A DECISION SUPPORT TOOL FOR A HOSPITAL EMERGENCY DEPARTMENT BASED ON ATTENTION QUALITY MEASUREMENT PARAMETERS

L. N. Pizán. Toscano, M. J. F. de Oliveira

RESUMEN

La toma de decisiones en el área de emergencia, dada su implicancia de atención a pacientes en estado de riesgo, es sumamente sensible. Una decisión inadecuada puede hacer la diferencia entre la vida y la muerte. El sistema debe responder rápida, eficiente y eficazmente, y el factor humano médico juega el papel protagonista. Se puede concluir entonces, que la adecuada distribución del potencial humano disponible en el momento de la emergencia, es determinante para brindar una atención adecuada al paciente. En este trabajo se presenta, un modelo que estima las configuraciones adecuadas de los equipos médicos en el área de emergencia, basado en parámetros medidos cuantitativamente por simulación, los cuales son utilizados para estimar la calidad de la atención. Estos parámetros respaldan a cada uno de los requerimientos de la respuesta. Se tienen parámetros basados en el control del tiempo de respuesta, para asegurar la rapidez de la atención según la urgencia del paciente. Además, se tienen otros parámetros, que controlan si el paciente fue atendido por el equipo médico necesario, de acuerdo a su urgencia, en el momento adecuado, y en todos los instantes en que, dentro del departamento el paciente necesitó de un equipo médico para su atención. La relación médico paciente fue modelada desde los dos aspectos tanto el médico como el de los pacientes. Los pacientes fueron modelados de acuerdo a su urgencia, considerando cuatro tipos de pacientes. El trabajo del personal médico fue modelado teniendo en cuenta aspectos característicos del trabajo médico, como su trabajo en equipo, el paralelismo en la atención a pacientes de los diversos equipos médicos, la jerarquía de trabajo dentro de la conformación de los equipos, y la posibilidad de que el médico con más experiencia forme parte de todos los equipos médicos donde sea necesario su participación. Esta herramienta puede ser usada para soportar en la toma de decisiones relativas a la programación del personal médico en el área de emergencia de un hospital, y ha sido validado con datos estadísticos de dos hospitales, del hospital Antonio Pedro (Niteriói-Brasil) y del hospital Cayetano Heredia (Lima-Perú).

Palabras claves: Calidad de la Atención, modelage de Sistemas, medicina de emergencia, Simulación discreta estocastica y soporte a la toma de decisiones.

ABSTRACT

The decision taking in the emergency area, given to its requirements of attention to patients at risk, is extremely sensitive. An inadequate decision can do the difference among life and death. The system should respond quickly, efficiently and efficaciously, and the physician human factor plays the main character role. It can be concluded then, that the adequate distribution of the available human potential at the moment of the emergency, is determinant to offer an adequate attention to a patient. Here, we introduce a model that estimates the adequate medical staff configurations in the area of emergency, based on parameters measured quantitatively by simulation, which are

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used to measure the quality of the attention. These parameters support each one of the requirements of the emergency answer. They are parameters a) based on answer time control, to assure the quickness of the attention according to the urgency of each patient. b) based in patient attention control, they research if the patient was attended by the adequate medical staff, according to its urgency at the right moment. And at every time in which, inside the department, the patient needed medical staff for its attention not only in the arrive moment. The relationship between patient and physician was built up upon both aspects: from the doctor's point of view and from the patient's point of view.The patients were treated according to their urgency, considering four types of patient. The medical personnel job was measured by keeping in mind characteristical aspects of the medical job. (eg. their teamwork, the parallelism in the attention to patients of several medical staffs, the hierarchy of work inside the making-up of the team, and the possibility that the doctor with more experience takes part of all the medical activities where its participation should be neccesary. This tool can be used to support the decision making related to the programming of medical staff in the hospital emergency department, and it has been validated with statistical data of two hospitals, from Antonio Pedro (Niteriói-Brazil) Hospital and from Cayetano Heredia (Lima-Peru) Hospital.

