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Implementation of Queuing Theory in Stock Level RFID based Retail Supply Chain

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ABSTRACT

Implementation of RFID in the context of retail supply chain using queuing model as a tool for analysis. waiting has a very high opportunity cost and hence reducing waiting time in queues is important. Usually, we need to invest more in technology such as RFID, in order to reduce waiting times in queues. our empirical results support the basis of implementation of RFID in the retail supply chain and its associated practical scenarios. another outcome of this paper is the result of the checkout analysis of the retail store. We have shown that there is potential benefit of adopting the RFID technology at item level at the point of sales.

KEYWORDS

RFID, queuing, retail supply chain, checkout, Tag cost

INTRODUCTION

When RFID is used for tracking /tracing products in the retail supply chain, it facilitates in reducing inventory and paves the way for strong collaboration among the different actors. According to [1], Retail supply chain constitutes various determining players, namely, manufacturer, Suppliers, distributor, retailer and consumer. RFID is perceived as a potential technology by most of the major retailers to establish better coordination with their respective supply chain and strengthen efficiency by lessening the error. Consequently, it would help in cutting down the operational cost remarkably.

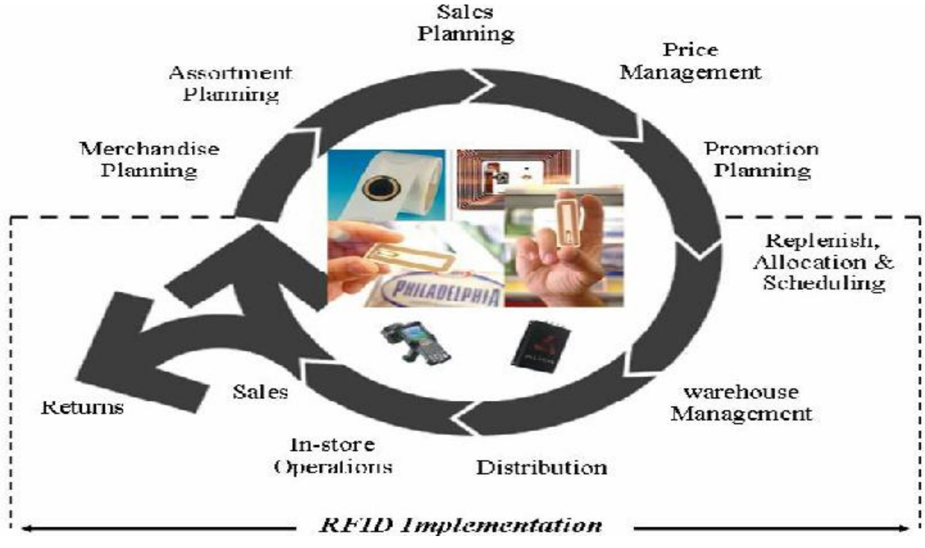

Fig.1.1 Usage of RFID in different areas of retail Sector
(Source: Adapted from Callana, 2006)

The financial condition for executing the RFID technology throughout the supply chain is a major factor to better comprehend the timeline in support of the execution at the unit level RFID:

