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Congestion Problem during Covid-19 in the University College Hospital, Ibadan, Oyo State, Nigeria: An Application of Queuing Theory

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ABSTRACT: *Outpatient services have become an important component of healthcare especially during the era of pandemic (Covid-19). The amount of time a patient spends waiting in an outpatient setting may have an impact on their satisfaction with the service(s) provided. In this research, an attempt was made to investigate the arrival and service rates of patients for the period of one month between the hours of 9:00am and 2:00pm at the University College Hospital (UCH), Ibadan during Covid-19 using Poisson Process in order to deduce traffic intensity (ρ), expected number of patients at a steady rate (L), expected queue length (Lq), expected waiting time (Wq), total patients waiting (W) and mean number of Patients in the system. Results showed that more patients visit the clinic everyday of the week due to the high traffic intensity close to 100% and the high minutes spent in the hospital before being attended to. Conclusively, waiting time on Saturdays and Tuesdays are much compared to the remaining days.*

KEYWORDS: congestion, outpatients, services, waiting time, poisson process.

INTRODUCTION

Coronavirus Diseases (Covid-19) commenced in December of 2019 when a virus from an animal infected someone at the now-famous seafood market in Wuhan, China. The disease had spread throughout China within one month, then to the United States, the United Kingdom, Spain, Singapore, Thailand, Japan, and a number of other countries [2,4]. The World Health Organization (WHO) identified Covid-19 a public health concern on January 30, 2020 [3]. As a result of the disease' quick spread and high fatality rate, it was deemed a pandemic on March 11, 2020.

Congestion problem have grown increasingly crucial in healthcare, particularly in this period of pandemics (Covid-19). The length of time a patient wait in an outpatient setting may affect their satisfaction with the service(s) given. Customer happiness has grown to be a major priority in the service sector. In the healthcare sector, numerous initiatives have been put in place to raise customer satisfaction.

The aim of this study was to look at the arrival and service rates of patients at the University College Hospital (UCH) in Ibadan for a month between the hours of 9:00 a.m. and 2:00 p.m. in order to investigate the service time and the idle time of the server in the system, to measure the waiting time that a patient has to wait for service in the system, thereby capturing the traffic intensity and to obtain the expected number of patients in the system at a steady rate. In light of this, the current investigation is being carried out and it is hoped that the findings of this study will allow one to achieve the aforementioned goals.

LITERATURE REVIEW

Numerous studies in the healthcare industry have examined how long patients should have to wait before receiving medical attention. After a while, waiting lists were perceived as the result of a "backlog" in healthcare needs (often indirectly). Management experts believe that waiting results from the demand's strong buffering or smoothing. The queueing theory has a lengthy history of use in the healthcare industry in addition to other fields like call center architecture. Therefore, it is reassuring to think of waiting as a "time price" as opposed to a "money price" [5].

Based on analytical models offered by queuing theories, useful information was given for building availability models like waiting time, traffic intensity, queue length, expected number of patients and so on. The usage of queuing models is to establish availability factors linked to data center operations and management challenges. Additionally, some extensions to this general model are presented in order to propose its application for the particular computer systems used in integrated airspace control centers, where operational control may depend on human controllers in charge of civil or military air defense operations. This is done to propose this general model's application for these computer systems [6].

In 2022, the empirical evidence from the use of queueing theory and management of waiting times using several server models was carried out. It had now been established that most patients were unhappy with the hospital's level of customer service. This corresponds to the fact that there are more patients than there are doctors, nurses, and other support workers in the hospital [1].

RESEARCH METHODOLOGY

Poisson Process and Exponential Distribution

In developing this queuing model, it is assumed that inter arrival times and service time obey the exponential distribution or equivalently, that the arrival rate and service rate follow a Poisson distribution. We consider an arrival process $\left[\mu(t), t \geq 0\right]$ where $\mu(t)$ denotes the total number of arrival up to $\mu(0)=0$, and satisfies the following three assumptions.

- The probability than an arrival occurs between time t and time $t+\delta t$ is equal to $\lambda\delta t+\delta t$, i.e. Pr. (arrival) occurs between t and $t+\delta t$ = $\lambda\delta t$ + 0 (δt). Where λ is a constant independent of $\mu(t)$, δt is an increment element and 0 (δt) denotes a quantity that becomes negligible when composed to δt is $\delta t \neq 0$; that lim 0(δt)=0.
- Pr. (more than one arrival between t and $t+\delta t$ = 0(δt).
- The numbers of arrivals in non-overlapping intervals are statically independent, that is, the process has independent increments.

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

Expected Waiting Time (Wq) and Total Patients Waiting Time (W)

The expected waiting time (wq) can be obtained using the expression below:

$$W_q=\frac{\lambda}{\mu(\mu-\lambda)} \quad (2)$$

The total time a patient had to spend on the system including service time is given by;

$$W=\frac{1}{\mu-\lambda} \quad (3)$$

Suppose λ is the arrivals rate and μ is the service rate. The traffic intensity is

$$\rho=\frac{\text{Mean Arrival Rate}}{\text{Mean Service Rate}}=\frac{\lambda}{\mu} \quad (4)$$

Expected Number of Patients at a Steady Rate (L)

The mean number of patients when the system is at a steady rate can be derived using the below formular;

$$L=\frac{\lambda}{\mu-\lambda} \quad (5)$$

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The Mean number of patients that can be found or obtained in the system using the equation;

$$N = \frac{\rho}{1-\rho} \quad (6)$$

RESULTS AND DISCUSSION

The data were collected between the hours of 9:00am and 2:00pm from the Clinic of UCH for a week (5th April to 14th May, 2021), Ibadan. An interval of minutes was taken as a unit of time from the data observed in the Hospital.

