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Simulation optimization of an emergency department by modeling human errors

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ABSTRACT

Emergency department (ED) is considered as one of the most critical elements in health-care systems. This paper describes a simulation optimization of an emergency department in a general hospital in Iran by modeling human error. Human error is defined as combination of committed errors by nurses and technicians. In this study three types of errors are evaluated including repeated venipuncture, unsafe transportation and sampling errors. These errors are considered in simulation model. Seventy appropriate scenarios approved by experts in ED are defined to assess various alternatives. Scenarios are examined and evaluated by stochastic data envelopment analysis (SDEA). Then, the optimum scenarios are identified. In this study, expense cost, number of nurses and physicians are considered as inputs whilst patient duration, queue length, and number of three different committed errors are considered as outputs of SDEA and DEA model. The results show that addition of nurse and physician in ED would reduce the human errors, patient duration and queue length. Then, proposed approach is validated and verified by statistical test. Finally, queue length is identified as the most important indicator through sensitivity analysis. To the best of our knowledge this is the first paper that examines human errors in a general hospital by simulation, DEA, and SDEA approaches. Moreover, human errors are classified based on skill, rule, and knowledge (SRK) based behavior to help decision makers in order to improve the quality of care for this particular ED.

1. Introduction

Hospital is one of the important sectors of healthcare organizations and the emergency department (ED) is one of the most crowded departments of hospital. Leaving hospital without receiving any treatment, high queue length of patient and increase in waiting time and probability of human errors are events that occur in crowded emergency department [12]. ED is an environment with resource restriction, different patient priorities, and several levels of treatment in comparison with other departments of the healthcare system [23]. In EDs, patients arrive without beforehand appointments [4] and working on different shifts and different days during the week are inevitable issues for staff in ED [51]. Therefore in this high-pressure environment, medical errors can occur [47]. A few historical information about the patients, the necessity to act immediately, crowdedness, and having obligation to do several tasks are factors that result in occurring errors by

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nurses in ED [20]. Assessing human errors in EDs and proposing the approaches to predict the occurrence of these errors can improve patient safety and quality of care. In this regards, this study integrates simulation technique with stochastic data envelopment analysis (SDEA) and data envelopment analysis (DEA) in order to enhance the quality of care in ED by modeling three different human errors. Moreover, human errors are classified based on skill, rule, and knowledge (SRK) based behavior for this particular case study to help decision makers in order to improve the quality of care. The simulation model includes the occurrence of human errors and the processes of error consequences. SDEA is used to evaluate different scenarios and select the best one. Based on our recommendations the hospital management can assess different alternatives before implementation and this study demonstrates the considerable improvement in ED by applying appropriate strategy.

Emergency department is a risky environment with high probability of human error occurrence. This is the first study to model human errors of emergency department in a real case by simulation method and evaluates different scenarios of real ED by SDEA method. The results of the proposed approach help decision makers to enhance performance by considering human error. Moreover, human errors are classified based on skill, rule, and knowledge approach to help the mangers of ED in identification of errors sources. In addition, the most important and influential shaping factors are identified through sensitivity analysis and the weight of each indicator is calculated.

This study is organized as follows: Section 2 reviews the related literatures. Section 3 presents the methodology which is used in this study. Section 4 describes a real case study and Section 5 shows the computational results and discussion. Finally in Section 6 the conclusion of the study is presented.

2. Literature review

In this paper, simulation approach is applied to model human errors in a real ED. To do this, the related literatures are reviewed in this section.

2.1. Discrete event simulation

Simulation models present specific features or behavior of a desired system which is stochastic inherently [31]. Barjis [11] introduced a classification of healthcare simulation which includes clinical, operational, managerial, and educational simulation. Indicating patient flow with particular probability function for each process, performance measurement, evaluating the impact of changing the resource level, identifying the best system configuration in ED [52], improving the ED performance and decreasing waiting time [3], and assessing the possible ways in order to reduce the patient duration in ED [50] can be obtained by a simulation model. Applying simulation in order to make decision in healthcare has been increased in recent years [52]. Simulation studies within ED have been used to improve the performance and reduce the patients waiting time by several scenarios such as increasing the number of physicians, staff, and medical devices [3]. Measuring patient duration [1,42,43,50], patient average waiting time [13,17,42,51,52], resource utilization [1,3,46], number of patient served [2,3,13,43], evaluating resource allocation [13,16,24], patients satisfaction [7], and ED productivity [1] are such different objectives of discrete-event simulation in recent studies. Many researchers used this simulation technique to investigate the problem of ED and enhance the quality of care. For example, Yeh and Lin [51] used simulation and genetic algorithm for solving the nurse scheduling problem without increasing the staff. Hoot et al. [22] developed a simulation model as a forecasting tool and applied it to predict different measures of ED crowding including waiting time, the number of patients in waiting room, the total number of patients in ED beds divided by total treatment beds, patient duration, the number of patients waiting for hospitalization in other units, waiting time for hospitalization. The results showed significance correlation between simulation forecasts and real data. Ahmed and Alkhamis [2] presented a simulation optimization methodology in order to maximize the number of patients received health service and reduced queue length by considering cost constraint. Brenner et al. [13] investigated the optimal number of physicians and nurses by a simulation modeling of ED in order to reduce crowding and enhance quality of care service. Zeng et al. [52] presented a simulation model of ED and a sensitivity analysis by changing the number of resources (nurses and physicians) and testing equipment to reduce crowding. Azadeh et al. [6] applied fuzzy simulation to find the best nurse scheduling by considering patients waiting time. A split-flow process in order to reduce the average time patients spend in ED was presented by Konrad et al. [27]. Patient acuity and parallel processing were considered in this process and discrete-event simulation was used for evaluating the effect of this process. Al-Refaie et al. [3] used cellular manufacturing model to propose multiple nurse assignment scenarios to develop utilization of nurse and reduce waiting time of the patient by considering the nurses as operators and the different rooms of ED as machines. In addition, they used DEA technique to select the best scenario. Cabrera et al. [14] used an agent-based modeling simulation and presented a decision support system for ED. The goal of this research was improving the performance of ED. Kadri et al. [24] presented a decision support system and used simulation to predict the inconvenience situations in ED and offered some suggestions to improve these situations. Hurwitz et al. [23] simulated a model of ED in both average academic and nationally ED environments. They proved that applying similar strategies like recourse addition in order to enhance performance of ED have different impacts on these two types of environments. Norouzzadeh et al. [32] considered patient throughput time as the performance evaluation index. They proposed three different scenarios to enhance quality of care which were about the bed assignment, changing the process of reporting to inpatient units and replacing hospitalist instead of care physicians if necessary. The results indicated that applying the scenarios simultaneously could provide the most reduction in the average throughput time.

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