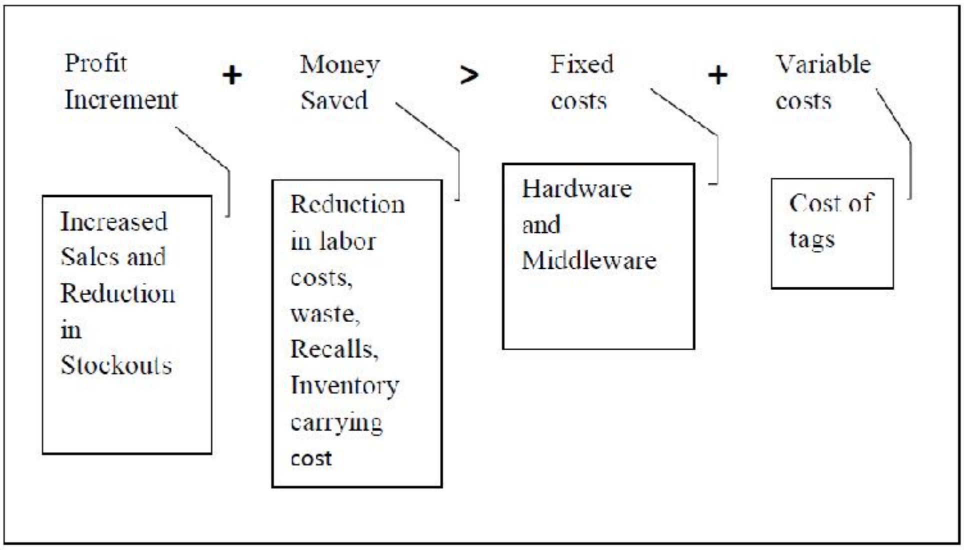

Fig. 1.2 Applying RFID in essential situations

If the above circumstances reflected in the figure 1.2 are adopted in the whole supply chain in retail, the use of RFID would be more accepted and viable. To determine the time factor for the implementation of RFID the execution of barcode technology should be taken care of in their adoption rate. Though the past records show a period of 15 years to adopt barcode technology to become really efficient, it is readily accepted by the recent technology friendly environment. Jonas (Lidl) apprehends the less acceptance of RFID by the unit level will persist as a minimum for 8 to 10 years. The factors like Tag costs and middleware software are the major stumbling block on the way of adopting RFID technology at the unit-level.

The integration of RFID technology results in saving the cost in supply chain. It also facilitates retailers to avail integrated marketing opportunities. It enables them to speed up the service in stores. These benefits are realized only when the RFID tags are introduced at the unit level. As a result, it can be inferred that an evolution in the market is a condition for widespread adoption of RFID technology which will bring in a paradigm shift in manufacturers' demand for RFID instead of enforcing this technology by the retailers.

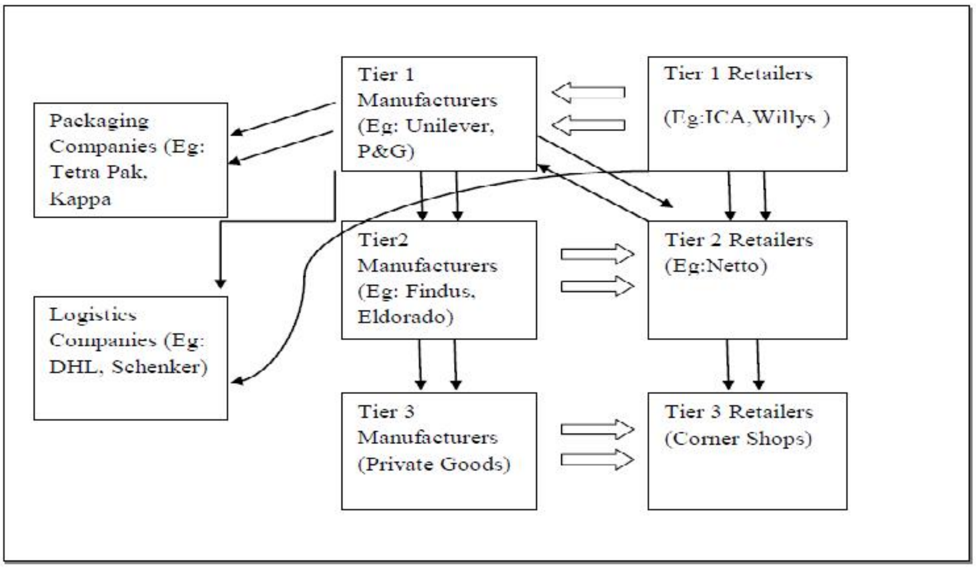

Fig. 1.3 RFID Network in retail industry

The evolution in the marketplace due to the top level retailers' influence on major manufacturers to accept RFID will be a launching pad for the second tier retailers to go for these cost savings RFID technology. It can also be inferred that when retailers or manufacturers will be gaining more profits with the increased use of RFID technology, it will certainly be used by more and more people throughout the industry.

