APPLICATION OF DISCRETE SYSTEMS SIMULATION TO REDUCE WAITING TIME IN THE OUTPATIENT SERVICE OF A HOSPITAL IN THE CITY OF SÃO PAULO, BRAZIL

Alexandre Augusto Massote[(a)], Domenico Caruso[(b)], João Batista Gonçalves Sousa[(c)]

[(a)]Centro Universitário da FEI
[(b)] Centro Universitário da FEI
[(c)] Centro Universitário da FEI

[(a)]massote@fei.edu.br[(b)]domenico-caruso@hotmail.com[(c)]jbg.sousa@terra.com.br

ABSTRACT
This paper aims to analyze failures in a service at the arrhythmology outpatient units, using as support the simulation of discrete systems, the sizing of an outpatient service unit in terms of the nursing staff required, the room occupation and the waiting time. In particular, the cardiology outpatient service in a hospital located in São Paulo, Brazil, is investigated. The simulation model developed showed consistent results and proved to be an excellent tool to support the decision-making and to enhance the quality of care.

Keywords: simulation, health management, decision support system

1. INTRODUCTION

Hospitals and outpatient services around the world are seeking ways to increase efficiency in outpatient care by reducing waiting time and its variability. The objective of this study was to evaluate the flaws in an answering service in the arrhythmology outpatient units and generate alternative scenarios that could provide improved customer service. For this purpose, we developed a discrete event simulation model which allowed the assessment of nursing staff requirements, the room occupation and the waiting time. The unit is composed of offices dedicated to treatment in the field of electrophysiology and rooms dedicated to tests, such as installation procedures Hölters, ABPM (Ambulatory Blood Pressure), ECG (Electrocardiogram), SAECG (High Resolution Electrocardiogram), Tilt-test (Test of Slope) and CETE (Transesophageal Cardiac Stimulation.)

The sector of arrhythmia occupies the 5th floor of a complex of buildings of a hospital in São Paulo. The total area occupied by the sector is 240 m² and attends an average of 106 patients per day in consultations with medical specialists in arrhythmology. Currently, the service has a waiting time for the patient which exceeds the legally acceptable 30 minutes. Additionally, the incidence of overtime of scheduled working hours for the nursing staff is high. The waiting room remains crowded over the day and it is not uncommon that the closing time has to be delayed by as much as two hours.

According to Jun (et al., 1999) and Dittus (et al., 1996), the simulation has been used extensively to plan health services. Katsaliaki and Mustafee (2009) conclude in their article that the simulation allows stakeholders to make appropriate decisions based on statistical parameters that represent the reality of the simulated system, providing the same experiment with different strategies for resource allocation. Quality improvement in decision making leads to better utilization of available resources, which improves the quality of health services provided to citizens. According to Brailsford (2005), the simulation has been studied in universities for 66 years and 46 are used in health care. The health system in the UK has used simulation models since 1962. From these early experiences, the work of simulation in health care has generated excellent results, supported clinical decision making, facilitated the planning, allocated resources for evaluating and redesigning processes.

Several studies have proven that the simulation of discrete systems is useful in improving care services for outpatients. Ashton et al. (2005) used simulation to identify problems in a call center "walk-in" and suggest improvements in the waiting room and triage processes. Stahl et al. (2004) used simulations to analyze alternative configurations of a staff of anesthesiologists to increase efficiency in performing surgery. Stafford and Aggarwal (1979) developed a model of discrete event simulation for outpatient care of a university clinic. The model was used to explore the effects of different levels of staff and the aggregation of two or more service units within the clinic. Chwen et al. (2003) reported that consumers are demanding more nowadays than ever before. In an intensely competitive world, the pressure, the expectations, and the need to perform more tasks in less time are increasing rapidly.

