Application of Queuing Theory in Hospital System: Ante Natal Care Unit Mubi

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Abstract: **Ante Natal Care (ANC) is a medication provided to pregnant women after pregnancy. This treatment entails register provision, physical review, doctor's appointment, pharmacy services, laboratory screening, and general health education. Primary Health Care (PHC) delivers certain services to pregnant women. Area of interest to the researchers was the time spent by women during the ANC. Many women remained in the hospital the entire day and some finally went home unattended. This paper attempts to explore the reasons responsible for the hospital's waste of time and its potential health consequences for these fragile pregnant women. The researchers have analyzed the waiting time, service time and overall time spent in a queue. 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*: Ante natal, queue, women, pregnant, waiting, service**

I.INTRODUCTION

Nigeria's Maternal Mortality was over 800 deaths per 100,000 live births which was approximated to be 58,000 maternal deaths. The figure accounts for 10 percent of all maternal deaths in the world. The numbers are even more alarming in northeastern Nigeria (World Health Organisation, 2019; Nigeria Demographic and Health Survey Preliminary Report 2019) revealed that lack of antenatal care, trained caregiver at birth, delays in the treatment of complications linked to pregnancy, poverty and low status of women are some of the factors found in Northeastern Nigeria that lead to high maternal mortality (World Health Organization, 2019). Therefore, it is important to look for strategies and interventions that would strengthen maternal, neonatal and infant health more generally in the country and in Nigeria.

Ante Natal Care (ANC) is the treatment that pregnant women get after pregnancy. This treatment requires Registry Provision: (Name, Status, Parity, Maternal History, Gestational Age, etc.), Prescription Care; (Supplement Provision: Iron fesolate, folic acids, B-complex vitamins; and sulphurdoxine perimethamine for prophylaxis; laboratory monitoring and diagnostic examinations; (blood group checks, genotype, HIV screening, syphilis and other sexually transmitted diseases, screening for malaria, vital signs, height, weight, prenatal tests), counselling and health education (World Health Organization, 2015).

In most homes, the value of prenatal treatment is frequently overdone, since pregnant women are overwhelmed with suggestions about what is right and what is wrong for them. Any of this guidance is unsafe and can pose a risk to her or her unborn child, resulting in injuries that can unintentionally lead to death during conception, labour and/or post-delivery. After a missing menstrual cycle, women are encouraged to make their first appointment to an antenatal clinic as soon as practicable. It guarantees that they have competent assistance when appropriate.

Another importance of prenatal treatment is that a woman can bear certain diseases such as Toxoplasmosis without any obvious signs before pregnancy (Davis et al., 2003). It is necessary to detect and treat it early in such a case to prevent complications. The ride to the Antenatal Clinic has other advantages as well. The female's blood pressure can be tested and it is possible to control her weight. In addition, it is possible to identify any variables that could adversely affect the growth of the infant, such as dietary disorders (including frequent vomiting), illnesses and potentially harmful drug treatment. It is possible to scan and avoid complications such as intra uterine growth retardation.

One of the many reasons contributing to the current high maternal mortality ratio in Northeastern Nigeria is the under-use of maternal, neonatal and infant health services (MNCH) during pregnancy (World Health Organization 2019). The case was worsen during the year 2020 Covid-19 lockdown where most people are at home due to government orders and some are afraid to go out because of the fear of contacting the virus(Covid-19). Other factors include client waiting time quantified in the valuation of their opportunity expense (waiting cost) during ANC visits, waiting time seen in the value of patient satisfaction, reluctance of women to pay for MNCH services, low literacy, unawareness/ignorance of pregnancy hazard signs, religious causes, socio-cultural patterns, limited access to health facilities, adequate 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.

II. LITERATURE REVIEW

Queuing theory is the analysis of waiting lines, or queues, mathematically (Davis et al., 2003). In the theory of queuing, a model is developed to predict queue lengths and waiting time. The principle of queuing is commonly considered a branch of operations science and the findings are mostly used when making business decisions on the services required to deliver a service (Larson & Odoni, 1999). It has its roots in Agner Krarup Erlang's study as he developed models to define the telephone exchange in Copenhagen. Since then, the principles have seen applications such as telecommunications, traffic engineering, coding, and plant, store, office and hospital service architecture (Larson & Odoni, 1999).

