



Design of Queuing Model for Electronic Medical Records System

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Abstract

This study examines how patients wait for long time in the healthcare facility before they are attended to by the health personnel. This trend is on the increase and it is a potential threat to healthcare services. Queuing has become a symbol of inefficiency of public hospitals in the world and Nigeria is not an exception. Managing queue is one of the challenges facing most hospitals. The study focuses on out patients, who are generally hospitalized at random times and the patient flow was analyzed probabilistically. The study adopts a queuing theory/model the M/M/1 to minimize waiting time, determine the actual waiting time. Simulation was used written in Java environment, the result of the study shows that the proposed full dynamic model outperforms the partial existing model which was based on 2 well-known mathematical exponential distributions combined with Poisson distribution.

Keywords: Queue, Hospital, Out patients, Queuing theory, Poisson distribution, M/M/1

Introduction

The Hospital is a healthcare facility where patients receive treatment and get effective and efficient services from specialized staff and equipment. In Healthcare industry, a number of initiatives have been introduced to enhance customer satisfaction. The healthcare industry is experiencing increasing pressure to concurrently reduce cost and improve the access and quality of care they deliver, this can be achieved by the introduction of IT (Obamiro, 2010). Many healthcare institutions are confronted with long waiting times, delays, and queues of patients. Long waiting time in any hospital is considered as an indicator of poor quality and needs improvement (Obamiro, 2010).

Queue is a general phenomenon in everyday life. Queues are formed when customers (human or not) demanding service have to wait because their number exceeds the number of servers available; or the facility doesn't work efficiently or takes more than the time prescribed to service a customer (Bakari, Chamalwa, & Baba, 2014). Queuing theory/model can be applied in different areas such as Health Care Systems, Sales Systems, Computer Systems, Application in Communication Systems, Traffic control etc. (Al-Matar, 2017).

Queuing is a challenge for most of the healthcare systems in the developing countries (Ishan, Sandeep, & Pranay, 2013). Considerable research has been done on how to improve queuing systems in various hospitals but unfortunately, this has not been the case in developed countries (Sam & Alex, 2014). The core objective of queuing system is to provide digital system to public hospitals and also to bring its practical value to further enhance decision making in hospitals (Vasilakis & Marshall, 2005). There are problems in health care system which can be solved using queuing system such as; long waiting time at outpatient department and booking an appointment with a specialist. In many hospitals, Patients wait for long time in the healthcare facility before they are attended to by the health personnel. This trend is on the increase and it is a potential threat to healthcare services. The ratio of the number of population (patients) compared to the number of physicians is so high. It has been observed that patients queue up for several hours from one unit of the hospital to another takes a long waiting time at outpatient department even before consultation. Long waiting time for treatment in the outpatient department followed by short consultations has long been a complaint (Fatma & Mursyid, 2013). This is the case in many public hospitals in developing countries. Most patients leave their homes very early in the morning in order to be among the first group to see the doctor. Otherwise, they may end up wasting whole day without due attention (Afrane & Appah, 2014).

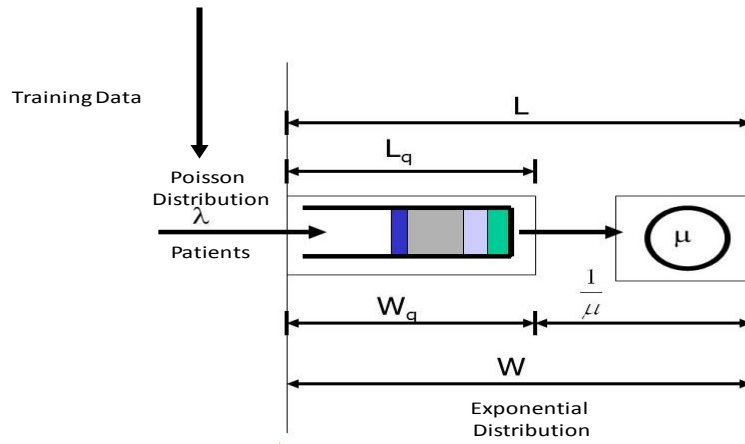
Existing proposals of queuing for Electronic Health Records system failed to address bottleneck issues, as such designing a system by simulation will be necessary to address variables that affects bottleneck (Fatma & Mursyid, 2013). Zhong, Prakash, Petty and James (2018) suggest that there is still lack of using proper training data regarding the bottleneck analysis in reducing delay in healthcare sector. In hospitals we have request and service, so the number of request is higher than the services rendered. Queuing Theory is a collection of mathematical models of various queuing systems. It is used extensively to analyze production and service processes exhibiting random variability in market demand (arrival times) and service times. It also provides the technique for maximizing capacity to meet the demand so that waiting time is reduced drastically (Obamiro, 2010).

