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Application of Queuing Theory in Ante Natal Care Clinic for Pregnant Women in Gombe State

Nathan Nachandiya [1] Asta Musa[2], Aliyu Maidamisa[3]
[1]Management Department, Modibbo Adama University of Technology, Yola
[2]Computer Science Department, Adamawa State University, Mubi..
[3]Statistics/Operation Research Department, Modibbo Adama University of Technology, Yola.
e-mail: [2]amusa@pactworld.org; [1]nachandiya@yahoo.com; [3]imed6691@mautech.edu.ng.

Abstract

Ante Natal Care (ANC) is a care given to pregnant women during their pregnancy. This care includes provision of registry, medical examination, consulting with the Doctor, pharmaceutical care, laboratory screening, and general health education. The Primary Health care (PHC) in Kodong Local Government of Gombe State provides such services to pregnant women. The time spent by women during the ANC became an issue of concern to the researchers. Most women spent the whole day in the hospital and some eventually returned home unattended. This research intends to investigate factors responsible for waste of time in the hospital and its corresponding health implication on these delicate pregnant women. The researchers also investigated the waiting time in a queue, service time, and the total time spent in the system. The data was analyzed using TORA package and the result reveals an average arrival rate (lambda) of 31.00, service time (Mu) = 5.00 at the Registration/ File retrieval unit; an average arrival rate (Lambda) of 5.00, Mu = 4.00 at the BP, Weight, Temperature check unit; an average arrival rate (Lambda) of 5.00, Mu = 4.00 Consulting with Doctor; an average arrival rate (Lambda) of 4.00 , Mu = 32 at the Health Talk unit and finally average arrival rate (Lambda) of 29.00, Mu = 5.00 at the Pharmacy. This analysis revealed that reasonable amount of time is spent by these women on queue, and service discipline of First in First out (FIFO) is not always observed, the researchers then recommends a modified Single Queue – Multiple - Serial Server for the PHC which increased the service rate and also encouraged support by other staff during the Ante Natal services.

Keywords words: Queue, Arrival Time, Arrival Rate, Service Rate, Service Time, Waiting Time,

Introduction

The Nigeria's Maternal Mortality Ratio is one of the highest in the world, accounting for 10% of all maternal deaths in the world. The figures are even more worrisome in Northeastern Nigeria, with a maternal mortality ratio of 1,549 deaths per 100,000 live births (World Health Organisation, 2015; Nigeria Demographic and Health Survey Preliminary Report 2013). Lack of antenatal care, skilled attendant at birth, delays in the treatment of pregnancy related complication, poverty and low status of women are some of the factors identified contributing to high maternal mortality in Northeastern Nigeria (World Health Organization, 2007). It is critical therefore, to look for solutions and approaches that will improve maternal, neonatal and child health in the region and in Nigeria more broadly.

The Ante Natal Care (ANC) is the care given to pregnant women during their pregnancy. This care includes provision of Registry: (Name, Age, Parity, Maternal History, Gestational Age, etc.), Pharmaceutical Care; (Provision of Supplements: Iron Fesolate, Folic Acids, Vitamins of B complex; and Sulphurdoxine Perimethamine for prophylaxis), Laboratory Screening and Medical Examinations; (Blood tests for Blood group, Genotype, HIV Screening, Syphilis and other Sexually Transmitted Infections, Malaria Screening, Vital Signs, Height, Weight, Fetal examinations), Counselling, and Health Education(World Health Organization, 2015).

The importance of antenatal care is often overdone in most households as the pregnant women are flooded with advice about what is right and what is wrong for her. Some of this advice is dangerous and may pose a risk to her or her unborn child resulting in complications during the pregnancy, labor and/or post-delivery which may inadvertently lead to death. Women are advised to make the first visit to an antenatal clinic as soon as possible after a missed menstrual period. This ensures that they have professional help when needed.

World Health Organization (2017) another importance of antenatal care is that a woman may be

carrying some diseases such as Toxoplasmosis before pregnancy without any visible symptom. In such a case, it is important to identify and treat it early to avoid complications. The trip to the Antenatal Clinic has other benefits too. The woman's blood pressure can be checked and her weight can be monitored. Besides, any factors that could negatively influence the baby's development such as nutritional deficiencies (including excessive vomiting), infections and potentially hazardous drug therapy can be detected. Complications like intra uterine growth retardation can be screened and prevented. The gynaecologist also helps the woman plan for the delivery; advise her on the care of the newborn and her future reproductive health.