Key words: *quality of the attention, systems modeling, medicine of emergency, estocastical discrete simulation and support to decision making.*

INTRODUCTION

Emergency services are facing new challenges after recent disasters happening at the beginning of the new century. Cities are vulnerable to new types of emergency situations that could appear. Some are complex, either natural or caused by man, and our authorities will need a training device to be prepared to meet these challenges [1]. It is now desirable the availability of an adequate number of professionals to take care of the hospital medical emergency attention. It is also necessary to have a number of volunteers for the attention of emergencies in non-common situations.

There is a remarkable number of publication in the field of emergency management over the last few years [2, 3, 4, 5, 6, 7, 8, 9]. Most of the earlier studies concentrate on management considerations and administrative issues such as the demand for services [10], evacuation planning [11], location of vehicles [12, 13] and other interesting problems that arise from this broad subject.

Simulation is a decision support tool which offers the possibility to carry out a previous evaluation of the system dynamic behavior without interference in the real system. Previous research show that simulation is one of the most important management analysis and operative tools. [4, 7, 14].

With the objective to determine the appropriate number of members of staff for quality medical attention in different emergency levels, a simulation model is described in this paper. The model concentrates on the emergency attention hospital system and is part of a project that includes the development of an integrated emergency decision support tool for the public emergency systems in the city of Rio de Janeiro [15]. The project started with a general study of the attention to patient in the emergency room of two different hospitals, with the aim of modeling the existing problems [16].

THE MODELING ENVIRONMENT

The models presented here focus on the actual demand behavior and the medical teams work of the hospitals Antonio Pedro (Rio de Janeiro-Brasil) and Cayetano Heredia (Lima-Perú). A macroscopic simulation model is developed inside a discrete event framework of a Simscript model. The examples presented here are taken from the study of the general medicine specialty of the hospital complex. When the patient arrives in the hospital, inside the emergency room, it is considered in the model that it has happened the event emergency.

The simscript model

The real life objects are represented as entities, and their attributes are stored in a register field. The real life occurence in a specific time are modeled as events. The real life occurence in a time period are modeled as process. The process has star and finish ocurrence (two event inside). The processes and events are routines that can be linked to one or more entities. Simulation is directed by the execution and management of processes and events. It has an internal clock and selects the next process or marked event.

It is used a function that uses Lehmer technique to represent random phenomena based on multiple congruency. Thus, the software has a functions library known as: Uniform, Normal, Exponential, Gamma, Beta, Weibull, Poison, etc.

The patient model

The patient is a temporary entity created in the event "patient arrival", see 6.1. According to the behavior observed in the emergency room, the patients arrival follows the Gamma distribution with two parameters: average arrival time and a constant k. The adjustment is made by the Chi square test. The criterion used to select patients is the urgency of the case.

The classification follows the international norms of triage, adds one completes class (urgency 4), to model this type of observed patient [17]. The patients are initially classified in one of three degrees of urgency. Eventually, a fourth category is considered. That is the case of a patient who shows, for example, an unexpectedly breath stop or some another life risk sign. In this case the patient is reclassified as urgency 4.

The required number of staff necessary to treat each urgency level is shown in table 1, and they were obtained by observation in the room of emergency.

Table 1. *Minimum staff required for each urgency level.*

Patient	Senior-Doctor	Doctor	Nurse	Auxiliary
Urgency 1	0	1	1	1
Urgency 2	1	1	1	1
Urgency 3	1	1-2	1	1-2
Urgency 4	1	2	1	2

The Care model

In order to obtain excellence in the quality of attention of the emergency patients, the most important medical requirements are modeled and implemented in the model [18]. The following teamwork policies are implemented:

The health professionals in the emergency shift are supposed to give attention to any of the patients. The right number of medical personal should be available in specific periods of the day, in order to build teams and there should always be appointed an experienced physician in the team for important decision making. The attention to each patient is carried out by sub-teams and each one of them should be able to cope with more than one patient at the same time.

- The attention policy is implemented according to the degree of urgency of the arrivals. Patients with a urgency level 3 and 4 have to be immediately taken care and patients with urgency level 1 and 2 could wait a while before attendance. The event attention begins when the patient arrives.

- Because of ethical and medical considerations all patients should receive a standard attention. However, if a patient arrives with death risk and there is no possibility to build an exclusive team for the attention, then member other teams involved with lower priority tasks may be called up occasionally. As far as the simulation model is concerned, this means that the event that represents attention is placed on a waiting status while the higher risk activity is carried out. It is clear that the quality measurement will be affect by that action.

