



Reduction of Boarding Times to the Emergency Department

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ABSTRACT

Emergency hospital services (ED) was the main hospital entrance door and so was the almost obligatory passage for patients before admission in most health units.

The practice of blocking admitted patients (patients IP) on stretchers in the corridors of the hospital emergency services for hours or days, called "boarding" causes emergency space and can be harmful to patients. Boarding increases patient morbidity, length of hospital stay, and mortality.

In this article, we make the modeling of boarding patients in the emergency department to minimize overcrowding in emergency departments, using a network of queues open to the MMC, (The Model M/M/C is a multi channel queueing system with poisson arrival and exponential distribution) .

The results of this paper help the hospital administration to test alternative policies to improve overall performance.

Indexing terms/Keywords

Queues, statistical analysis, Emergency department, Boarding.

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1.INTRODUCTION:

The hospital emergency departments (ED) are an essential element in the movement of patients in a hospital. Emergency services typically have large volumes of patients, working under high use service many types of patients, and patients go out of most other areas of the hospital. Although the majority of patients in the emergency department returned to the house, about 20% of ED patients are referred to an IP device (IP patient) such as intensive care units, operating room, obstetric units.

One patient remained IP (board) to the hospital emergency department (ED) it is admitted to an IP unit and has no bed available.

The main problems caused by boarding patients in the emergency department ED

- Decrease the ability of ED service using emergency rooms with patients boarded.
- Increased waiting time ED patients, an increase in patients leaving without treatment because of the long waiting time

The purpose of this article is to provide a useful aid to decision makers for the service, and modeling boarding patients in the emergency department.

The article is structured as follows.

In section 2, the analysis of the state of the art.

In section 3, the modeling problem is presented.

In section 4, hospital estimation of ed boarding.

In section 5, conclusion.

1-STATE OF THE ART:

Given its complexity, the emergency department has been the subject of numerous studies dealing with issues related to the modeling, simulation and optimization of patient flow. In this sense, [Chausalet et al, 2006] aims to model the flow of patients in a health care system with an application in a geriatric ward in the UK, to provide a useful decision aid for the controller service. They use a closed network of queues with the hypothesis of a system always full. This means that the system operates at maximum capacity, the waiting list admissions to hospital is never empty, and in each phase output is immediately replaced by a new admission in the first phase. Using data from a Department of Geriatrics in the United Kingdom which contains three phases (acute care, rehabilitation and long-stay care).

Gorunescu et al (2002) use a model queue $M / PH / c / N$ to show how the use of waiting rooms can improve performance while controlling costs. Using statistical data and the theory of queues, they show how changes in three performance criteria (length of stay, admission rates, allocation of beds) influence bed occupancy, release into the geriatric department.

Against this backdrop, Koizumi et al (2005) extend the existing studies in the literature on networks of queues with blocking to analyze congestion in a psychiatric hospital in Philadelphia. Mathematical results and the simulation results are presented and compared. First, they use a model without blocking. Then they analyze this model with blocking by introducing the concept of "effective time of service", which contains two types of service time, called "processing time" and "blocking time". Model queues focuses on the phenomenon of blocking three psychiatric departments and the allocation of resources. The simulation is then used to analyze the behavior of the system and test the robustness of the proposed mathematical model. If the simplified mathematical model is useful for analyzing long-term performance, the simulation models are essential for the analysis of short-term performance.

Bruin et al (2007) examine the congestion patient flow in the department of cardiac emergencies. They want to determine the optimal allocation of beds for several levels of service given a maximum number of denied admission. Another objective is to show the relationship between natural variation in arrival, length of stay and occupancy rates. For the data they used, they verified that all admission rates and service time always follow the Poisson and exponential distribution and they study each department individually as a $M / c / c$ queue.

In this article, we make the modeling of boarding patients in the emergency department by using a network of queues open to the MMC.

Modeling the boarding of patients in emergency departments can be quite difficult because of the complex network of IP devices and the necessary theoretical models queues input estimates.