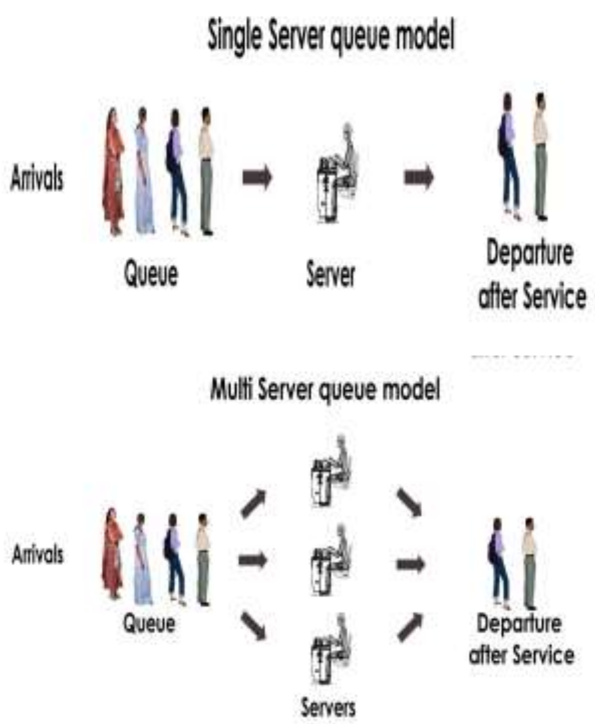

Figure 1.1. Illustrating single queue with single processing unit and single queue with multiple processing unit.

The general Kendall‟s Notation for specifying queuing Characteristics is V/W/X/Y/Z where V = Arrival Pattern, W = Service Pattern, X = Available server and Y = System capacity, Z= queuing 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

This paper is based on M/M/1 queue, the M/M/1 is a basic model where jobs that arrive according to a Poisson process are handled by a single server and have exponentially dispersed service requirements. In an M/G/1 queue, G stands for general and implies an arbitrary distribution of probability. Felix Pollaczek solved the M/G/1 model in 1930, a solution that Aleksandr Khinchin later recast in probabilistic terms and is now known as the Pollaczek-Khinchine formula operation (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.

Queue networks are schemes in which a variety of queues are interconnected via customer routing. It will reach another node and queue for service or exit the network while a customer is serviced at one node. The state of the device can be represented by an m-dimensional vector (x1,x2,...,xm) for a network of m, where xi represents the number of clients at each node.

The first Jackson networks, for which there is an effective product-form stationary distribution, and the mean value analysis that enables average metrics such as throughput and sojourn times to be measured, were the first significant results in this field. If the total number of customers in the network stays stable, the network is considered a closed network and has also been shown in the Gordon-Newell theorem to have a stationary product-form distribution. This outcome was applied to the BCMP network, where it is seen that a network with very general operating time, schemes and customer routing often exhibits a stationary product-form distribution. The normalizing constant can be calculated with the Buzen's algorithm, proposed in 1973 service (Larson & Odoni, 1999).

Several research on the use of the queuing principle in hospitals have been carried out. For example, John (2010) used the Tora Optimization method in his research entitled 'Queuing Theory and Patient Satisfaction: An Outline of Terms and Implementation in Ante-Natal Care Unit' to examine data collected over a three-week period from the ante-natal care unit of a public teaching hospital in Nigeria. The study found that in the first week, pregnant mothers spent less time in the queue and system than during the other two weeks that followed. 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.

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

A research on reducing queues at a Nigerian hospital pharmacy was undertaken by Ndukwe, Omale, and Opanuga (2011). The findings of their research revealed that a single server-multiple queue model was the queue characteristics that occurred at the pharmacy during the situation review. However, the streamlined procedure lowered the waiting time from 167.0 to 55.1 minutes after the intervention requiring personnel re-orientation was completed. Queue discipline was exclusively instituted by planned, serially numbered tally cards. The characterization and discipline developed tackled and/or abolished the shunting, balking or jockeying obstacle and decreased reneging. The result further showed that the waiting area to pharmacy space ratio, gave a good result of 1:9.

