Reducing the Throughput Time for Patient Flow in Emergency Department: Simulation and Modelling Overview

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Reducing the Throughput Time for Patient Flow in Emergency Department: Simulation and Modelling Overview

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Abstract-Satisfaction of patient considered as a main issue of quality of service in the healthcare sector. Typically, this satisfaction depends on the services quality provided by hospitals. Emergency Department (ED), as a critical department in the hospital, has a complicated registration system that may lead to increase the patient throughput time. Thus, to minimize this growing in the throughput time, numerous simulation and modelling, in the literature, have been developed and introduced. However, the throughput time in ED still represent in issue need for improvement to increase the ED performance. Therefore, in this paper, the main objective is providing an overview related to the characteristics and significance of current simulation and model techniques. As a result, in the ED realistically, integrating Agent-Based Simulation (ABS), Desecrate Event Simulation (DES), and System Dynamic (SD) techniques has been preferred as the solution to modelling the patient flow in ED and in turn may lead to decrease the throughput time. The proactive and independent characteristics of aforementioned techniques can contribute to the good representation the patients flow and their throughput time in ED.

Keywords: *Department Emergency, Simulation, Patient Flow, Throughput Time.*

1. Introduction

Simulation, as a high significant technique, has been developed to simulate the stochastic behaviour of sophisticated systems[1, 2]. The simulation models are overwhelmingly constructed to analyse adjustments on a system[3]. For example, the health care field is one of the most important service sectors, the service level is an key issue that has often been analysed depends on studies of simulation because the popularity of that system is too complicated [4]. Furthermore, many optimization methods correlated to health care field cost have a vast chances to be studied[5-8]. Currently, decision-making processes strategic and operative can depend on further accurate estimating [9, 10] , which can be achieved by using simulation modelling. The decision-maker grows a pearl of wisdom into the behaviour of the system, towards dissimilar possible options before committing efforts and resources, based on the result of that simulation studies [11]. Moreover, simulation and modelling are good ways to emulate the actual systems. They are applied in several sectors, such as simulation of technology for optimization the performance, safety, education, engineering, testing, video games and healthcare sector. Due to data analysis alone cannot give vision into healthcare systems that are quickly evolving into complex and dynamic systems, the simulation and modelling in healthcare sector is thriving[12]. Thus, the concept of enhancing the healthcare quality in

recently years of service has been frequently argued in patient satisfactions. Providers of healthcare attempt to introduce better treatment to patients. The patients come back to the hospital depend on the fulfilled with their experience of services [13]. Due to throughput time as a major element of patient satisfaction/dissatisfaction various researches have regarded patient in this term [14, 15]. Additionally, in [8], the relevant significance of numerous patient satisfaction factors are listed as well as locating the service throughput time to be one of the key factors. The significant healthcare indicator outcomes is the patient satisfaction and it plays a key role in enhancing the quality of healthcare for patients[11]. Consequently, growth the quality level and the efficiency of healthcare units without producing side effects to the health of staffs is the main goal of a healthcare system design via further pragmatic approach[16].
In many existing review studies, the effectiveness of modelling and simulation in healthcare departments are discussed, such as; ED, operating suits, nursing units, ambulatory patient care and auxiliary services[17]. In spite of this, the existing review studies fall short of sufficiently covering the simulation for the patient's throughput time in the ED with respect to its concept and the existing techniques. Therefore, this paper aims to give an overview on simulating the patient's throughput time in the ED.
The paper is organized as follows. Section II provides simulation of emergency department. Section III described the simulation technique for ED to improvement the performance by reduce the patient's throughput time. the conclusions and future sets are covered in the last section.

2. Simulation of patient flow in Emergency Department

Simulation is an extremely sturdy method that has been usage to learning the random probability behaviour of service systems and complicated manufacturing [1]. The ED is a medical treatment capability, specializing in critical status of patients who come without any previous appointment. The main anxiety according to the systems of healthcare is the issue of department of emergency overcrowding that has been extensively studied especially in the USA [18, 19]. The overcrowding in the ED is a thoughtful problematic, which has a serious effect on the safety of patient and reduce the survival opportunity of severe patients in some instances because of long throughput time. Subsequently, the whole national healthcare system and its competence to offer the minimal service in any country is endangered [19, 20].