The first ever queuing theory was developed by a Danish telecommunication engineer, Agner Krarup Erlang, where he analyzed a single facility M/M/1 queue called Erlang C mathematical model where arrivals of customers are based on a poisson process (Erlang, 1918). Another major milestone in the history of queuing theory was David G. Kendall (Kendall, 1953). Kendall introduced the A/B/C notation called the “Kendall’s notation” which depict the characteristics of a queuing system which has become the standard in classifying queuing theory.

Brahma (2013) stated that queuing system can be characterized by four (4) components or four main elements. These are: the arrival, the queue discipline, the service mechanism and the cost structure.

Methods

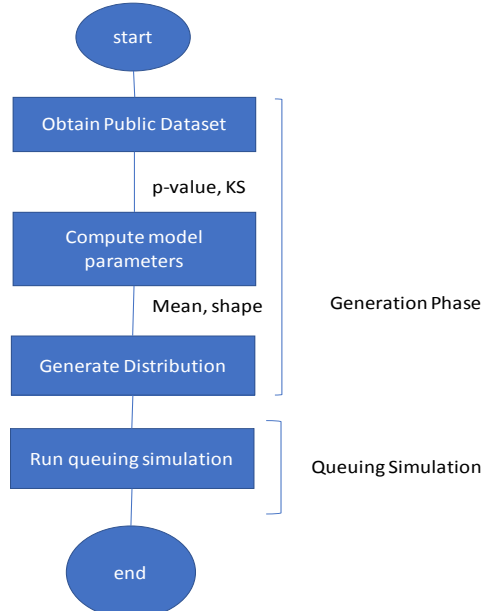
The proposed model of queuing for the patients waiting system is shown below and comprises of arrival module, service module and a queuing model. L is defined to be the average number of customers in the queue at any given moment of time, L_q is the average number of customers waiting in the queue, W is the average time a customer spends in the queuing system, W_q is the average amount of time spent in the queue itself and λ is the arrival rate into the system



Proposed Queuing Model

Adapted from Dharmawirya & Adi (2011)

Methodology adopted



Simulation will be used based on M/M/1 queuing model and will consider it because it will help in to estimating the number of providers needed. Arrivals occur according to a Poisson process and the service duration has an exponential distribution. Poisson distribution is a discrete distribution that shows the probability of arrivals in a given time period.

The performance metrics for the experiment is based on Poisson distribution with parameter λ and computed using

$$\frac{\lambda^n e^{-\lambda t}}{n!} \quad \dots (1)$$

where n is the number of arrivals. We find that if we set $n = 0$, the Poisson distribution is thus written in short as:

$$e^{-\lambda t} \quad \dots (2)$$

which is equal to $P(T > t)$ from the exponential distribution.

Results

The average service time at arrival time with mean 60 is shown in Figure 1. The result shows that the modified model shows better service time than the existing partial queuing model. For requests 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, and 10000, the dynamic model produced a result 0.012850074, 0.07027417, 0.003871144, 0.126036076, 0.134464003, 0.030769736, 0.062551691, 0.128171139, 0.367749692, and 0.193664847 respectively.

