Using the queuing model to evaluate and predict optimum outpatient pharmacy dispensing service in Lagos University Teaching Hospital

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ABSTRACT

Background: Waiting times for health services arise because capacity does not match demand or capacity or demand is not well managed. Queuing theory is a powerful operational research tool which assists managers to make vital decisions capable of optimizing the performance of a health system facility, minimize operational costs and enhance the satisfaction of all interest groups.

Objective: To simulate the queuing model in the outpatient pharmacy in order to evaluate its performance and to develop necessary strategies for optimizing dispensing service.

Methods: The study was carried out at the Pharmacy Unit of Family Medicine / General Outpatient Department (GOPD) of Lagos University Teaching Hospital employing workflow analysis and time study. A sample size of 123 Ambulatory Patients was studied and data were collected daily over a period of four weeks. Data analysis was done using SPSS version 10.0 to determine waiting time for prescription validation and assessment, payment, filling, collection and counselling. The queuing system in Pharmacy was then simulated to determine measures such as Service Utilization Factor, Average Queuing Time in the queue and in the system, Average number of patients in queue and in the system, Waiting cost and Service cost all of which are necessary for evaluating service delivery in the outpatient setting.

Results: The study revealed a total patient waiting time of 79.24 min with the process component accounting for 7.9 ± 5.58 min (9.97%) and delay component responsible for 71.34 ± 66.93 min (90.03%). It was established that optimal service delivery would be achieved with two service points requiring six pharmacists in the pharmacy unit. This arrangement is expected to give an 88.1% reduction in mean total patient waiting time and 50% deduction in total cost when compared with existing system.

Conclusion: Significant reduction in waiting time can be made by facilitating service delivery at the prescription validation and assessment point. The excessive waiting time contributed by delay components underscored the need to employ more pharmacists to improve on the service system. Service efficiency would be optimized by increasing the number of service points to two in order to minimize the total operating costs.

Keywords: Waiting time, Queuing model, Outpatient pharmacy, Optimizing dispensing service.

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Utilisation du modèle de mise en file d'attente pour évaluer et prédire le service de distribution optimale de pharmacie ambulatoire au centre hospitalier universitaire de Lagos

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RESUME

Contexte : Les temps d'attente pour les services de santé surviennent parce que la capacité ne correspond pas à la demande ou que la capacité ou la demande n'est pas bien gérée. La théorie des files d'attente est un puissant outil de recherche opérationnelle qui aide les gestionnaires à prendre des décisions vitales capables d'optimiser les performances d'un établissement du système de santé, de minimiser les coûts opérationnels et d'améliorer la satisfaction de tous les groupes d'intérêt.

Objectif : Simuler le modèle de mise en file d'attente en pharmacie ambulatoire afin d'évaluer ses performances et de développer les stratégies nécessaires pour optimiser le service de distribution.

Méthodes : L'étude a été menée à l'unité de pharmacie de médecine familiale/Département de consultations externes générale (GOPD) du centre hospitalier universitaire de Lagos en utilisant l'analyse du flux de travail et l'étude du temps. Un échantillon de 123 patients externes a été étudié et les données ont été collectées quotidiennement sur une période de quatre semaines. L'analyse des données a été effectuée à l'aide de la version 10.0 du SPSS pour déterminer le temps d'attente pour la validation et l'évaluation des ordonnances, le paiement, le remplissage, la collecte et le conseil. Le système de mise en file d'attente en pharmacie a ensuite été simulé pour déterminer des mesures telles que le facteur d'utilisation du service, le temps moyen d'attente dans la file d'attente et dans le système, le nombre moyen de patients en file d'attente et dans le système, le coût d'attente et le coût du service, qui sont tous nécessaires pour évaluer la prestation de services en consultation externes.

Résultats : L'étude a révélé un temps d'attente total du patient de 79,24 min, le composant du processus représentant 7,9 ± 5,58 min (9,97%) et le composant de retard responsable de 71,34 ± 66,93 min (90,03%). Il a été établi qu'une prestation optimale de services serait obtenue avec deux points de service nécessitant six pharmaciens dans l'unité de pharmacie. Cette disposition devrait permettre une réduction de 88,1% du temps d'attente total moyen des patients et une déduction de 50% du coût total par rapport au système existant.

Conclusion : Une réduction significative du temps d'attente peut être réalisée en facilitant la prestation de services au point de validation et d'évaluation des ordonnances. Le temps d'attente excessif causé par les éléments de retard a souligné la nécessité d'employer plus de pharmaciens pour améliorer le système de services. L'efficacité du service serait optimisée en augmentant le nombre de points de service à deux afin de minimiser les coûts totaux d'exploitation.