However, some studies also show the difficulty of simulation models implementation in health institutions. Watt (1977) and Wilson (1981) describe the factors that may be barriers to the implementation of simulation projects in hospitals: the culture of health institutions, where medical professionals and nursing are highly resistant to change; the high cost of simulation software and training of professionals specialized in this area; the low quality of existing data systems in hospital management; and the high cost of specialized consulting in this area. This factor takes the health institutions to join the universities participating in theoretical studies, which conflicts with the need for hospital administrators, who want a simple and rapid implementation. There is also the difficulty of generic models application in hospitals, since each institution sees its internal processes as totally different from other hospitals, generating the need to create a multitude of different models.

The research carried out by Wilson (1981) shows that from the 200 articles analyzed on simulation projects in health, only 16 were successful. The common characteristics of these articles were: at least one of the authors should be part of the hospital staff and have an interest in solving the problem, the problem must be of high priority for the institution, the funding for the project must be outside and there must be a detailed description of existing data for analysis. Fortunately, all these assumptions cited characterized the development of this study.

As in most health facilities in the country, the application of discrete simulation systems to improve hospital processes is new. Traditionally, empirical methods are used to quantify the nursing staff, and the dimensions and capacity of the reception and waiting room. These measures are determined based solely on experience and observation of similar services within the institution or elsewhere.

The simulation results are consistent with the perception of health professionals and proved to be an excellent tool to support the decision-making. The results provided important information for managerial decision making in relation to the sizing of staff and enhancing the quality of care.

The approach presented in this paper can also bring an important contribution to the design and management of the Brazilian health system, because these services receive a greater number of patients every day with increasing levels of demand, requiring improvements in efficiency and quality of care. Since Brazil is an emerging country, the resources available for investment in the area do not follow the increasing demand, which implies an absolute necessity to invest in the best way possible. Hospitals and outpatient services from around the world are seeking ways to increase efficiency in outpatient care, reducing waiting time and its variability. A simulation model can be a great advantage, providing an overview of the care process and allowing the adjustment of several variables, such as layout, staffing and patient flow.

2. MODEL DEVELOPMENT

Site visits were conducted to monitor the care process and measurement time for each procedure performed in the service. The frequency of patient arrival was obtained through the records of entry into the building's concierge and reception service.

Two nurses accompanied these visits: the manager of the building where the service works and the nurse coordinator, who in addition to other areas, manages the work in the sector of arrhythmology.

2.1. Collected Observations and Information

Visits were made in locus to monitor the process of care and perform measurements of service time for each procedure performed in the service unit. Figure 1 shows the simplified layout of the simulated system.

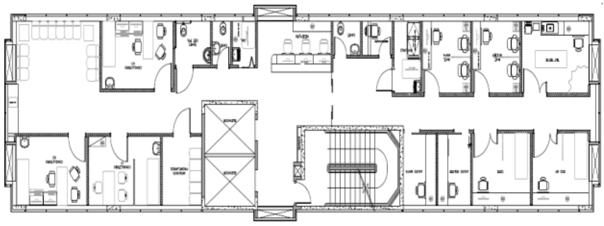

Figure 1: Layout of the simulated system

2.1.1. Structural Information

The Arrhythmia Service is open Monday through Friday, from 7 am to 7 pm. Following are the features of the simulated system before the exams, which are the main focus of the study:

- Board of nursing staff: Two nursing technicians per shift of six hours.
- Reception Service: Capability to care for two patients at a time.
- Waiting Room: Capacity for 12 patients.

2.1.2. Flow of Patients and Time Collected

Figure 2 shows the flow of patients by type of examination performed in the field of arrhythmia, with the average time measured during visits to the sector.

