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SIMULATION MODEL FOR IMPROVING THE OPERATION OF THE EMERGENCY DEPARTMENT OF SPECIAL HEALTH CARE

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ABSTRACT

This paper presents a simulation model which describes the operations in the Emergency Department of Special Health Care at the Central Hospital of Jyväskylä, Finland. It can be used to test different process scenarios, allocate resources and perform activity based cost analysis. By using the simulation model we demonstrate a new operational method, which makes the operation of the Emergency Department of Special Health Care more effective. This operational method is called the triage-team method and it has been studied from two different points of view. The results showed that this method improves the operation of the Emergency Department of Special Health Care substantially (over 25 %), if it is implemented properly and includes all the necessary tasks.

1 INTRODUCTION

The Emergency Department (ED) at the Central Hospital of Jyväskylä has 34,000 patient visits annually. The situation is going to change however, because several units and their operations will be combined in the near future. It means that the number of patient visits is going to double presenting an extremely big challenge to health care managers. They have to reconsider the processes and resources in order to keep operations effective, as well as maintain the good quality of care.

In order to rise to the challenges, a new Emergency Department is under construction and a special project has been launched to find the best layout for operation. It is called the NOVA-project (quick response). The main goal is that 80 % of patients would go through the system less than two hours. That goal will be achieved by developing new process scenarios, allocating resources in the most effective way, and using technological solutions.

Because the Emergency Department of Special Health Care and all of its processes were very complex, consisted of many dynamic variables, and also contained random features, there definitely was need for an effective method. The hospital administration needed a tool allowing them to study the operation of the Emergency Department more closely, and which would work as a decision support tool. Simulation has been proven to be an excellent and flexible tool for modeling these kinds of environments as well in NOVA-project. In the literature there are several studies where simulation has been used to model the operation of an emergency department using patient waiting times and throughput times as the main target variables. The solutions have mainly been sought from operational changes and resource allocation.

The studies, which have concentrated on resource allocation, have tried to make the operation of an ED more efficient by finding the optimal amount of staff for every phase of the process. This kind of work has been done by (Kirtland, et al. 1995; Evans, et al. 1996; McGuire 1997; Chin & Fleisher 1998; Rossetti, et al. 1999; Centeno, et al. 2003).

Many solutions have also been sought from operational changes by many researchers and research groups. The focus has been on patient flows, waiting times and throughput time. Gentano et al. (1995) focused, for their part, on fast-track solution. Bed occupancy has been under examination by Bagust, et al. (1999) and Brailsford, et al. (2005). Glick, et al. (2000) expanded their model by using it in Activity-Based-Cost analysis as well.

In this study, a simulation model of the Emergency Department of Special Health Care is developed and is used to present a new triage-team method. Its effect on the patient waiting times and especially patient throughput time is examined as well. First, the model construction is described phase by phase. Then, the validity of the model is proven, in order that the results can be trusted. After the model development has been described, it is used to present a new triage-team method, which can solve the problems that were located in the existing system. The problems were related to resources and operations. The time before the patient was seen by a doctor for the first time was too long. The utilization of the specialists was too high as well. Earlier, the solutions have been sought from resource allocation and experimental design (operational alteration) separately, but in our approach these two points of view have been combined by developing a new method, which combines certain resources and operations. The new method is called the triage-team method. The triage-team method will be implemented in the Emergency Department of Special Health Care at Central Hospital of Jyväskylä, Finland, and it is also a control element.

2 SIMULATION MODEL OF THE EMERGENCY DEPARTMENT OF SPECIAL HEALTH CARE

The model was developed using the simulation package MedModel (see www.promodel.com). The model creation consisted of many different phases. At first the structural development was carried out. The actual layout was used as a background, because in that way the whole operation of the Emergency Department of Special Health Care and the future changes were much easier to present to the staff.
The treatment areas and the other operational areas were defined in the layout using the graphical elements of MedModel. Among other graphical elements were Counters for the waiting areas and utilization meters for treatment areas. The counters were used to give visual information on the amount of patients in the waiting areas, and the utilization meters showed how much the resources were used.

When all areas were defined in the model, both shared and separate areas, it was time to define the paths for the entities (patient, blood test, and laboratory results) and resources (staff). The path network included all the possible paths, which the patient, all the other entities, and staff members could use when moving from one point to another in the ED. After the paths were created, the structural definitions were made.

The information needed for the simulation model to become functional included following specifications: information on entities, information on resources, logic definition and the use of data.

2.1 Entity definition

The Emergency Department of Special Health Care consisted of five different branches: Surgery (trauma), Surgery (GE), Neurology, Internal Medicine and Children's Medicine. These five groups have partially their own processes but also shared processes, which is why it was important to include these five patient groups in the model, and define the logic for them individually. The patients weren't the only 'entities' in the model. Blood test samples and laboratory test results were also considered entities. This made possible to interlink the tests and patients. The patient wasn't able to proceed in the process until the results were ready. This made the model more accurate, and it was also very important for future work.

