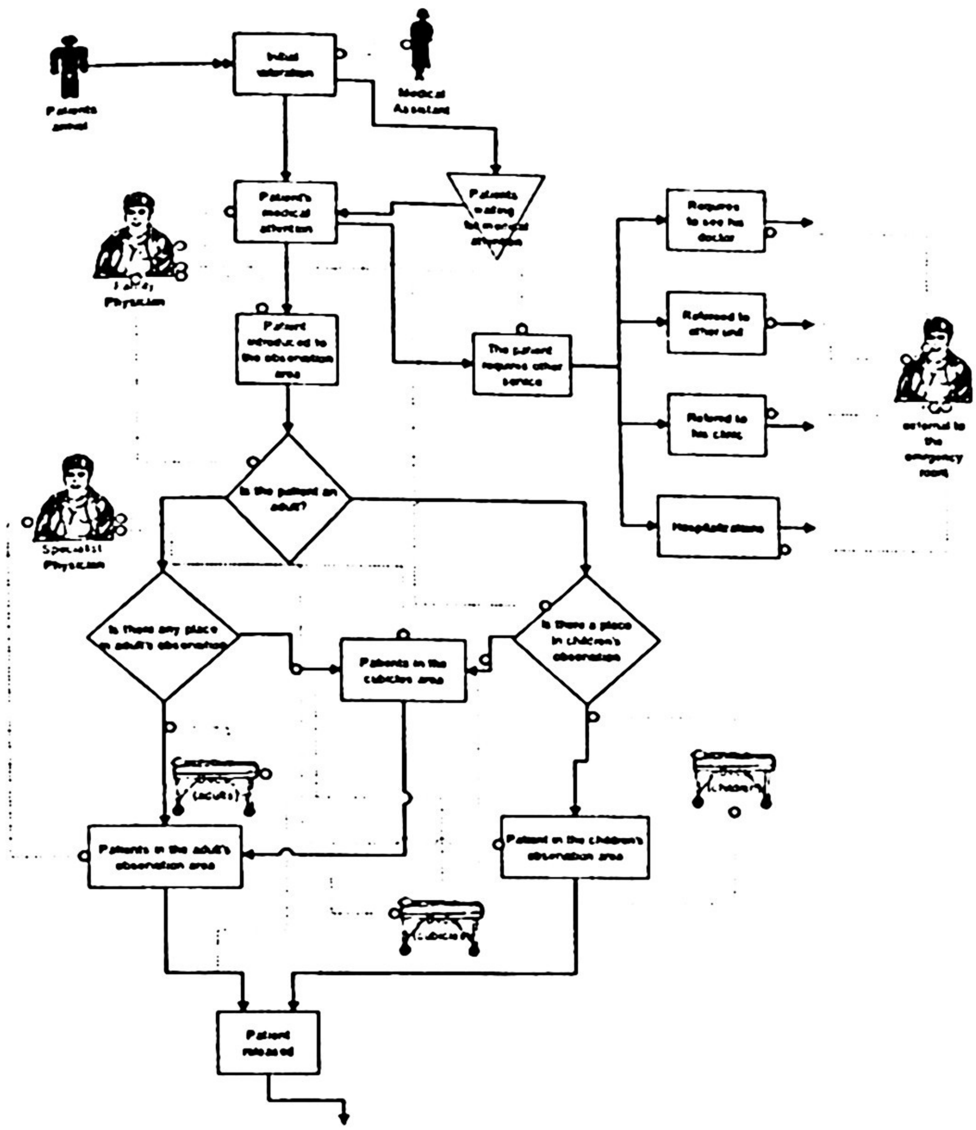

Figure 4. Simulation model of the *patient's emergency medical attention and reception subprocess.*

To perform the experiments we defined some variables in the model for both collecting the statistical data and introduce part of the flow of the process, for instance:

1. If there are not beds left at the observation area, the patient has to be located in the cubicles.
2. A variable to monitor the beds usage in each area, in such a way that if one is free, to transfer a patient from the cubicles to the observation area.
3. Also, it is necessary to monitor the availability of physicians that are providing consultations to the patients that do not need hospitalization.

One experiment carried out was to simulate the subprocess for a period of 744 hours, which corresponds to a month of service. This was performed to analyze and predict the capacity of service of the emergency room. The process was simulated for a month (simulation time) as it is the format (per month) that the hospital uses to analyze and compare the services provided. Table I presents the results obtained from the simulation of the process.

Table I. Results obtained from the *patient's emergency medical attention and reception subprocess* simulation.

Statistics	Result per month
Patients provided with medical attention	2378
Patients in the adults observation area	817
Patients in the children's observation area	216
Patients requiring consultation with their physician	12
Outcoming patients referred to their clinics	1036
Patients referred to other hospitals	14
Patients sent to hospital	283

Table I shows that the capacity of service of the emergency room is of 2378 patients attended per month, according to the established conditions. From those, 817 are adults, while 216 are children. From the total 1345 need some sort of referral to other services. The results obtained from the simulation were compared with concentrated of data provided from the head of the emergency room and the simulation was very close to the data. The simulation of the model enabled us to analyze the rate of utilization of the resources. Figure 5 shows the result of the human resources and Figure 6 the utilization of beds.