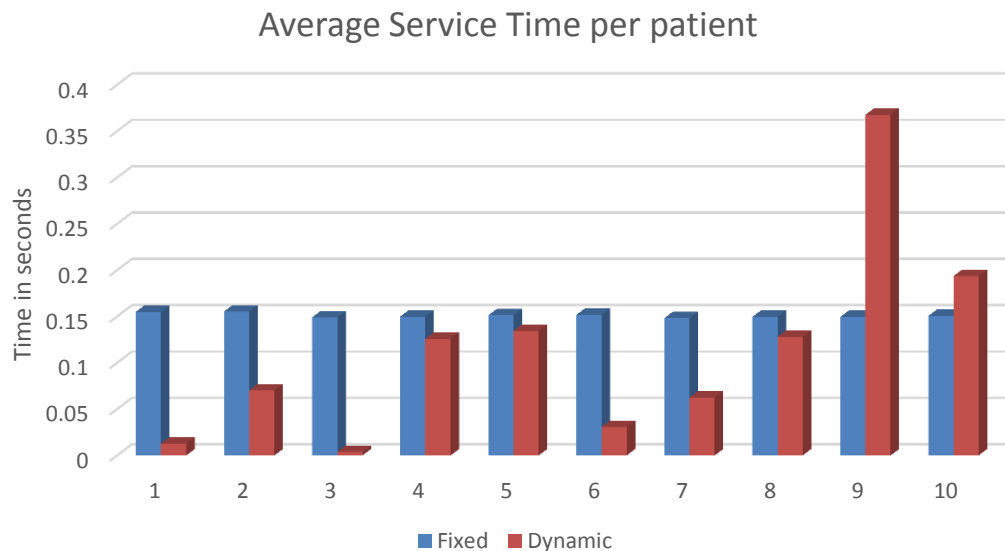


Figure 1: Time queue where arrival has a Poisson distribution with mean 60

Table 1: Average Patients Waiting in the Queue

Patient Request	Partial Poisson Model (Analytical)	Dynamic Model (Simulated)
1000	5352	2
2000	7940	4635
3000	10634	0
4000	13507	7810
5000	15956	13104
6000	18494	8463
7000	21134	15619
8000	24055	20943
9000	26494	26138

The partial model available in the literature (Zhong *et al.*, 2018) is shown to perform below the proposed full dynamic model. The proposed full dynamic outperformed the partial model with a lower waiting patient time. To achieve high performance, the fixed input service time proposed in (Zhong *et al.*, 2018) is replaced with a service time obtained from a publicly available training data. This makes it possible to achieve better cumulative difference across all the waiting patients between the proposed model and existing model.

The dynamic service model proposed in the work is significant in reducing the bottleneck as result of over provisioning. Consequently, the proposed dynamic model outperforms the partial model in terms of the service time per patient's request.

The significant improvement obtained on time spent in queue enables better for performance with the dynamic model clearly outperforming partial model at requests at 70% of the evolution times. This can be attributed to the reduction in service bottleneck due the efficiency of the model to assign service time optimally and reduce the resource under utilization associated with static assignment.

The new model also ensures a better arrival distribution. At various simulation timelines, The result shows additional improvement of the proposed model over the existing model. At all the different request points, the proposed dynamic model outperformed the existing partial model with a wide positive significant margin.

Conclusion

This research proposes an approach to the problem of hospital queue modelling to reduce time spent on queue since managing queue is one of the challenges facing healthcare facility. The research aims to address the limitations of lack of using proper training data. An existing queuing model is chosen and the required components to facilitate the modification and enhancement proposed in the objectives of study introduced. The proposed model is based on well-known mathematical exponential distributions combined with Poisson distribution.

The simulation experiment is written in Java. Training data obtained from publicly available dataset is used to estimate the parameters for the distribution models. The result obtained from using the chosen simulation method is collected by running the experiment many times. The Result of the experiment also shows that the best queuing discipline that suits the healthcare sector or hospital management system is the First in – First out (FIFO) except in the case of emergency.

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