The under-utilization of Maternal, Neonatal and Child Health (MNCH) Services during pregnancy is one of the many factors that contribute to the existing high Maternal Mortality Ratio in Northeastern Nigeria (World Health Organization 2016). This factor is attributed to many causes such as Client waiting time during ANC Visits quantified in the value of its opportunity cost (waiting cost), waiting time viewed in the value of patient satisfaction, inability of women to pay for MNCH services, low literacy, Unawareness/Ignorance of the danger signs in pregnancy, religious causes, socio-cultural practices, poor access to Health Facilities, Inadequate staffing of the Health Facilities, as well as Attitude & Friendliness of Health Care givers, among other causes. These causes have been, and may further be, researched independently and dependently.

Queueing theory is the mathematical study of waiting lines, or queues. In queuing theory, a model is constructed so that queue lengths and waiting time can be predicted. Queueing theory is generally considered a branch of operations research because the results are often used when making business decisions about the resources needed to provide a service (Larson & Odoni, 1999). It has its origins in research by Agner Krarup Erlang when he created models to describe the Copenhagen telephone exchange. The ideas have since seen applications including telecommunication, traffic engineering, computing and the design of factories, shops, offices and hospitals service (Larson & Odoni, 1999)

The general Kendall's Notation for specifying queueing Characteristics is V/W/X/Y/Z where V = Arrival Pattern, W = Service Pattern , X = Available server and Y = System capacity, Z= Queueing Discipline. Single queuing nodes are also usually described in similar manner using other forms of the Kendall's notation as *A*/*S*/*C*, where *A* describes the time between arrivals to the queue, *S* the size of jobs and *C* the number of servers at the node. Many theorems in queuing theory can be proved by reducing queues to mathematical systems known as Markov chains, first described by Andrey Markov in his 1906(Larson & Odoni, 1999)

Agner Krarup Erlang, a Danish engineer who worked for the Copenhagen Telephone Exchange, published the first paper on what would now be called queueing theory in 1909. He modeled the number of telephone calls arriving at an exchange by a Poisson process and solved the M/D/1 queue in 1917 and M/D/k queuing model in 1920. In Kendall's notation:

(i) M stands for Markov or memoryless and means arrivals occur according to a Poisson process
(ii) D stands for deterministic and means jobs arriving at the queue require a fixed amount of service
(iii) *k* describes the number of servers at the queueing node (*k* = 1, 2,...). If there are more jobs at the node than there are servers then jobs will queue and wait for service

The M/M/1 queue is a simple model where a single server serves jobs that arrive according to a Poisson process and have exponentially distributed service requirements. In an M/G/1 queue the G stands for general and indicates an arbitrary probability distribution. The M/G/1 model was solved by Felix Pollaczek in 1930, a solution later recast in probabilistic terms by Aleksandr Khinchin and now known as the Pollaczek–Khinchine formula service (Larson & Odoni, 1999).

After World War II queuing theory became an area of research interest to mathematicians. In 1953 David Kendall solved the GI/M/k queue and introduced the modern notation for queues, now known as Kendall's notation. In 1957 Pollaczek studied the GI/G/1 using an integral equation. John Kingman gave a formula for the mean waiting time in a G/G/1 queue (Kingman's formula).

The Matrix Geometric Method and Matrix Analytic Methods have allowed queues with phase-type distributed inter-arrival and service time distributions to be considered. Problems such as performance metrics for the M/G/k queue remain an open problem.

Networks of queues are systems in which a number of queues are connected by customer routing. When a customer is serviced at one node it can join another node and queue for service, or leave the network. For a network of m the state of the system can be described by an m–dimensional vector $(x_1,x_2,...,x_m)$ where x_i represents the number of customers at each node.