– In the case of the arrival of a serious case and the impossible to find a complete team because the staff is busy with patients of equal seriousness, then the first available staff member available near to the patient that had just arrived is called. In simulation terms, the sub team would be able take care of more than one patient at a time. Only in extreme cases the staff may interrupt the attention of the most serious cases.

Figures 1, 2 and 3 show the composition of teams for different urgency levels. The arrow that goes from the physician to the patient, in figure 1, indicates a one-to-one relationship and the arrows in one of the physician's head of figure 2, represents the decision making process in the attention of the urgency level 2. The arrows over the nurse indicate that simultaneous attention to patient is required.

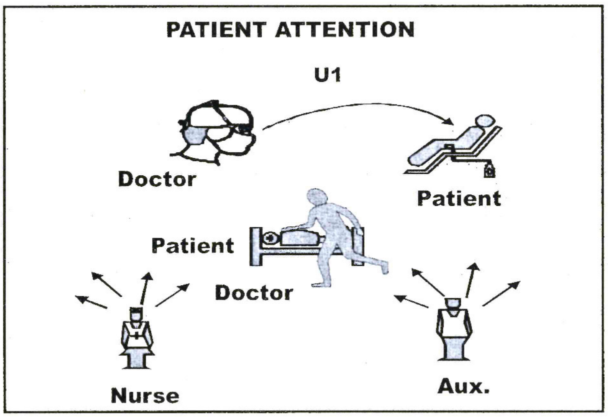

Fig. 1 Staff required for urgency level 1.

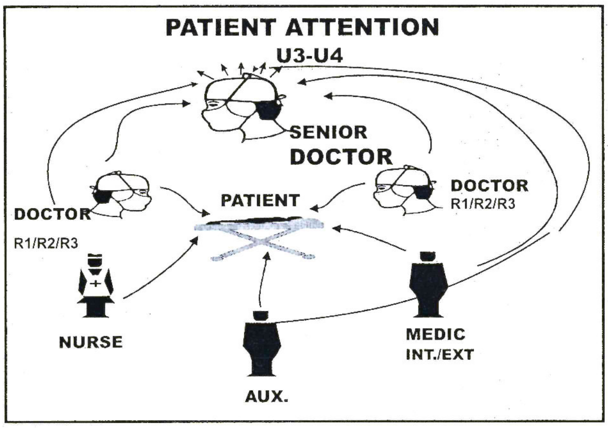

Fig 2 Staff required for urgency level 2.

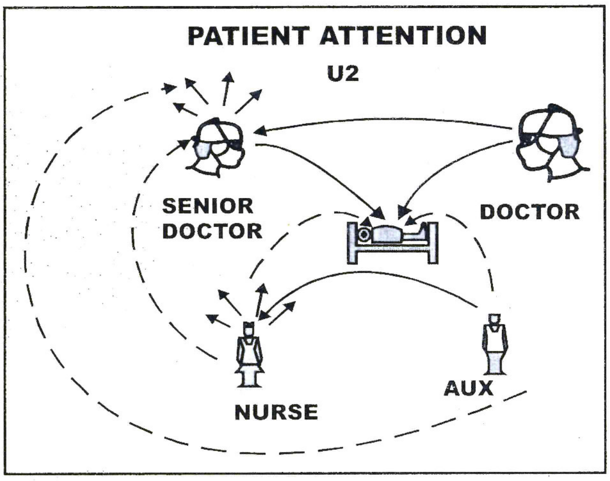

Fig. 3 Staff required for urgency level 3.

MODELING ATTENTION PROCESS

The events

The event "patient arrival" considered to happen at the moment when the patient actually enters the emergency area of the medicine specialty. As soon as this event is activated in the simulation model, the entity "patient" is created with all its attributes.

The patient care primary process is modeled by the events: start and finish of the primary attention. In these two events, the waiting time and the quality of the attention are registered and calculated, among others things. Depending on the case, the event "start of the treatment" is also programmed.