Mots-clés : Temps d'attente, Modèle de file d'attente, Pharmacie externe, Optimisation du service de distribution.

INTRODUCTION

Operational research is an approach to the analysis of operations that to an extent adopts scientific method as well as explicit formulation of complex relationships. The primary purpose of operational research is obviously to identify the optimum way of operating. Since the attempt of Bailey and Lindley to resolve outpatient clinic dissatisfaction, many operating research techniques have been developed to understand the underlying problems better.[1,2] These techniques include the queuing theory, mathematical programming, modeling and simulation.[3] Queuing theory is an operational research tool which has been applied in the assessment of prescription filling time, patient waiting time, patient counseling time, staffing levels, waiting and service costs, patient satisfaction among others.

With the knowledge of queuing theory, managers can make decisions that can optimize the performance of the system, minimize operational costs and enhance the satisfaction of all interest groups. A queue forms at anytime when the demand for a service exceeds the capacity of the service facility. Any group of people or objects awaiting their turn for service constitutes a queue. One reason for studying queues is to enable the optimum service facility to be selected so that the overall cost of a service is minimized. Wait times for health services arise because capacity does not match demand or capacity or demand is not well managed.

Setting capacity levels entails an unavoidable tradeoff between waiting times and resource utilization. When capacity significantly exceeds average demand, queues will be short and wait times minimal. When capacity is significantly below average demand, system resources will be fully utilized and wait times excessive and grow over time. To ensure that a low proportion of patient wait times exceed specified targets, capacity must be set sufficiently high so that idle time is inevitable.[4]

In Pharmacy, queuing theory had been employed to assess the relationship among the number of pharmacy staff, prescription dispensing processes and outpatient waiting times.[5] Nosak and Wilson also emphasized the use of queuing theory to assess amplitude of factors such as prescription filling time, patient waiting time; patient counseling time and staffing levels and that application of the theory may be of particular benefit in pharmacies with high volume outpatient workloads and/or those that provide multiple points of service.[6]

Furthermore, Lin *et al*. used work measurement and computer simulation to assess the reengineering of community pharmacies to facilitate patient counseling.[7] In a similar vein, Venuri used computer simulation with a queuing model to assess patient waiting time in the outpatient pharmacy at the Medical College of Virginia, USA.[8] He concluded that the most significant factor contributing to patient waiting times was the interaction between pharmacy service providers specifically, the typist and the technician. There are various quality assurance indicators for healthcare system. In the outpatient pharmacy setting, waiting time is the main indicator. Thus, to improve service quality, the waiting and service times are of prime considerations.[9]

Afolabi and Erhun studied the dispensing procedure in a Nigerian teaching hospital, investigated the possible operational problems that may lead to excessive patient waiting times as prescriptions are filled and also examined patient dispositions to perceived delays at the Pharmacy. This was achieved through the techniques of workflow analysis and time study of the dispensing process and also the use of questionnaires as an instrument to measure level of satisfaction with pharmaceutical services rendered. The waiting time for a dispensing process was found to average 17.09 min and 89.05% of the total waiting time was due to delay components. They identified operational problems such as indirect access to dispensing pharmacist and the tortuous procedures for billing of prescriptions and payments. They also concluded that patients were not satisfied with undue delay encountered in the pharmacy.[10] Long waiting times affect the efficiency of the pharmacy and cause patients' dissatisfaction.

There are numerous other studies on waiting times from different parts of the World. In a descriptive analytical study conducted in a military hospital in Tehran, Iran in 2013, involving 220 patients attending the outpatient pharmacy of the hospital in two shifts - morning and evening, results showed that the queue characteristics of the studied pharmacy were and that increasing staff strength by one in filling prescriptions led to a decrease of 10 persons in the average queue length and 18 minutes in the average waiting time.[11] Another study conducted at the Outpatient Pharmacy of National Orthopaedic Hospital, Lagos in Nigeria revealed a total process waiting time of 31.9min[12] In the main outpatient pharmacy in Lagos University Teaching Hospital, a cross-sectional intervention study was carried out by streamlining queue behaviour and pattern as well as to measure the impact of streamlined queue characteristics and queue discipline on patient waiting time. After the intervention was done involving staff re-orientation, the streamlined process reduced waiting time from 167.0 to 55.1min and queue discipline was instituted by designed tally cards that were serially numbered.[13]

Operational research has also been employed in planning resource allocation. In general, the demand for and cost of better health care increases at a faster rate than the augmentation of clinic resources such as health care staff and space. Health care services frequently find it difficult to acquire more resources to cope with rising cost. Resource allocation in health care planning is crucial to maintaining quality health services.[14] Simulation helps hospital administrators to decide on the capacity of new facilities before they are set up.