In their study entitled Using Queuing Theory and Simulation Model to Improve Hospital Pharmacy Efficiency, Mohammadkarim, Seyed, Ramin, and Ehsan (2014). In a military hospital in Iran, they used a descriptive-analytical analysis and a survey of 220 patients. The outcome of their research showed that in morning and evening shifts, the queue characteristics of the analyzed pharmacy during the condition review were very undesirable. In the morning and evening, the average number of patients in the pharmacy was 19.21 and 14.66, respectively. The overall time spent by clients on the device was 39 minutes in the morning and 35 minutes at night. 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 research conducted by John, David, and Akua (2014), on Improving Patient Flow and Resource Utilization in Out Patient Clinic: A Comparative Study of Nkawie Government Hospital and Aniwaa Health Center in Ghana, the findings showed that the estimated mean arrival rate and waiting period for the public hospital at the OPD were 23 and 0.5 hours, and 25 and 0.5 hours for priwaa Health Center, respectively.

Kembe, Onah, and Iorkegh (2012) performed a survey in the Federal Medical Centre Makurdi, Benue State, on a study of waiting and service costs in a multi-server queuing model. The tools used during data collection were direct observation and the researcher's informal interview and questionnaire management. Data for (4) weeks has been obtained. The data was evaluated using TORA optimization tools as well as descriptive statistics. The results showed that the overall queue length, patient waiting time and overuse of physicians at the clinic could be minimized at an optimum server level of 12 physicians and at a minimal net expense relative to the existing 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. Moreso, studies by Achanta, Karthikeyan & Vinothkanna (2020); Sampath Dakshin (2021); Achanta Karthikeyan, & Vinothkanna (2019) viewed the concept of queue beyond the conventional hospitals system. They opined that queue and its management is an integral part of a dynamic systems, its proper management is key in achieving an ideal system required in physical, social, mechanical and electronic systems.

In summary, the above mentioned literatures attempted to optimize hospital systems with the view of reducing waiting times. Most of the approach mentioned above has resulting cost implications on the organization. This paper attempted and resolved the issues of queue by simply reorganizing the existing service structure in a cost effective manner.

III. MATERIALS AND METHODS

There are two fundamental approaches to solving a queuing problem these are:

1) Mathematical Method: The mathematical method employs the use of probability approach to demonstratearrival and service rates.
2) Simulation Method: The simulation method is an iterative method that generate approximate solution to the problem through simulated experiment that based on random samples drawn from inter-arrival and service timedistribution.

This paper used the mathematical method.

3.1 Notations and model used.

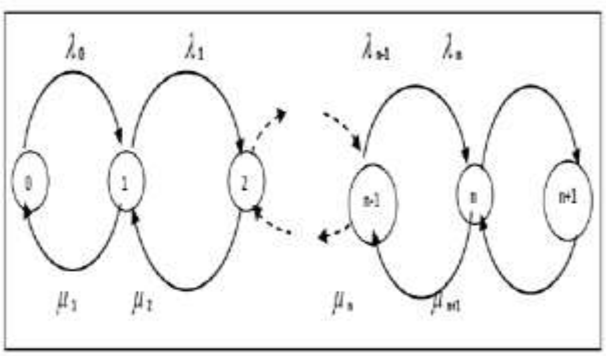

Figure 2. A birth (□□and Death(μ) process (Adopted from Kembe et al., 2018)

Different quantities are used for modeling queues, their performance measures are all the same. We define the notations used for various performances measures of the given systems as given below:

Mean rate of Arrivals per time period $= \phi$
Mean rate of Service per time period $= \gamma$
Total number of customers in the system per time period = n

Utilization factor for the service system $= \beta$

$$\beta = \frac{\phi}{\gamma}$$

Average number of customers in the system (Ac)

$$Ac = \frac{\phi}{\gamma - \phi} = \frac{\beta}{1-\beta}$$

Average number of customers in the queue (Aq)

$$Aq = \frac{\lambda^2}{\gamma(\gamma - \lambda)} \quad \frac{\beta^2}{1-\beta}$$