The triage is a process that does exist in any emergency room, where patients wait sometimes for initial attention, according to their needs and priority. This process comprises the events: "start and finish of the triage". The triage is planned and carried out by the general practitioner of the existing team in the room. It happens when both a doctor becomes available and there are patients waiting for it. The waiting list is always reorganized according to the priorities of the moment and the call of a new patient is activated.

The treatment process is modeled by the events:

- Start treatment.- this happens when the patients starts the medical care. The waiting period and the measures of the quality are set by the simulator is this event.

- End treatment.- this happens when the medical care finishes. The observation event is programmed if necessary.

The observation process is modeled by the events:

- Start observation.- this occurs when patients remain in the observation room. It requires medical staff service. Waiting times and quality of the attention can also be evaluated.

- End observation.- this stops the observation. The availability of the staff and the number of patients in observation are brought up-to-date and the patient entity is deleted.

Finally, the event Stop simulation: After a pre-established time this event is activated and it stops the arrival of new patients.

The Entities

There are four entities in the model the patient, the doctor, the assistant, and the nurse. The patient is a temporary entity having the following attributes:

- The time required to receive the necessary primary care;
- The treatment time;
- The observation time;
- The urgency level;
- The arrival time.

For the other entities are modeled only the quantity and the state (free or busy).

The Attention Quality Parameters

The simulation model incorporates variables that register the prominent events according to the objectives of the project.

The statistical calculations based on these measurements are used to evaluate the attention quality degree. Among the most important variables are:

- The patient's waiting times in all the events of their medical attention. For example, the primary attention, treatment and observation.

- The fulfillment of the medical requirements. That is the control of the right number and configuration of the staff in every moment of the attention.

- The variations in the attention process. For example, the situations where the number members the medical team change due to the arrival a serious case.

- The registration of situations where patients of urgency levels 3 or 4 had to wait.

These variables do affect the performance of the system and are used according to their importance.

The evaluation of the quality of the attention is based upon statistical measures obtained from specific runs of the simulation.

Some of the results are shown in global form for all patients, see figure 8. Also, for the patient urgency level 1; see figure 9.

The Information Required

Three pieces of data are required to handle the simulation:

- The desired number of personnel required for a quality attention, however defined;
- The type of professionals that should integrate the medical team of a certain specialty;
- The daily arrival of patients in each specialty.

The services required, the configuration of the staff and the attention process are previously defined by the medical team.

Figure 4 shows the flow of patients with urgency levels 1 and 2. It can be seen that there is the possibility of a waiting line outside the room. The patient arrives, enters and goes through to the reception where a first evaluation of the case is made.

Figure 5 shows the arrival flow of patients with urgency levels 3 and 4.

The arrows that are aimed directly from the professional doctors of the room, that are attending to a patient, indicates that they have abandoned a patient, less urgent, to give attention to the patient at life's risk.

The medical staff configuration.- The simulation is carried out based on a model that involves four urgency levels named u1, u2, u3 and u4.

The calculations inside the simulation model considers, the distinctive attention requirements by each urgency level, based on the following considerations:

1. The primary needs of u1 and u2 are based on information obtained from the work pattern of the intensive care unit of the hospital studied. The data with requirements for the u3 and u4 are gathered from the observation of the medical team at work in the emergency sector;

2. The estimation of the number of professionals required for the treatment and observation events of each urgency level is based upon the medical literature [19, 20, 21, 22].

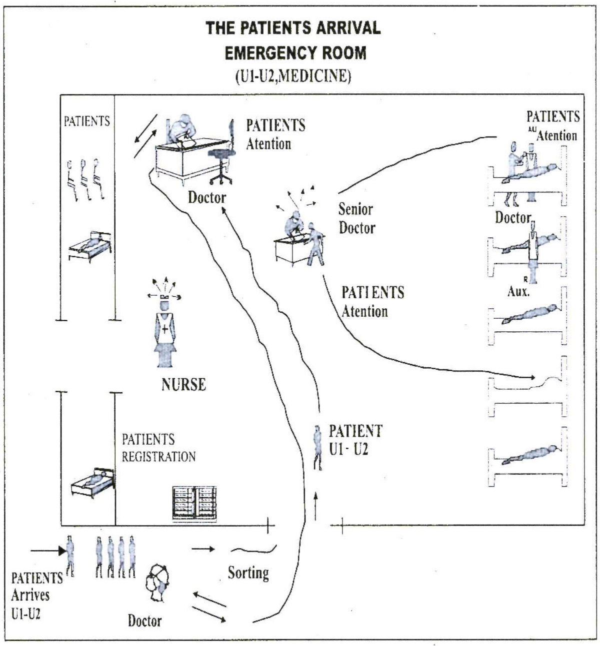

Fig. 4 The Patient arrival in the emergency room for Urgency Patients 1-2.

