DESIGNING AN EXPERT SYSTEM FOR THE ECONOMIC EVALUATION OF OPERATIONAL AND STRUCTURAL CHANGES IN EMERGENCY DEPARTMENTS

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Abstract

During the last two years a simulation tool was developed at the Industrial Engineering and Management Faculty at the Technion. The simulation tool is capable of evaluating the impact of various changes, planned or forced, have on the different ED performance measures such as bed utilization, medical and service staff work-load, patient length of stay, equipment utilization etc. Nevertheless, simulation results will still be depended on the quality of the operational decisions made by the managers. Smart, effective and correct decisions will improve the performance of the ED. On the other hand, wrong decisions may lead to less desirable effects or even deterioration in the system's performance.

The scope of the operational decisions which may be required, to keep the ED operating in satisfactory manner, is very large; while at the same time the mutual relations between the different system's elements and their impact on the system's performance is not always clear. System performance is based on several dimensions such as time, cost, utilization and quality. Each of these dimensions has unique performance measures, by which the overall system's performance can be assessed. It is clear that an action which is aimed at improving a certain measure may have an adverse effect on another measure.

In order to mechanize this decision-making process an Expert System is needed which is capable of assessing the current state of the system and decide what is best course of action to improve its performance if possible. This study will try to develop such an Expert System and integrate it with the simulation tool described earlier.

Scientific Background and research Significance

Until a few decades ago the service industry used simple methods, if at all, to design, analyze and operate systems. However, in recent years, in light of the increase in the required capacity of these systems; coupled with the raising cost of providing services, management shifted attention to system efficiency. As a result, the service industry is changing, introducing modern design and evaluation techniques based on data gathering and information technology to better utilize existing resources.

The health care industry is going through exactly the same changes. In the face of an increase in the number of patients who arrive to Emergency Departments (ED) seeking medical care; hospitals are vigorously searching for ways to reduce cost and improve productivity due to dwindling resources. As a result ED overcrowding (Gallagher and Lynn 1990) coupled with shortages in the nursing staff and limited resident hours (Wright et al., 1992) have become an acute problem in many large urban hospitals in recent years. As a result, it has been recognized by hospital managers and other health care decision makers that new types of information techniques and more elaborate tools are needed to improve hospital operations in general and ED productivity and efficiency in particular.

Why Simulation

Discrete event simulation is one of the most powerful analytical tools at our disposal to model and analyze large, highly complex and dynamic systems, EDs most definitely fall under this category. Therefore, it is obvious that that discrete event simulation has to be the prime candidate for these tasks. Simulation models provide us with a good assessment of the ED's performance measures, efficiency, effectiveness, its resource needs and utilization, as well as the impact, changes in the ED parameters, have on its performance measures.

Rakich et al. (1991) state that simulation can assist hospital management to develop and enhance their decision-making skills. These decisions have to be made whether planned structural or operational changes are required, or external events force such changes. Over all simulation can be a powerful medium and long term managerial tool:

- Simulation can assist management in determining how to distribute scarce resources efficiently and evaluate different operational alternatives in order to improve existing EDs or even assist in planning and designing new EDs.
- Simulation enables management to analyze different What-If questions and view the consequences of this analysis with no impact or disturbances to the operating ED. Simulation.
- Simulation can assist management in finding out what are the mutual effects between the different elements which make up the ED and how external change impact these elements and the performance of the entire ED.

During the last two years a simulation tool was developed at the Industrial Engineering and Management Faculty at the Technion. This simulation tool was based on observations and findings made through a large field study of the operations of different EDs. The simulation tool is capable of evaluating the impact different changes, planned or forced, have on the different ED performance measures such as bed utilization, medical and service staff work-load, patient length of stay, equipment utilization etc.

For example, as a result of a clinical incident which occurred in the ED an increase in the frequency of a specific expensive medical procedure was observed. Although this constitutes a forced and un-planned change, it is important to assess immediately (not wait until data can be gathered) how this change may impact other ED performance measures such as patient length of stay and medical staff work-load equipment utilization etc. This assessment will lead management to devise operational or structural changes which may counter any possible adverse effects.

Although the clear benefits management may gain from using such simulation tools very few success stories are reported in the literature. Washington and Khator (1997) state that the reason simulation models are not used more often in health-care systems settings, is management's lack of incentives to do so. Incentives, which stem from comparing the expected benefits (which are not fully understood or accepted) to the time and cost that have to be invested in order to build a detailed simulation tool.

In order to improve the widespread proliferation of simulation in health-care systems in general and EDs in particular, Lowery (1994) suggests that hospital management should be directly involved in the development of simulation projects in order to build up the models' credibility. In addition, it is important to simplify the simulation processes as much as possible and use visual aids or animation to gain more confidence in the model's ability.

In light of what was stated earlier, it is apparent that a different approach to health-care simulation in general and ED simulation in particular has to be taken. For management to be able use simulation effectively and efficiently. The tool has to adhere to several basic guide-lines and principals:

- The simulation tool has to be general and flexible enough to model every possible ED setting.

- The tool has to be intuitive and simple to use. This way mangers, hospital engineers and other nonprofessional simulation modelers, can build and run simulation models with very little effort.
- The tool has to include base-values for all (or most) of the system parameters. This will reduce the need for comprehensive costly and time consuming time studies which are usually one of the first steps in building any simulation model.

By incorporating these three principals, management's involvement in developing simulation models will increase as a result management's confidence in the models will increase as well. At the same time, due to a decrease in the effort required to develop new simulation models, management's incentive to use simulation will increase.

