

**COST ANALYSIS OF SUGAR TABLET IN APOLLO PHARMACY  
BASED ON STOCHASTIC QUEUING-INVENTORY SYSTEM**

Submitted in partial fulfillment of the requirements for the award of

Master of Science Degree in Mathematics

By

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**DEPARTMENT OF MATHEMATICS  
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**SATHYABAMA**

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC I 12B Status

by UGC I Approved by AICTE

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## DEPARTMENT OF MATHEMATICS

### BONA FIDE CERTIFICATE

This is to certify that this project report is the Bonafide work of SOWNDHIRIYA.M (41630006) who carried out the project entitled "COST ANALYSIS OF SUGAR TABLET IN APOLLO PHARMACY BASED ON STOCHASTIC QUEUING-INVENTORY SYSTEM" under our supervision from JANUARY 2023 to APRIL 2023.

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### DECLARATION

I SOWNDHIRIYA.M (41630006) hereby declare that the project report entitled "COST ANALYSIS OF SUGAR TABLET IN APOLLO PHARMACY BASED ON STOCHASTIC QUEUING-INVENTORY SYSTEM" done by me under the guidance of Ms. V. VINITHA at SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY submitted in partial fulfillment of the requirements for the award of Master of Science Degree in Mathematics.

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## **ABSTRACT:**

We consider a single server queueing – inventory system. This system has finite size waiting space ( $N$ ) and the maximum number of sugar tablets in Apollo pharmacy is  $S$ . The customers arrive according to Poisson process, and we adopted  $(s, Q)$  ordering policy. Furthermore, the service time and lead times are exponentially distributed. Finally, we showed the minimize the total cost.

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# **CHAPTER 1:**

## **1. INTRODUCTION:**

### **1.1 QUEUEING SYSTEM:**

The mathematical study of the creation, function, and congestion of waiting lines, or queues, is known as a queueing system. Queues arise when there are insufficient resources to provide a service. As we know queues are a common every day experience.

#### **EXAMPLE:**

Transportation-waiting for a train or a bus.

### **1.2 INVENTORY SYSTEM:**

An inventory system is the process of tracking your items across the whole supply chain, from purchase through manufacture to final sales. It regulates how you handle inventory management in your company.

### **1.3 QUEUEING- INVENTORY SYSTEM:**

When a customer is serviced, the system instantly exits and the on-hand inventory reduces by one. An outside supplier supplies the inventory. This is referred to as a queueing-inventory system.

#### **EXAMPLE:**

Grocery stores, Transportation, Hospitals, etc.,

### **1.4 (s, Q) ORDERING POLICY:**

In the (s, Q) policy, s represents the reorder level and Q represent the fixed order quantity. In this case, the number of items to be refilled is fixed and equals  $Q=S-s$ .

### **1.5 LEAD TIME:**

When you place an order, it may take some time before it is delivery. Lead time is the amount of time that elapses between the time an order is placed and the time it is delivered. If the replenishment is immediate. The lead time is 0. Otherwise, the lead time is positive.

## **1.6 COST FUNCTIONS:**

A proper cost function is required to solve an inventory problem. The expenses listed below are typical costs for a cost function.

### **❖ Holding Cost:**

The cost of transporting or storing inventory in a warehouse is referred to as holding cost.

### **❖ Fixed Ordering(set-up) Cost:**

The fixed ordering cost refers to the costs incurred each time an order is placed to obtain items from suppliers.

## **1.7 IMPATIENT CUSTOMER:**

An impatient customer may have been waiting in line longer than usual, and they may be running late for their next appointment or restless while you search for a solution to their issue or concern.

# **CHAPTER 2:**

## **2.1 LITERATURE SURVEY:**

Hans Daduna and Rushan Krenzler [1] consider a performance analysis for loss system with many subscribers and concurrent services. Services who appear on the system under the Poission arrival process make subscribers service, and the server makes concurrent service during idle time. Service times of subscribers or concurrent services under Exponentially Distribution.

Gabi Hanukov [2] consider a queueing-inventory model with skeptical trusting customers. Customer who appears on the system under the Poission arrival process make skeptical customers, and the server makes trusting customer during idle time. Service times of skeptical or trusting customers under Exponentially Distribution.

K.Jeganathan, M.Abdul Reiyas, S.Selva Kumar and N.Anbazhagan [3] consider a Analysis of retrial queueing inventory system with stock department demand rate:(s, S)versus(s, Q) ordering policies. Ordering policies who appear on the system under the Poission arrival process make (s, S) ordering policy, and the server makes (s, Q) ordering policy during idle time service times of (s, S) versus (s, Q) ordering policies under Exponentially Distribution.