Attention Time.- The duration of time required by each process involving patients is programmed is studied and modeled separately. The duration of the primary attention is estimated directly from observation in the emergency area. The duration of time for the process treatment and observation are estimated from information emergency inpatients.

After observation the time required by each process, the data is adjusted with functions of random variables in order to estimate the time requirements for the attention of each type of patient, according to the medical procedure involved in the simulation model.

Analysis of Behavior and Applications of The Model

Following, we present simulation outputs in form of boards and graphics, which show the types of results that are obtained from the model, as well as their usefulness. In figures 6, 7, 8, 9, 10 and 11, we show a simulation results with the following medical team: 2 Doctors, 1 Nurse, and 2 Auxiliaries. The arrival of patient is modeled with a Gamma function, the arrival time parameter among patients of 15 minutes and constant k=0.95. After 6 hours of simulation the patient arrival is blocked, and the ones inside the room are attended only until all gets attention. After 14.763 hours, the system obtains to attend to all patients that arrived in the morning shift. The number of patient that arrived at the system in six hours is 26, distributed by degree of urgency in the following way: 22 of

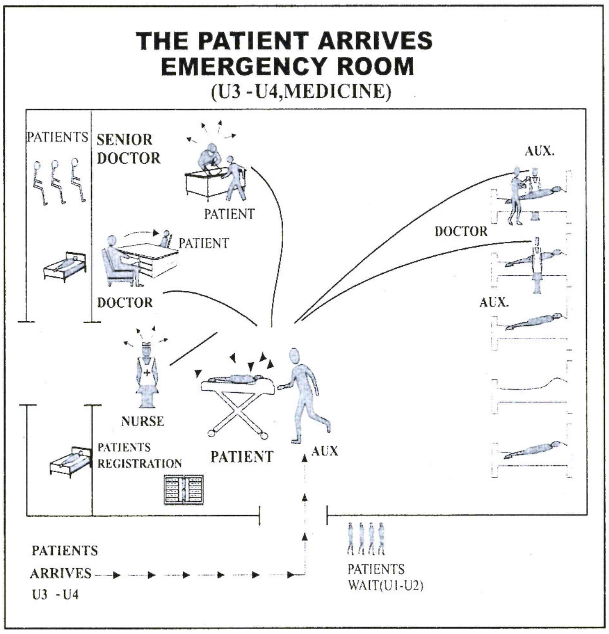

Fig. 5 The Patient arrival in the emergency room for Urgency Patients 3-4.

urgency 1 "U1", 2 of urgency 2 "U2", 2 of urgency 3 "U3", and we do not have patient of urgency 4 "U4".

In figure 6, we have the global times of waiting for all patients and in figure 7 we have urgency-1 patients waiting time. In figure 8 the global qualities of attention for all patients and in figure 9 the qualities of attention for urgency-1 patients. In figure 10 we can appreciate the times we needed of a simultaneous specific number of doctors, similarly in figure 11 we can appreciate a specific number of infirmary auxiliaries.

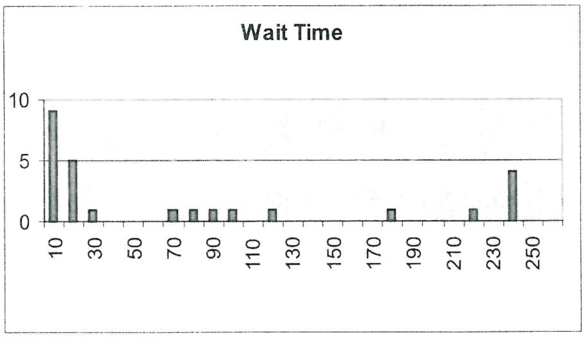

Fig. 6 Patients frequency X wait time (min).