Furthermore, the simulation broadly used to model the composite systems such as ED. Simulation is approved to emulate the present case of any procedure. Hence, the simulation allows decision-makers to emulate the actions of the system and offers a test bed to measure the operations and managerial policies changes and asses several options[21]. Meanwhile, the simulation technique used in ED, Agent-Based Simulation (ABS), Discrete-Event Simulation(DES), and System Dynamic(SD) are the furthermost employed tools for modelling and analysing systems regarding to the interests of users and the specify task addressed. DES is a tool for measuring the delivery structures efficiency, estimating changes in patient flow and testing the efficiency of resource in staffing. SD concern of construction on behaviour. SD is commonly used for higher level problems instead of addressing individual transactions like strategic managing controls, policy changes, or decision-making. ABS is relying on a "bottom-up" structure for the delivery of emergent phenomena based on individual interactions of resource units. Fig.1.1 illustrate the basic process of patient flow in ED[1]. The patient arrival to ED by walk-in or ambulance. Then, walk-in, the patient goes to registration or waiting room. Next, the triage nurse give assist for patient body condition and go to treatment, examination, or waiting room. Then, the examination takes the sample for patient and send the result for treatment. Finally, the treatment gives the patient report to end of diagnosis discharge, transfer to another hospital, or ward. In case of ambulance arrival, the patient goes directly to treatments part[1, 8, 22, 23].

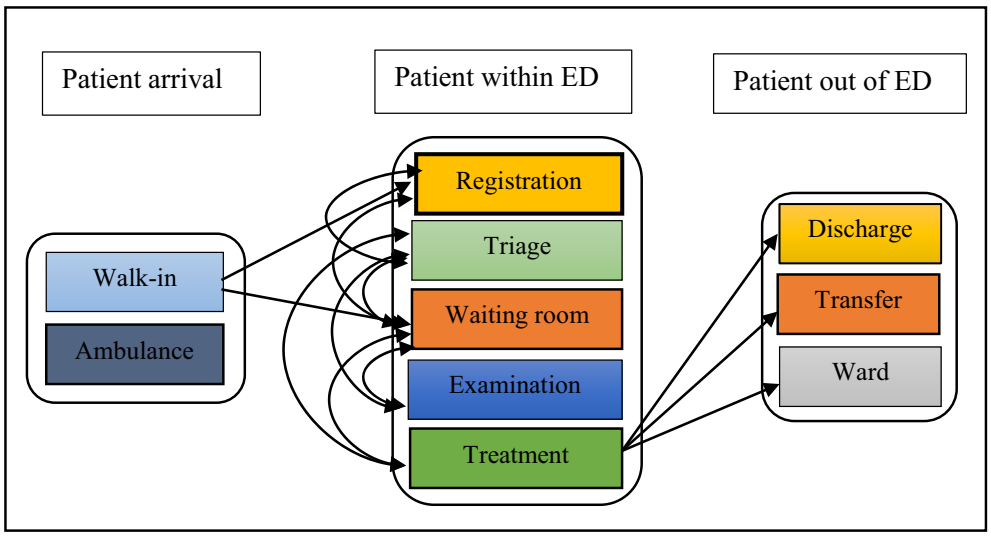

Figure 1. The Process of Patient Flow in Emergency Department

3. Simulation Technique for ED

Many simulation techniques for ED have been developed in the previous works. Thus, in this section, the author/s successful to discuss the common and powerful works introduced. In the work [24], the authors presented lengthy of ED length of Stay (LOS) related with patient experience and poorer medical outcomes. At the hospital community, the trauma patients were experiencing expanded LOS in commensurate with their medical diagnosis. The goal was to find if the modifications of functioning in the patient flow would decrease the LOS for trauma patients. Another work [25], introduced an agent-based simulation modelling in the ED. In a conventional approach, manager assigns the resources, like nurses, receptionist, doctors, and so on, to various units rely on the personal experience or by using decision-making tools. In that work, each agent of staff, based on their observation in their respective sections, took a part in the process of assigning resources, which gave the system the benefit of utilizing all the obtainable human resources through the work day by being assigned to a various unit. The yields of each simulation were number of patients who leave the emergency department without being attended, number of deaths, waiting time, length of stay, and total number of discharged patients from the ED.

