Improving decision-making and management of an emergency department resources using discrete event simulation model and multi-criteria analysis

Ibtissem Chouba[1,2], Lionel Amodeo[1], Farouk Yalaoui[1], Taha Arbaoui[1], Stéphane Sanchez[2], David Laplanche[2]

[1] Institut Charles Delaunay, LOSI, Université de Technologie de Troyes 2019, CNRS 12 Rue Marie Curie, CS 42060 10004 Troyes cedex, France

[2] Pôle d'Information Médicale et Évaluation des Performances, Centre Hospitalier de Troyes, 101 Avenue Anatole France, 10000, Troyes, France

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Introduction

The crowding and the increasing demand on hospital emergency departments (ED's) have increased the waiting time of patient and impacted the management of the resources that ensure good quality of care. Therefore, making decisions about resource management is not a trivial activity and incorrect decision-making may have serious impacts on the quality of health care services. For this reason, managers need to be aware of everything that impacts ED performances. Once the current situation is understood, what-if scenarios can be used to establish ways of making decisions that result in ED performance improvement. Because of the complexity of the ED system, simulation is a useful tool to model it. In this paper, we present an efficient simulation-based optimization approach to test and validate different strategies in order to smoothen the patient's flow and optimize resource planning considering different criteria at the hospital center of Troyes (France). A discrete event simulation model (DES) is created to model the complex logistic flow of patients. The novelty of this paper, is first to take into account the daily patient arrival forecasts, obtained from a previous work [1], as input for this model that will serve as a tool for evaluating ED performances as well as evaluating solutions in the optimization approach. Second, multi-criteria analysis is integrated in the optimization part. VIKOR method coupled with entropy method is used to rank possible scenarios to present decision support for selecting the significant and appropriate scenario. A new benchmark was created to test different strategies. The model allows us to reduce the waiting time of patients and optimize emergency staff scheduling.

Methods

A DES model is created with ARENA simulation tool to simulate the patient complex flow. The patient arrival is assumed to be non-homogenous during the hours of the day and the day of the week. Also, the forecasted patient's arrival obtained from a previous work [1] can be introduced as input data. The operations of medical tests are detailed, and virtual queues of patients' specimens are considered separately from patient queues. Based on the simulation results and the current situation, we have proposed with the managers of the ED of Troyes different scenarios that could improve ED performances. These scenarios can be classified into three categories. The first category is related to human resources adjustment strategy, the second category is related to examination rooms adjustment and the third category is related to process improvement strategy. To analyze these scenarios, we consider three criteria: waiting time, inpatient stay and the cost related to the add of resource. 164 scenarios were created which allowed us to have a new benchmark that does not exist in the literature.

Therefore, VIKOR method [4] was applied to rank scenarios by considering conflicting criteria, entropy method [2] to specify the weight of each criterion. We justify the use of VIKOR method with the growth in the number of papers published related to this method from a single article in 2004 to 180 articles in 2015 in different fields. However, only 5 papers are related to health care field [3]. All in all, these premises made the model a new approach in order to reflect the reality as much as possible in the model and also aimed to assist decision makers to select the best alternative effectively. Figure 1 shows the simulation based-optimization approach.

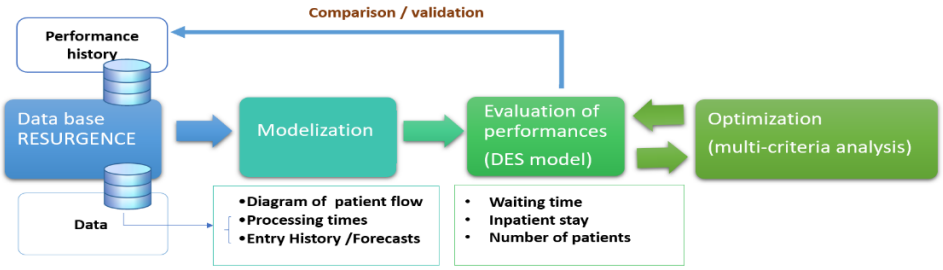

FIG. 1 – Simulation-based optimization approach

Results and Conclusion

The comparison between the real and the simulated performances of the DES model shows a gap less than 9%. This deemed the model validated and apt to support experiments. Using this efficient model, different strategies have been proposed to evaluate the impact of each scenario. This led to a multi-criteria analysis through VIKOR and Entropy methods to help the decision maker to find the best decision. Results analysis related to human resources adjustment scenario and VIKOR method application shows that implementing the first scenario in the ranking list would reduce the patient's waiting time by approximately 22 minutes and by 9 minutes for inpatient stay, and it require the add of a nurse from 6AM to 13PM. For category 2, results analysis of examination rooms adjustment scenario showed that there is no significant impact on performances when we close or open other examination rooms. However, in category 3, the results related to process improvement scenario shows that closing the fast Track area from 10PM to 10AM will reduce waiting time with an average of 5 minutes in fast track area and 25 minutes in urgent care unit. However, this modification has almost no impact on the average inpatient stay. Also, adding a second triage nurse during the shift 10pm to 10am will reduce the waiting time with an average of 5 min and the inpatient stay with an average of 2 minutes in fast Track area and urgent care unit.

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