The first significant results in this area were Jackson networks, for which an efficient product-form stationary distribution exists and the mean value analysis which allows average metrics such as throughput and sojourn times to be computed. If the total number of customers in the network remains constant the network is called a closed network and has also been shown to have a product–form stationary distribution in the Gordon–Newell theorem. This result was extended to the BCMP network where a network with very general service time, regimes and customer routing is shown to also exhibit a product-form stationary distribution. The normalizing constant can be calculated with the Buzen's algorithm, proposed in 1973 service (Larson & Odoni, 1999).

Several studies have been conducted on the application of queuing theory in hospitals. For instance John (2010) in his study titled "Queuing Theory and Patient Satisfaction: An Overview of Terminology and Application in Ante-Natal Care Unit" used Tora Optimization system to analyze data collected from ante-natal care unit of a public teaching hospital in Nigeria over a three-week period. The study showed that pregnant mothers spent less time in the queue and system in the first week than during the other succeeding two weeks. This implies that there are less average pregnant women in the queue and system in the first week than in the other weeks except on the third week when less expectant mother waited in the system.

Adeleke, Ogunwale, and Halid (2009) in their study entitled "Application of Queuing Theory to Waiting Time of Out-Patients in Hospitals" they used a total of 14days to collect data from 100 patients in University of Ado-Ekiti, Health Center. Their findings revealed that the average arrival rate was 0.1058 per hour, the average service rate was 0.1253 per hour, the average number of patients in queue was 5, the average time a patient waited in queue was 43 minutes, the average time a patient spent in the hospital was 51 minutes, and the probability that a patient will queue on arrival to the hospital was 0.8444.

Ndukwe, Omale, and Opanuga (2011) conducted a study on reducing queues in a Nigerian hospital pharmacy. The results of their study showed that queue characteristics existing at pharmacy during the situation analysis was a single server-multiple queue model. However, after the intervention was done involving staff re-orientation, the streamlined process reduced waiting time from 167.0to 55.1 min. Queue discipline was strictly instituted by designed tally cards that were serially numbered. The characterization and discipline that was instituted handled and/or eliminated the challenge of shunting, balking or jockeying and reduced reneging. The result further showed that the waiting area to pharmacy space ratio, gave a good result of 1:9.

Mohammadkarim, Seyed, Ramin, and Ehsan (2014) in their study entitled "Using Queuing Theory and Simulation Model to Optimize Hospital Pharmacy Performance". They used a descriptive-analytical study in a military hospital in Iran and a sample of 220 patients. The result of their study revealed that the queue characteristics of the studied pharmacy during the situation analysis were very undesirable in both morning and evening shifts. The average numbers of patients in the pharmacy were 19.21 and 14.66 in the morning and evening, respectively. The average times spent in the system by clients were 39 minutes in the morning and 35 minutes in the evening. The system utilization in the morning and evening were, respectively, 25% and 21%. The simulation results showed that reducing the staff in the morning from 2 to 1 in the receiving prescriptions stage didn't change the queue performance indicators. Increasing one staff in filling prescription drugs could cause a decrease of 10 persons in the average queue length and 18 minutes and 14 seconds in the average waiting time. On the other hand, simulation results showed that in the evening, decreasing the staff from 2 to 1 in the delivery of prescription drugs changed the queue performance indicators very little. Increasing a staff to fill prescription drugs could cause a decrease of 5 persons in the average queue length and 8 minutes and 44 seconds in the average waiting time.

Olorunsola, Adeleke, and Ogunlade (2014) carried out a study on Queueing Analysis of Patient Flow in Hospital. Their findings showed that there is easy flow is approximately 24 in the ICW and 132 in the MSW for the test hospital under consideration.

In another study conducted by John, David, and Akua (2014), on Optimizing Patient Flow and Resource Utilization in Out Patient Clinic: A Comparative Study of Nkawie Government Hospital and Aniwaa

Health Center in Ghana, the findings indicated that the estimated mean arrival rate and the waiting time at the OPD for the public hospital were 23 and 0.5 hours respectively, and 25 and 0.5 hours for private hospital.