Hashimoto and Bell developed a simulation model of an outpatient clinic to improve staff strength. They found that the idle time of all services in the clinic could be reduced by increasing the number of Doctors.[15] With this measure and subsequent retraining of medical staff to increase efficiency; the time spent in the clinic by patients was reduced by 24%. Swisher and Jacobson used an object-oriented discrete event simulation model of a family practice health care clinic to determine optimum staff and physical resources in the clinic.[16]

Two basic costs considered in the outpatient setting are waiting cost and service cost. Waiting cost is associated with clients having to wait for service. This includes loss of business as some patients might not be willing to wait for service and may decide to go to competing organizations, cost due to delay in care or the value of the patient's time (opportunity cost) and decreased patients' satisfaction and quality of care. Service cost is the cost of providing service. This includes salaries paid to employees and servers and cost of waiting space facilities, equipment and supplies. Using the estimation of waiting cost allows decision makers to be able to determine the optimal number of servers by minimizing the total cost.[17]

When considering improvements in service, the health care manager weighs the cost of providing a given level of service against the potential costs of having patients waiting for service. The goal of optimization is therefore to minimize the total cost to the system. Economic analysis of these costs helps the management to make a trade-off between the increased cost of providing better service and decreased waiting cost which clients would be subjected to in receiving. This cost analysis is illustrated by the following equations.

Expected Service

Cost E(SC) $= S.C_s.$ 1

Expected Waiting Cost

E(WC) $= (.W_s)C_w$ 2

Expected Total Cost E(TC) $= E(SC)+E(WC)$ 3

E(TC) $= S.C_s + (W_s)C_w$ 4

Where

Ws = Average time a client spends in the system

Cw = Opportunity cost of waiting by clients

Cs = Service cost for each server calculated as the hourly salary of each health care provider

S = Number of servers

A= Average arrival rate of clients into the system

There is an inverse relationship between the two costs. With an increase in number of servers, the service costs increase while the waiting costs decrease.[18] The hourly waiting cost of a client receiving service from the pharmacy has been calculated by using the per capita annual income of the population of the country.[19]

Many different mathematical equations can be used to describe queue formation and behaviour. Tables 1 and 2 show formulas for determining performance indicators for a single server system and also for multichannel service facility.[11,17,20,24] Most queuing research applications are now completed through some form of computerization due to the complexity of the models and the accessibility of off-the-shelf software. By better understanding queuing theory, service managers can make decisions that have a beneficial impact on the satisfaction of clients, staff and management while relying on several tools such as computer simulation and modeling that can assist in this optimization.[20]

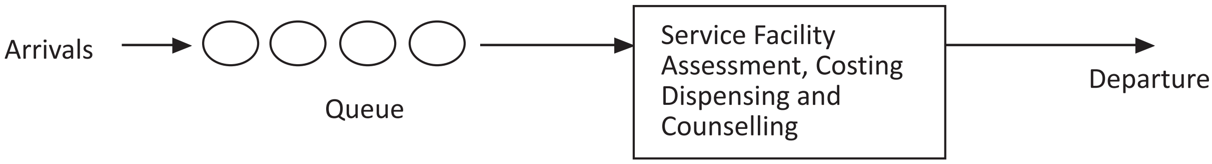
Queuing theory is in this study being applied to determine the key performance indicators and in the simulation of the multichannel service system to develop strategies for enhanced performance. There are standard notation systems for classifying queuing models.[13] These are illustrated in figure 1. Figure 2 is a sketch of Family Medicine/GOPD Pharmacy Unit in Lagos University Teaching Hospital where this study was carried out. This gives a description of the size, design and layout of the Pharmacy Unit and intends to elicit an appraisal of the need to evaluate its appropriateness or otherwise for the services it is meant to offer.