QUEUING THEORY

It is a natural tendency with the people that they are reluctant to wait for anything and to reduce the waiting time in the queue demands high price/ investment. To reach a decision whether or not to invest in certain area / project, usually depends on the investment outcome by reducing waiting time. Researchers mostly use queuing model\technique to achieve this fussy function. "Queuing models provide us with a powerful tool for designing and evaluating the performance of queuing systems" [3]. As a usual process, customers desired service have to wait and it is capable of customer to choose for a server queue. The mechanism which according to [2] is known as 'shortest queue or shortest workload'.

The service related to customers requirements are addressed by the a service mechanism that manages the whole process when a customer leaves a queue. The mechanism is assisted by 3 types of models namely, single server and single queue (figure 1.4), multiple servers and single queue (figure1.5) multiple servers and multiple queues (figure.1.6) [4],

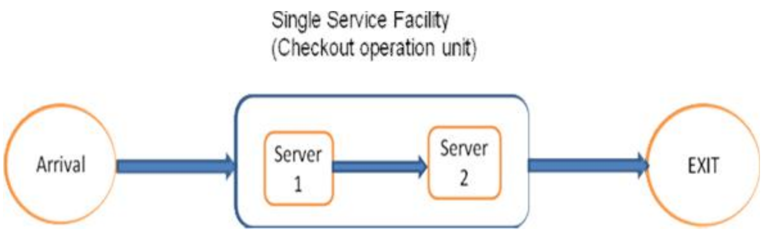

Fig.1.4 Single server with single queue Model 1

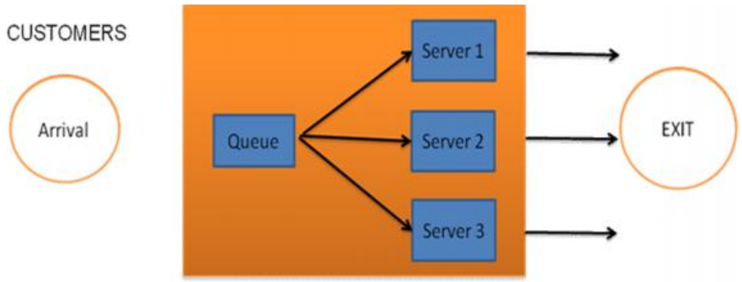

Fig. 1.5 Multiple servers with Single queue Model 2

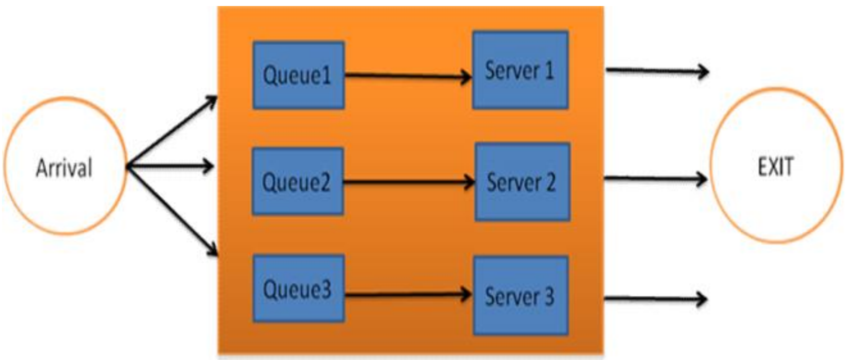

Fig 1.6 Multiple servers with multiple queues, Model 3

Three sub-processes can be seen in the above models:

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Table 1.1 queuing model Sub-processes

Arrival process	It involves The number of Customers' arrival types, and demand types of customers, arrival distance and intensity of arrival of the customers.
Waiting process	It highlights about nature of service and length of the queue (FIFO)
Server process	Server process focuses on type of server , rate and time of service.

In the M/M/c/K queuing model 1st 'M' stands for Markovian exponential inter-arrival times distribution and the 2nd 'M' talks about service time Markovian exponential distribution. 'c' stands for no. of servers, & 'K' stands for no. of consumers in a queuing system. The model represents single limited no. of K consumers in the system. When K= infinity, the no. of consumers are unlimited and the model is known as M/M/c [5].