Kembe, Onah, and Iorkegh (2012) conducted a research on a Study of Waiting and Service Costs of a Multi-Server Queuing Model in Federal Medical Centre Makurdi, Benue State. The methods employed during data collection were direct observation and personal interview and questionnaire administering by the researcher. Data were collected for (4) weeks. TORA optimization software as well as descriptive statistics was used analyzed the data. The findings revealed that average queue length, waiting time of patients as well as overutilization of doctors at the Clinic could be reduced at an optimal server level of 12 doctors and at a minimum total cost as against the present server level of 10 doctors with high Total Cost which include waiting and service costs.

In a recent study, Nidhi and Belwal (2016) applied Queuing Theory to Patient Satisfaction at Combined Hospital, Srinagar Garhwal Uttarakhand and the result revealed that quite a reasonable time in a queue waiting for service.

Materials and Methods

Research regarding the arrival pattern of patients and the overall queue system were conducted in the ANC clinics in Kodong PHC. Direct observations and interviews were conducted for three weeks during different times of the day and analyzed using the TORA package.

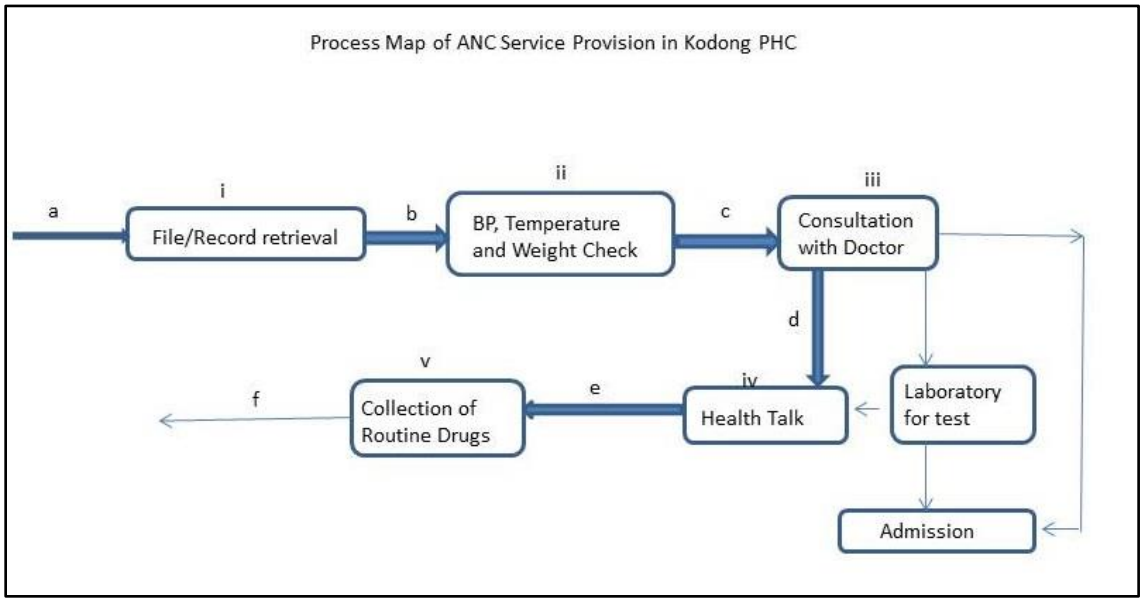

Figure 1: Illustrating a specialized Single Queue -Multiple Serial Servers at Kodong PHC

The patient codes (1-140) represent the different names of women that came for Ante Natal during the research work. The women arrived at the hospital at random at different times. The field work revealed that the women do come as early as 6:30 to join a queue. In the case of patient code 1, the woman arrived the hospital as early as 6:40 am. The staff reasonable for File arrived work at 8:30 am. The arrival of all the patients was random and the time of each arrival was recorded.