Table 1: Formulas to determine performance indicators for a single server system

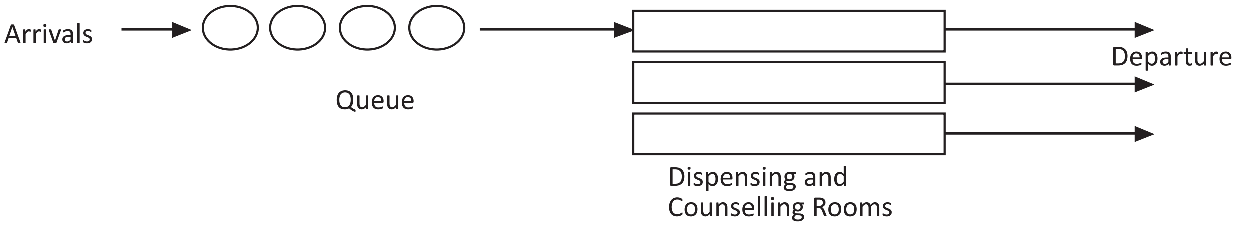
	Performance indicator	Formula
1.	Service Utilization Factor, (Traffic Intensity)	$\rho = \lambda/\mu$
2.	Average number of Patients in queue (Lq)	$\rho^2 / 1- \rho$
3.	Average number of Patients in System (Ls)	$\rho / 1- \rho$
4.	Average time a patient is in queue (Wq)	$\rho / \mu - \lambda$
5.	Average time a patient is in the system (Ws)	$1 / \mu - \lambda$
6.	Average time of service = Average time in system – Average time in queue	Ws – Wq
7.	Probability of not queuing on arrival	$1- \rho$
8.	Probability of having n patients in the system	$(1-\rho)\rho^n$

Table 2: Formulas to Determine Performance Indicators for a Multichannnel Service Facility

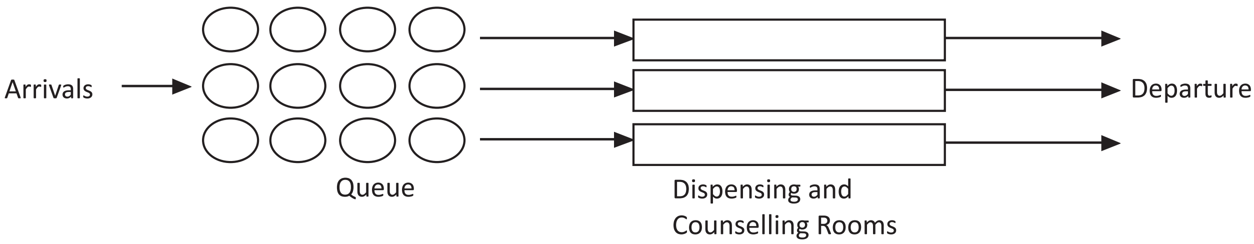
	Performance Indicator *Where C = Number of Servers*	Formula
(i)	Traffic Intensity (Utilization factor)	$\rho = \lambda/c\mu$
(ii)	Probability of queuing for service	$\frac{\rho_o (C\rho)^c}{C!} \times \frac{1}{1 - \rho}$
(iii)	Average number of Patients being served	$C\rho$
(iv)	Average number of Patients in the queue (Lq)	$\frac{\rho_o (C\rho)^c}{C!} \times \frac{\rho}{(1 - \rho)^2}$
(v)	Average number of Patients in the system (Ls)	$C\rho + \frac{\rho_o (C\rho)^c}{C!} \times \frac{\rho}{(1 - \rho)^2}$
(vi)	Average queuing time (Wq)	$\frac{\rho_o (C\rho)^c}{C!} \times \frac{1}{\mu C (1 - \rho)^2}$
(vii)	Average waiting time (Average time spent in system) Ws.	$\frac{\rho_o (C\rho)^c}{C!} \times \frac{1}{\mu C (1 - \rho)^2} + \frac{1}{\mu}$
(viii)	Probability that there are no elements in the system, ρ_o Where C = number of servers	$\rho_o = \frac{C! (1- \rho)}{(C\rho)^c + C! (1 - \rho) (\sum^{c-1} 1/n! (C \rho)^n)}$