PARAMETERS IN QUEUING MODELS

n Total no. of consumer in the system

C Servers Number

λ Consumers arrival rate

μ Server service rate

cμ Service rate (when c>1)

p Consumption factor = (λ/cμ)

QUEUING MODELS NOTATIONS

P_0 Idle servers steady -state probability in the system,

$$P_0 = \left[\sum_{n=0}^{c-1} \frac{\gamma^n}{n!} + \frac{\gamma^c}{c!(1-\rho)}\right]^{-1}$$

Where $\gamma = \frac{\lambda}{\mu}$

P_n - In the system n customers steady -state probability

$$P_n = \frac{\lambda^n}{c!\,c^{n-c}\mu^n} P_0 \quad n>c$$

L_q - In the waiting line avg. no of consumers.

$$L_q = \frac{\gamma^c \rho}{(c)!\,(1-\rho)^2} \times P_0$$

W_q- In queue consumer spends avg. waiting time excluding the service time

$$W_q = \frac{L_q}{\lambda}$$

Because of the complex nature in networks of multiple queues (figure 1.4), no prefixed formulas can be adopted to solve the problem. The networks with multiple queues can be solved by the help of simulation. Above formula can be used for solving the problem with the help of models shown in (figure1.4) & (figure.

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1.5). Designing of Queuing system generally revolves round the following decisions points such as: no. of servers, efficiency of Servers and no. of service facilities. In every queuing situation, trade-off decision is a peculiar problem. It is a way to measure the additional charge to provide quick service that talks about more inspection counters, and service employees in comparison to the inbuilt cost of waiting. For example, if staffs use all their time in entering data by hand, then a process should be improved by drawing a comparison between benefits of increased productivity and the cost of investing in barcode scanners. Likewise, if consumers are parting the queues because of less no of consumer support staff, a comparison is to be drawn in the hiring cost/ recruiting fresh individuals maintained by the customer loyalty through the value of increased revenues.

Figure 1.4 graphically represents a the link of service capacity and queuing cost. They are inversely related. It implies that with increase of the service capability there is a decrease in the number of consumers in the stripe & their waiting times. It reduces the overall cost in queuing. Generally, the most favorable total cost is traced at the meeting point between the waiting line curves and the service capacity. We can estimate the total cost mathematically as follows:

E(SC) + E(WC) = E(TC)

Where, the cost of service = E(SC) & the cost of waiting = E(WC)

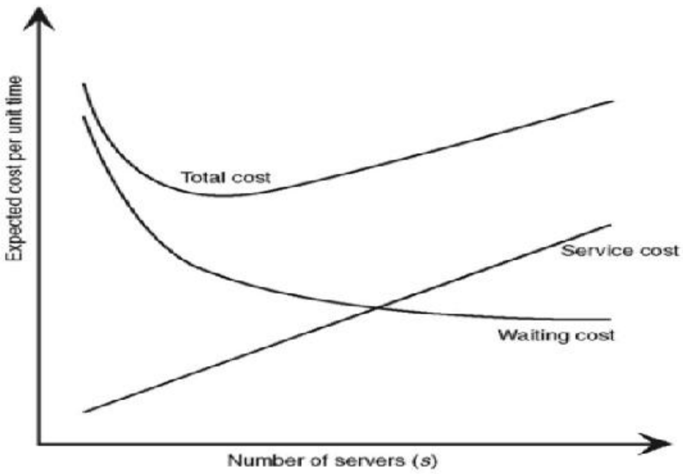

Fig. 1.7 Graph showing the cost of queuing

SIMULATION IN QUEUING MODELS

Processing levels, demand variability and arrival times are the components of waiting time. It shows how the system utilizes the restricted resources to the elements of waiting to be served. In the classification of M/M/c structure with Queuing systems represents further multiple queues or more than one queue provide no. of consumers in a queue is finite and in the system designed for solving those difficult calculations & models computation. Investigative calculation of service rate is almost impossible. "We have used a standard Monte Carlo simulation algorithm that fixes a regenerative state and generate a sample of regenerative cycles, and then use this sample to construct a likelihood estimator of state" (Nasroallah,(2004)).

