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Application of Queuing Model in the Hospital Pharmacy Unit-A Case Study

V. Suseela Triveni*
**Department Of Mathematics, Geethanjali College Of Engg. & Tech., Cheeryal (V), Keesara (M),Medchal Dist., Telangana, India,*

ABSTRACT
The Objective Of This Study Was To Analyze Various Design Alternatives In Determining The Manpower Requirements Needed To Run A Hospital's Pharmacy Unit Efficiently. Several Queuing Models Are Used For This Analysis. This Study Enable The Hospital Administration In Understanding And Effectively Using The Manpower Available In Reducing The Waiting Times Of Prescription Orders Under Different Conditions. Three Different Operating Procedures Were Evaluated In Order To Give A Complete Analysis Of The Prescription Order Process Taking Place In The Pharmacy Unit. These Were A Multiple Server Queuing Model With No Priorities, A Priority Discipline Queuing Model Without And With Pre-Emptive Service.
Keywords – Arrivals, Queuing Model, Pharmacy Unit, Service

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I. DATA OF THE PROBLEM

This Study Was Carried Out In The Military Hospital, Situated In Hyderabad. The Primary Responsibility Of The Pharmacy Unit Is To Fill Prescriptions. During The Day, Prescription Orders Are Delivered Either By Messenger Or By Service Personnel At The Pharmacy's Service Window. They Arrive Both As Individual Orders And In Bulk. The Pharmacist Must Perform A Patient Profile On Each Prescription And Update Their Records. When Filled, The Pharmacist Checks Afterwards To See That It Was Done Accurately.

Arriving Orders Are Usually Classified Into Two Categories And Processed According To A Priority System. The Most Urgent Or Stat Orders Are Processed Immediately So That Service On Non-Stat Prescriptions In Progress Is Pre-Empted. All Other Arrivals Are Considered Regular And Include New And Refill Prescription For Non-Emergency Units, Auxiliary Hospital Units And Floor Supplies. Because Of Probabilistic Elements In The Pharmacy's Operation, Queues Tend To Form. Prescription Orders Arrive At Random And The Time Required To Fill An Order Is Random. When No Pharmacist Is Available For Service, Orders Must Wait In Line. The Working Of Pharmacy Unit Was Observed For One Week Duration In Order To Determine The Nature Of The Queue, Arrivals And Services. Throughout This Time, The Data Were Collected During The Busiest Part Of The Day.

II. QUEUE

A Single Line Forms For All Prescription Orders Wait For Service. There Is Always More Than One Pharmacist Working At Any Time. The Sequence In Which Prescriptions Are Filled Is Based On A Priority System. Two Priority Classes Exist: 1 With Stat Orders Receiving The Highest Priority And 2 With Regular Orders, Including Other New Prescriptions, Refills And Floor Supplies, Receiving The Lowest Priority. In Addition, Service Is Pre-Emptive So That Service On An Order Is Interrupted If A Higher Priority Order Enters The Queuing System. The Low Priority Regular Order Resumes Service From The Point At Which It Was Pre-Empted When There Are No More Stat Orders Waiting To Be Processed.

III. ARRIVALS

Prescription Arrives Throughout The Day, Being Delivered By Messenger Or Service Personnel At The Pharmacy Window. Though Some Arrivals Are Makeup Of Several Prescription Orders In Bulk, They Are Treated As Individual Orders Arriving At The Same Time. Arrivals Were Measured Separately For The Two Priority Classes When Data Were Collected Over Consecutive 20 Minute Intervals. The Mean Arrival Rate $\Lambda 1$ And $\Lambda 2$ Of Orders And Regular Orders Are Found To Be 0.092 And 0.27 Per Minute, Respectively.

IV. SERVICE

Data Were Obtained For The Time Required To Service Prescription Orders For Each Of The Two Priority Classes. In That Time, The

Pharmacist Fills The Prescription And Updates His Records. Each Order Processed During A One Month Period Was Recorded. It Was Found That The Average Service Time For Stat Orders (1/µ1) And Regular Orders (1/µ2) Were 1.62 And 5.71 Minutes, Respectively. Both Types Of Orders Follow General Service Distributions.

V. DEVELOPMENT OF QUEUING MODELS

In Order To Apply Analytical Formulas To A Priority Discipline Queuing Model It Is Necessary To Make The Assumption That The Mean Service Time Is The Same For All Priority Classes And Form An Exponential Distribution. The Single Service Time Distribution Lies Somewhere Between 1/ µ1 And 1/µ2. Therefore,

$$1/\mu = (\lambda_1/\lambda_2)/\mu_1 + (\lambda_2/\lambda)\mu_2 \qquad (1)$$

Where Λ= Λ1 + Λ2. In This Problem Λ = 0.362. Then The Mean Service Time 1/ µ Is 4.67 And Is Assumed To Be The Parameter Of All Exponential Distribution. Since The System Utilization Rate, Λ/Sµ Is Greater Than 1; More Than One Pharmacist Is Needed. To Study The System Under Steady-State Conditions, It Is Necessary For Λ/Sµ<1, Where's Is The Number Of Servers.

Three Different Operating Procedures Are Designed And Evaluated In Order To Give A Complete Analysis Of The Prescription Order Process Taking Place At The Pharmacy Unit. For Each Procedure The Expected Waiting Time Of An Order Lq Is The Characteristic Of Interest As A Function Of The Number Of Pharmacists.