2.2 Resource definition

There were partially shared resources in the ED of Special Health Care, which served all patients at some point of the process. There were also individual resources for each patient group. The amount of the resources also varied according to the shift. That's why the shifts were included in the model and the necessary amount of resources for every shift in every patient group was defined accurately. The resource definitions are shown in figure 1.

Surgery (trauma + GE)	Morning shift	Evening shift	Night shift
Nurse	3	3	2
Doctor	1	1	1
Neurology			
Nurse	1	2	1
Doctor	1	1	1
Internal Medicine			
Nurse	2	2	2
Doctor	1	1	1
Children's Medicine			
Nurse	0	1	0
Doctor	0	1	1
Shared resources			
Secretary	2	2	2
Lab staff	1	1	1
X-ray staff	1	1	1

Figure 1: Resources of the emergency department of special health care

2.3 Model logic

This section describes the main process logic for the simulation model of the Emergency Department of Special Health Care. This same logic has been used for each patient group in the model, but it has been defined individually, because every group also has resources of their own (specialized nurses and doctors) and therefore they are routed to different locations for treatment.

The process starts with the patient arrival. The patient enters the model with their own arrival distributions. The next phase is registration where a secretary gathers the patient's basic information. A secretary also identifies the special field and guides the patient to the correct waiting area.

The patient is then seen by the specialized nurse, who defines the urgency (triage), interviews the patient, takes the basic tests (measuring blood pressure, etc.), and then decides where to send the patient next. There are three possibilities in the model where the patient can be routed after being seen by the nurse. Number one is to send the patient to see the doctor for the first time. The doctor examines the patient and orders the necessary tests. Number two is to order the tests without seeing a doctor and send the patient to the laboratory or x-ray. Number three is to send the patient to the doctor for final diagnosis, if there is no need for tests.

If the patient is sent to the doctor for the first time, the route from there takes the patient either to the laboratory or to the x-ray, depending on the tests ordered. If only laboratory/X-ray tests have been ordered, the patient goes to the laboratory/X-ray. In the case of both tests (laboratory and x-ray) the patient's route depends on the length of the queues. The patient is sent to tests where the queue is shortest first and after that to the other tests.

If the specialized nurse orders the tests without sending the patient to the doctor, the route to the tests is selected according as for seeing the doctor for the first time. The only difference here is that the patient might be seen by the doctor between the laboratory and x-ray tests.

When all the tests have been taken and the results are ready, the patient is seen by the doctor for final diagnosis. After the diagnosis has been made, the patient goes either home and leaves the ED of Special Health Care, or to the waiting area for their case history. If the patient goes home that is the end of the process, but if the patient is transported to the ward or some other welfare institution, the case history must be ready and the patient has to wait for that. After the case history is written, the patient is ready to leave the system. The initial process flow is shown in figure 2.

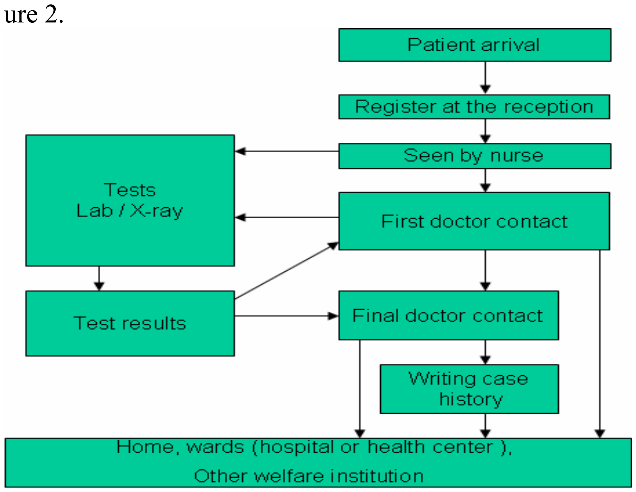

Figure 2: Process flow in the ED of special health care

2.4 Data collection

Data was collected by observing patients in the Emergency Department for two weeks. The patients were observed 24 hours a day and seven days a week. In addition, the observation data from earlier research was also available. The research was conducted half a year earlier and its data was also used in this project. Altogether there was six weeks data available. The total number of visits was a little under 4000.

In both cases the data was collected with a special form, which was created for this project. The form included information on the patient's arrival (how they have arrived), the amount of patients, symptoms, urgency (triage), and process times.

Data collection was done by the specialized nurses and secretaries, who filled the form as the patient went through the process. The form was among the patient's other documents and thus followed the patient from one point of the process to another. After the patient left the emergency department, the data on the form was entered into the Access database and processed with statistical software SPSS and Stat: Fit. Process time for each phase of the process in each patient group separately is summarized in figure 3.