The hospital system used the specialized M/M/1 system where there is only a single queue with multiple serial processing servers. A close look at when the patient enters the file room was recorded and the respective time spent in the room. Patient no 1 enters the consulting room at about 9:30 am and was immediately attended by the doctor at 9:30 am unlike observation no 4, where despite arriving the consulting room, the patient was not attended to until 10 minutes latter (10:20 am – 10:30 am)

The time spent by the doctor while attending to the patient was also taken. In the case of observation 1, the real consulting started at about 9:30 am– 10:45 am. Such records gave us the idea of time spent by patient in a queue, time spent receiving service and also the time spent in the system. More so,

observation 1, revealed that the patient spent 2hours 40 minutes in a queue waiting for doctor, and a period of 15 minutes receiving service. A total of 2hourd 55 minutes was then observed as the time spent by the patient in the system. This goes for all the 140 observations. Moreso, after a patient have seen a doctors, the diagnosis may involve going to the laboratory, go for Health Talk or admission. And in every stage queue and service was involved. It is worth mentioning that some women do come to hospitals and still go home without been attended to in a day. The officer in charge of giving files stops attending to patients at 12:30. While the doctor leaves work by2:00 to give room for Health Talk and other activities.

Results and Discussion

Table 1: captured the response of the pregnant women on the "real" time they spent during ANC at Kodong PHC.

Table 1: Time spent during ANC

Option	Frequency	Percentage
0 – 2hrs	12	8.57
2 – 4hrs	10	7.14
4 – 6hrs	18	12.86
6- 8hrs	30	21.43
0ver 8hrs	70	50
Total	**140**	**100**

Source: Field survey, 2017

It is evident from table 1.1 that 50% of the women spent more than 8hrs in the hospitals before getting service .

Table 1.2, captured the proposed time the women wished to spent in a queue.

Option	Frequency	Percentage
0 – 2hrs	80	57.14
2 – 4hrs	42	30
4 – 6hrs	10	7.14
6- 8hrs	8	5.71
0ver 8hrs	0	00
Total	**140**	**100**

Table 1.2: proposed time the women wished to spent during ANC
Source: Field survey, 2017

Table 1.2 revealed that 57.14 of the respondents wish to spent a maximum of 2hrs in the hospital system during ANC, contrary to 30% that wished to 2 – 4hrs, 7.14% that wished to 4-6hrs, 5.71% that wished to spent 6-8hhrs and none wish to exceed 8hrs during the ANC

Analysis of arrival, service, and time spent on the system by the pregnant women was run on a TORA package. The following results were displayed

Independent Analysis of scenario 1: Registration/ File retrieval

The result revealed an average arrival rate (Lambda) of 31.00, Mu = 5.00, Rho/c = 6.20 , Lambda eff = 3410.045, Ls = 29.99, Lq = 28.99, Ws = 0.0088, Wq = .0085 Pn of 0 at 1-28,

Independent Analysis of scenario 2: BP, Weight, Temperature check

The result revealed an average arrival rate (Lambda) of 5.00, Mu = 4.00, Rho/c = 1.25, Lambda eff = 550.036, Ls = 29.99, Lq = 28.99, Ws = 0.05453, Wq = 0.05271 Pn of 0 at 1-28,

Independent Analysis of scenario 3: Consulting with Doctor

Revealed an average arrival rate (Lambda) of 5.00, Mu = 4.00, Rho/c = 1.25, Lambda eff = 550.036, Ls = 29.99, Lq = 28.99, Ws = 0.05453, Wq = 0.05271 Pn of 0 at 1-28,

Independent Analysis of scenario 4: Health Talk

The result revealed an average arrival rate (Lambda) of 4.00, Mu = 32.00, Rho/c = 0.125, Lambda eff = 440.31022, Ls = 29.99, Lq = 28.99, Ws = 0.06796, Wq = 0.06569 Pn of 0 at 1-25,

Independent Analysis of scenario 5: Pharmacy

The result revealed an average arrival rate (Lambda) of 29.00, Mu = 5.00, Rho/c = 5.800, Lambda eff = 3190.04511, Ls = 29.99, Lq = 28.99, Ws = 0.0094, Wq = 0.00909, Pn of 0 at 1-29,

General observations (all scenarios integrated)

The result revealed an average arrival rate (Lambda) of 31.00, Mu = 6.00, Rho/c = 5.1667, Lambda eff = 3410.05415, Ls = 29.99, Lq = 28.99, Ws = 0.0088, Wq = 0.0085, Pn of 0 at 1-28,

In general, the result from TORA revealed that quite a reasonable time is spent by these women waiting for service. Hence the figure model is recommended for Kadong PHC to be adopted during ANC service provision. This recommendation intends to reduce the service rate from 6 persons per hour to 10 persons per hour.