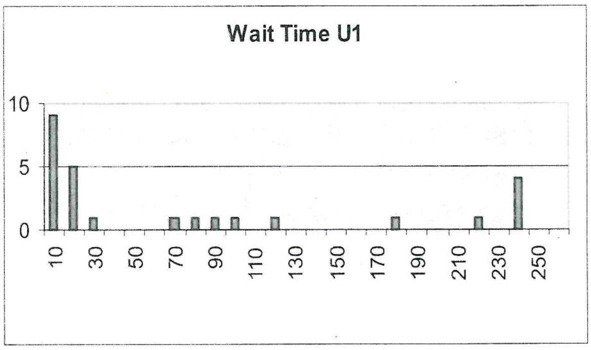

Fig. 7 Patients frequency U1X wait time (min).

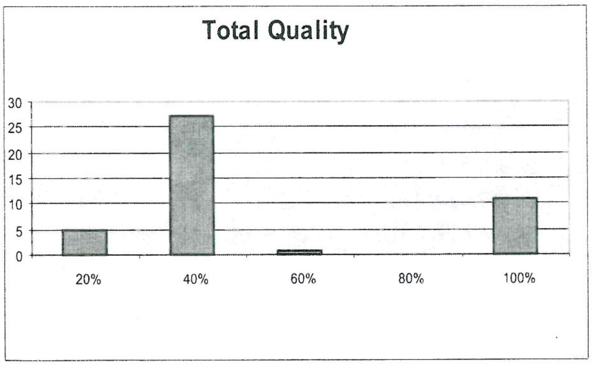

Fig. 8 Patients frequency X% attention quality.

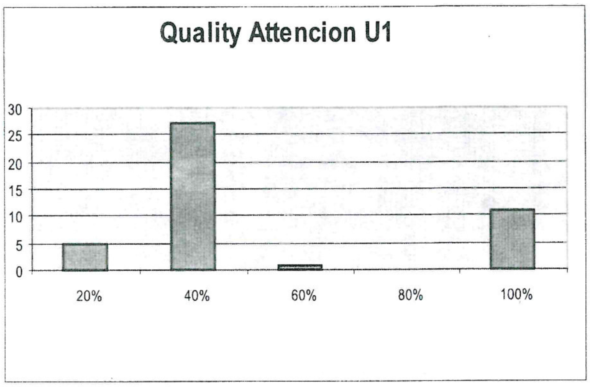

Fig. 9 Patients frequency X % quality attention U1.

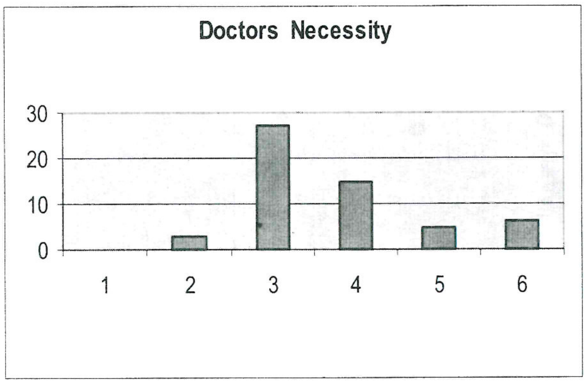

Fig. 10 Frecuency XPhysicians Necessity.

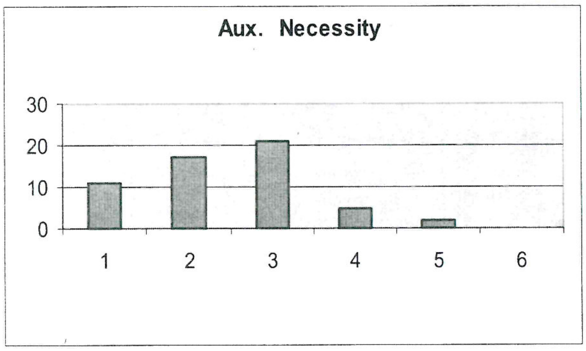

Fig. 11 Frequency X necessity aux. of infirmary.