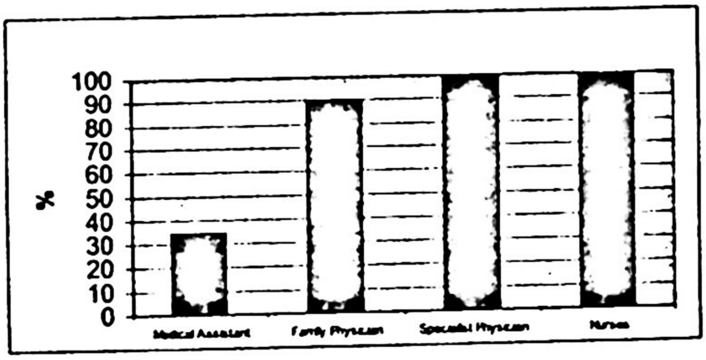

Figure 5. Utilization rate of the human resources of the process.

Figure 5 shows how the physicians, medicine students and nurses are always at their maximum level of utilization (90, 99.61 y 99.18), while the medical assistant only at a 34.5%; this is in the patient's evaluation not at the administrative tasks. If we add the last to the medical assistant his rate of utilization will go to the top. Other resources necessary to provide medical attention to patients in the emergency room are beds in the observation area. It is important to determine its rate of utilization.

Figure 6 shows this for cubicles, adults and children observation. The three go up of the 90%, showing that they are in constant use.

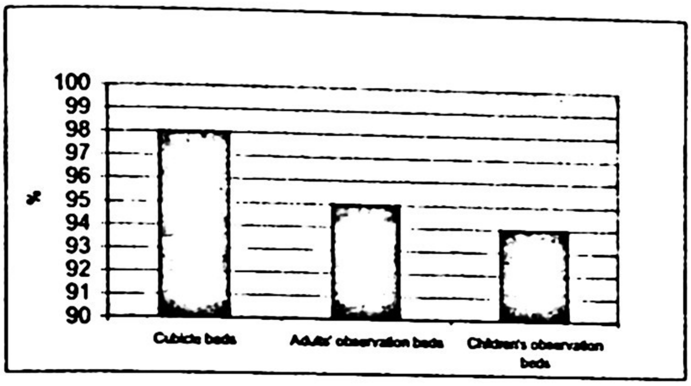

Figure 6. Utilization rate of the beds in the observation area.

Finally, the average time of permanence in the service of each area are: adult observation = 10 hours 43 minutes and children observation = 9 hours 44 minutes. The average number of patients waiting in the queue is of 740 patients per month. From the data, we could also observe many times the emergency room full and there with real emergencies still waiting to be attended. Therefore, the hospital tries to arrange sketchers and wheelchairs on the halls to provide medical attention to those who need it. This means that there is one more waiting line inside the area for medical attention; this is patients waiting for a bed. From the simulation we obtained that: 734 patients a month wait for medical service in this form.

From the analysis of the dynamic model we can determine the need of more human and material resources to increase the service capacity. On the other hand with the static model we found some socio-technical problems to be addressed in order to improve the form the process is perform. In order to improve the process performance a process redesign was proposed and evaluated.

4 Process Redesign

From the analysis performed we proposed a process improvement. Some aspects to improve were suggested by for the process owners while others emerged from the static and dynamic analysis done previously.

The static analysis enabled us to detect the need to create a new role in the reception area. It is the medical assistant who classifies the emergencies without much medical training. A proposal for improvement provided by the head of the emergency room when discussing the process model was to implement an area with a physician and a nurse (TRIAX) to perform the first medical evaluation of the patient. Here, it will be the physician who will define the kind of emergency. Other possibility for improvement will be to increase (double) the size of the area of the emergency room to allocate more observation beds. This was detected with the dynamic model. In the TO-BE (redesign) simulation model we perform some experiments with 10 more beds that in the current model (this is 20), 5 for adults' observation and other 5 for children's observation. Also, as we observed the rate of human resources utilization is higher than the 90%, therefore we increase the personnel by 2 more physicians and 1 more nurse for each observation area. This is 4 more physicians and 2 more nurses.

Table II. Results obtained from the redesigned process simulation model.

Statistic	Result per month
Patients provided with medical attention	2794
Patients in the adults observation area	1150
Patients in the children's observation area	349
Patients requiring consultation with their physician	15
Outcoming patients referred to their clinics	1041
Patients referred to other hospitals	17
Patients sent to hospital	278

The redesigned dynamic model was simulated for the same period of time of the original process model (744 hours). The results obtained are illustrated in table II.

