

# Application of Lean System Principles in Healthcare Services Using Arena Simulation

Dhuha Kadhim Ismayyir

Aseel Jameel Haleel

*Department of Production Engineering and Metallurgy, University of Technology, Baghdad, Iraq*

[70215@uotechnology.edu.iq](mailto:70215@uotechnology.edu.iq)

[70216@uotechnolog.edu.iq](mailto:70216@uotechnolog.edu.iq)

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## Abstract

This research aims to apply lean principles to the Emergency Department (ED) at Sheikh Zayed Hospital. Lean techniques are used in order to eliminate waste, waits and increased patient satisfaction. Lean defines the wastes but not identify which waste should be eliminated for this reason Arena 14.00 Rockwell simulation software used to analyze the ED performance. Patient's flow chart was created to study the total duration of patients stay in the ED, the waiting time and the utilization of resources based on the lean principles approach. The results identified and concluded from simulation model were as the follows, the patient flow time was (65) minute for each patient (total time that patient spent from the beginning of his entry into the ED until he discharged), while patient throughput in morning shift about (241) patient (the number of patients attending the department during morning hours). On the other hand, the utilization ratio of doctors, nurses, receptionists were (83 %, 13 %, and 95 %) respectively. This is demonstrating the applicability and effectiveness of lean principles to ED processes using the simulation model as a pre-implementation tool for improvements in health care sectors.

**Keywords:** Lan principles, Health care, Patient flow, ED, Waiting time, Arena.

## 1. Introduction

Customer satisfaction in health care institutions is a higher priority than industrial companies because the patient is the client and patient health is the goal. Therefore, a methodology such as Lean that can help in raising patient satisfaction is workable and useful for implementation in health care sectors [1]. Lean was used in the construction, electronics, finance and aerospace industries as well as in healthcare. Over half a century of the past decade, lean approaches have become more widely embraced, especially in industrial and manufacturing industries. similarities, whether manufacturing a car for example or providing health care, the health care varies in many ways from manufacturing, there are great attention for patient health care, the workers should have applied various complex processes in order to achieve jobs and provide value to the customers or patients. The time and money wastes or the flow of patients / workers, supplies or goods will diminish the value [2,3]. The lean thinking in the health care sector was presented in an organized and structured techniques in 2006. The (Lean Enterprise Academy LEA) is a "British non-profit organization devoted to the study and dissemination of lean thinking", created the first conference on the application of the lean principles in the health services [4]. Long waiting times, increased medical errors, delayed test results, and others of examples, leads to patient dissatisfaction. For that reasons, the lean principles provide a better way to determine a good quality serving that satisfy the patients. Lean in Healthcare is based on facilitating processes by comprehension what adds value as well as waste elimination. Simulation is a simple lean principle tool that helps to see the bottlenecks of the current status and the influence of implementing it the system statistically [5].

## **2.Literature Review**

All the organizations even health care organization, contain a combination of processes, or collection of activities designed to generate value for those who use or depend on them (customers / patients). Lean principles didn't only apply in manufacturing area but also widely applied in the serving sector, cause most serving operations are delayed and include too much inventory work during the process, so that's causing unnecessary complicated in the serving/ product offering [6]. Dickson et al. 2009 [7] provided an example about the long waiting periods for doctor's examinations and long walking distances to describe a lean waste. Patients do not want to face these kinds of delays through their ED trips. Problems including the waiting time at each stage in the ED affect the process in a negative manner. Mazukato et al. 2012 [8] conclude that the waiting time problems are mainly acquired from the breakdown of the process, these problems must be minimized and the process flow should be considered. Robinson et al. 2012 [9] reported that the lean principles and simulations should be applied simultaneously in the health care sector, by using a separate lean with event simulation the process will be better designed than applied lean as a tool. Weerawat et.al 2013 [10] create a simulation model to identify bottlenecks in delayed times and resources. Khlie and Abouabdellah 2015 [11] proposed modeling and simulation of the path of the patient in order to better understand the demand, to highlight the need in terms of human resources, as well as to uncover the various waste sources present in the value chain. Simwita and Helgheim 2016 [12] developed different scenarios to determine the best resource elasticity scenario and explore the impact of resource flexibility on patient waiting time, productivity, and future changes in demand. Improtta et al 2018 [13] applied lean in ED for fastening patient flow and improve processes that facilitate patient flow during different medical treatments.