An explored effect on throughput times of patient and resource of nursing request from the fast track additional unit in the ED using a queue-based Monte Carlo simulation in MATLAB [26] . in this model, the principles of queueing theory and expanded the discrete event simulation to account for time-based arrival rates are integrated. Furthermore, the nursing resource demand and ED occupancy are analysed and modelled using the Emergency Severity Index (ESI) patients' levels, rather than the number of beds in the department. Simulation results specified that the extension of a separate fast track with an additional nurse reduced overall median wait times.

In another research [18], the authors reported that in order to improve the processes of the ED, there is need to consider the various factors and targets in dynamic and unpredictable environment. This could therefore make the whole decision-making process more challenging[9, 27, 28]. As such, a possible way through it is to utilize different tools and techniques to facilitate the decision-making process. A novel approach in healthcare which combined DES, Simulation Based Multi-Objective Optimization, and Data Mining

techniques were introduced. This technique was applied to ease the analysis of the system in a Swedish ED. Overall, the result of the system helped to proffer a suitable way to decision-makers in designing rules which could significantly reduce the length of stay and waiting times for patients in the ED.

Throughout the literature by [16], the authors derive a DES model to examine the patient walk-in clinics where patients are assisted without schedules. A case study is argued that a considers a walk-in clinic located in central Texas. The computational study provides useful insights that are appropriate to any walk-in health care services. In this study, presenting the application of Business Process Model (BPM) in healthcare part using the Business Process Model and Notation (BPMN), together with a multidimensional ABS of resources multidimensional organizational network and geographical. In the work [29], a technique for improving the performances at an ED in a large hospital has been developed, where the long throughput times and unstable utilization produce issues for patients and staff of ED. This technique, simulates patient flow in the ED firstly and then, finds bottlenecks that give rise to uselessness in the performance of ED. In the simulation model, patient arrival is assumed to be non-homogenous and the operation of medical tests such as MRI, CT scan, pathology testing, laboratory testing, ultrasonography, and radiology are detailed, and virtual queues of patients' specimens are considered separately from patient queues.

The research work by [25] , proposed approach for integration of DES and ABS to decrease the throughput time of patient and is the first try to apply this way to resolve the issue throughput time on orthopaedic departments. Based on the gathered data, patient behaviours are modelled and assimilated into a massive ABS. The introduced approach is an assistance analysing and modifying orthopaedic department procedures, allows us to provides more reliable results and consider far more details.

Other than that, [23] are extending application domain of meta-models into decision-making in the EDs by developing a DES model combined with suitable meta-models. This is used as a novel decision support system to improve the patients flow and relieve congestion by changing the number of ED resources (i.e., the number of receptionists, nurses, residents, and beds). This new tool could be used for decision-making in operational, tactical, and strategic levels. Experimental results with the current ED budget verify that after using the resource allocation obtained from the proposed model, the total throughput time of patients is reduced. However, according. Cassettari et al in [30] used the SD simulation and modelling in a variety of ways related to emergency medicine. SD has been used for crowding problem which is a common target to uncover essential flaws in an ED teamwork scheme. SD approaches have extensive efficacy on decision-making, which it seems highly applicable to emergency medicine.

Zhao et al.[31] , introduce a method for detecting the bottleneck in the ED, and to improve them through the use of benchmarking and design of experiments (DOE) in simulation model. Notably, overcrowding in the ED is well known to be an increasingly critical challenge to public healthcare. The bottlenecks that influence overcrowding in the ED have been identified in order to improve the flow of patients. Originality/value of integration of benchmarking and DOE in simulation modelling proposed in this research presents a potential time-saving process for identifying bottlenecks in the operations of the ED. This approach introduced by The work by [32] showed that about 50% or more patients may be attended to in a "fast track" process in comparison with the conventional procedures in many some ED. However, most of the researches on ED fast track processes were based on evidence without actually making use of a competent decision tool depict the applicability of the obtained results. On the contrary, an agent-based simulation tool was proposed by [33] to assess fast track treatment (FTT) in an ED. The simulation results provided detailed information for the FTT implementation procedures at the ED in order to reduce patient waiting time.