Nisha Mathew, V.C.Joshua and A.Krishnamoorthy [4] consider A queueing inventory system with two channels of services. Services who appear on the system under the Poission arrival process make two channels of services, and the server makes two channels during idle time. Service times of two channels of the services under Phase-type Distribution.

Sonja Otten and Hans Daduna[5] consider A Stability of queueing inventory system with customers of different priorities. Services who appear on the system under the Markovian arrival process make customers of different priorities, and the server makes customers of different priorities during idle time. Service times of customers of different priorities under Exponentially Distribution.

Dhanya Shajin, Jaison Jacob and A.Krishnamoorthy [6] On a queueing inventory problem with necessary and optional inventories. Services who appear on the system under the Markovian arrival process make necessary inventory, a server makes optional inventory during idle time. Service times of necessary or optional inventories under Phase-type Distribution.

Dhanya Shajin, A.Krishnamoorthy [7] On a queueing inventory system with impatient customers, advanced reservation, Cancellation, overbooking and common life time. Services who appear on the system under the Poission arrival process and Markovian arrival process make impatient customers, advanced reservation, Cancellation, overbooking, a server makes common life time during idle time. Service times of impatient customers, advanced reservation, Cancellation, overbooking or common life time under Phase-type Distribution and Exponentially Distribution.

V.Vinitha [8] consider a Steady state analysis of impulse customers and cancellation policy in queueing inventory system. Services who appear on the system under the Markovian arrival process make impulse customers, a server makes cancellation policy during idle time. Service times of impulse customers or cancellation policy under Exponentially Distribution.

Yuying Zhang [9] consider an Analysis of the queueing inventory system with impatient customers and mixed sales. Services who appear on the system under the Poission arrival process make impatient customers, a server makes mixed sales during idle time. Service times of impatient customers or mixed sales under Exponentially Distribution.

Yuying Zhang [10] consider a queueing inventory system with random order size policy and server vacations. Services who appear on the system under the Poission arrival process make random order size policy, a server makes server vacations during idle time. Service times of random order size policy or server vacations under Exponentially Distribution.

## **CHAPTER 3:**

### **3.1 OBJECTIVE AND SCOPE:**

- ❖ To Find the Probability Vector.
- ❖ Verify the stability condition of the system.
- ❖ To Minimize the total cost.
- ❖ Reduce the waiting time of the customers.

# **CHAPTER 4:**

## **4.1 MODEL DESCRIPTION:**

This work, we look at a single server queueing-inventory system. The maximum number of sugar tablets in Apollo pharmacy  $S$  is a queueing-inventory system.  $(s, Q)$  is ordering policy,  $s$  is an ordering point and then  $Q$  is an ordering quantity. Waiting space size  $N$  in a queueing-inventory system in Apollo pharmacy. Poission Arrival process and  $\lambda$  are an Arrival Process and Arrival rate in an inventory system. Service time and rate are Exponential distribution and  $\mu$  in queueing-inventory. A queueing-inventory system in Lead time is Exponential distribution and Lead time rate  $\beta$ . And  $i\alpha$  is an impatient customer arrival rate and its exponential distribution in Apollo pharmacy in queueing-inventory system.

## **CHAPTER 5:**

### **5.1 MATHEMATICAL ANALYSIS:**

In this sector, we construct the transition rate matrix on the queuing-inventory system. The Markov process of the from  $\{(X_1(t), X_2(t)); t \geq 0\}$  with state space.

We consider the two-dimensional random variables are

$X_1(t)$  = No of customers in the waiting space(N)

$X_2(t)$  = No of sugar tablets in Apollo pharmacy(S)

With state space.

$$E = (0,1, \dots, N) \cup (0,1, \dots, S)$$

## 5.2 TRANSITION MATRIX:

The process's infinitesimal generator P is generated by

$$\begin{array}{c}
 \begin{array}{cccccc}
 & 0 & 1 & 2 & \dots & N-1 & N \\
 \begin{array}{c}
 0 \\
 1 \\
 2 \\
 \vdots \\
 N-1 \\
 N
 \end{array}
 & \begin{bmatrix}
 A_{00} & A_{01} & 0 & \dots & 0 & 0 \\
 A_{10} & A_{11} & A_{01} & \dots & 0 & 0 \\
 0 & A_{20} & A_{22} & \dots & 0 & 0 \\
 \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\
 0 & 0 & 0 & \dots & A_{N-1N-1} & A_{01} \\
 0 & 0 & 0 & \dots & A_{N0} & A_{NN}
 \end{bmatrix}
 \end{array}
 \end{array}$$