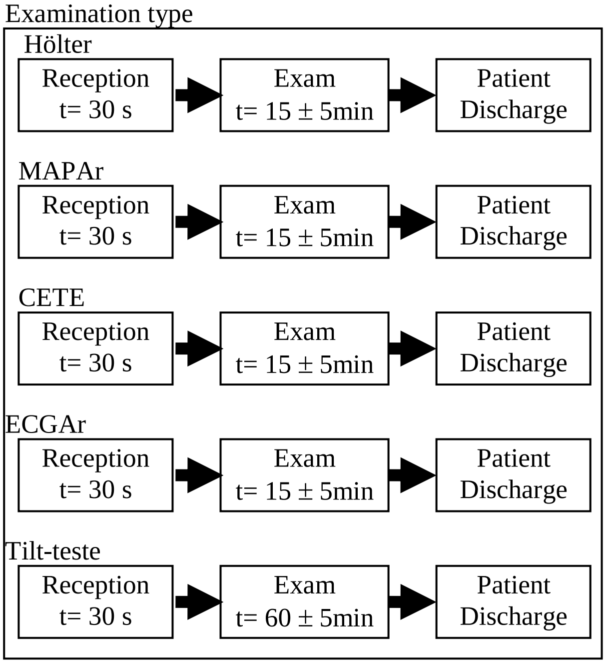

Figure 2: Flow of patients and time for each examination type

The collected data were statistically analyzed and the result is the probability distribution of the time variable in all types of test, following a uniform probability distribution.

Figure 3 shows the flow and the time for queries.

Consultations (Offices 1, 2 and 3)

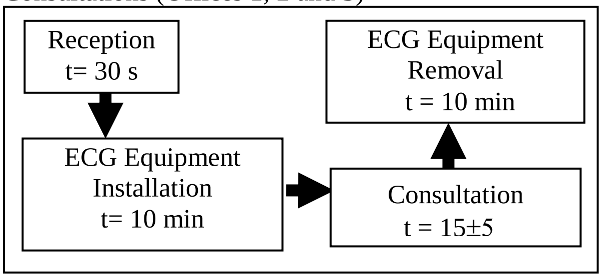

Figure 3: Flow of patients and time for queries

2.1.3. Information about the demands

We analyzed the agenda of patients who used the services sector of arrhythmia during a month. The average daily attendance is 106 patients. We chose to stratify patients by type of care performed by creating percentages of the total number of daily visits.

2.1.4. Development of Simulation Model

From the information collected was used Promodel simulation software, version 7.0, to implement the model, considering the typical work and for generating the various scenarios analyzed.

At first, it was not allowed by the direction of the hospital to consider scenarios involving possible changes to the layout to improve flow of movement, as well as changes in the provisions of the various rooms and offices. Therefore, the only variable that could be modified in various scenarios was analyzed for the quantity of nursing staff accompanying examinations and consultations. Appendix A shows the developed model.

3. RESULTS

Table 1 shows the average utilization of the nursing resources in percentage according to the dimensioning of the nursing workforce by scenario.

Table 1: Nurses utilization

Scenario	Number of Nurses	Quantity Utilized	Utilization %
1	2	96	92.06
2	3	132	87.99
3	4	132	77.68

Table 2 presents the number of patients who were treated within the prescribed period between 7 am and 7 pm. One can assess the demand is met within the service in the simulations involving three four nursing technicians per shift.

Table 2: Demand Achievement

Scenario	Number of Nurses	Demand	Patients Treated
1	2	106	78
2	3	106	106
3	4	106	106

Table 3 presents information on the occupation of the waiting room, according to the design of the framework for nursing. The waiting room was kept fully occupied in 84.04% of the time, with two nursing technicians. As shown in table 4, the average waiting time of patients enrolled in the waiting room was 28.41 minutes for the same situation. This reality is not compatible with the quality of care being provided by the service in question. According to the laws of the country, the maximum waiting time for care in a service is 30 minutes. In the configuration shown, the highest average waiting time is very close to the limit accepted. Certainly, there are patients waiting longer than prescribed by law.

In the configuration that uses three practical nurses per shift, the waiting room remains full for 38.7% of the time, but does not cause failures in patient care. That means the maximum waiting is 31.11 minutes. The configuration with four nursing technicians also presents acceptable values of the waiting room occupancy and maximum average for care.