1- MODELING

Network queues

A network of queues [Gelenbe and Pujolle, 1998] is a set of stations queue consisting of a queue, where the entities are waiting for a service and a server on which the entities enjoy a service. Network theory of queues allows the calculation of several performance criteria, including the average waiting time in the queue or in the system (in our case, this is the queue of patients), the average number of patients waiting to receive a service.

This section presents a model of the theory of queues and estimation methodology to quantify ED boarding time. This method considers the Emergency Department as two multi-server Markov queues in series.

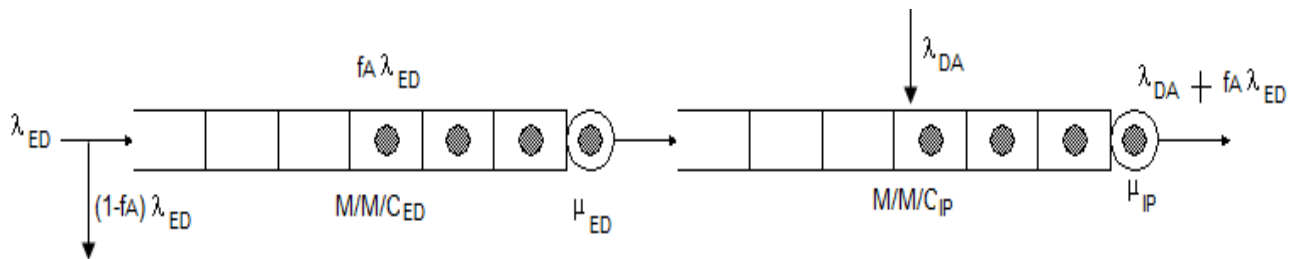


Figure 1: The ED and IP displayed as two queues in series.

The system studied is clearly stochastic, by the arrival of unpredictable emergencies and random times of the waiting time. This naturally refers to the theory of queues. Indeed, assuming a Poisson arrival process emergencies.

Table 1: lists the variables used in this formulation and a description of each.

Symbole	déscription	type
λ_{ED}	Arrival rate	Hospital Data
λ_{DA}	Arrival rate of patients who do not go through the ED emergency department	Hospital Data
μ_{ED}^B	ED bed per service rate including boarding time	Model Fit
μ_{ED}	Bed per service rate ED boarding off time	Model Fit
μ_{IP}	Service rate per IP bed	Model Estimate
W_q^{ED}	Expected value of waiting time in ED	Model Estimate
W_q^B	Expected value of boarding time	Model Estimate
w	The average time in ED	Hospital Data
f_A	Observed fraction of patients admitted to the emergency	Hospital Data
C_{IP}	Number of IP beds	Hospital Data
C_{ED}	Number of ED beds	Hospital Data
α	Fraction of time reduction boarding	Model Estimate
b	average boarding time observed for the admitted patients	Hospital Data

Variables with the "Hospital data" type are variables that are directly estimated from hospital data. Variables "Fit model" type variables are fixed with queues based on statistical estimates described below. Variables "estimation model" type are variables that are estimated by the queue after statistical adjustment.

The model assumes that the system is in a stable state.

$$W_q^{ED} = \left(\frac{r_{ED} C_{ED}}{C_{ED}! (C_{ED} \mu_{ED}^B) (1 - \rho_{ED})^2} \right) P_0^{ED} \quad (1)$$

$$P_0^{ED} = \left(\sum_{n=0}^{C_{ED}-1} \frac{r_{ED}^n}{n!} + \frac{r_{ED} C_{ED}}{C_{ED}! (1 - \rho_{ED})} \right)^{-1} : \text{The probability that ED is empty.}$$

$$\rho_{ED} = \frac{\lambda_{ED}}{\mu_{ED}^B} : \text{The utilization rate of ED.}$$



$\rho_{ED} = \frac{r_{ED}}{c_{ED}}$: The utilization ratio

Equation 1: Expected Value of waiting time in the unit ED.

$$\mu_{ED}^B = \left(\frac{1}{\mu_{ED}} + f_A W_q^B \right)^{-1} = \frac{\mu_{ED}}{1 + \mu_{ED} f_A W_q^B} \quad (2)$$

Equation 2: Represents the rate of ED service.