4. Conclusion and Future Sets

The findings of this research paper discussed the techniques with throughput time in the ED used to model patient emergency. Several techniques have been used individual or integrated to model the patient flow to save throughput time in the ED. DES is the greatest common and most regularly applied in many studies to model patient emergency throughput time. Whereas, SD effected on strategic decision-making, controls, management, or policy changes. Otherwise, the combination of ABS and DES is the newest and that is becoming more useful method. Nevertheless, there is a few works have been found so far, that modelling patient's throughput time in the hospital by using the techniques of decision-making. As a future work, the authors will be going to use the simulation technique to standardised more EDs and validate the result adaptability. The optimization for the ED performance, simulation model may be integrated with optimization methods. Additionally, several healthcare sub systems, such as EDs, out patient service units, and in patient units have to be integrated and simulated.

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Reference

[1] N. Hamza, M. A. Majid, K. Adam, and N. A. A. Bakar, 2019, "A Review on Simulation and Modelling for Patient Flow in Emergency Department," in *IOP Conference Series: Materials Science and Engineering*, p. 012037.

[2] M. A. Majid, K. Z. Zamli, and M. A. I. Fakhreldin, *2015,*"Modelling a Complex Human Centre Queuing System for Enhancing the Capability of Agent Based Simulation," in *Proceedings of the International Conference on Data Engineering (DaEng-2015)*, 2019, pp. 383-391.

[3] J. A. Paul and L. Lin, 2012, "Models for improving patient throughput and waiting at hospital emergency departments," *The Journal of emergency medicine,* vol. 43, pp. 1119-1126.

[4] D. Daldoul, I. Nouaouri, H. Bouchriha, and H. Allaoui, 2018 ,"A stochastic model to minimize patient waiting time in an emergency department," *Operations Research for Health Care,* vol. 18, pp. 16-25.

[5] F. Hujainah, R. B. A. Bakar, M. A. Abdulgabber, and K. Z. Zamli, 2018,"Software Requirements Prioritisation: A Systematic Literature Review on Significance, Stakeholders, Techniques and Challenges," *IEEE Access,* vol. 6, pp. 71497-71523.

[6] Z. Liu, D. Rexachs, F. Epelde, and E. Luque, 2017,"A simulation and optimization based method for calibrating agent-based emergency department models under data scarcity," *Computers & Industrial Engineering,* vol. 103, pp. 300-309.

[7] K. Wylie, J. Crilly, G. Toloo, G. FitzGerald, J. Burke, G. Williams*, et al.*, 2015,"Emergency department models of care in the context of care quality and cost: A systematic review," *Emergency Medicine Australasia,* vol. 27, pp. 95-101.

[8] E. Alhroob, M. F. Mohammed, C. P. Lim, and H. Tao, 2019, "A Critical Review on Selected Fuzzy Min-Max Neural Networks and Their Significance and Challenges in Pattern Classification," *IEEE Access,* vol. 7, pp. 56129-56146.

[9] F. Hujainah, R. B. A. Bakar, and M. A. Abdulgabber , 2019,"StakeQP: A semi-automated stakeholder quantification and prioritisation technique for requirement selection in software system projects," *Decision Support Systems,* vol. 121, pp. 94-108.

[10] W. Abo-Hamad and A. Arisha, 2013,"Simulation-based framework to improve patient experience in an emergency department," *European Journal of Operational Research,* vol. 224, pp. 154-166, .