STUDY OF POINT OF SALES SERVICE IN RELIANCE

In the Reliance Trendz service sales checkout, there are six waiting stripes. Consumers are given service on first in first out (FIFO) basis and in the form of parallel cash counter. From 2 out of 6 servers the data was collected. The checkout in sales unit has 6 similar counters. Two of them were experiential (every counter has a sales person to serve the consumers waiting in the queue). The probability of the checkout units might be idle. Collected data are tabulated and then we calculate the parameters for queuing theory analysis.

QUEUING CALCUATIONS

Expected queue length is found out by using survey data from Reliance Trendz. The average number of customers in a system can be calculated only after observing the number of customers waiting in a queue. The average is equal to (1+2+3+. . . . . . +1+1)/55 = 1.87 or 2 customers per minute.

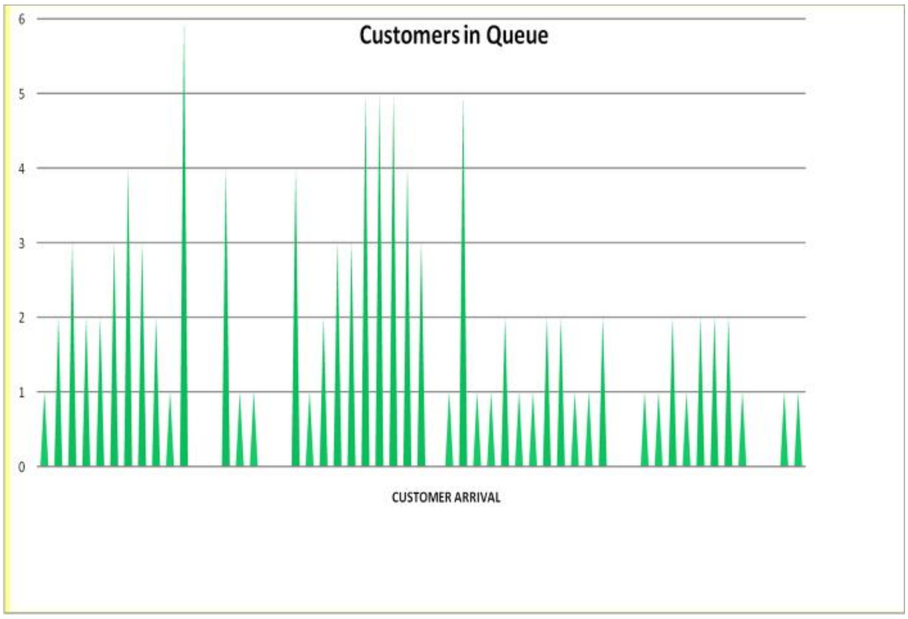

Fig. 1.8 Customers Queue in Checkout

The data that we have collected reveals that customers arrive at an average of 80 per hour and 48 customers are served per hour by a salesperson.

Results: Queuing model 1

Assuming the steady-state condition, the parameters in Queuing Model M/M/1 are:

Table 1.2 Model-1 Queuing results

No. of servers	c = 1
Arrival rate	λ = 40 customers/hr
Service rate	μ = (48 customer /hr)/server
System utilization	P = 0.833 or 83.3 %
probability of idle server	P_0 = 0.169 or 16.9%
In the queue Avg. no. of customers	L_q = 4.204 customers
In the queue Avg. waiting time	W_q = 0.105 hrs

The performance of service in sales checkout is satisfactory; we have experiential that use of servers is .833. Average no. of consumers in a queue is 4.204 customers and the waiting time is 0.105 hrs or 6.307 minutes.

Results: Queuing model 2

Let the parameters in Queuing Model M/M/2 in the steady-state condition are:

Table 1.3 Model-2 Queuing results

No. of servers	c = 2
Arrival rate	λ = 80 customers per hour
Service ate	μ = 48 customer per hour per server
Rate of service(1st and 2nd server)	c μ = 96 customers per hour
System utilization	P = 0.833 or 83.3 %
Probability of idle server	P_0 = 0.090 or 9%
In the queue Avg. no. of customers	L_q= 3.730 customers
In the queue Avg. waiting time	W_q = 0.046 hours

The performance of service in sales checkout is reasonably satisfactory. We have experimented that use of servers is .833.In a queue avg no. of consumers is 3.730 consumers/2 servers. In a queue the time of waiting is 0.046 hrs or 2.76 minutes. A closed form solution is not feasible by solving a set of equations for multi-queue models. Nevertheless, the solution can be obtained without difficulty with simulation techniques. Our simulation exercise is conducted by using the software Win QSB for the same data as model 2.