In practice, the service time of ED equals the time the patient is treated with more urgency the time the patient is stuck in an emergency. Therefore, the service rate of ED should (μ_{ED}^B) can be written as a function of time of treatment provided in the emergency department without waiting ($1/\mu_{ED}$) .

$$W_q^B = \left(\frac{r_{IP} c_{IP}}{c_{IP}! (c_{IP} \mu_{IP}^B) (1 - \rho_{IP})^2} \right) P_0^{IP} \quad (3)$$

$$P_0^{IP} = \left(\sum_{n=0}^{c_{IP}-1} \frac{r_{IP}^n}{n!} + \frac{r_{IP} c_{IP}}{c_{IP}! (1 - \rho_{IP})} \right)^{-1} : \text{The probability that IP is empty.}$$

$$r_{IP} = \frac{\lambda_{DA} + f_A \lambda_{ED}}{\mu_{IP}} : \text{The utilization rate of IP.}$$

$$\rho_{IP} = \frac{r_{IP}}{c_{IP}} : \text{The utilization ratio.}$$

Equation 3: Expected Value of boarding time for patients admitted to the unit IP.

To mount the service level, we use the method of moments of statistical estimation. The method of moments is a statistical estimate approximates the distribution parameters estimates based on the sample moments in the data.

$$\mu_{IP}^* = \operatorname{argmin}_{\mu_{IP}} ((W_q^B - b)^2) \quad (4)$$

$$\mu_{ED}^* = \operatorname{argmin}_{\mu_{ED}} ((W_q^{ED} - w)^2 | \mu_{IP} = \mu_{IP}^*) \quad (5)$$

Equation 3 and 4: Estimating the optimal rates

The performance is evaluated by the hospital boarding probability, namely the probability that the patient refused.

Too high a probability boarding indicates the need to increase the capacity of health units (add additional hours for surgeons, add beds, increase the time of use rooms surgeries).

Calculate the optimal value μ_{ED} sought to be built so that it minimizes the value $(W_q^B - b)^2$

$$\alpha = 100 \times \left(1 - \frac{(W_q^B | \mu_{IP} = \mu_{IP}^* / (1-K))}{(W_q^B | \mu_{IP} = \mu_{IP}^*)} \right) \quad (6)$$

$$\delta = 100 \times \left(1 - \frac{(W_q^{ED} | \mu_{IP} = \mu_{IP}^* / (1-K))}{(W_q^{ED} | \mu_{IP} = \mu_{IP}^*)} \right) \quad (7)$$

K: the rate increased resources in IP care units ($0 \leq K < 1$).

Equation 3 and 4: Estimate the percent reduction in ED boarding α and ED waiting δ respectively given a K.



HOSPITAL ESTIMATION OF ED BOARDING

This section concerns the statistical estimate based on waiting described above in a hospital in Morocco (IBN Rushd) file.

symbole	λ_{ED}	C_{ED}	f_A	w	λ_{DA}	C_{IP}	b	μ_{ED}	μ_{IP}
Hospital Data	7,5	60	0,5	1,5	0,4	160	3	0,07	0,01
Unité	Patient/heure	ED beds	proportion	heure	Pateint/heure	IP beds	heure	Patient/heure	Patient/heure

Table 2 provides the necessary input to the formulation estimates for a period of one month

Using the data of Table 2 and the Newton-Raphson method to solve the equations 4 and 5,

If this hospital increases capacity of health units IP 100k percent, while boarding will reduce the fraction α

Figure a and b show the percent reduction of loading and nominal reduction and percent of ED expected wait time.

CONCLUSION

We presented a method to estimate the time of boarding patients in the ED through the use of networks of queues. The model considers the emergency and standby ip as two markov queues in series. statistical estimation is used the method of moments where variables used in this model are estimated so that the resulting estimates of waiting and boarding time is roughly equal to estimates of hospital data.

This formulation was motivated by research that finds ED boarding is problematic in many hospitals. The case study of the hospital found that small percentage increase in the capacity of health units produce significant reductions in ED boarding and waiting.

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