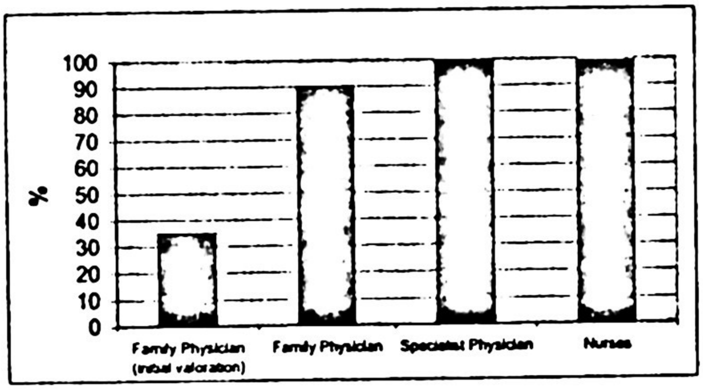

Figure 6. Rate of utilization of the human resources after process redesign.

Table II shows the effects of the redesign process: the emergency room provides service to more patients, 2794 consultations per month, 1150 attended in the adult's observation area and 216 to the children's observation. Of the 2794 patients, 2408 required to be referred.

Concerning the resources rates of utilization, the redesigned process simulation gave us very similar results (Figure 6 and 7). That is because the demand for medical service is still very high.

In the simulation of the AS-IS process we did some experiments, and we could observe bottlenecks generated in the waiting (for medical attention) and observation area (waiting for a bed). However, in the experiment of the TO BE process, we doubled the number of beds for observation and increased the number of human resources in the observation areas and with these changes the queue lengths in the waiting and observation area decreased. This behavior is because more patients were provided with medical attention. In the observation area (including halls) the queue completely disappeared with the increment in the number of beds.

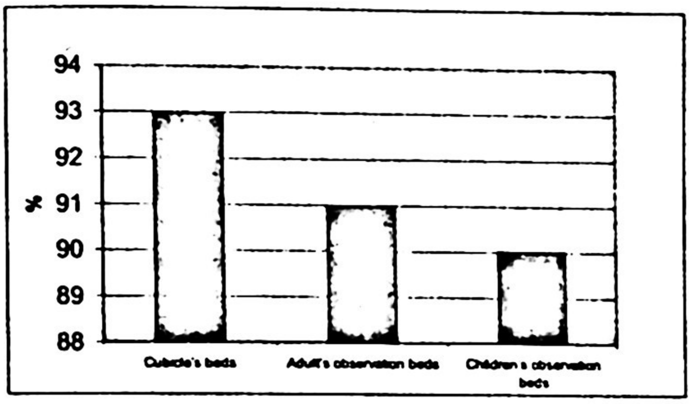

Figure 7. Rate of utilization of beds in the observation area for the redesigned process.

With all the proposed changes the number of patients provided with medical attention will increase around a 20%. Many more experiments can still be performed to verify the improvement in the process redesign or evaluate other alternatives.

5 Conclusions

In today's competitive environment the need for process analysis and improvement is everyday more evident. Therefore, process innovation or re-engineering projects will continue. To make more accurate decisions concerning changes in the way process are being executed, it is necessary to contemplate different alternatives that can be evaluated by the analysis of the process with simulation studies.

The process study presented, permitted us to evaluate under a real case scenario, the benefits that can be obtained from the use of both, static and dynamic analysis. The static analysis enabled us to understand and get a general vision of the process, as well as to obtain information about the socio-technical problems and provide some support in that area. On the other hand, the dynamic analysis enabled us to get a dynamic vision of the process behavior and its current state, observed problems such as bottlenecks, availability and utilization of resources, and to predict the results of changes in the process behavior by performing "what if" experiments.

The results obtained from the process analysis were presented to the head of the emergency room. He considered the process analysis results very useful for future changes in the process. The process model provides him with a feedback of the process and will be useful to communicate the process activities to new staff. On the other hand, the simulation model will provide him support to predict the process behavior and to validate possible changes in the process.

We can conclude that, a tool of this type with the integration of process modeling and simulation would be very useful in the health sector, particularly to predict patients behavior and be able to configure the resources for medical attention in the different processes of the hospitals and clinics.. The combination of both approaches provides a more detailed analysis of a process. On one hand the static process model facilitates the detection of fundamental problems (unnecessary or duplicated activities, no defined responsibilities, etc.). On the other hand, simulation permits us to evaluate the current process behavior and predict the impact of change.

Currently, we are developing a tool that integrates process modeling and simulation in the same software platform, where the simulation model is generated directly from process models captured in RADs. Furthermore we are working in the transfer of the knowledge of these kinds of means for process improvement with the medical sector and in the development of process support according to the information gather from real case studies and following a socio-technical perspective.

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Acknowledgments: This work was partially supported by CONACYT under grant C01-40799