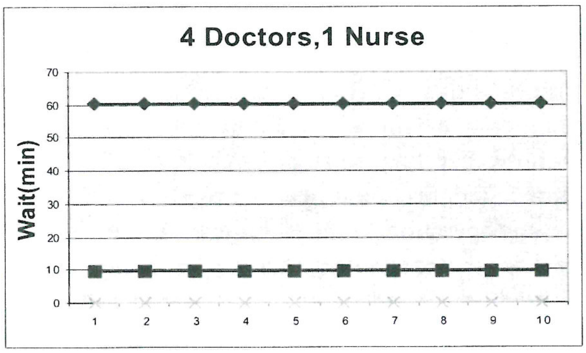

Fig. 12 No auxiliaries.

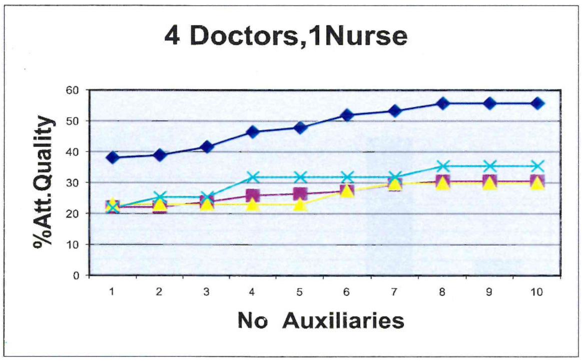

Fig. 13 No auxiliaries.

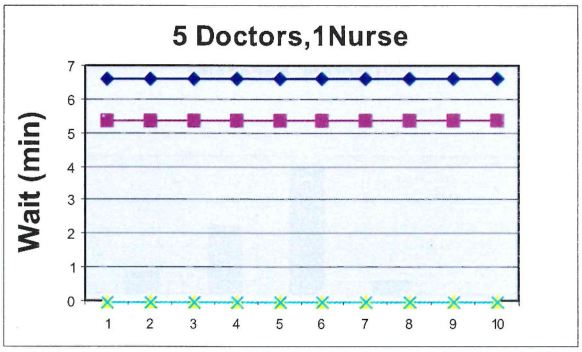

Fig. 14 No auxiliaries.

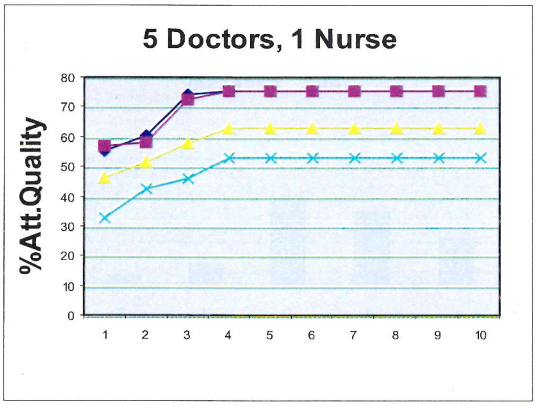

Fig. 15 No auxiliaries.

Following figures 12, 13, 14 and 15 results of simulations are appreciated, where each point of the figures represents one simulation. The figures show the sensibility of the waiting times and attention qualities of the model, facing the increasing number of more than one infirmary assistant. As it can be appreciated, the model can be used to evaluate the present operation of an emergency room, from the point of view of achieving the excellence in the quality of attention. Besides, we need to do an anticipated evaluation in order to analyze possible changes in specific parameters of the system.

CONCLUSIONS

The main contribution of this paper is the model of the Doctor/Patient interrelation, the work model of the medical teams and the models integration in the emergency attention system This allowed to obtain coherent results with the patients necessities and the expectations of the medical teams. Also, in the figures is possible to confirm, the insignificant influence that the increment of auxiliary has in the reduction of the wait times and in the increment of the attention quality. On the other hand we can analyze the sensibility of the system in front of increments in the number of doctors and nurses.