Average time a customer spends in the system (At)

$$At = \frac{1}{\gamma - \phi}$$

Average time a customer spends in the queue (As)

$$As = \frac{\phi}{\gamma(\gamma - \phi)}$$

Probability that there is no customer in the system (P0)

$$P0 = 1 - \frac{\phi}{\gamma}$$

Probability of having 'n' customers in the system (Pn)

$$Pn = \left(\frac{\phi}{\gamma}\right)^n P0 = \left(\frac{\phi}{\gamma}\right)^n \left[1 - \frac{\phi}{\gamma}\right]$$

If (*n* If there are n expectant mothers in the queuing system at any point in time, then the following two cases may arise, Kembe et.al. (2018);

1) If (*n* □ *K*) (number of pregnant women in the system is less than the number of servers),

then there will be no queue. However, (K - n) number of servers will not be busy. The combined service rate will then be $\gamma_n = n\gamma, n < K$

2) If $(n \geq C)$ (the number of expectant mothers in the system exceeds or equivalent to the number of Doctors) then all servers will be busy, and the maximum number of Pregnant women in the queue will be $(n-K)$. The combined service rate will be $\gamma_n = K\gamma, n > K$.

The system being a multi-server system has the following performance parameters:

i) The traffic intensity/utilization factor of the system is given by:

$$\beta = \frac{\phi}{K\gamma}$$

ii) The probability of zero customers in the system $(P0)$

$$P0 = \left\{\sum_{n=0}^{c-1} \frac{(K\beta)^n}{n!} + \frac{(K\beta)^c}{c!} \frac{1}{1-\beta}\right\}^{-1}, \beta < 1$$

iii) Probability of having n customers in the system (Pn) is given by:

$$Pn = \left(\frac{\phi^n}{\gamma(\gamma)(\gamma)....(\gamma)}\right) P0 = \left(\frac{\phi^n}{n!\gamma^n}\right) P0 = \left(\frac{(CP)^n}{n!}\right) P0 \text{ For n<K}$$

$$Pn = \left(\frac{\lambda^n}{\mu(u)(u)....(u)}\right) P0 = \left(\frac{\lambda^n}{n!\mu^n}\right) P0 = \left(\frac{(K\beta)^n}{n!}\right) P0 \text{ for } n \geq K$$

iv) The average numbers of customers in the queue is given by:

$$Ac = \left(\frac{\beta'\phi\gamma}{(K-1)![K\gamma - \phi]^2}\right) P0$$

v) The average numbers of customers in the system (Waiting + Service) is given by:

$$As = Ac + \frac{\phi}{\gamma}$$

vi) The expected waiting time in the queue after an arrival is given by:

$$Aq = \frac{Ac}{\phi}$$

vii) The expected total time spent in the system (Waiting + Service) is given by:

$$At = \frac{As}{\gamma}$$

In the ANC clinic in Mubi PHC, study was carried out in relation to the arrival pattern of patients and the overall queue system. At various times of the day, direct observations and interviews were performed for three weeks and analyzed using the TORA kit.

During the study work, the patient codes (001-140) reflect the various names of women who came to Ante Natal. At different hours, the women arrived at the hospital at random. The field work showed that females come to enter a queue as early as 6:30am. In the case of patient code 1, as early as 6:40 am, the woman arrived at the hospital. The File-reasonable workers arrived at work at 8:30 am. The arrival was random for all the patients and the time of each arrival was registered.

The advanced M/M/1 system was used by the hospital system, where multiple serial processing servers only provide a single queue. A quick look at the recording of the patient entering the file room and the subsequent time spent in the room. Patient No 1 entered the consultation room at about 9:30 a.m. and was promptly attended by the practitioner at 9:30 a.m. unlike observation No 4, where the patient was not attended until 10 minutes later (10:20 a.m.-10:30 a.m.) after arriving in the consultation room.