Table 1: Summary of the Data used for the Study

Time (min)/am	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday	
	λ	μ	λ	μ	λ	μ	λ	μ	λ	μ	λ	μ	λ	μ
9 – 10	82	100	100	115	128	175	123	143	109	190	124	141	83	97
10 - 11	100	97	104	121	108	166	104	134	121	123	102	116	113	118
11 - 12	91	88	99	135	141	153	135	136	122	164	124	132	80	132
12 – 1	67	111	93	104	128	176	107	157	87	174	124	120	80	124
1 – 2	69	105	105	101	119	157	145	144	107	200	120	108	116	105

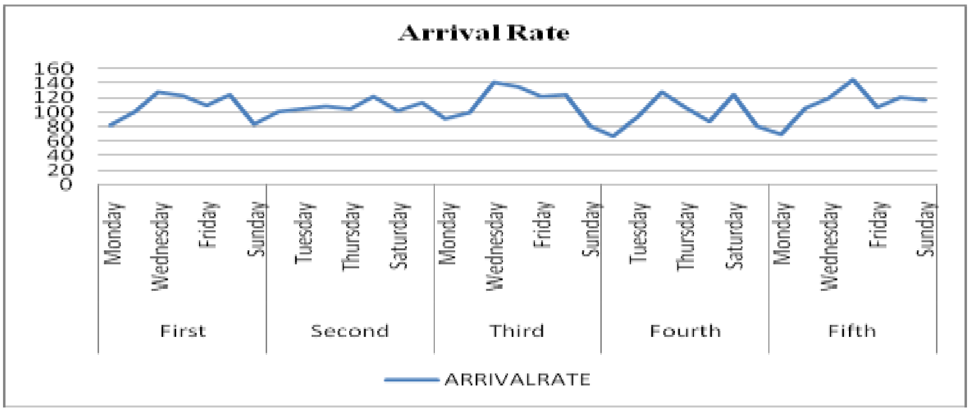

Figure 4.1: Graph of Patients' Arrival Rate at UCH

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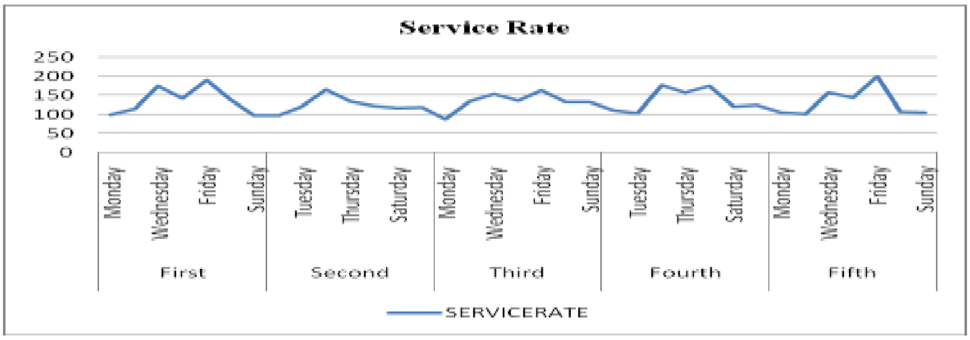

Figure 2: Graph of Patients' Service Rate at UCH

Suppose λ is the arrivals rate and μ is the service rate. The traffic intensity is

$$\rho = \frac{\textit{Mean Arrival Rate}}{\textit{Mean Service Rate}} = \frac{\lambda}{\mu}$$

Table 2: Traffic Intensity of the Process

Days	λ	μ	ρ	μ – λ
Monday	410 (16.4)	501 (20)	0.8174	91 (3.6)
Tuesday	501 (20)	575 (23)	0.8704	74 (3)
Wednesday	624 (25)	826 (33)	0.7557	202 (8)
Thursday	614 (24.6)	714 (28.6)	0.8604	100 (4)
Friday	546 (21.8)	851 (34)	0.6418	305 (12.2)
Saturday	594 (23.8)	618 (24.7)	0.9616	24 (0.9)
Sunday	472 (18.9)	576 (23)	0.8191	104 (4.1)

Table 3: Data Summary of Poisson distribution and Poisson Process

Statistics	Days of the five (5) weeks						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Traffic (ρ) Intensity	0.82	0.87	0.76	0.86	0.64	0.96	0.82
Number expected at steady rate	5	7	3	6	2	24	5
Expected queue length	4	6	3	5	1	24	4
Expected waiting time	14	17	6	13	3	64	12
Total patients waiting time	17	20	8	15	5	67	15
Mean number of patients in the system	5	7	3	6	2	26	4

CONCLUSION

In this research, poisson process was used as the methodology via traffic intensity (ρ), expected number of patients at a steady rate (L), expected queue length (Lq), expected waiting time (Wq), total patients waiting (W) and mean number of Patients in the system. Results showed that more patients visit the clinic everyday of the week due to the high traffic intensity close to 100% and the high minutes spent in the hospital before being attended to. Conclusively, waiting time on Saturdays and Tuesdays are significantly longer than on other days.

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