$$\begin{array}{c}
 \begin{array}{ccccc}
 & 0 & 1 & \dots & S-1 & S \\
 A_{01} = & \begin{bmatrix}
 \lambda & 0 & \dots & 0 & 0 \\
 0 & \lambda & \dots & 0 & 0 \\
 \vdots & \vdots & \ddots & \vdots & \vdots \\
 0 & 0 & \dots & \lambda & 0 \\
 0 & 0 & \dots & 0 & \lambda
 \end{bmatrix}
 \end{array}
 \end{array}$$

$$A_{i0} = \begin{matrix} & \begin{matrix} 0 & 1 & 2 & \dots & S-1 & S \end{matrix} \\ \begin{matrix} 0 \\ 1 \\ 2 \\ \vdots \\ S-1 \\ S \end{matrix} & \begin{bmatrix} i\alpha & 0 & 0 & \dots & 0 & 0 \\ \mu & i\alpha & 0 & \dots & 0 & 0 \\ 0 & \mu & i\alpha & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \dots & i\alpha & 0 \\ 0 & 0 & 0 & \dots & \mu & i\alpha \end{bmatrix} \end{matrix}$$

Where,

$$i = 1, 2, 3, \dots, N.$$

$$A_{00} = \begin{matrix} & \begin{matrix} 0 & 1 & 2 & \dots & s-1 & s & s+1 & \dots & Q-1 & Q & Q+1 & \dots & S-1 & S \end{matrix} \\ \begin{matrix} 0 \\ 1 \\ 2 \\ \vdots \\ s-1 \\ s \\ s+1 \\ \vdots \\ S-1 \\ S \end{matrix} & \begin{bmatrix} -(\lambda + \beta) & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \beta & 0 & \dots & 0 & 0 \\ 0 & -(\lambda + \beta) & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & \beta & \dots & 0 & 0 \\ 0 & 0 & -(\lambda + \beta) & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \dots & -(\lambda + \beta) & 0 & 0 & \dots & 0 & 0 & 0 & \dots & \beta & 0 \\ 0 & 0 & 0 & \dots & 0 & -(\lambda + \beta) & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \beta \\ 0 & 0 & 0 & \dots & 0 & 0 & -\lambda & \dots & 0 & 0 & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & -\lambda & 0 \\ 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & -\lambda \end{bmatrix} \end{matrix}$$

$$A_{ii} = \begin{matrix} & \begin{matrix} 0 & 1 & 2 & \dots & s-1 & s & s+1 & \dots & Q-1 & Q & Q+1 & \dots & S-1 & S \end{matrix} \\ \begin{matrix} 0 \\ 1 \\ 2 \\ \vdots \\ s-1 \\ s \\ s+1 \\ \vdots \\ S-1 \\ S \end{matrix} & \begin{bmatrix} -(\lambda + \beta + i\alpha) & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \beta & 0 & \dots & 0 & 0 \\ 0 & -(\lambda + \beta + \mu + i\alpha) & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & \beta & \dots & 0 & 0 \\ 0 & 0 & -(\lambda + \beta + \mu + i\alpha) & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \dots & -(\lambda + \beta + \mu + i\alpha) & 0 & 0 & \dots & 0 & 0 & 0 & \dots & \beta & 0 \\ 0 & 0 & 0 & \dots & 0 & -(\lambda + \beta + \mu + i\alpha) & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \beta \\ 0 & 0 & 0 & \dots & 0 & 0 & -(\lambda + \mu + i\alpha) & \dots & 0 & 0 & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & -(\lambda + \mu + i\alpha) & 0 \\ 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & -(\lambda + \mu + i\alpha) \end{bmatrix} \end{matrix}$$

Where,

i= 1, 2, ..., N-1.

