A Review on Simulation and Modelling for Patient Flow in Emergency Department

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Abstract. At the moment, most of the hospitals are more interested in patient satisfaction because this has been identified as a main issue of quality of service indexes. In most of the Asian countries the type of registration system being operated in the healthcare systems are a sort of mixed-mode. Specifically, there are scheduled patients, as well as patients who just walk in and register. Unfortunately, this type of registration structure could increase the patient waiting period even in emergency cases. Interestingly, various methodologies have been explored in order to shorten this undesirable waiting time. This paper focuses on exploration of the characteristics and significance of existing models and simulation techniques from the literature. The combination of agent-based modelling (ABM), DES and integration of DES and ABS technique has been chosen as the solution to modelling patient emergency waiting time in the emergency department realistically. The proactive and independent characteristics of agents in both approaches will contribute to the good representation of patient emergency waiting time in the especially in the emergency department.

1. Introduction

Simulation is one of the most robust approaches that have been explored for studying the seemingly problematic nature of some complicated service and manufacturing systems [1]. In general, simulation models are constructed to evaluate the changes in a system. For example, healthcare is one of the most important service sectors. Hence the level of service provided by the healthcare sector is of great importance and it has been often evaluated through simulation studies. This is particularly because most of these important sectors could be sometimes complex. On the other hand, the cost involved with the health care sector is reasonably large. As such, different optimization processes may be carried required. These days, it is possible to obtain credible forecasting and predictions based on results generated from simulation processes [2].

In another vein, modelling and simulation and modelling make it easier to reproduce a prototype of actual systems. This may then be used for purposes including performance simulation for optimization of certain technological processes, education and safety engineering purposes, testing, as well as healthcare and video games. As such, simulation and modelling are becoming more common in the healthcare sector [3]. In fact, the need to improve the performance quality of services rendered by the healthcare sector has suggested over time. As such, healthcare providers make it a priority to provide
quality services to patients especially in form of improved treatment among others [4]. Among the
various factors that may influence a patient’s satisfaction level, waiting time has been identified as
very crucial, as reported in literature [5,6]. Many researchers have argued the effectiveness of
modelling and simulation in healthcare departments, such as emergency departments (ED) [7].
Therefore, this paper aims to present a review on simulation with respect to patient’s waiting time in
the emergency department (ED), so as to reduce the waiting time.

The paper is organized as follows. Section 2 presents the emergency department simulation while
section 3 summarises the existing literature about ED improvement by simulation modelling to shorten
the patient’s waiting time. Section III is followed by the conclusion of this review and the
recommendations for subsequent studies.

2. Emergency Department Simulation
Healthcare is one of the notable sectors that have been extensively evaluated in recent times [7,8]. One
of the major issues associated with healthcare systems is challenge from overcrowding of patients in
the emergency department. This has been particularly investigated severally in many countries,
especially the U.S. [8,9]. Overcrowding at the ED is such a serious problem that it holds a critical
influence on patient safety. In fact, in some cases, it is capable of reducing the chances of survival for
patients who are severely injured, because of time length for which they have to wait [9, 10].

3. Overview of Existing Literature
The attention of different nations has been drawn to the consequences and negative impacts of
overcrowding and long waiting times in ED. As such different potential solutions have been put
forward [11]. Generally, the usual causes of overcrowding in the ED include non-availability of
sufficient resources [12], and increasing demand for services from the ED [13]. Notably, decision-
making in EDs is usually not very easy and it is in fact a very delicate process. This is particularly
based on its potential effect on the quality of services that may be obtained. It could also influence
mortality levels as well as the number of unattended patients in the ED [14,15]. Generally, the
challenges faced by the decision makers in the ED includes how to reduce congestion, how to shorten
the patient’s waiting time, and the less availability of the resources required in EDs for maintaining
high standards of patient services. On the other hand, emergency care units may be somewhat complex
due to the irregularities in patient arrival times, as well as lack of pre-knowledge about the type of
treatment they would require. It should however be reminded that the major duty of an ED is to attend
patient’s emergency and life-threatening conditions rather that to manage less or mildly injured or sick
patients. [14]. Figure 1 illustrates the patient flow in ED to three-parts input, processing, and output.

![Figure 1. Overview of the patients flow in the emergency department.](image-url)
Several methods have been explored for modelling the ED. Notably, three-modelling approaches have been explored such as agent-based modelling (ABM), Discrete Event Simulation (DES), and an integration of DES and ABS. In a particular study [15], the agent-based modelling (ABM) framework was proposed for use, to simulate the behaviour of patients leaving the ED of government hospitals unnoticed. This was termed leaving without being seen (LWBS). Observed that the number of LWBS patients was reduced by about 42.14%. Likewise, there was reportedly a decrease of around 6.05% in the patient’s average length of stay (LOS) [15]. ABM technique is a facile tool that may be used to represent any particular environment. It is also a very important tool to assist decision-makers to evaluate the relative influence of their control systems.