Applying Queuing model 3 results for Weekday

Table 1.4 Model-3 Queuing results

1st SERVER	
Mean of inter-arrival time	0.75 min
Summation of service time	1.25 min
System utilization	83.3 %
Served consumer	68
In the queue Avg. no. of customers	L_q= 15.7686 customers
In the queue Avg. waiting time	W_q = 11.6577 min
2nd SERVER	
Summation of inter-arrival time	0.75 min
Summation of service time	1.25 min
System utilization	83.3 %
Served consumer	86
In the queue Avg. no. of customers	L_q= 26.4315 customers
In the queue Avg. waiting time	W_q = 16.3177 min
1st SERVER & 2nd SERVER	
Summation of inter-arrival time	0.75 min
Summation of service time	1.25 min
System utilization	83.3 %
In the queue Avg. no. of customers	L_q= 42.2001 customers
In the queue Avg. waiting time	W_q = 13.9877 min

The checkout service sales results of two servers with their matching queues have been reflected by Simulation methods. Servers found to be quite busy (83.3%) & simulation was run for 50 hrs. In the queue Avg. no. of customers waiting is 42.2001 & in the queue the avg. time consumer spends 13.9877 minutes which is relatively a long time. By enabling RFID exit gates, the long queue of this type can be reduced to zero.

Estimation Cost in Queuing

For the purpose of calculating queuing cost the graph is used for finding out the most favorable no. of servers to provide service suitable to the consumers. Calculation of the total cost requires the cost of waiting/ consumers in the queue. During this situation the waiting cost estimated is used/ consumer i.e. INR 250/consumer/hr & the server cost is INR150/hr.

let us consider in the steady state situation the analysis is made by using at least two servers (rate of arrival = 80 consumers/hr, rate of service = 48 consumers/hr)

Table 1.5 using different number of servers with total waiting cost estimation

Servers. no.	No. of Consumers in queue.	Waiting Cost in queue	Server cost (c * cost of 1st server)	Total Cost
2	3.730	932.5	300	1232.5
3	0.442	110.5	450	560.5
4	0.237	59.25	600	659.25
5	0.092	23	750	773

It could be observed that in case of utilizing two servers, the total cost is at its climax and quickly decreases with the three servers. More increases in the no. of servers prove again increases waiting cost i.e. 773 INR &659.25 INR respectively. During this situation the most favorable could be using three servers.