REFERENCES

1. **Deslandes, S.F.** "O atendimento às vítimas de violência na emergência: Prevenção numa hora dessas" In: Ciência & Saúde Coletiva, 4(1), 81-94, 1999.
2. **M.J.F. de Oliveira**, "An integrated decision support system for planning of emergency and elective admissions to hospital wards". In: 24th Annual meeting of OR applied to health services, Roma, Italia, 1998.
3. **F. de Oliveira, M.J., P. Toscano, L.N.** "An integrated emergency information support system IEISS". In: 25th Annual meeting of OR applied to health services (EURO), Latvia, 1999.
4. **Mcguire, F.** "Using simulation to reduce length of stay in emergency departments". Jsoc Health Syst, 5(3): 81-90, 1997.
5. **P. Toscano, L.N., F. de Oliveira, M.J.** "Models of the Emergency attention to Patients". World congress on medical physics and biomedical engineering, July 23-28, Chicago, USA. http://www.medphys.org., 2000.
6. **P. Toscano, L.N., M.J.F. de Oliveira**, "An integrated emergency information support system". World congress on medical physics and biomedical engineering, July 23-28, Chicago, USA. http://www.medphys.org. 2000.
7. **Washington, M.A., Khator, L. Michael, Suresh, K.** "Computer simulation in health care". Annual quest for quality and productivity in health services conference. IIE, Norcross, GA, USA, 201 – 210, 1997.
8. **Lagergren, M.** "What is the role and contribution of models to management and research in the

health services". European Journal of Operational Research, 105(2), 257-266, 1998.

9. **Largergren, M.** "Modelling as a tool to assist in managing problems in health care". In D. Boldy, J. Boldy, J. Braithwaite and I. Forbes (editors). Evidence based management in health care: The role of decision support systems. Asustralian studies in health service administration, Australia, 2002.
10. **F. de Oliveira, M.J.** "A patient-oriented modeling of the emergency admission systems of a brazilian hospital". Paper presented at EURO XIII, Glasgow, July 19-22, 1994.
11. **Pidd, M., De Silva, F.N., Eglese, R.W.** "A simulation model for emergency evacuation". European Journal of Operational Research, 90 (3), 413-419, 1996.
12. **Chaiken, J., Larson, R.** "Methods for allocating urban emergency units: a survey". Management Science, 19, 110-130, 1998.
13. **Savas, E.** "Simulation and cost-effectiveness analysis of New York's emergency ambulance service". Management Science 15 August, 1969.
14. **Lehaney, B., Paul, R.J.** "Use of soft systems methodology in the development of a simulation of out-patient services at Watford General Hospital". Journal of the Operational Research Society, 47(1), 864-870, July, 1996.
15. **F. de Oliveira, M.J., P. Toscano, L.N.** "Emergency information suport system for brazilian public hospital". In M.S. Rauner and K. Heidenberger (editors), Quantitative approaches in health care management, Peter Lang, Frankfurt am Main, Berlin, Bern, Bruxelles, New York, Wien, Oxford, 235-251, 2003.
16. **P. Toscano, L.N.** "Uma ferramenta integrada de suporte a decisões em casos de emergências médicas hospitalares", Dsc Thesis, Federal University of Rio de Janeiro, 2001.
17. **Morales, C., Escalona, E.** «Triage extra e intrahospitalario». Manual de Urgencias y Reanimación Fundación Lucas Sierra, Viña del Mar, Volumen N°1, págs 4:14 - 4:29. 1990-1991.
18. **Perez, I., Montaut Merino, CarrilloBecerra, I., Cases Garrido, A., Lirio Fernández, Mª. D.** "Sistemas de Garantia de Calidad en Urgencias y Emergencias". Cuidados Críticos y Emergencias. Centro de Salud de Las Lagunas. Málaga – España. http://www.medynet.com/usuarios/jraguilar/joserra.html.
19. **Mobley Sheryl, C. S.** "Medical Staff Management: Forms, Policies, and Procedures for Health Care Providers. Aspen Publishers, Inc.; Book and Disk edition - January 1996. ISBN: 0834205394.
20. **Ordner, R., Weitl, J.** "Calculation of nursing personnel for intensive care stations". Krankenpflege (Frankf). 47(7-8):452-4. PMID: 8377453. Jul-Aug. 1993.
21. **Cuthbert, MI.** "Prediction, calculation and allocation of staff required for patient care". Aust Nurses J. 1983 Sep; 13(3):48-51. PMID: 6557809.
22. **Smallwood, R.W., Sando, M.J., R.B., H.** "Medical staff needed in a hospital to service anaesthesia and intensive care". Anaesth Intensive Care. 1981 Feb; 9(1):3-14. PMID: 7258596.