$$\begin{array}{c}
\begin{array}{cccccccccccccc}
0 & 1 & 2 & \dots & s-1 & s & s+1 & \dots & Q-1 & Q & Q+1 & \dots & S-1 & S
\end{array} \\
A_{NN} = \begin{array}{c}
\begin{array}{cccccccccccccc}
0 & 1 & 2 & \vdots & s-1 & s & s+1 & \vdots & S-1 & S
\end{array}
\left[ \begin{array}{cccccccccccccc}
-\beta + i\alpha & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \beta & 0 & \dots & 0 & 0 \\
0 & -(\mu + \beta + i\alpha) & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & \beta & \dots & 0 & 0 \\
0 & 0 & -(\mu + \beta + i\alpha) & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 \\
\vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\
0 & 0 & 0 & \dots & -(\mu + \beta + i\alpha) & 0 & 0 & \dots & 0 & 0 & 0 & \dots & \beta & 0 \\
0 & 0 & 0 & \dots & 0 & -(\mu + \beta + i\alpha) & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \beta \\
0 & 0 & 0 & \dots & 0 & 0 & -\mu + i\alpha & \dots & 0 & 0 & 0 & \dots & 0 & 0 \\
\vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\
0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & -\mu + i\alpha & 0 \\
0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & -\mu + i\alpha
\end{array} \right]
\end{array}
\end{array}$$

## **CHAPTER 6:**

### **6.1 STEADY STATE ANALYSIS:**

The Markovian Process  $\{(X_1(t), X_2(t)); t \geq 0\}$  on the finite state space  $E$  is irreducible.

Hence, the limiting distribution.

$\phi^{(i_1, i_2)} = \lim_{t \rightarrow \infty} P_r [X_1(t) = i_1, X_2(t) = i_2 | X_1(0), X_2(0)]$  exists and is independent of the initial vector.

Let,  $\phi = (\phi^0, \phi^1, \phi^2, \dots, \phi^N)$

$$\phi^{i_1} = (\phi^{(i_1, 0)}, \phi^{i_1, 1}, \dots, \phi^{(i_1, s)})$$

Then the vector of limiting probabilities  $\phi$  satisfies  $\phi A = 0$  and  $\phi e = 1$ .

## **6.2 GAVER ALGORITHM:**

❖ Determine recursively the matrices

$$F_0 = A_{00}$$

$$F_{i_1} = A_{i_1 i_1} + A_{i_1 0}(-F_{i_1-1}^{-1})A_{0 i_1}, i_1 = 1, 2, \dots, N$$

❖ Compute recursively the vectors  $\phi_i$  using

$$\phi^{i_1} = \phi^{i_1+1} A_{i_1+1 0}(-F_{i_1}^{-1}), i_1 = N-1, N-2, \dots, 0 \rightarrow (1)$$

❖ Solve the system of equation

$$\phi^N F_N = \mathbf{0} \rightarrow (2) \text{ and}$$

$$\sum_{i=0}^N \phi^i \mathbf{e} = \mathbf{1} \rightarrow (3)$$

From the system of equation (2), vector  $\phi^N$  could be determined uniquely, up to a multiplicative constant. This constant is obtained by using (1) and (3).

### **6.3 SYSTEM PERFORMANCE MEASURES:**

❖ Expected inventory level.

$$\eta_I = \sum_{i_1=0}^N \sum_{i_2=1}^S i_2 \phi^{i_1} e$$

❖ Expected number of customers in the waiting hall.

$$\eta_e = \sum_{i_1=0}^N i_1 \phi^{i_1} e$$

❖ Expected reorder rate.

$$\eta_R = \sum_{i_1=0}^N \mu \phi^{(i_1, S+1)}$$

❖ Number of customers lost.

$$\eta_L = \sum_{i_2=0}^S \lambda \phi^{(N, i_2)} + \sum_{i_1=1}^N i_1 \alpha \phi^{i_1} e$$

## **6.4 COST ANALYSIS:**

$$T_c(S, s) = c_h \eta_I + c_s \eta_R + c_w \eta_c + c_l \eta_L$$

Where,

$c_s$ : Setup cost per order.

$c_h$ : The inventory carrying cost per unit item.

$c_w$ : Cost of a waiting customer in the waiting hall per unit item.

$c_l$ : Lost cost per customer.