Nevertheless, simulation results will still be depended on the quality of the operational decisions made by the managers. Smart, effective and correct decisions will improve the performance of the ED. On the other hand, wrong decisions may lead to less desirable effects or even deterioration in the system's performance.

The Research – Objectives and Methods

The scope of the operational decisions which may be required, to keep the ED operating in satisfactory manner, is very large; while at the same time the mutual relations between the different system elements and their impact on the system's performance is not always clear. This is mainly due to the complexity in defining what is good or even acceptable system's performance. System's performance is based on several dimensions such as time, cost, utilization and quality. Each of these dimensions has unique performance measures, by which the overall system's performance can be assessed. Following are possible performance measures for each dimension:

Time dimension

- Patient length of stay in the system
- Sum of all the patient waiting time
  - Waiting time to be seen by a nurse
  - Waiting time to be seen by a physician

- Waiting time for specialist advise

Cost Dimension

- Cost of physicians
- Cost of nurses
- Cost of service staff
- Operation cost of the medical equipment
- Purchase cost of medical equipment
- Material costs

Utilization dimension

- Physician work-load
- Nurse work-load
- Bed utilization
- Equipment utilization

Quality dimension

- Ratio of patients' total waiting time to patients length of stay in system
- Percent of patients returning within a week with the same complaints
- Mortality rate in the ED
- Mortality rate in the hospital

It is clear that an action which is aimed at improving a certain measure may have an adverse effect on another measure. For example, lets assume that improving the time dimension through a reduction of the patient's length of stay by 10% can only be achieved by adding a certain piece of medical equipment or by adding one additional physicians to the evening shift. It is obvious that such a change has an adverse effect on the cost dimension. In order to evaluate and decide whether the change is worth while to consider, it is imperative to be able to compare between time and cost. This can be achieved through translating all performance measures each with its relative weight into one combined measure. One possible way to determine the relative weight is the Analytic Hierarchy Process (AHP) method Saaty (1987).

In order to mechanize this decision-making process an Expert System is needed which is capable of receiving the current state of the system and decide what is best course of action to improve its performance if possible. This study will try to develop such an Expert System and integrate it with the simulation tool described earlier.

The study will list through interviews, with ED managers and other health-care decision-makers, all the different performance measures and their relative importance to the ED's overall performance. Based on these inputs and the understanding of the mutual interaction between the different elements which make up the ED, an Expert System will be developed and integrated with the ED simulation tool. The Expert system will be able to receive from the simulation tool the current status of the ED as described by the different performance measures, and decide based on the relative importance of these measures what is the best course of action to improve the EDs performance. This process will go through several iterations until convergence is reached. A possible system structure is illustrated in Figure 1.

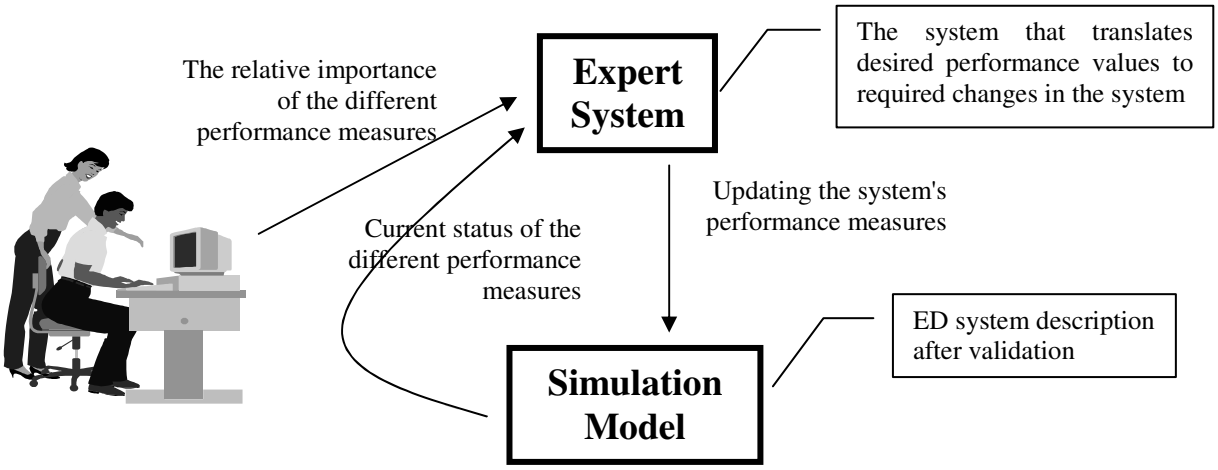

Figure 1. System structure

The suggested system will handle three out of the four dimensions described earlier. The quality dimension is different from all the rest since it is effected by the clinical operations performed by the medical staff, no model can simulate and assess these. It is only possible to estimate these performance measures statistically after the desired structural and/or operational changes to the ED are made. Therefore, quality is not part of this study.

Research Means and Facilities

The Study will be conducted at the Research Center for work Safety and Human Engineering at the Faculty of Industrial Engineering and Management at the Technion – Israel Institute of Technology. As such, the graduate and under-graduate students working at the center and the research center's clerical and professional staff will serve as the logistical and professional work-force of this study. The research center

was and still is involved in several studies related to health-care systems such quality of service and human errors and other hospital operations related studies. During this time the research center has gained considerable experience in this field. In addition the computer facilities of the research center and those of the Faculty of Industrial Engineering and Management are very capable and will support this study.

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