As a solution to overcoming the challenges associated with patient waiting times and other related challenges, the introduction of fast track, or entirely different section was proposed for low-acuity patients in the ED. This was done through a queue-based Monte Carlo simulation in MATLAB [9]. The model combined the principles of queuing theory and broadened the discrete event simulation in order to cover the time-based arrival rates. In addition, the ED habitation and nursing resource demand were designed and evaluated using the Emergency Severity Index (ESI) levels of patients, instead of the number of bed spaces in the department. The result of the simulation revealed that the introduction of a separate fast track with an additional nurse helped to reduce the overall median waiting times.

Generally, from literature, it was observed that authors made use of a DES model in which patients just walk-in to clinics without prior schedule [16]. A case study was carried out on a walk-in clinic situated in central Texas. The research work by [8] presents the application of Business Process Model (BPM) in healthcare sector, using the Business Process Model and Notation (BPMN), coupled with a multidimensional Agent Based Model (ABM) of multidimensional organizational network of resources and geography.

The research work by [17], proposed a technique for incorporating discrete event simulation (DES) and agent-based simulation (ABS) in order to reduce patient waiting time. This was the first time such approach was attempted to solve this critical problem faced by orthopaedic departments. From the data generated, the behaviours of patients were modelled and integrated into an extensive agent-based simulation. The proposed technique helped the orthopaedic department in their analysis, and to carry out necessary modifications as required. It also helped them to be more detailed and to come out with credible results.

Other than that, [18] are tried to extend the application domain of metamodels into decision-making in the EDs. This was done by fabricating a discrete event simulation (DES) model in combination with other suitable metamodels. This was used as an innovative support system for decision-making in order to improve the flow of patients, and to reduce congestion by introducing changes to the number of ED resources (i.e., the number of receptionists, nurses, residents, and beds).

4. Conclusions
Based on the review of the existing literature, it summarizes and concludes the findings from the articles. There are individual and combined techniques which has been used to model patient emergency waiting time in the emergency department. It can be seen that DES is the most popular and most frequently used by the researchers to model patient emergency waiting time. On the other hand, the integration between ABS and optimization method is the most recent and it is fast becoming a more powerful approach. However, there are few reports so far with respect to modelling patients waiting time in the hospital by using the decision-making techniques. Thus, this paper proposes that this approach should be used to model flow of patient in the ED of hospitals so as to improve the waiting time by using the simulation techniques discussed in this literature review. Furthermore, future studies should focus on investigating the simulation models for ED simulation technique which will show a good representation of the real-world patient flow in emergency department (ED) in term of waiting time. As future work, will be using the simulation technique to calibrated more EDs to validate the result adaptability. More health care sub systems, such as EDs, out-patient service units,
and in-patient units should be simulated and connected together in subsequent studies. On the other hand, simulation model may be combined with optimization algorithms to optimize the performance of ED systems.

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References
[1] Paul J A et al (2012) The Journal of Emergency Medicine 43(6) 1119-26
[2] Bocciarelli P et al (2014) Proceedings of the 2014 Winter Simulation Conference 3012-23
[3] Freeman K et al (2008) Journal of Peri Anesthesia Nursing 23(6) 387-393
[4] Eilers G M (2004) Journal of American College Health 53(1) 41-48
[5] Rohleder T R et al (2011) Health Care Management Science 14(2) 135-145
[6] Bernhart M H et al (1999) Social Science & Medicine 48(8) 989-996
[7] Richardson L D et al (2001) Academic Emergency Medicine 8(11) 1056-63
[8] Uriarte A G et al (2017) Operations Research for Health Care 15 102-122
[9] Jun J et al (1999) Journal of the Operational Research Society 50(2) 109-123
[10] Trzeciak S et al (2003) Emergency Medicine Journal 20(5) 402-5
[11] Paul S A et al (2010) Simulation 86(8-9) 559-571
[12] El-Masri S et al (2012) Journal of Medical Systems 36(6) 3917-23
[13] Afifal M et al (2016) IFAC-PapersOnLine 49(12) 721-6
[14] Nidal H et al (2018) National Conference for Postgraduate Research 2018 (NCON-PGR 2018)
[15] Bai J et al (2018) Health Care Management Science 21(1) 1-24.
[16] Yousefi M et al (2018) Brazilian Journal of Medical and Biological Research 51(3)
[17] Huang D et al (2018) The American Journal Of Emergency Medicine 36(10) 1874-79
[18] Reese H D et al (2017) Proceedings of the 2017 Winter Simulation Conference 2764-73