## **3. Lean Management in Hospitals**

The critical role of health care in people's lives and improved quality of sanitation, which increases efficiency among health care institutions, has led to significant improvements in the healthcare sector. Several problems such as waiting times and medical errors can lead to fail in the healthcare process. Lean philosophy began to be used in hospitals to treat these wastes [14]. Lean's successful implementation can lead to less rework, shorter time periods, higher financial savings, and fewer stocks, making small enterprises flexible in dynamic markets and more responsive. Healthcare operations are arranged in a systemic way with a concentration on doctors, nurses and different clinical staff and are often not improved for patients. Given the complexity of healthcare systems, much of the work done within the healthcare environment does not add value directly from the patient's point of view. It is seldom determined how processes work best in health care operations. The result is inconsistent care, unreliable access to processes and resources, and persistent interruptions, which in turn means inefficiency, long waiting times, increased likelihood of errors, and worker frustration [15]. Therefore, the simulation model proved to be an effective tool used to improve the process, especially when combined with the Lean principle. Emergency Department (ED) is the main area where a large number of patients stream during the day.

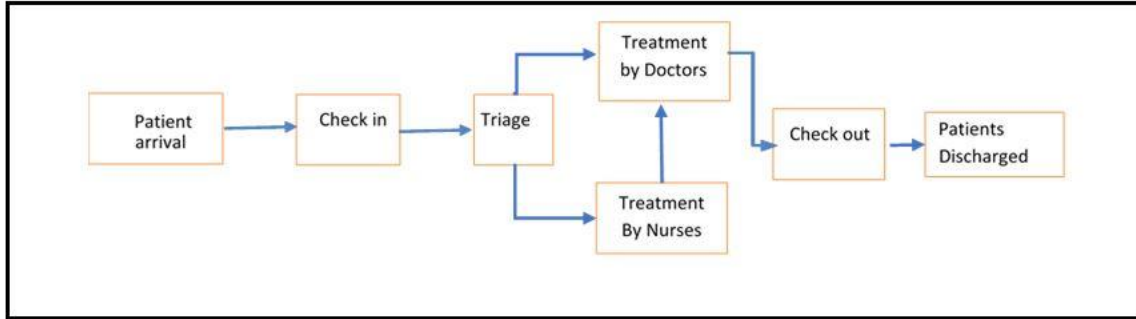
## **4. Methodology**

### **4. 1 Data Collection**

To get a full understanding about patient's flow time and utilization of resources at the Emergency Department (ED) in Sheikh Zayed hospital that is one of the hospitals in Baghdad city for emergencies as well as providing services in the field of neurology, several interviews with ED staffs and the income patients were performed. The interviews scheduled for three months' periods, and it's done to get information that's aid to construct a simulation model. Sheikh Zayed hospital provides medical care to the people through 24 hrs. with two shifts (morning and evening). Medical staff of the morning shift consists of three receptionists at the reception room, six doctors on the premises, and fifteen nurses.

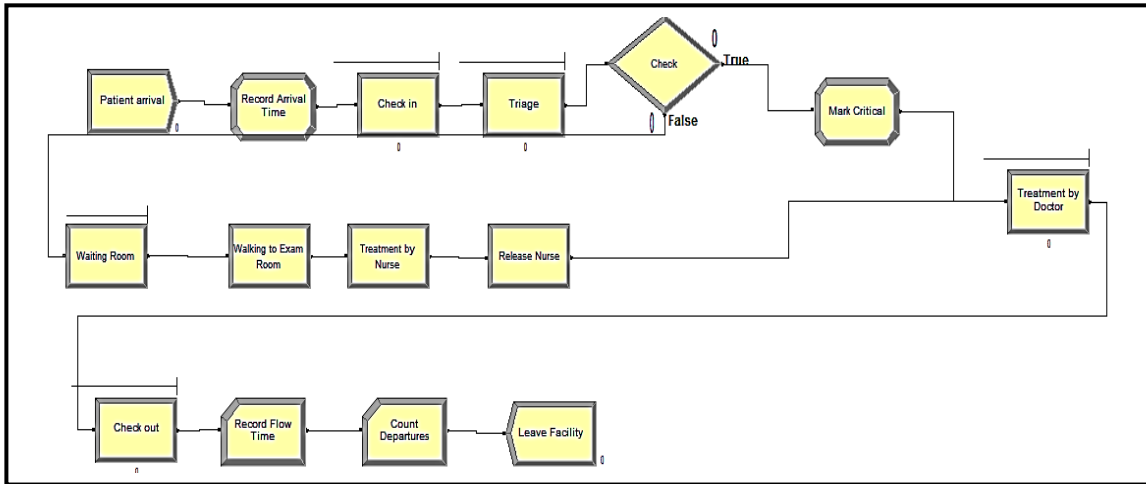
### **4. 2 Construct Arena Simulation Model**

Due to increasing healthcare delivery complexities, simulation has proved to be an effective that can be used to improve healthcare processes. Lean thinking can be a driving point to improve a patient's journey through the different stages starting from the time entering the department, taking a token number, waiting for an initial checking in triage and waiting for a doctor to check the patient until the time the patient is leaving the hospital. Figure (1) illustrates the patient pathway in ED.