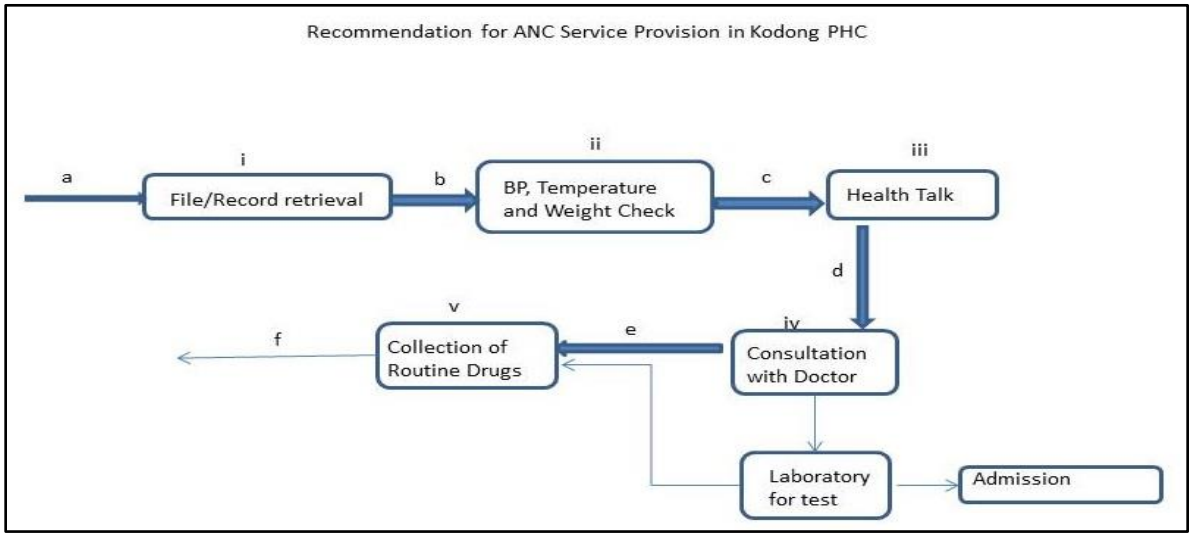

Figure 2: Proposed Model (Modus Operandi)

Conclusion

The current study represents a distinctive application of queueing model in optimization. The analysis of this model plays a vital role in providing information to the hospital management about the extensive waiting times and associated factors that need to be addressed in order to improve the queuing system. Mainly, the results of the proposed model showed that patients don't have to wait for a long period of time in a queue waiting to be serviced.

Hence, the model developed in the current study is dynamic in the sense that it can be adopted by any public hospital, with either the same or different level of priority of any variable depending on the preference by the administrators.

Recommendations

The proposed model be adopted, considering the results. The management can approach the problem of extensive waiting times by adopting appropriate staff scheduling strategies. For instance, more staff members (GDMOs, pharmacists and other medical/non-medical personnel) are required to be present during the busiest time periods to cater for the high patient flow. Therefore, some additional information regarding the patient flow during different times of a day or different days of the week is required to identify the busiest times. The consultation might be reduced by identifying different activities that take place during this time. It might be possible that these routine tasks (such as temperature, blood pressure, other pre-diagnosis information from the patient etc) are conducted prior to when the 'actual' consultation starts. This will allow for proper effective treatment of the patients, leading to increased satisfaction. The analysis has shown that long waiting times are involved during file retrieval. Therefore, it might be possible to increase the number of servers to meet the increasing demand of these woman. In this way, the flow of patients will be distributed, hence reducing the waiting times. The current study provides evidence of the usefulness of queueing analysis. However, this is the first step to address a bottlenecked patient flow system in a developing country. Hence detailed study specifically aiming at evaluating some other factors affecting the queuing system in a hospital system with additional supporting data is required, in order to provide specific recommendations for improvement.

Further studies

More researches should be done using Queuing Techniques and more sophisticated model be

developed integrating queueing model and Data Envelopment Analysis (DEA), more researches be carried out on queues in Accident and Emergency Unit(A&) Out- Patient – Department (OPD) , Pharmacy and other units in the hospital systems.

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