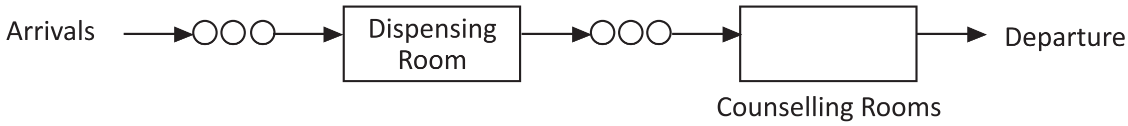
Single server single queue model



Multiple Parallel services single queue model



Multiple Parallel Services Multiple Queue Model



Service Facility in Series

Figure 1: Queuing models in the pharmacy

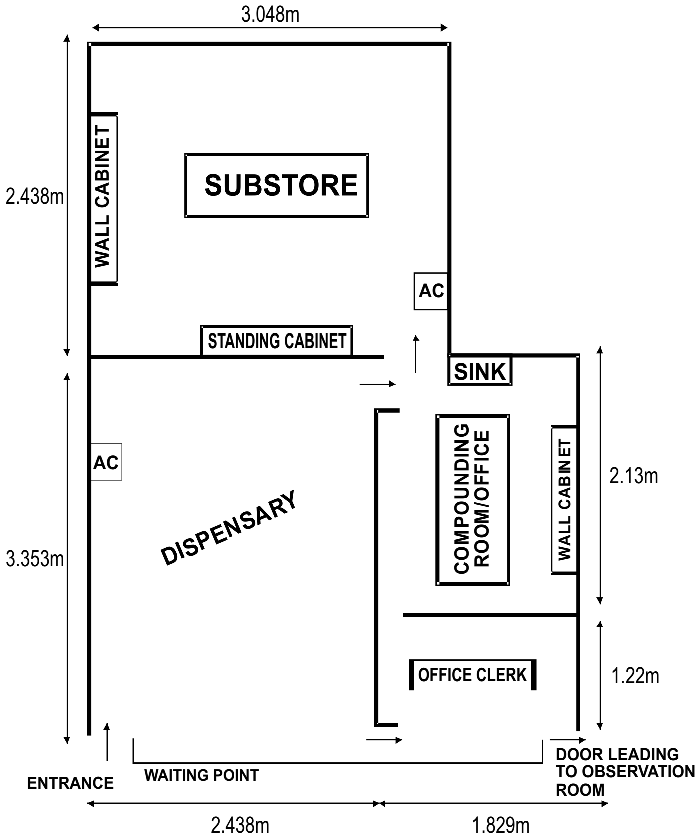


Figure 2: A Sketch Of Family Medicine / GOPD Pharmacy Unit

METHODS

Study design:

This was a prospective analytical observational study done by simple random sampling of patients seeking pharmaceutical care in the Outpatient Pharmacy.

Study setting:

The study was carried out in the Pharmacy Unit of Family Medicine / General Outpatient Department (GOPD) of Lagos University Teaching Hospital (LUTH). The Pharmacy renders Pharmaceutical services to patients in GOPD (fee paying patients), Schools in LUTH viz. Schools of Nursing, Basic Dental Nursing, Post Basic Nursing, Midwifery, Health Information Management on retainership and University of Lagos students who are on Tertiary Institution Students Health Insurance Programme (TISHIP) as well as patients on National Health Insurance Scheme (Primary and Secondary). It serves an average of 55 patients daily and has a floor space of 21.74m2.

Population / sample and sampling:

A sample size of 123 Patients were selected in accordance with Cochran's formula using a finite population correction factor.21 The assumptions were that at least 10% of Patients visiting the Pharmacy Unit would experience service delay (P =0.1) at 5% desired margin of error and 95% level of confidence.

Inclusion criteria:

Any patient attending Family Medicine / General Outpatient Department and who received a prescription to access pharmaceutical care at the Pharmacy Unit during the four week period of the study. The subjects were required to give a written consent to participate in the study by completing and signing a Respondents informed Consent Form.

Exclusion criteria:

All patients who did not consent and those below 18 years of age who were not accompanied by adult care givers.

Data collection:

Instrument and administration

This employed the use of time monitoring chart to measure patient waiting time in the Pharmacy. The dispensing procedure was studied and then divided into 'delay' and 'process' components and time spent on each component measured. This method highlighted sequence of activities involved in the dispensing procedure starting from patient arrival, submission of prescription sheet by patient and its subsequent flow through vetting by pharmacists for appropriateness, costing of the prescription items and its subsequent payment to the cashier, dispensing, patient counseling, drug collection and patient departure. Data were collected daily over a period of four weeks. Two Intern Pharmacists were trained as research assistants for a day on the data collection instrument. They also participated in the selection of subjects and in the recording of time monitoring chart.

Data analysis:

The data were analyzed using SPSS version 10.0 to determine mean waiting times for prescription assessment, payment, filling, collection, counselling and their various frequency distributions and percentages. The data obtained were used to analyze the arrival process as well as the service process. The dispensing process was resolved into two components viz. process and delay components and the total waiting time determined. The mean arrival and service rates were employed in the calculation of key performance indicators (Tables 1 and 2) both for a single server system and a simulated multi channel service facility. Simulation of the queuing system also enabled the determination of waiting and service costs for an optimal service performance.

Ethical approval:

Ethical approval was obtained from Health Research and Ethics Committee of Lagos University Teaching Hospital prior to commencement of study.

RESULTS

Table 3 presents the time study analysis of processing and delay components for the Family Medicine / GOPD Pharmacy unit. The mean total waiting time was determined to be 79.24 minutes with the process component accounting for 7.9 5.58 minutes (9.97%) and the delay component responsible for 71.34 66.93 minutes (90.03%).

