

# Modelling and Simulation of Patient Flow in the Emergency Department During the COVID-19 Pandemic Using Hierarchical Coloured Petri Net

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## ABSTRACT

The emergency department (ED) faces great challenges during the corona pandemic, which has greatly affected the course of work, as the medical staff works to maintain the quality of service and more guarantee the health of patients and staff. With the rapid spread of the coronavirus, ED has become the focus of attention of many researchers, where most of them focused on reducing waiting time and the duration of the patient's length of stay (LOS) through the restructuring of ED. In this study, the authors propose a simulation model using the hierarchical coloured-petri nets (CP-Nets). Several improvement scenarios have been suggested in order to arrive at the optimal solution. Scenarios were compared and solutions were presented to decision makers. This study was conducted at the Hassani Abdelkader Hospital in Sidi Bel Abbes. The authors obtained a model that could be generalized to other hospitals.

## KEYWORDS

Decision-Makers, Healthcare, Length of Stay, Optimization, Patient Flow, Simulation Model, System Modeling, Waiting Time

## INTRODUCTION

A hospital emergency department (ED) is an important unit that requires a high degree of interconnectedness and coordination between the physical and human elements. The ED also requires its employees to work at different hours, day and night, and weekends. Therefore, planning in the emergency department is one of the most difficult problems for medical staff (Yeh & Lin, 2007). The ED employs the best doctors and nurses who have been specially trained in the field of emergency medicine. Providing emergency care requires the necessary skill in life-saving techniques, and extensive knowledge of all types of diseases and injuries. The COVID-19 outbreak has posed many problems for the ED, requiring an urgent restructuring of many aspects of ED. Also, the way of work must be reviewed, and safe and rapid measures taken for all patients, while preserving the safety of employees (Kraftin, et al., 2020).

To improve and develop the ED services, several methods were used which include demand management, process mapping, statistical forecasting, queuing theory, critical path identification, and computer simulation (Eitel, et al., 2010).

Nowadays, the simulation approach is the technique commonly used in health care management. Simulation has been used successfully in many different fields such as system services, manufacturing, transportation, medical sector, supply chain, and so on. Moreover, the simulation approach has become one of the best techniques for decision-makers to analyze, evaluate and review any operating systems, whether simple or complex (Najmuddin, et al., 2010).

The main objective of this paper is to reduce the patient's length of stay (LOS), which is an important key performance indicator (KPI) for the ED, and has been focused on by several researchers (Yousefi& Ferreira, 2017; Nas&Koyuncu, 2019), to assess the level of Healthcare quality and patient satisfaction. In this study, we used modeling by a Hierarchical Coloured-Petri Nets (CP-Nets) to create a generic model of ED, a modality widely used to describe complex systems (Jensen, et al., 2007; Derni, et al., 2019).

The remainder of this article is organized as follows. In Section 2 we mention some of the literature that was used in the emergency department. The hospital in which the study was conducted is described in Section 3. Section 4 contains a research methodology through which we present the simulation model and discuss scenarios for improvement. The final section contains a summary of future work and solutions.

## LITERATURE REVIEW

The use of computer simulations in the healthcare domain is not new, as it dates back to the late 1970s (Hancock, et al., 1979). Several researchers have focused on solving the problem of patient LOS in the ED using simulation techniques (Yousefi&Ferreira, 2017). Simulation has been applied in a multitude of issues such as analysis of patient data, mastery and optimisation of flows, process modeling, and resource scheduling (Derni, et al., 2019). For example, to reduce the patients' LOS, Nas and Koyuncu (2019) developed a simulation model to determine the optimal number of beds in the ED.

Mathematical models and algorithmic frameworks(Ala &Chen, 2019) were proposed to reduce patient waiting time and determine the timing of emergency center services, and to solve the patient scheduling problem, Tabu search method and L-shaped algorithm was used. Derni et al. (2019)[2] designed the Fuzzy Logic system in order to determine the appropriate amount of resources that could be added to ED, and to measure the improvement achieved, a CP-Nets simulation model was constructed and compared to the current state of the system.

Another study by Hsieh (2017), in which he proposed a sustainable architecture and a flexible scheduling scheme that dynamically allocates available resources in the hospital, in order to respond quickly to patients and provide timely healthcare services, in this study, the multi-agent system, the contract net protocol and the workflow specification models based on the Petri net were combined. For optimal resource planning in emergency departments, Yousefi et al. (2018) relied on an efficient method based on agent-based simulation, genetic algorithm, and machine learning, whereby many resources are modified, including the number of doctors, nurses, and receptionists, taking into account a number of limitations in the same Time.

To model medical protocols, Mahulea et al. (2014) depended on Petri net, the stages of the medical protocol followed by the patient are modeled in the form of a Petri net, at each stage of the protocol, the necessary resources are added to the model, in the last the complete model is obtained. To improve patient flow in the ED, Bappy and Rahman (2019) proposed a simulation-based model, in which a patient workflow was modeled while suggesting several alternative scenarios. The Analytical Hierarchy Process method was used in order to obtain a better scenario, where some resources are added and some are eliminated.

Providing timely information is very important, especially in critical times, so Niranjnamurthy et al. (2020) developed a web application and an application, the goal of this work is to obtain more information about the Coronavirus, these applications help decision-makers in the ED to make crucial decisions.

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