# CHAPTER 7:

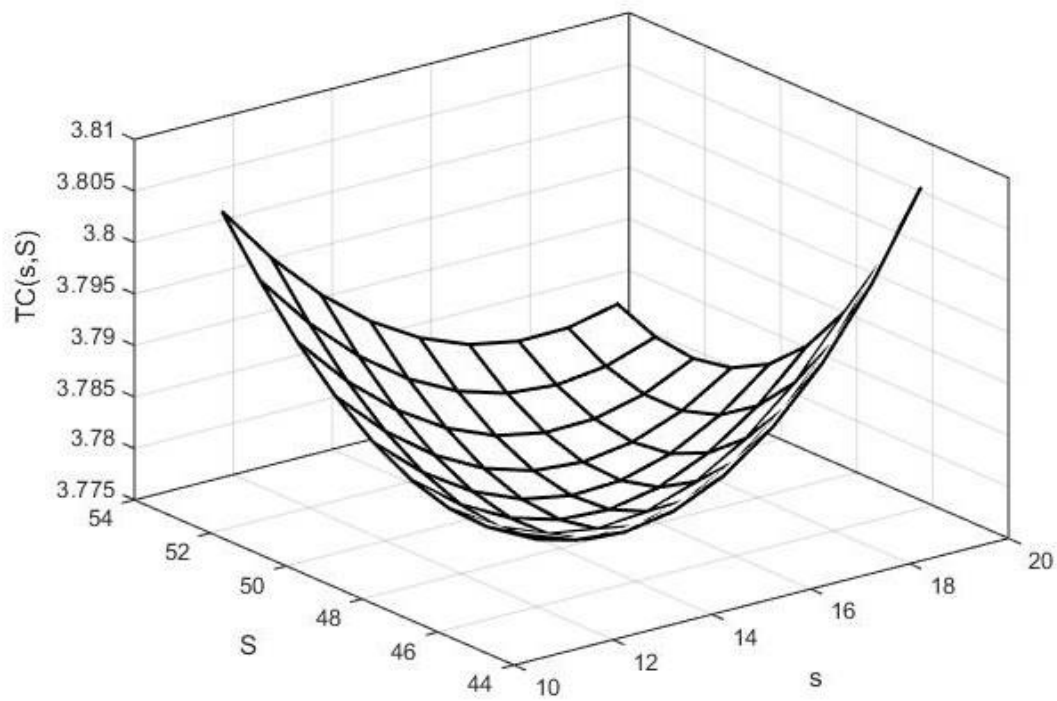
## 7.1 NUMERICAL ILLUSTRATIONS:

Table gives the behavior of the total cost function of two variables  $s$  and  $S$ . The least cost rate of each column is shown in bold letter and the least cost rate of each row is underlined. Therefore, a value (bold and underlines) shows the local minimum of the function  $TC(s, S)$ . The optimal cost value  **$TC^*=3.77730$**  is obtained at  **$S^*=48$** ,  **$s^*=14$**  with other parameters  $\lambda=5$ ,  $\mu=10$ ,  $\alpha=2$ ,  $c_s=4$ ,  $c_h=0.05$ ,  $c_w=5$ ,  $c_l=1.5$ .

## 7.2 TABULAR COLUMN:

| S\s | 11             | 12             | 13             | 14                    | 15             | 16             | 17             |
|-----|----------------|----------------|----------------|-----------------------|----------------|----------------|----------------|
| 45  | 3.78154        | <u>3.78032</u> | 3.78033        | 3.78159               | 3.78415        | 3.78804        | 3.79333        |
| 46  | <b>3.78111</b> | 3.77921        | <u>3.77848</u> | 3.77895               | 3.78064        | 3.78359        | 3.78784        |
| 47  | 3.78169        | <b>3.77918</b> | <b>3.77779</b> | <u>3.77755</u>        | 3.77847        | 3.78059        | 3.78392        |
| 48  | 3.78322        | 3.78016        | 3.77818        | <b><u>3.77730</u></b> | <b>3.77753</b> | 3.77890        | 3.78143        |
| 49  | 3.78563        | 3.78207        | 3.77956        | 3.77811               | <u>3.77772</u> | <b>3.77843</b> | 3.78024        |
| 50  | 3.78888        | 3.78487        | 3.78187        | 3.77990               | <u>3.77897</u> | 3.77908        | <b>3.78024</b> |
| 51  | 3.79290        | 3.78848        | 3.78505        | 3.78262               | 3.78118        | <u>3.78076</u> | 3.78135        |

### **7.3 DIAGRAM:**



**FIGURE-1**

## **CHAPTER 8:**

### **8.1 CONCLUSION:**

we introduced the sugar tablet in Apollo pharmacy based on stochastic queuing-inventory system. This work helps to minimize the total cost of a queuing-inventory system. We presented the behaviour of the total cost with variables  $s$  and  $S$  under exponential distribution. We analysed the total cost with various distributions system have finite size waiting space and maximum number of sugar tablets in Apollo pharmacy, arrival streams. We analysed the lead time, service time with various arrival process like exponential distribution. Finally, we showed the minimize the total cost.

# **CHAPTER 9:**

## **9.1 REFERENCE:**

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