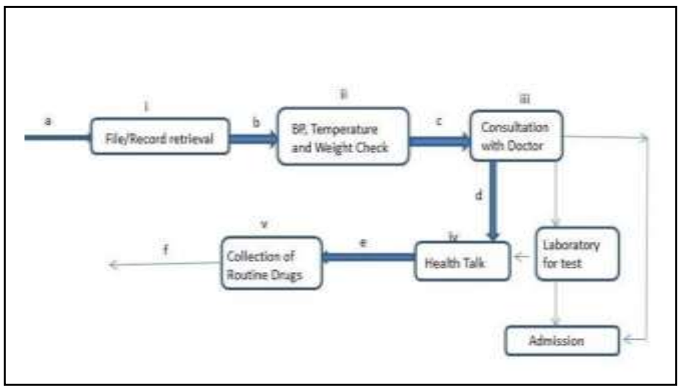

Figure 1: Illustrating a specialized Single Queue -Multiple Serial Servers at Mubi PHC

IV. RESULTS AND DISCUSSION

Table 1/; time Spend 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, 2020

Table 1: captured the response of the pregnant women on the “real” time they spent during ANC at Mubi PHC.

Source: Field survey, 2020

Table 1.2 showed that 57.14 of the respondents preferred to spend a median of 2 hours in the hospital system during the ANC, compared to 30 percent who wanted 2-4 hours, 7.14 percent who wanted 4-6 hours, 5.71 percent who wanted to spend 6-8 hours and no one wanted to reach 8 hours during the ANC

A TORA package was run on an overview of arrival, service, and time spent on the device by pregnant women. The findings shown below have been

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

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

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,

Independent Analysis of scenario 6: 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)
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,

The results from the above analysis showed that these women spent a lot of time in a queue waiting to be served. This is not good for them considering their delicate nature as pregnant women. A change in structure (see figure 2) has proved to have yielded a better result at little or no cost. Just the reorganization of the Ante natal care delivery.

Figure 2: Proposed Model

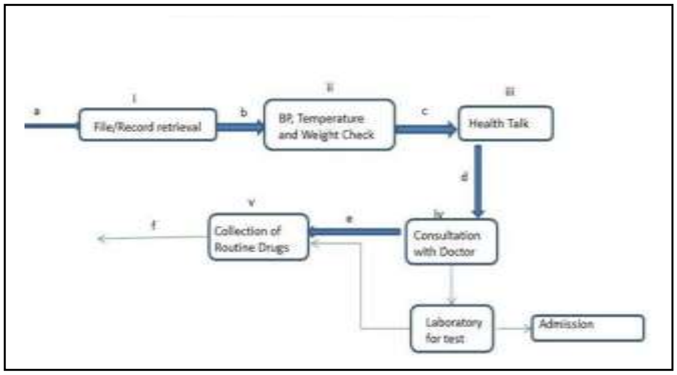

Figure 2 is recommended for adoption during the provision of the ANC in the facility. This recommendation if adopted will increase the service rate from 6 people per hour to 10 people per hour thereby directly reducing the waiting times in a queue.

V. CONCLUSION

The paper reflects a distinctive use of queuing paradigm 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. In fact, the findings from the initial structural model showed that quite a reasonable period of time lost during the ante natal activities. The proposed model showed that patients should not have to wait so long a queue waiting to be service. The model built in the current study is therefore flexible in the sense that every public hospital will follow it, based on the discretion of the management, with either the same or different degree of priority for any variable.

VI. RECOMMENDATIONS

Considering the results, the new model should be followed. By implementing suitable workforce scheduling methods, management may resolve the issue of lengthy waiting times. For e.g., to compensate for the heavy patient traffic, more staff members (GDMOs, pharmacists and other medical/non-medical staff) are expected to be available at the busy time periods. Therefore, to determine the busiest times of the week, some additional knowledge about the patient flow at various times of the day or different days of the week is needed. By recognizing multiple events that takes place at this period, the consultation may be minimized. These routine tasks (such as temperature, blood pressure, other patient pre-diagnosis details, etc.) can be done prior to the start of the "actual" appointment. This will encourage patients to be better handled effectively, contributing to improved satisfaction. The study found that during file extraction there are long waiting periods involved. Therefore, to satisfy the growing demand for these women, the management can expand the number of servers. The flow of patients would be spread in this manner, thereby reducing the waiting times. This research gives proof of the utility of queueing analysis. This is, however, the first step in solving a patient flow system problem. Therefore, in order to include concrete guidelines for change, a comprehensive analysis explicitly aimed at analyzing some other variables impacting the queuing mechanism in a hospital system with additional support evidence is needed.

Further studies

More researches should be done using Queuing Techniques and more sophisticated model be developed integrating queuing model and Systems Dynamics models, 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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