[11] A. B. Tehrani, S. R. Feldman, F. T. Camacho, and R. Balkrishnan,2011, "Patient satisfaction with outpatient medical care in the United States," *Health Outcomes Research in Medicine,* vol. 2, pp. e197-e202.
[12] K. Freeman and S. A. Denham, 2008,"Improving patient satisfaction by addressing same day surgery wait times," *Journal of PeriAnesthesia Nursing,* vol. 23, pp. 387-393.
[13] G. M. Eilers, "Improving Patient Satisfaction With Waiting Time,2004," *Journal of American College Health,* vol. 53, pp. 41-48, 2004/07/01.
[14] T. R. Rohleder, P. Lewkonia, D. P. Bischak, P. Duffy, and R. Hendijani, 2011,"Using simulation modeling to improve patient flow at an outpatient orthopedic clinic," *Health care management science,* vol. 14, pp. 135-145.
[15] M. H. Bernhart, I. Wiadnyana, H. Wihardjo, and I. Pohan, 1999,"Patient satisfaction in developing countries," *Social science & medicine,* vol. 48, pp. 989-996.
[16] M. Sbayou, Y. Bouanan, G. Zacharewicz, J. Ribault, and J. François,2017, "DEVS modelling and simulation for healthcare process application for hospital emergency department," in *Proceedings of the 50th Annual Simulation Symposium*, p. 4.
[17] L. D. Richardson and U. Hwang, 2001,"America's Health Care Safety Net Intact or Unraveling?," *Academic Emergency Medicine,* vol. 8, pp. 1056-1063.
[18] A. G. Uriarte, E. R. Zúñiga, M. U. Moris, and A. H. Ng, 2017,"How can decision makers be supported in the improvement of an emergency department? A simulation, optimization and data mining approach," *Operations Research for Health Care,* vol. 15, pp. 102-122.
[19] S. Trzeciak and E. P. Rivers,2013, "Emergency department overcrowding in the United States: an emerging threat to patient safety and public health," *Emergency medicine journal,* vol. 20, pp. 402-405.
[20] J. Jun, S. H. Jacobson, and J. R. Swisher,1999, "Application of discrete-event simulation in health care clinics: A survey," *Journal of the operational research society,* vol. 50, pp. 109-123.
[21] N. Hamza, M. Abdul Majid, and M. Abdullateef ,2018,"IoT Cloud Simulation Managing Resources: An Overview," in *National Conference for Postgraduate Research 2018 (NCON-PGR 2018)*, UMP Gambang, p. 7.
[22] F. Hujainah, R. B. A. Bakar, B. Al-haimi, and M. A. Abdulgabber, 2018,"Stakeholder quantification and prioritisation research: A systematic literature review," *Information and Software Technology,* vol. 102, pp. 85-99.
[23] H. Hajjarsaraei, B. Shirazi, and J. Rezaeian, 2018,"Scenario-based analysis of fast track strategy optimization on emergency department using integrated safety simulation," *Safety science,* vol. 107, pp. 9-21.
[24] M. Yousefi, M. Yousefi, F. Fogliatto, R. Ferreira, and J. Kim, 2018,"Simulating the behavior of patients who leave a public hospital emergency department without being seen by a physician: a cellular automaton and agent-based framework," *Brazilian Journal of Medical and Biological Research,* vol. 51.
[25] C. Kittipittayakorn and K.-C. Ying, 2016,"Using the integration of discrete event and agent-based simulation to enhance outpatient service quality in an orthopedic department," *Journal of Healthcare Engineering,* vol. 2016.
[26] K. Fitzgerald, L. Pelletier, and M. A. Reznek, 2017,"A Queue-Based Monte Carlo Analysis to Support Decision Making for Implementation of an Emergency Department Fast Track," *Journal of healthcare engineering,* vol. 2017.
[27] M. H. Yarmohammadian, F. Rezaei, A. Haghshenas, and N. Tavakoli, 2017,"Overcrowding in emergency departments: a review of strategies to decrease future challenges," *Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences,* vol. 22.
[28] A. Nahhas, A. Awaldi, and T. Reggelin, 2017,"Simulation and the Emergency Department Overcrowding Problem," *Procedia Engineering,* vol. 178, pp. 368-376.

[29] A. Gharahighehi, A. S. Kheirkhah, A. Bagheri, and E. Rashidi,2016, "Improving performances of the emergency department using discrete event simulation, DEA and the MADM methods," *Digital Health,* vol. 2, p. 2055207616664619.
[30] L. Cassettari, R. Mosca, A. Orfeo, R. Revetria, F. Rolando, and J. B. Morrison, 2013,"A System Dynamics Study of an Emergency Department Impact on the Management of Hospital's Surgery Activities," in *SIMULTECH*, pp. 597-604.
[31] Y. Zhao, Q. Peng, T. Strome, E. Weldon, M. Zhang, and A. Chochinov, 2015,"Bottleneck detection for improvement of Emergency Department efficiency," *Business Process Management Journal,* vol. 21, pp. 564-585.
[32] A. Kaushal, Y. Zhao, Q. Peng, T. Strome, E. Weldon, M. Zhang*, et al.*, 2015,"Evaluation of fast track strategies using agent-based simulation modeling to reduce waiting time in a hospital emergency department," *Socio-Economic Planning Sciences,* vol. 50, pp. 18-31.
[33] F. Zeinali, M. Mahootchi, and M. M. Sepehri, 2015,"Resource planning in the emergency departments: A simulation-based metamodeling approach," *Simulation Modelling Practice and Theory,* vol. 53, pp. 123-138.