Table 3 : Time Study Analysis Of Processing And Delay Components For The GOPD/Family Medicine Pharmacy, LUTH

Variables of Dispensing Components	Components of dispensing Procedures	
	Processing Mean ± SEM (%) Time Spent (Minutes)	Delay Mean ± SEM (%) Time Spent (Minutes)
Queuing time before Prescription Validation and Assessment	-	30.87 ± 24.10 (38.96%)
Prescription Assessment Time	3.07 ± 2.79 (3.79%)	-
Time to visit NHIS, TISHIP and Payment Points	-	18.59 ± 15.95 (23.46%)
Prescription Filling Queuing time	-	14.11 ± 13.54 (17.81%)
Prescription Filling and Packaging	3.52 ± 2.27 (4.44%)	-
Queuing time before collection	-	7.77 ± 13.34 (9.81%)
Collection and Counseling time	1.31 ± 0.52 (1.65%)	-
Total	**7.90 ± 5.58 (9.97%)**	**71.34 ± 66.93 (90.03%)**

Traffic intensity is the probability that a patient has to wait in a queue. It is also the same as service utilization factor.

Results showing performance parameters of the system at different number of servers are presented in Table 4. These were obtained after simulation using different number of servers. There was a progressive decline in the operating performance measures as the number of servers increases. There were significant reductions in the average waiting time in queue and also average waiting time spent in the system with increase in the number of servers from 1 to 4.

Table 4: Performance parameters of the system at different number of servers

Parameters	No of Service Points 1	2	3	4
Arrival rate (λ) per minute	0.1145	0.1145	0.1145	0.1145
Service rate (per minute)	0.1266	0.1266	0.1266	0.1266
Service Utilization (ρ)	0.9	0.45	0.30	0.23
Probability that no patient in system (ρo)	0.1	0.38	0.40	0.40
No of patients in queue (Lq)	8.56	0.23	0.03	0.005
No of Patients in System (Ls)	9.46	1.13	0.93	0.92
Average time in queue (Wq) minutes	74.74	2.01	0.29	0.04
Average time spent in system (Ws) minutes	82.64	9.91	8.19	8.19

Table 5 shows the proposed staffing structure for the pharmacy unit and the service cost per hour with different number of service points. The service cost varies directly with staff strength in the unit.

Table 5: Proposed staff structure for the pharmacy unit

Service Points	Staffing Structure	Staff Strength	Monthly Salary (Service Cost) (₦)	Salary Per Hour (Service Cost Per Hour) (₦)
n = 1 Existing	Asst. Director	1	335,867.49	1,161.22
	Chief Pharmacist	1	267,358.99	
	Intern Pharmacist	2	245,048.34	
	Total	**4**	**848,274,82**	
n = 2 Proposed	Asst. Director	1	335,867.49	1,583.29
	Chief Pharmacist	1	267,358.99	
	Pharmacist l	2	308,317.66	
	Intern Pharmacist	2	245,048.34	
	Total	**6**	**1,156,592.48**	
n = 3 Proposed	Deputy Director	1	411,554.00	2,146.68
	Asst. Director	1	335,867.49	
	Chief Pharmacist	1	267,358.99	
	Pharmacist l	2	308,317.66	
	Intern Pharmacist	2	245,048.34	
	Total	**7**	**1,568,146.49**	
n = 4 Proposed	Deputy Director	1	411,554.00	2,710.01
	Asst. Director	1	335,867.49	
	Chief Pharmacist	2	534,717.98	
	Pharmacist l	3	462,476.49	
	Intern Pharmacist	2	245,048.34	
	Total	**9**	**1,979,664.30**	

Table 6 shows total hourly waiting cost, total hourly service cost and the total cost (Expected) per hour. The optimal level of service is achieved when the number of servers is 2 with a minimum total cost of N1,905.57 per hour as against the existing single, service point with a total cost of N3,850.75 per hour. This is illustrated also in Figure 3 indicating that optimal service is obtained with two service points. Furthermore, utilization factor which is a measure of how busy the system is was found to decrease as level of service increases (Figure 4).