Surgery (trauma) patient	**Time (min)**		**Surgery (GE) patient**	**Time (min)**
Reception time	N(5,1)		Reception time	N(5,1)
Nurse contact	E(8.24)		Nurse contact	W(1.4, 15.2)
First doctor contact	IG(10.2, 11.2)		First doctor contact	L(1.79, 11)
Blood test	5 min		Blood test	5 min
Walking time between lab and ED	L(2.95, 0.649)-5 min		Walking time between laboratory and ED	L(2.95, 0.649)-5 min
Tests at the laboratory	W(1.78,47.1)		Tests at the laboratory	W(1.78,47.1)
X-ray	U(10,2)		X-ray	U(10,2)
Final doctor contact	W(1.44, 17.9)		Final doctor contact	W(1.42, 13.8)
Writing case history	L(2.69, 0.795)		Writing case history	E(20.7)
Neurology patient	**Time (min)**		**Internal disease patient**	**Time (min)**
Reception time	N(5,1)		Reception time	N(5,1)
Nurse contact	W(1.63, 14)		Nurse contact	W(3.3,3.16)
First doctor contact	W(1.66, 12.8)		First doctor contact	IG(11.2,9.57)
Blood test	5 min		Blood test	5 min
Walking time between lab and ED	L(2.95, 0.649)-5 min		Walking time between lab and ED	L(2.95, 0.649)-5 min
Tests at the laboratory	W(1.78,47.1)		Tests at the laboratory	W(1.78,47.1)
X-ray	U(23,3)		X-ray	U(15,2)
Final doctor contact	ER(6, 2.69)		Final doctor contact	P5(4.15,55.7)
Writing case history	L(2.7, 0.846)		Writing case history	IG(49.9,26.8)
Children patient	**Time (min)**			
Reception time	N(5,1)			
Nurse contact	W(2.44,13.9)			
First doctor contact	E(9.03)			
Blood test	5 min			
Walking time between lab and ED	L(2.95, 0.649)-5 min			
Tests at the laboratory	W(1.78,47.1)			
X-ray	U(10,2)			
Final doctor contact	T(4,4,46.9)			
Writing case history	E(13.1)			

Figure 3: Processing times for each patient group (N=Normal, E=Exponential, IG=Inverse Gaussian, L=Lognormal, W=Weibull, U=Uniform, ER=Erlang, P5=Pearson 5)

2.5 Model validation

The model was verified and validated using its visual and numerical information. The structure of the model was examined via the animation and then discussed with the staff (nurses and doctors). The logic of the model was presented phase by phase and compared to the conceptual model.

The model was validated by carrying out the confidence interval examination concentrating on the patients' average throughput time. Because each patient group had partially their own resources and process routes, and partially shared resources and process routes, the average throughput time of all patients was the best target variable. The average throughput time included all the individual and shared processes and described how the ED of Special Health Care operates:

$$\text{The average throughput time} = \frac{1}{n}\sum_{i=1}^{n} p(t)_i\,,\quad p(t)_i = \text{time of the patient i in the system}$$

First the throughput time of the real system was defined statistically from the real data. The value of the real system was then compared to the value which the model gave after a simulation run. The results showed that the difference between the output values of the model and the real system was 3 % (accuracy 97 %) and therefore the model was valid and it could be used as a decision support tool.

3 DESCRIPTION OF THE TRIAGE-TEAM METHOD

Triage has been studied in few contributions. Martinez-Garcia & Mendez-Olague (2005) discovered in their study that the person who classified the emergencies was a medical assistant without much medical training. There was a need for a more experienced person to do the evaluation, thus they created a new role in the reception area (an area with a physician and a nurse). In that way the emergency was much more accurately defined. Mahaputra, et al. (2003) presented a new ESI 5 level triage system. Levels 1 and 2 dealed with patient acuity and levels 3, 4 and 5 dealed with predicted resource need.

The triage-team method presented in this paper differs from the above by altering the structure of the patient process and by allocating the resources differently. Earlier the process started at the reception, where the receptionist documented all patient's basic information and then guided the patient to the correct waiting area. The patient was next seen by the specialized nurse, who defined the triage, made the first examinations (measured blood pressure, etc.) and ordered the tests that nurses could order without a doctor. The general protocol in the ED is that the nurse can't order the x-ray tests which is why they are done only after the patient has seen the doctor. This has been the factor which has increased the throughput time of the patient, and caused a high degree of utilization of the specialists. The triage-team method offers a solution to this problem. The purpose of the group is to reduce the utilization of the specialists and enable the ordering all the tests the patient needs right after arrival, and in that way quicken the referral to treatment.