Table 3: Waiting room occupation

Scenario	Number of Nurses	Fully Occupied (%)	Partially Occupied (%)
1	2	84.04	13.71
2	3	38.07	56.50
3	4	0.00	91.06

Table 4: Average waiting time per patient

Scenario	Number of Nurses	Average Waiting Time (min)
1	2	28.41
2	3	11.31
3	4	3.03

The simulation model was developed with a specific objective of evaluating the staff necessary to meet the demand for an outpatient service. It should be noted that the need for new employees can be met by idle professionals from other sectors, or by improving the efficiency of service processes. Currently, the overtime necessary to meet the demand of the service accounts for 12% of the cost of hiring, wages, and benefits of the employees. The annual cost of a nursing technician comes to $48,800.00.

Defining the two most appropriate scenarios, and taking into account the premise that the design of two practical nurses per shift does not meet the needs of service demand, the manager responsible for the sector may make the decision to hire new staff or not, with reference parameters that allow a decision about quality with high reliability and within the policies established by the institution and the costs involved in hiring new workers. Appendix B shows a typical Promodel report.

4. CONCLUSIONS

Brazil has today a strong demand for health services. According to Ceres et al. (2008), the private insurance market is significant in the Brazilian health system. In December 2006, involving 44.7 million bonds of beneficiaries, of whom 82.7% to health care plans and 173% exclusive dental plans, 2,070 operating companies, more than 20,000 plans and thousands of service providers. The population using health services is becoming more demanding about quality.

The simulation showed results consistent with the perception of industry professionals. It has been shown by several researchers that the simulation can clearly represent a real situation, with details that support a logical decision. In this particular case, the largest benchmark was used in the waiting time simulation, which was very similar to the real time. This article presents a model that provides important management information for decision making in relation to the scale of staff and enhancing the quality of care. In a health service, the great need to reduce costs and increase process efficiency creates an environment conducive to the use of simulation models of discrete systems.

APPENDIX A - THE DEVELOPED MODEL

Locations

Nome	Cap	Unidade	Estatísticas
Recepção	inf	1	Série de Tempo
Sala_de_espera	12	1	Série de Tempo
Tilt_teste	1	1	Série de Tempo
Mapa	1	1	Série de Tempo
Posto_de_enfer.	1	1	Série de Tempo
Holter	1	1	Série de Tempo
ECG_AR	1	1	Série de Tempo
Consultório_2	1	1	Série de Tempo
Consultório_1	1	1	Série de Tempo
Consultório_3	1	1	Série de Tempo
CETE	1	1	Série de Tempo

Entities

Nome	Velocidade (mpm)	Estatísticas
Paciente_exame	50	Série de Tempo
Paciente_tilt	50	Série de Tempo
Paciente_mapa	50	Série de Tempo
paciente_holter	50	Série de Tempo
Paciente_ECG_AR	50	Série de Tempo
Paciente_cete	50	Série de Tempo
Paciente_cons1	50	Série de Tempo
Paciente_cons2	50	Série de Tempo
Paciente_cons3	50	Série de Tempo