Table 6: Table showing total cost at different number of service points

No of service points	Total hourly service cost E(SC)	Arrival rate, λ (per hour)	Expected waiting time in system (Ws) in hour	Total hourly waiting cost E(Wc) = Cw (λWs)	Total expeced cost per hour E(TC) = E(SC) + E(WC)
1	₦ 1,161.22	6.9	1.377	₦ 2,689.53	₦ 3,850.75
2	₦ 1,583.29	6.9	0.165	₦ 322.28	₦ 1,905.57*
3	₦ 2,146.68	6.9	0.137	₦ 267.59	₦ 2,414.27
4	₦ 2,710.01	6.9	0.132	₦ 257.82	₦ 2,967.83

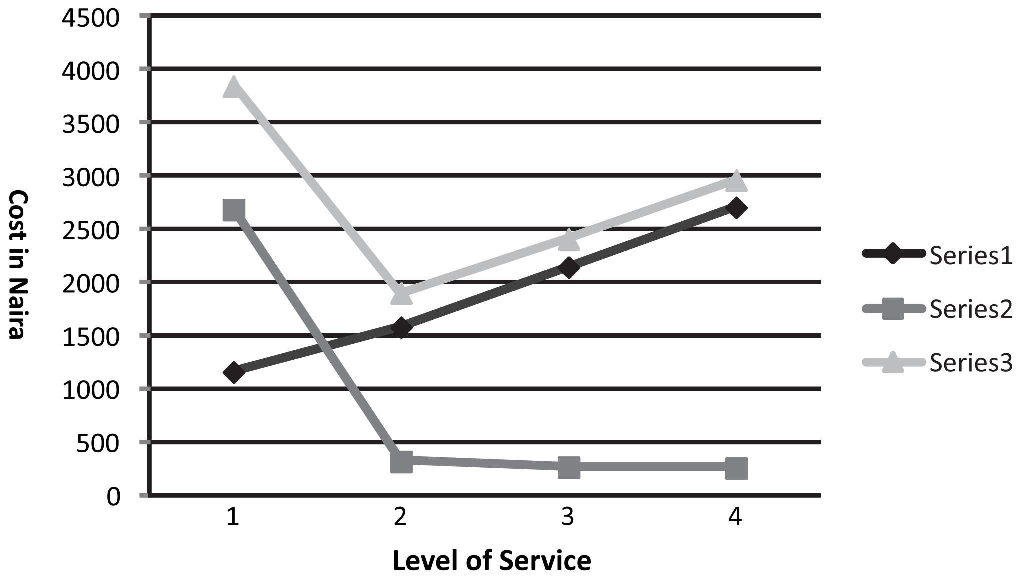


Figure 3: Graph Of Cost Vs Level Of Service

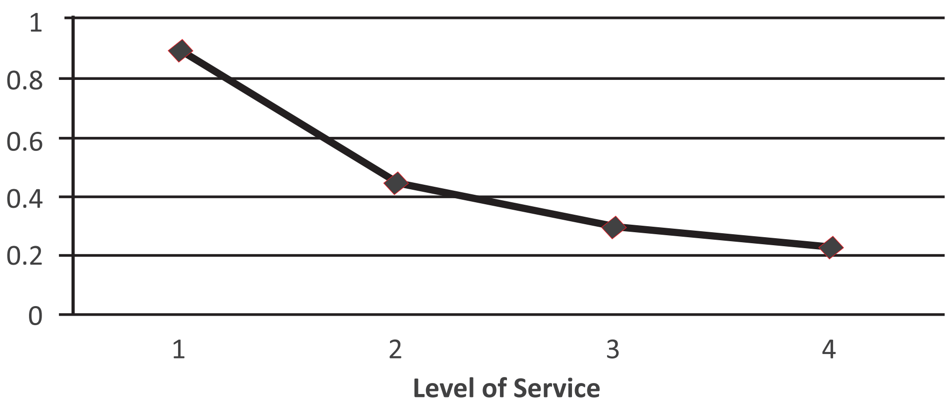


Figure 4: Graph of level of service vs service utililzations

DISCUSSION

The results of this study reveal a total waiting time in the pharmacy unit of 79.24 min with the process component accounting for 7.90 ± 5.58 min (9.97%) while the delay component accounted for 71.34 ± 66.93 min (90.03%) (Table 3). There are four areas of delay which serve as a component of total waiting time. These comprise of delay before prescription validation and assessment; delay arising from visits to NHIS office, TISHIP office and payment points; delay after prescription submission and prior to filling as well as delay post prescription filling and before collection of drugs. The study indicated that waiting time for prescription validation and assessment took the largest portion of the total waiting time (38.96%) in the pharmacy unit. Patients faced a lot of delays arising from the queue experienced while waiting for prescription vetting and assessment and also in the cause of visits to NHIS and TISHIP offices for collection of retainership forms and transcription of prescription into NHIS and TISHIP prescription sheets. Large amount of time was also spent at payment points and photocopy centres (to photocopy NHIS / TISHIP retainership forms and prescription sheets). The payment points and photocopy centres are not sited within the vicinity of the pharmacy. Payment points located in the Medical Outpatient Department served the patients of GOPD as well as other departments and clinics in the Outpatient building. There is usually a large number of patients waiting to pay for different kinds of services.

