A Simulation Model for Performance Improvement of Triage-Based Emergency Care

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Abstract— **The paper presents a discrete event simulation model to evaluate the performance in an emergency department. Following evaluation of current state of emergency care, the study proposes establishing a general medicine clinic within or next to the emergency department such that patients with low emergency priorities can be directed to the clinic where they can see a non emergency physician. Results obtained from testing the proposed model illustrate performance advantage with respect to urgent classified cases ranging from 19.27% to 24.36% reduction in waiting time compared to it in the traditional emergency department system.**

Index Terms— **Emergency department, discrete event simulation, emergency care, triage**

I. INTRODUCTION

Emergency departments continually function to provide immediate and initial care for patients. Typically, patient arrives at the admission of the emergency department is directed to triage for examination and classification based on the severity of the case, and is transferred to section where she/he waits for a physician. Based on checkup, physician decides whether a patient needs confirmation tests, or prescribes medication and discharge the patient. Following checkup and laboratory or x-ray tests when needed, physician decides to admit or discharge the patient. Following triage and throughout the process, the patient assumes a bed in the section until discharged. For patients being admitted, the patient continues assuming the bed during the admittance process.

At triage, a nurse listens to, takes vital signs, estimates the severity of the case and classifies patient accordingly. Patients are then admitted to emergency department and are treated in an order of the severity of their situations. In a Manchester triage system, patients who need immediate care are tagged red, patients with very urgent situations are tagged orange, patients with urgent situations are tagged yellow and 75% of patients have normal situations who can wait for long times before treated are tagged in green and blue [1].

The large number of unscheduled arrivals, the high variety of cases and the limited capacity in space and staff results in long patient times in the department and hence low levels of satisfaction [2]. Consequently, initiatives are directed to optimize the use of resources and eliminating wastes [4]. In the literature, several efforts were dedicated to improving the performance of the emergency department using engineering tools. Such efforts include using lean principles to reduce length of stay at the department [3], process simulation to reduce time [5], design for six-sigma to reduce waiting time [2] and theory of constraints to manage capacities [6].

This research studies the advantages of splitting an emergency department into two units namely an emergency unit for red, orange and yellow tagged patients, and a general medicine clinic for treating green and blue tagged patients. The study utilizes discrete event simulation to analyze and improve the department.

II. MODELING THE EMERGENCY DEPARTMENT

The emergency department can be viewed as a limited capacity queuing system where patients arrive at the department and one or more physicians are available to provide the required healthcare. The number of patients in the department is limited by the number of available beds and hence, management tends to increase the number of beds at the department to house the increasing number of patients. Mandahawi, et al. [2] reported that the number of patients arriving per year at the emergency department of the hospital in their study increased from 75,800 to 128,000 between 2004 and 2008.

The emergency department under consideration [6] has 18 beds and patients are served by 3 physicians; nurses and clerks are not considered in the model. Patients arrive at the emergency department at a rate of 10 patients per hour. The triage process is normally distributed with a mean of 4.08 minutes and a standard deviation of 1.04 minutes, where 1.1% of patients are tagged red, 2.2% orange, 36% yellow, 33.7% green and 27% are tagged blue. Both green and blue tagged patients are called cold cases, a total of 60.7%, and are examined once by physician and then discharged where examination time is normally distributed with a mean of 12.35 minutes and a standard deviation of 1.54 minutes. For red, orange and yellow tagged patients, the checkup process is normally distributed with a mean of 4.24 minutes and a standard deviation of 1.06 minutes, laboratory work is normally distributed with a mean of 38.6 minutes and a standard deviation of 10.36 minutes, and following tests, the evaluation process for patients to be admitted is normally distributed with a mean of 2.6 minutes and a standard deviation of 1.14 minutes and is like it for cold cases for patients to be discharged. Admitted patients include all red and orange tagged patients and 20% of yellow tagged

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patients. While discharged patients leave the department immediately following treatment, admitted patients continue assuming their beds for the entire admittance process which is uniformly distributed between 15 and 30 minutes.

The simulation model of the current state of the emergency department is based on the following assumptions: a patient is held outside emergency department until a bed is available; following triage, a patient is seen by the first available physician; cold tagged patients are discharged after seeing the physician; and following laboratory work, a patient is given a priority higher than that she/he started with and is seen by the same physician who performed the checkup on her/him. Figure 1 illustrates the flow of patients in the emergency department.