The team consists of three staff members, who will receive all patients. The members serve all patients, regardless of their special field. There is a receptionist, a nurse and a doctor, who the patient will see first after arriving at the ED of Special Health Care. First they define the urgency (triage). The urgency includes four different levels: A, B, C and D. A means that the treatment has to start immediately, B means that the treatment has to begin in less than 10 minutes, C means that the treatment has to begin in less than one hour and D means that the treatment has to begin in less than two hours.

After defining the urgency, the patient is interviewed (basic information), the symptoms are defined, all necessary tests are ordered, and the patient is sent to the next phase depending on the definitions made.

The operation of this method and its effect on the overall operation has been studied from two different perspectives. The efficiency was first under examination. It was very important to define how fast the team should work in order to make the operation more effective. It was essential to find out the general time limits, because without that information it was very hard to define what tasks to include in the operation of the triage team, and what operations should be handled with the help of the specialized nurses.

The second point of view for examining the triage-team method was to define how many exceptional patients the team could operate without slowing down the whole operation of the ED. Exceptional patients are patients who need for longer the attention of the triage-team (for example level A patient), and therefore make the other patients to wait for longer.

In both cases the process times were defined by using uniform distribution. Because the standard deviation and other parameters weren't known beforehand, it was assumed that every value in the defined range of variation was possible, and it was also used because the variation was evaluated to be quite small by the staff.

4 EXPERIMENTS AND RESULTS

The triage-team method was tested using several alternative process time scenarios. The staff estimated that the process time would be somewhere between 0.5-1 minutes, if everything went well. Because it was just estimation, several different scenarios were taken under examination. It was also very important to find out how long the operation could take before it would have a negative effect on the operation of the ED. The different process scenarios were developed using uniform distribution and are shown in table 1.

All developed scenarios were tested and the results were compared to the existing operation, concentrating on the average throughput time of all patients. **The results showed that if the operation is as effective as the staff has estimated, there will be a 26 % reduction of the average throughput time.** The results also indicated that the

Table 1: Different process time scenarios for the triage-team

Scenarios	Distribution
Process time 0.5-1.5 min	U(1,0.5)
Process time 1-2 min	U(1.5,0.5)
Process time 2-4 min	U(3,1)
Process time 4-6 minutes	U(5,1)
Process time 6-8 minutes	U(7,1)
Process time 8-10 minutes	U(9,1)
Process time 10-12 minutes	U(11,1)
Process time 12-14 minutes	U(13,1)

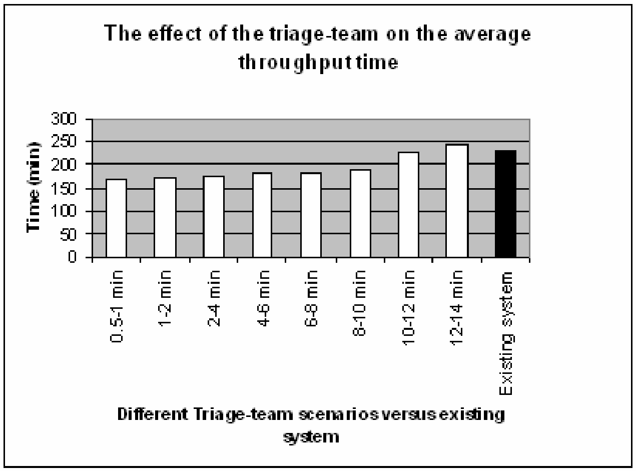

Figure 4: Comparison between different triage-team scenarios and the existing system

operation would become more effective if the process time is under 12-14 minutes. The results are shown in figure 4.

The variation of the process time was estimated to be quite small, because there are the standard procedures that the triage-team performs. That's why the minimum and maximum values were defined as being very close to each other in these scenarios. Of course there will be some exceptional situations and that's why the triage-team method was also tested with some exceptional scenarios. The main idea was to study how many exceptional patients the triage-team could handle and still keep the operation of the ED of Special Health Care effective. The scenarios and results are shown in figure 5.

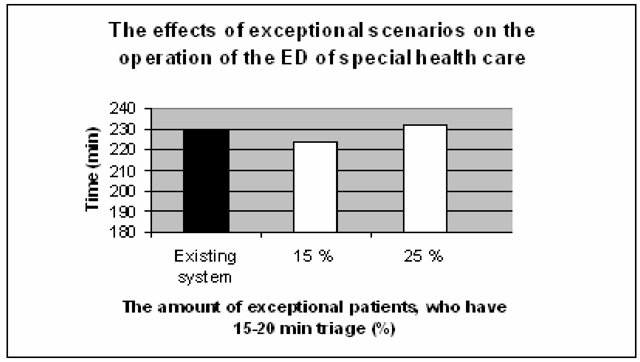

Figure 5: Comparison between exceptional triage-team scenarios and the existing system

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