**Figure (1): Patient pathway in ED**

The simulation model is constructed by using Arena 14.00 Rockwell Automation software. The model is simulated for three months period. The process starts with the arrival of the patient at the entrance of the Emergency Department and subsequent patient preregistration, and patient triage. Whereas, Patients arrive to emergency room with mean interval time equal to (3) minutes, assuming that the patient arrivals were exponentially distribution. Firstly, the income patients checked between (2-5) minutes by the receptionist at the reception room. Then each patient undergoes triage (first aid treatment given to the patient) in order to check the criticality level by the doctor based on First in First Out (FIFO) order with time spent between (4-7) minutes. In this stage, critical and non-critical patients have been identified. Treatment time of critical patients is between (20-25) minutes. Non critical patient's condition is waiting in the waiting room, then treated by nurses in examination room include measuring blood pressure, and other simple examinations. The time spent to reach the patient for examination room was between (1-4) minutes, and treatment time taken by nurse was between (3-8) minutes. Also arrival mean of non-critical patients for doctors based on FIFO to approve the treatments which takes time between (3-5) minutes. All patients (critical and non-critical) checked out at the reception room which takes time between (4-6) minutes. Then the patients leave the ED. Figure (2) shows the simulation model of patient process flow.



**Figure (2) Simulation model of patient process flow at ED**

### 4.3 Results and Discussion

From table (1) through table (3) represents reports of the simulation results run for (three months' period, for morning shift 12 hr.) (64.800 minutes) for the patient process flow at ED. Four key performance indicators have been calculated as follows:

- a) Utilization of ED staff (doctors, nurses, and receptionists).
- b) Average waiting time of the patients.
- c) Patient flow time in the ED.

d) Patient throughput (number of patient served per simulation time horizon) of ED.

Patient flow time through ED is illustrated in Table (1) whereas divided into three sections. In Tally section average total time of patient from arrival time to leave time was (65) minutes. However, the sojourn times have significant variability as shown by the minimum and maximum patient flow times. The counter section displays that the emergency department treated over (21,000) patients during its three months' period, while in output section display daily patient throughput about (241) patients.

**Table (1): Statistics of Patient Flow Time through ED**

| <b>Replication 1</b>     |                | Start Time:       | 0.00           | Stop Time:     | 64,800.00 | Time Units: | Minutes |
|--------------------------|----------------|-------------------|----------------|----------------|-----------|-------------|---------|
| <b>Tally</b>             |                |                   |                |                |           |             |         |
| <u>Interval</u>          | <u>Average</u> | <u>Half Width</u> | <u>Minimum</u> | <u>Maximum</u> |           |             |         |
| Patient Flow Time        | 65.4087        | 8.36513           | 20.0720        | 204.09         |           |             |         |
| <b>Counter</b>           |                |                   |                |                |           |             |         |
| <u>Count</u>             | <u>Value</u>   |                   |                |                |           |             |         |
| Count Departures         | 21,692.00      |                   |                |                |           |             |         |
| <b>Output</b>            |                |                   |                |                |           |             |         |
| <u>Output</u>            | <u>Value</u>   |                   |                |                |           |             |         |
| Daily Patient Throughput | 241.02         |                   |                |                |           |             |         |

While Table (2) shows utilization of the resources in ED. In usage section utilization of ED human resources and the number of real available resources is clarified. The instantaneous utilization has been calculated from an average time of which is the fraction of busy resources to real available resources at any specific time.

**Table (2): Utilization of Resources in ED**

| <b>Usage</b> |                  |                 |                  |                   |                   |  |
|--------------|------------------|-----------------|------------------|-------------------|-------------------|--|
|              | <u>Inst Util</u> | <u>Num Busy</u> | <u>Num Sched</u> | <u>Num Seized</u> | <u>Sched Util</u> |  |
| Doctor       | 0.83             | 4.97            | 6.00             | 43,402.00         | 0.83              |  |
| Nurse        | 0.13             | 1.89            | 15.00            | 15,261.00         | 0.13              |  |
| Receptionist | 0.95             | 2.85            | 3.00             | 43,398.00         | 0.95              |  |

The last report represents the statistics of waiting lines in ED as shown in Table (3) below.