Path networks

Nome	Tipo	T/S	De	Para	BI	String
Red1	Não-Pass	Veloc.& Dist.	R1	R2	Bi	17.76

Recursos

Nome	Unid	Estatísticas	Pesquisar
Enfermeira	4	Por Unidade	Mais Próx./Velha

Caminho	Movimentação
Red1	Vazio: 50 mpm Cheio: 50 mpm

Process

Operation

Entidade	Local	Operação
Paciente_exame	Recepção	wait 0.5

Rote

Bl	Saída	Destino	Regra	Lógica de Mov.
1	Paciente_exame	Sala_de_espera	first 1	

Operation

Entidade	Local	Operação
Paciente_exame	Sala_de_espera	

Rote

Bl	Saída	Destino	Regra	Lógica de Mov
1	Paciente_tilt	Tilt_teste	0.030000 1	move with Enfermeira
	Paciente_mapa	Mapa	0.240000	move with Enfermeira
	Paciente_holter	Holter	0.250000	move with Enfermeira
	Paciente_ECG_ AR	ECG_AR	0.19	move with Enfermeira
	Paciente_cete	CETE	0.020000	move with Enfermeira
	Paciente_cons1	Consultorio_1	0.09	move with Enfermeira
	Paciente_cons2	Consultório_2	0.09	move with Enfermeira
	Paciente_cons3	Consultorio_3	0.09	move with Enfermeira

Operation

Entidade	Local	Operação
Paciente_tilt	Tilt_teste	wait u(60,5) Free Enfermeira

Rote

Bl	Saída	Destino	Regra	Lógica de Mov
1	Paciente_tilt	EXIT	first 1	

Operation

Entidade	Local	Operação
Paciente_mapa	Mapa	wait u(15,5) Free Enfermeira

Rote

Bl	Saída	Destino	Regra	Lógica de Mov
1	Paciente_mapa	EXIT	first 1	

Operation

Entidade	Local	Operação
paciente_holter	Holter	wait u(15,5) Free Enfermeira

Rote

Bl	Saída	Destino	Regra	Lógica de Mov
1	paciente_holter	EXIT	first 1	

Operation
Entidade **Local** **Operação**
Paciente_ECG_AR ECG_AR wait u(15,5)
Free Enfermeira

Rote
Bl **Saída** **Destino** **Regra** **Lógica de Mov**
1 Paciente_ECG_AR EXIT first 1

Operation
Entidade **Local** **Operação**
Paciente_cete CETE wait 15
Free Enfermeira

Rote
Bl **Saída** **Destino** **Regra** **Lógica de Mov**
1 Paciente_cete EXIT first 1

Operation
Entidade **Local** **Operação**
Paciente_cons1 Consultorio_1 wait 10
Free Enfermeira
wait 15
get Enfermeira
wait 10
Free Enfermeira

Rote
Bl **Saída** **Destino** **Regra** **Lógica de Mov**
1 Paciente_cons1 EXIT first 1

Operation
Entidade **Local** **Operação**
Paciente_cons2 Consultório_2 wait 10
Free Enfermeira
wait 15
get Enfermeira
wait 10
Free Enfermeira

Rote
Bl **Saída** **Destino** **Regra** **Lógica de Mov**
1 Paciente_cons2 EXIT first 1

Operation
Entidade **Local** **Operação**
Paciente_cons3 Consultorio_3 wait 10
Free Enfermeira
wait 15
get Enfermeira
wait 10
Free Enfermeira

Rote
Bl **Saída** **Destino** **Regra** **Lógica de Mov**
1 Paciente_cons3 EXIT first 1

Chegadas
Entidade **Local** **Quantidade** **Primeira Vez**
Paciente_ exame Recepção 1
Ocorrências **Freqüência** **Lógica**
106 U(5,1)

APPENDIX B – PROMODEL REPORT

File View Tools Window Help
Views: <undefined view>

General Report (Execução Normal - Rep. 1)

General | Locations | Location States Multi | Location States Single | Resources | Resource States | Node Entries | Failed Arrivals | Entity Activity | Entity States