Design I: Multiple Server Queuing With No Priorities

Applying A Queuing Model In Which There Are Priorities Given To Orders And A Arrival Rate And Service Time For All Orders. Assuming That The Arrival Rate Is Poisson And Service Time Is Exponential, We Have The Following Standard Results:

For Design I, Λ=Λ1 + Λ2=0.362 And $\frac{1}{\mu}$ = 4.67

(I) Probability That No Orders Are Waiting Is :

$$P_0 = 1/\left(\sum_{j=0}^{s-1}(\lambda/\mu)^j/j! + (\lambda/\mu)^s/s!(1-\lambda/s\mu\right)$$

(2)

(Ii) Probability That As Servers Are Busy Is :

P=P(Busy)=

$$(\lambda/\mu)^2 P_0/s!(1-\lambda/s\mu)$$

(3)

(Iii) Expected Waiting Time Of An Order Is :

Lq=P(Busy)/(Sµ-Λ) (4)

Design Ii: Priority Discipline Queuing Model

Applying A Priority Queuing Model With Two Priority Classes. The Arrival For Each Class Is Poisson, Service Is Non-Pre-Emptive And Service Times Are Assumed Exponential For Each Priority Class With The Same Mean Service Time.

The Model In Design Ii Assumes That There Are Two Priority Classes. High Priority Class 1, Representing Stat-Orders, And Lowest Priority Class 2, Representing Regular Orders.

For, Λ1=0.092; Λ2=0.27; Λ=0.362 And 1/µ=4.67, We Define

(Iv)

$$\sigma_m = \sum_{j=1}^{m}\lambda_j/\mu;$$

For $a(s-\sigma_{m-1})(s-\sigma_m)$ 11M Priority Classes

(5)

Where Σ0 = 0; Σ1= 0.429; Σ2=1.619

The Expected Waiting Time For Orders Class M Is:

(V) Lqk = s/μ P(Busy) / $(s-\sigma_{m-1})(s-\sigma_m)$

(6)

Where P(Busy) Is Found Form (3).

Design Iii: Priority Discipline Queuing Model With Pre-Emptive Service

Applying The Same Model Described In Design Ii But Allow The Pre-Emptive Service. In Design Iii, The Waiting Times For Priority Class 1 Customers Are Not Affected By The Presence Of Orders In Lower Priority Classes When Pre-Emptive Service Is Introduced. Therefore, Lq1 Is Found Using (4) Where 1/µ=4.67 And Λ= Λ1=0.092. Now Let Lq1-2 Be The Expected Waiting Time Of A Random Arrival In Either Class 1 Or 2, Then Probability Is Λ/(Λ1+ Λ1) = 0.254 That This Arrival Is In Class 1, And Λ2/(Λ1+ Λ2)=0.746 That It Is In Class 2. Therefore, Lq1-2 = 0.254 Lq1+0.746 $L_{q2}$and$l_{q1\text{-}2}$ Can Be Found Using (4) With 1/ µ=4.67 And Λ=0.362.

Thus

$L_{q2} = [(\Lambda_1+\Lambda_2)/\Lambda_2]\, L_{q1\text{-}2} - (\Lambda_1+\Lambda_2)\, L_{q1}$

(7)

$= 1.341\, L_{q1\text{-}2} - 0.341\, L_{q1}$

VI. RESULT AND DISCUSSION

For Each Of Three Design Alternatives, Prescription Order Waiting Time Are Expressed As Functions Of The Number Of Pharmacists.

Table 1: Expected Waiting Time For Multiple Service Queuing Model With No Priorities.

Number Of Pharmacists	Order Waiting Time In Minutes
2	11.69
3	1.11
4	0.22

Table 2 Represents The Priority Discipline Queuing Model. The Average Waiting Time Of Stat Order Having The Highest Priority Is Lq1 While That Orders With The Lowest Priority Is Lq2. Again, These Waiting Times Deceases As The Number Of Pharmacists Is Increased. One Can Also Observe That For The Same Number Of Pharmacists Is Table 1, The Introduction Of Priorities Will Decrease The Waiting Time Of The High Priority Stat Orders While Increasing The Waiting Time Of The Priority Regular Orders.

Table 2: Expected Waiting Time For Priority Discipline Queuing Model

Number Of Pharmacists	Waiting Time In Minutes	
	Stat Orders	Regular Orders
2	2.3	14.89
3	0.56	1.29
4	0.14	0.24
5	0.053	0.045

Table 3 Represents The Waiting Times For The Two Priorities With The Introduction Of Pre-Emptive Services. As Compared Table 2, Where There Was No Pre-Emptive Service, The Waiting Time Of The Priority Stat Orders Are Further Reduced And That Of The Low Priority Regular Orders Increased. It Is Possible To Essential Eliminate Average Waiting Time For Stat Orders When The Number Of Pharmacists Is Four Or More.

Table 3: Expected Waiting Time For Priority Discipline Queuing Model With Pre-Emptive Service.

Number Of Pharmacists	Waiting Time In Minutes	
	Stat Orders	Regular Orders
2	0.19	15.13
3	0.1018	1.29
4	0.0012	0.024
5	0.0009	0.049

In Table 1 The Average Waiting Time Lq Is Shown For The Multiple Server Queuing Model With No Priorities. As The Number Of Pharmacists Increase, The Average Waiting Time Of An Order Decreases Rapidly.

VII. CONCLUSION

In This Chapter We Design Various Alternatives In Determining The Manpower Requirements Needed To Run A Hospital Pharmacy Unit. Three Different Operating Procedures Were Evaluated In Order To Give A Complete Analysis Of The Prescription Order Process Taking Place In The Hospital Pharmacy Unit. With The Application Of Queuing Model Technique The Waiting Time Of The Priority Stat Orders Is Reduced And Low Priority Regular Orders Increased. The Queuing Technique Can Be Applied To Any Size Of The Hospital Pharmacy To Reduce The Waiting Time Of Medicines Requirement Of Emergency Cases To Improve The Patient Health Condition And Efficiency Of Pharmacy Unit.

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