Patients also experience queues having to wait for dispensing, counseling and collection of their medications. The total waiting time is exacerbated by chronic shortage of pharmacists and also the small size of the pharmacy (21.74m2) which does not permit efficient staff movement within the dispensary. This was found to restrict dispensing as well as counseling activities.

Particularly striking is the information available from Table 3, indicating that patient counseling time took only 1.31 0.52 minutes. The implication of this is that there is little or no patient counseling in the facility.

The size of the facility may contribute to the smaller process time as compared to a similar study done in Outpatient Pharmacy Department (OPD) of this hospital where the service time was found to be 17.05 minutes. [22]

The latter had a larger floor space, handled a bigger patient load with better facilities for dispensing activities e.g. compounding section and counseling rooms. In essence, operational problems identified included strenuous procedures for prescription validation and assessment as well as for payment for prescription items.

The results given above concerning the process and delay components of the total waiting time are in line with that obtained from a study carried out at Outpatient pharmacy of the University Hospital Inc. Cincinnati, Ohio, USA in which process components accounted for 10.5% of the total waiting time while the delay component took 89.5%.[23]

Fig. 3 shows that waiting cost decreases as number of service points increases. This arises from successive reduction in waiting time as the service level increases. It also reveals that service cost (SC) in the Pharmacy Unit increases as the number of service points increases. This is expected as provision of an enhanced level of service requires huge investment in manpower and facilities.

The smaller the service facility, the longer the queues and the higher the costs. On the other hand, it costs money to increase the capacity of the service facility. The greater the service capacity the quicker it will dispense queues, lower waiting cost and therefore the more often it will stand idle. Clearly one reason for studying queues is to enable the optimum service facility capacity to be selected so that the overall cost of a service is minimized.

Furthermore, optimal service level in the pharmacy unit is achieved when the number of service points is 2. For a 2 channel service level, 6 pharmacists comprising one Assistant Director, one chief pharmacist, two pharmacists and two intern pharmacists have been proposed for the unit in line with current realities in staffing situation in the hospital (Table 5). With this restructuring, there arises a significant reduction in average total waiting time from 82.64 min to 9.91 min (88.1% reduction) when compared to the existing system. This is comparable with the results of an earlier study on decreasing queues in a Nigerian hospital pharmacy, which showed a reduction in the patients waiting time by 67% through the application of queuing theory involving change in queuing model from multi-queue single server to single queue multi-server model.[13] This is also in line with results from a study obtained when the queuing characteristics of a customer care centre were analyzed using a Multi-server queuing model with FIFO discipline and waiting and service costs determined with a view to determining the optimal service level. The results showed that average queue length and average waiting time of the customers in the system were reduced at optimum level of service compared with the existing level of service.[19]

A number of limitations may be identified with regard to this study. At the beginning of operations, the queue situation is untypical and the service facility can be idle even though the system has a traffic intensity of greater than 1 or there can be a long queue even though the traffic intensity <0.1 if the queue begins to form sometimes before the service facility opens. In the application of queuing theory, it is difficult to obtain solutions when the system is in a transient state.

Mathematical models developed only apply to steady state.[24] In this study, there is the need to allow the system to ultimately settle down to a steady state before the commencement of data collection. Many real life systems are more complex than the theory assumes and the distributions observed are often less simple than is required by the theory.

Service costs and waiting costs have also been identified with a queuing system such as a pharmacy outpatient facility. Waiting cost may include indirect cost of lost business (opportunity cost) and the loss of future business due to the dissatisfaction of the customer or the direct cost of idle facilities and client. On the other hand, service cost is the cost of providing service. Apart from the direct costs in terms of salaries paid to servers in the course of service delivery to clients, other components of service cost include cost of waiting space, facilities, equipment and supplies. The limitation of this study is the difficulty of putting many of these associated costs into consideration. The approach favoured by many researchers on the subject is to consider service costs as hourly marginal cost of a server and the waiting cost by using the per capital annual income of a country's population.[17,18,19,25] The implication of this approach is that there may be underestimation of this total cost to the system.

CONCLUSION

The study established that optimal service level of the Pharmacy Unit would be achieved with a two channel service level requiring six Pharmacists. This gives an 88.1% reduction in average total waiting time and 50.1% reduction in total cost when compared with the existing system. Waiting time for prescription validation and assessment took the largest portion of the total waiting time in the Pharmacy Unit. Thus significant reduction in waiting time can be made by facilitating service delivery at this particular point. In addition, the excessive waiting time contributed by delay components underscored the need to employ more staff in order to improve on the service system. Queuing theory is thus a vital tool which can be employed to make important decisions that can optimize service delivery in an ambulatory pharmacy setting.

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