Name	Scheduled Time (HR)	Capacity	Total Entries	Avg Time Per Entry (MIN)	Avg Contents	Maximum Contents	Current Contents	% Utilization
Recepção	9,95	999999,00	106,00	0,50	0,09	1,00	0,00	0,00
Sala de espera	9,95	12,00	106,00	22,69	4,03	8,00	0,00	33,56
Tilt teste	9,95	1,00	1,00	61,56	0,10	1,00	0,00	10,31
Mapa	9,95	1,00	19,00	15,52	0,49	1,00	0,00	49,38
Posto de enfermagem	9,95	1,00	0,00	0,00	0,00	0,00	0,00	0,00
Holter	9,95	1,00	29,00	14,61	0,71	1,00	0,00	70,95
ECG AR	9,95	1,00	30,00	14,62	0,73	1,00	0,00	73,45
Consultório 2	9,95	1,00	10,00	38,03	0,64	1,00	0,00	63,68
Consultorio 1	9,95	1,00	8,00	36,12	0,48	1,00	0,00	48,39
Consultorio 3	9,95	1,00	8,00	37,82	0,51	1,00	0,00	50,67
CETE	9,95	1,00	1,00	15,00	0,03	1,00	0,00	2,51

modelo1.MOD (Execução Normal - Rep. 1)

Name	Scheduled Time (HR)	% Operation	% Setup	% Idle	% Waiting	% Blocked	% Down
Tilt teste	9,95	10,31	0,00	89,69	0,00	0,00	0,00
Mapa	9,95	49,38	0,00	50,62	0,00	0,00	0,00
Posto de enfermagem	9,95	0,00	0,00	100,00	0,00	0,00	0,00
Holter	9,95	70,95	0,00	29,05	0,00	0,00	0,00
ECG AR	9,95	73,45	0,00	26,55	0,00	0,00	0,00
Consultório 2	9,95	58,62	0,00	36,32	5,06	0,00	0,00
Consultorio 1	9,95	46,89	0,00	51,61	1,50	0,00	0,00
Consultorio 3	9,95	46,89	0,00	49,33	3,78	0,00	0,00
CETE	9,95	2,51	0,00	97,49	0,00	0,00	0,00

modelo1.MOD (Execução Normal - Rep. 1)

Name	Units	Scheduled Time (HR)	Number Times Used	Avg Time Per Usage (MIN)	Avg Time Travel To Use (MIN)	Avg Time Travel To Park (MIN)	% Blocked In Travel	% Utilization
Enfermeira.1	1,00	9,95	35,00	13,32	0,42	0,35	0,00	80,56
Enfermeira.2	1,00	9,95	34,00	12,59	0,40	0,36	0,00	73,97
Enfermeira.3	1,00	9,95	34,00	13,58	0,42	0,34	0,00	79,71
Enfermeira.4	1,00	9,95	29,00	15,26	0,47	0,36	0,00	76,39
Enfermeira	4,00	39,81	132,00	13,63	0,43	0,35	0,00	77,66

modelo1.MOD (Execução Normal - Rep. 1)

Name	Scheduled Time (HR)	% In Use	% Travel To Use	% Travel To Park	% Idle	% Down
Enfermeira.1	9,95	78,09	2,46	2,47	13,29	3,68
Enfermeira.2	9,95	71,69	2,28	2,46	20,06	3,52
Enfermeira.3	9,95	77,34	2,37	2,33	14,12	3,85
Enfermeira.4	9,95	74,10	2,29	2,19	17,73	3,68
Enfermeira	39,81	75,31	2,35	2,36	16,30	3,68

modelo1.MOD (Execução Normal - Rep. 1)

Name	Total Exits	Current Qty In System	Avg Time In System (MIN)	Avg Time In Move Logic (MIN)	Avg Time Waiting (MIN)	Avg Time In Operation (MIN)	Avg Time Blocked (MIN)
Paciente exame	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Paciente tilt	1,00	0,00	64,00	1,94	0,00	62,06	0,00
Paciente mapa	19,00	0,00	31,43	2,37	0,00	16,02	13,04
paciente holter	29,00	0,00	31,03	2,09	0,00	15,11	13,84
Paciente ECG AR	30,00	0,00	56,57	2,09	0,00	15,12	39,36
Paciente cete	1,00	0,00	16,41	0,91	0,00	15,50	0,00
Paciente cons1	8,00	0,00	43,70	2,08	1,12	35,50	5,01
Paciente cons2	10,00	0,00	62,15	1,21	3,03	35,50	22,42
Paciente cons3	8,00	0,00	57,83	0,96	2,82	35,50	18,55

REFERENCES

Albuquerque, C., et al., 2008. A situação atual do mercado da saúde suplementar no Brasil e apontamentos para o future; *Ciências e Saúde Coletiva*, 13(5), Brasil.