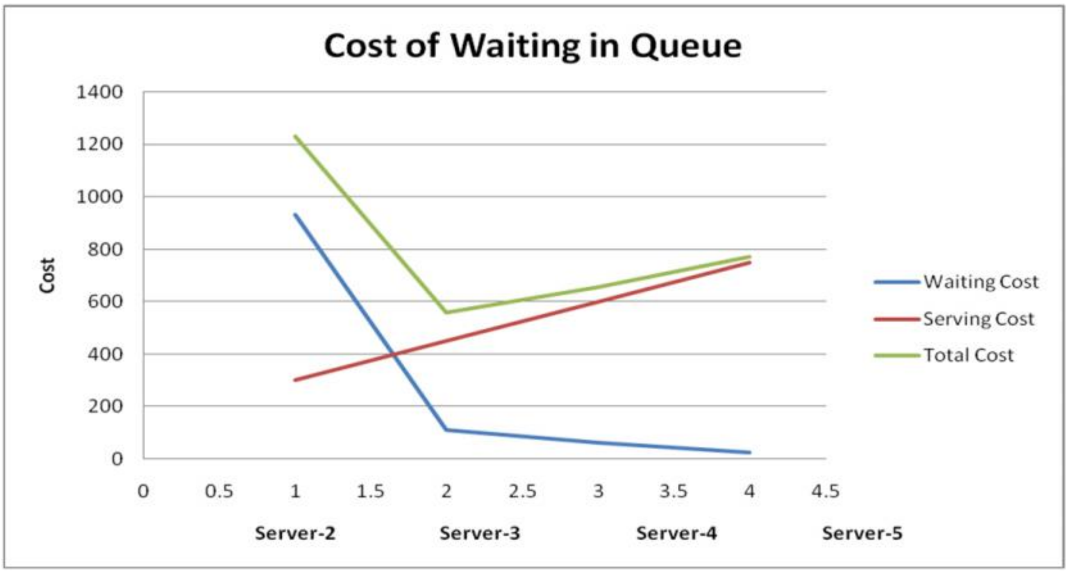

Fig. 1.9 In the queues waiting total cost is showing in the Graph

At POS Cost Analysis of Implementing RFID

This section describes the likely savings at the POS (point of Sales) by implementing RFID in the Reliance Trendz. Earlier it is discussed in the section 6.8 for RFID technology implementation, profit should be larger than variable & fixed costs. While ROI (Return on Investment) is calculating the cost tags by a large amount biggest concern and the requires to be optimized. When suppliers contacted on internet, it is found that the value of item tags is on 0.49 INR. The cost tags needs to be low down as 0.10 INR in introduced in the manufacturing unit according to the retailers & experts. However this problem would be justified, if we can include the advantages increases by shelf replacement, better visibility and RFID in the back door inventory. At POS, estimation of RFID implementation mainly takes into account savings on wastages because of inappropriate usage of POS. This is approximately 0.49% of monthly sales generation. The initial cost of execution of RFID readers at POS has been set up at around 175000 - 200000 INR after interviewing experts and contacting some suppliers. In Reliance Trendz the average no. of consumers visit is 54000 every month & 12 items on average/visit. At POS including income tax, further Reliance is paying 30,000 INR per employee to their staff working & about to 9.3 million INR is the monthly turnover.

The amount of initial investment (placement of readers, integration of software etc.), savings due to staff reduction and due to wastage, are given in the following table:

Table 1.6 savings & Cost investment (values in INR)

Initial Investment	200,000
Monthly Tag cost Monthly savings in employee reduction	317,520 150,000
Monthly wastage savings due to inappropriate use of POS	40,025

Table (1.6), reveals that when investment exceeds savings, we cannot compute the ROI. Our estimated monthly average Tag cost is equal to (0.49 INR * 12productd * 54000 consumers). This monthly Tag cost is greater than the benefit that is obtained from employee savings and saving on wastage due to inappropriate usage of POS.

Outline of Execution of RFID at Point Of Sale

It is found out after the queuing analysis that in the queues checkout, an average consumer waits for 2.8 minutes. This seems to be quite time-consuming in the current environment. If we multiply the no. of consumer/day with the average time that a consumer waits & because on an average 1800 consumers visit Reliance Trendz, it turn into (2.8 minutes * 1800)84hrs each day & (84 hrs * 30) 2520 hrs each month. Because we have used 250 INR/hr as average waiting cost for each customer, In this situation it turns out to be relatively a large amount of money i.e. (250 INR * 2520 hrs)(630,000) INR, which can be saved RFID enabled checkouts.

8. Conclusion

In this chapter we have used queuing model as a tool to explain RFID execution in the retail supply chain. Waiting has a very high opportunity cost and hence reducing waiting time in queues is important. Our empirical results support the process of RFID execution in different entities of supply chain in retail sector & its aligned realistic situations. The empirical findings of this chapter constitute a crucial feature of this thesis as it predicts RFID to assume a crucial place in the retail supply chain. The survey result proves that incorporation in item level of RFID may take some time. Till now, the implementation is done at the pallet-level. Cost & benefits allotments are the main factors that prevent the possible implementation in retail industry. Proper distribution of benefits and costs is not yet achieved with the dissimilar retail supply chain articles. Conclusion of survey shows that 78% respondents agreed on the fact that benefit is the main driving

force behind the adoption of RFID in supply chain. The survey also reveals various challenges in the implementation of RFID with cost issues as one of the main important factors. The challenging factors those are identified by the survey include need of industry standards for applying RFID, manpower planning factors & technical issues. We have also conducted checkout analysis. It shows that there is prospective advantage of accepting the item level RFID capabilities at POS. It will take some time for the retailers to adopt RFID in a holistic manner.

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