The simulation model of the proposed state of the emergency department is based on the following assumptions: a patient is held outside emergency department until a bed is available; following triage, all cold tagged patients are directed to a clinic and are seen by one physician and then discharged, while other patients are seen by the first available of the two emergency physicians for checkup; and following laboratory work, a patient is given a priority higher than that she/he started with and is seen by the same physician who performed the checkup on her/him. Figure 2 illustrates the proposed flow of patients in the emergency department.

III. MODELING RESULTS AND DISCUSSION

Both models are run over the hour (24 hours simulation period) for 365 days (number of replicates). Obtained results show that the average work in process for cold tagged patients increased from an average of 1.51 patients in current state to 16.28 patients in the proposed state, the average utilization of physicians was slightly less than 71% in current state and dropped for emergency physicians to about 45% and increased for clinic physician to more than 98% in the proposed state, Table 1 summarizes performance measures of the emergency department under the two scenarios.

Results in table 1 indicate improvement in the performance of the emergency department for non cold tagged cases. To further improve the proposed clinic system, management can increase the number of physicians at the clinic to lower the utilization of per physician, and limit the size of (number of patients in) the clinic system to reduce the expected time in the system. The low utilization of physicians at the emergency department can be contributed to several factors including the decreased arrival rate to the emergency department, long laboratory work times and long discharged times during which the patient assumes a bed waiting.

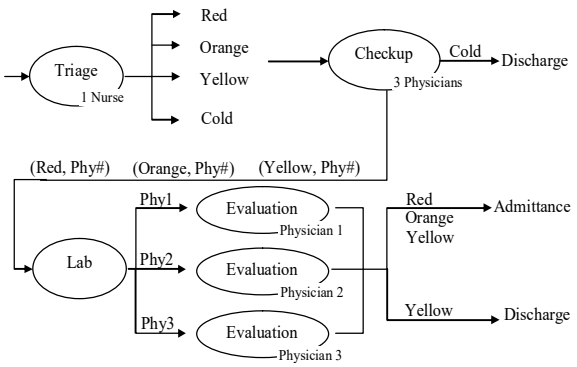


Fig 1. Flow of patients in the emergency department

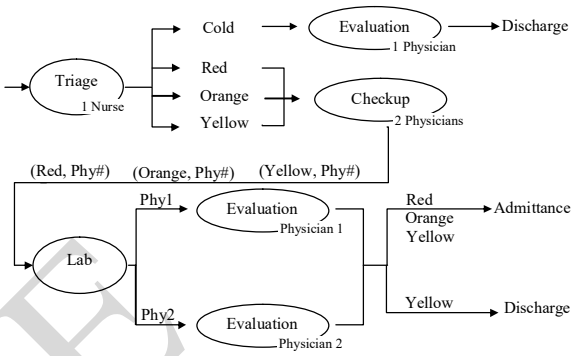


Fig 2. Proposed flow of patients in the emergency department

Table I: Performance Measures Of The Emergency Department

Measure State	**Average time in the system (half width)**				
	Red	***Orange***	***Admitted Yellow***	***Discharged Yellow***	***Cold***
Current	75.68 (2.63)	82.50 (1.21)	83.03 (0.44)	70.00 (0.29)	23.54 (0.27)
Proposed	73.86 (2.53)	80.28 (0.75)	80.51 (0.45)	67.69 (0.27)	169.5 (4.91)
% Improvement	2.40	2.69	3.04	3.30	-620.05
Measure State	**Average waiting time (half width)**				
Current	10.18 (0.80)	10.69 (0.55)	11.05 (0.34)	10.76 (0.24)	7.12 (0.27)
Proposed	7.70 (0.67)	8.63 (0.50)	8.79 (0.31)	8.51 (0.24)	153.07 (4.90)
% Improvement	24.36	19.27	20.45	20.91	-2049.86

IV. CONCLUSIONS

The study used discrete event simulation to compare the performance of an emergency department under two scenarios. The first scenario describes the current state of emergency care at the department, and the second scenario presents the proposed emergency care system based on treating cold tagged patients at a non emergency clinic within or next to the emergency department. Results obtained from

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testing the two models indicate a performance advantage for the proposed model over the current one in reducing the waiting times for urgent classified cases by 19.27% to 24.36% and hence reducing the total length of stay for patient at the emergency department. Further reduction on the total visit time per patient can be attained through reducing time waiting for laboratory results and time waiting for admittance.

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