**Table (3): Waiting Lines in ED**

| <b>Time</b>               |                       |
|---------------------------|-----------------------|
|                           | <u>Waiting Time</u>   |
| Check in.Queue            | 15.30                 |
| Check out.Queue           | 15.47                 |
| Treatment by Doctor.Queue | 3.25                  |
| Triage.Queue              | 2.40                  |
| Waiting Room.Queue        | 0.00                  |
| <b>Other</b>              |                       |
|                           | <u>Number Waiting</u> |
| Check in.Queue            | 5.13                  |
| Check out.Queue           | 5.18                  |
| Treatment by Doctor.Queue | 1.09                  |
| Triage.Queue              | 0.80                  |
| Waiting Room.Queue        | 0.00                  |

The average of waiting times is displayed in the time section; another section displays the average number of waiting patients in the lines of queues. We notice that waiting time of patients in the check in is the same waiting time of patients in checkout queues and are equal to (15 minutes), this is leading to higher averages of the patients waiting in the check in and checkout lines (five persons as average). The utilization of the receptionists is high and represent ratio (95%); this is an expected result of the fact that the receptionists are overworked. Also the average waiting time in the triage queue and treatment by doctor queue are over (2 minutes and 3 minutes) respectively. The utilization of the doctors is high equal to (83%), however the average of waiting patients in those lines an acceptable (one patient treated by a doctor in the queue and one patient in the triage queue as average). on the contrary, there is no waiting time for nurses in the waiting room, this is showing low utilization of nurses reach up to (13%) as a ratio.

### 5.Conclusion

In this work the Emergency Department (ED) at Sheikh Zayed Hospital\Baghdad was analyzed. The workflow in the ED was modeled using Arena simulation. The simulation model becomes a valuable tool which is helps in applying lean principles for continuous improvement efforts. The proposed simulation model considered various system performance measures such as patient flow time, patient throughput, patient waiting time and resources utilization. From the study results can concluding that if this model is to be implemented, it can potentially improve patient access in ED and identifying the number of doctors, nurses, and reception clerks that required for making the journey of patient short and effective, and if the patient throughput increase will result in reduction in patient waiting time, increase resources utilization and decrease the disorder in the emergency room. On the other hand, it's clear that the utilization ratio of the doctors was high and receptionists were overloading due to the high number of patients that access to this hospital compared with high number of nurses. This is lead to suggest for increasing the number of receptionists and doctors. Also, opening two access points, one for the ambulance and the other is for the entrance of the patients by foot in order to speed up the entry of patients to the ED.

### Conflicts of Interest

The author declares that they have no conflicts of interest.

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## تطبيق مبدأ نظام الترشيح في خدمات الرعاية الصحية باستخدام المحاكاة ببرنامج Arena

اسيل جميل

ضحى كاظم

قسم هندسة الانتاج والمعادن، الجامعة التكنولوجية، بغداد، العراق

[70216@uotechnology.edu.iq](mailto:70216@uotechnology.edu.iq)

[70215@uotechnology.edu.iq](mailto:70215@uotechnology.edu.iq)

### الخلاصة

يهدف هذا البحث لتطبيق مبدأ نظام الترشيح في قسم الطوارئ لمستشفى الشيخ زايد حيث يستخدم هذا المبدأ من اجل تقليل الضياعات واوقات الانتظار لزيادة رضا المريض. ان استخدام مبدأ لترشيح يحدد الضياعات ولكن لا يحدد اي الضياعات تحتاج للتقليل لذلك يتم الاعتماد على انظمة المحاكاة . تم إنشاء مخطط تدفق المرضى لدراسة المدة الإجمالية لبقاء المريض في قسم الطوارئ واوقات الانتظار واستغلال الموارد البشرية. حيث كانت النتائج من نموذج المحاكاة وكما يلي: الوقت الكلي للمريض الواحد من بداية دخول قسم الطوارئ الى خروجه (٦٥ دقيقة) و عدد امضى الواردين للقسم خلال الدوام الصباحي (٢٤١ مريض) من ناحية اخرى فأن معدل استغلال الموارد البشرية كانت ( الاطباء ٨٣% المرضين ١٣% وموضفي الاستعلامات ٩٥%). وهذا يوضح قابلية وفعالية تطبيق مبدأ نظام الترشيح باستخدام نموذج محاكاة كأداة للتنفيذ المسبق لتحسينات في قطاعات الرعاية الصحية.