Ashton, R., Hague, L., Brandreth., M., Worthington, D., Cropper, S., 2005. A simulation-based study of a NHS walk-in centre. *Journal of Operational Research Society*, 56, 153–161.

Dittus, R.S., Klein, R.W., Debrota, D.J., Dame, M.A.,. Fitzgerald, J.F., 1996. "Medical resident work schedules: design and evaluation by simulation modelling". *Management Science,* 1996, 42(6), 891-906.

Joint Comission Resources, Gerenciando o Fluxo de pacientes – Estratégias e Soluções para Lidar com a Superlotação Hospitalar; *Editora Bookman*, 1ª Edição, Brasil.

Jun J., Jacobson, S., Swisher, J., 1999. Application of discrete-event simulation in health care clinics: a survey. *Journal of Operational Research Society*, 50, 109–123.

Katsaliaki, K., Mustafee, N., 2010. Improving decision making in healthcare services through the use of existing simulation modelling tools and new technologie. *Transforming Government. People, Process and Policy*, 4,(2), 158-171.

Nerenz et al, 2011. A simulation model approach to analysis of the business case for eliminating health

care disparities. *BMC Medical Research Methodology*, 11-31.
Robinson, S., 2005. Discrete-event simulation: from the pioneers to the present, what next?". *Journal of the Operational Research Society*,. 56,(6), pp. 619-29.
Rohleder, T.R., Bischak, D.P., Baskin, L.B., 2007. Modeling Patient Services Centers with Simulation and System Dynamics. *Health Care Manage Science*, 10, 1–12.
Ruquet, M.E., 2000. Simulation Modeling Improves Service. *National Underwriter. Life & Health*, 104- 37.
Sheu, C., Mchaney, R., Babbar, S., 2003. Service Process Design Flexibility and Customer Waiting Time. *International Journal of Operations & Production Management*, 23, 7-8, Abi/Inform Global, pg. 901.
Smith, D.J., 1994. Computer Simulation Applications in Service Operations: A Case Study From the Leisure Industry. *The Service Industries Journal*, 14-3, Abi Inform Global,. 395.
Stafford E.F.Jr, Aggarwal, S.C., 1979. Managerial analysis and decision-making in outpatient health clinics. *Journal of Operational Research Society*, 30, 905–915.
Stahl, J.E., Rattner, D., Wiklund, R., Lester, J., Beinfeld, M., Gazelle, G.S., 2004. Reorganizing the system of care surrounding laparoscopic surgery a cost-effectiveness analysis using discrete-event simulation. *Medicine Decision Making*., 24, 461–471.
Watt, K, 1977. Why won't anyone believe us? *Simulation*, 28, 1-3.
Wilson, JCT, 1981. Implementation of computer-simulation projects in healthcare. *Journal of Operational Research Society*, 32: 825-832.

AUTHORS BIOGRAPHY

Massote, A.A.: Graduate in Mechanical Engineering by Centro Universitário da FEI (1979), Master in Industrial Engineering by COPPE/UFRJ (1991) and Ph.d. in Industrial Engineering by the Polytechnic School of the University of São Paulo (2001). Has experience in operational research, economic viability and production control. Research efforts are focused on the logistics, supply chain management and simulation. Currently he teaches simulation undergraduate degree in Industrial Engineering and master's program in Industrial Engineering, is also Head of Industrial Engineering Department of Centro Universitário da FEI, São Bernardo do Campo, Brasil