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RESEARCH ARTICLE

Incorporation of RFID Technology in the Inventory Management System to Optimize the Inventory Cost – 'C' Programming Approach

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Abstract

Objectives: To examine and justify the significance of Radio Frequency Identification technology in the inventory management system with scheduled shortages through a C programming approach. **Methods:** Radio Frequency Identification technology is examined in the inventory and analyzed between the two strategies namely i) non- Radio Frequency Identification technology and ii) Radio Frequency Identification investment in both ordering and Just In Time efficiency. The proposed methods were implemented and solved using C programming to evaluate their effectiveness and operational performance in managing inventory and reducing costs. **Findings:** An integrated investment evaluation model is established in this work and a comparative study has been made to analyze the assessment model with scheduled shortages in the absence and presence of Radio Frequency Identification technology by assigning the parameters using a numerical example performed by C programming. Results show that the total cost under non Radio Frequency Identification technology is 200547722.557505 whereas the total cost under Radio Frequency Identification technology investment is 100860759.476361. The number of orders placed each year under non Radio Frequency Identification technology and Radio Frequency Identification technology are 182 and 214 respectively. The results imply that the incorporation of Radio Frequency Identification technology in inventory management leads to improved efficiency and accuracy, resulting in increased profitability for an organization. **Novelty:** Radio Frequency Identification technology investment is incorporated into an inventory system to optimize inventory costs and annual order frequency using C programming, which remains unexplored in existing literature.

2020 Mathematics Subject Classification: 90B05.

Keywords: Radio Frequency Identification technology; Investment evaluation; Inventory cost; Shortages; Economic Order Quantity

1 Introduction

In a dynamic business environment, managing inventory is crucial for an organization to remain successful in the marketplace. Industries often design their strategies efficiently to meet customer expectations. A crucial component of the supply chain is inventory management, which plays a significant role in ensuring seamless operations and efficient resource utilization. Md. Kausar Alam investigated the inventory management systems of small and medium enterprises and proposed several suggestions to policymakers.[1] Madamidola and Olugbenga Ayomide reviewed and highlighted the insights of existing inventory management systems.[2] Inventory management often encounters several challenges, such as imprecise tracking, time-consuming manual processes, unpredictable demand forecasting, etc.., These issues can lead to stockouts, overstocking, and inefficiencies in the supply chain, ultimately affecting profitability. Poor inventory management is frequently caused by stockouts, in which merchandise is unavailable when clients place orders. Regular stockouts can harm the company's image, resulting in a decline in client trust and a sustained decline in order volume. When stock levels are recorded incorrectly, it can lead to discrepancies between what is physically available and what is documented in the system. This mismatch can cause stockouts, where items are unavailable when needed, leading to lost sales and dissatisfied customers. Jim Shi developed an optimization algorithm to reduce the risk of stockouts.[3] Conversely, businesses may also experience overstocking, where excess inventory ties up capital and increases holding costs due to storage and potential obsolescence.

Annual order frequency helps businesses determine how often orders should be placed over the year to balance inventory holding and ordering costs. A well-planned order frequency can also improve supplier negotiations as predictable ordering schedules may lead to better pricing or terms. Furthermore, it helps in forecasting future needs and adjusting inventory strategies based on market trends, ensuring that businesses are more agile and responsive to changes in demand or supply chain disruptions. The Economic Order Quantity (EOQ) is a technique for evaluating the quantity and regularity of orders required to satisfy a specific level of demand while minimizing the cost per order. Harris created this production scheduling model in 1913, and it's been modified over time. This model integrates all of a product's costs, including production costs, demand rate, costs of holding/storage, ordering charges, and costs of a shortfall. Cenk Caliskan proposed a technique for calculating economic order quantities through cost-difference analyses without the need for derivatives.[4] R. P. Tripathi constructed an EOQ model for deteriorating goods with time-sensitive demand, cash reductions, shortages, and allowable payment delays.[5] The method of analyzing the EOQ is to select the optimal number of items to order while keeping expenses for purchasing, shipping, and storage to a minimum. R. Sundararajan, S. Vaithyasubramanian & A. Nagarajan analyzed the effects of shortages, inflation, and late payments on an EOQ model with bivariate demand.[6]

Annual order frequency may also lack the flexibility needed to respond to sudden changes in market conditions, such as unexpected demand spikes or supply chain disruptions. The ability to accurately track and manage inventory can lead to significant cost savings, improved customer satisfaction, and streamlined operations. Conventional approaches to these challenges frequently have drawbacks, including manual errors, drawn-out procedures, and issues with real-time data changes. These issues can lead to erroneous stock levels, lost items, and delays in order fulfillment. To get beyond these obstacles, there is an increasing need for innovations that improve efficiency and accuracy. Hence we can overcome these factors by implementing a suitable technology to gain profit. Technology plays a vital role in optimizing processes, enhancing productivity, and driving innovation for sustainable growth and profitability.[7] one technology that is frequently employed in inventory management to prevent shrinkage in stocks is Radio Frequency Identification (RFID) technology.[8]

Radio Frequency Identification technology collects data using the electromagnetic field. In commercial and industrial applications, radio-based wireless technology is often used to monitor, connect, and even recognize persons. The implementation of this technology gaining momentum rapidly as technical, social, and market rivalry pushes businesses to reform and develop themselves. In Lee proposed an RFID investment evaluation model that provides a solid foundation to assess RFID business value.[9] Supply Chain Management (SCM) is becoming a more intricate and dynamic process. Supply chains face constant challenges from shifting customer needs, sudden and erratic changes to their routes, significant uncontrollable interruptions (like the COVID-19 outbreak and the following lockdowns), and legal and compliance difficulties related to the transfer of goods across international borders.In the supply chain, Radio Frequency Identification technology is anticipated to be crucial in meeting client demands.[10] RFID is a crucial component in the applications of IoT.[11] Pedro M. Reyes analyzed Radio Frequency Identification in supply chain management.[12] F. E. Alberto investigated the return on investment (ROI) of RFID-based intelligent inventory management systems.[13] Using RFID in inventory allows us to measure a large number of items at once, without having to look at them, and as specific objects with unique IDs (Identifications). Arun Kumar Biswal investigated Product subsidy and expected consumption with inventory inaccuracy by adopting RFID adoption in Indian public distribution system.[14] RFID has recently become more important in inventory management - ID badging, preventing pilferage, preventing counterfeiting, and so on. It is very beneficial for high-value items and sensitive items that require a high level of security, such as those in the food and healthcare industries.

To the best of our knowledge, there exists no literature that focuses on optimizing total costs, annual order frequency, and cycle time by integrating RFID technology into an inventory system through a C programming approach. C programming is valued for its efficiency and speed, making it an excellent choice for developing system software and applications that require direct hardware interaction. Its simple structure and wide applicability make it easy to grasp for individuals from non-technical fields, while its ability to run across various platforms ensures versatility in development. Additionally, C's portability allows these models to be run across different platforms, making the results accessible in a variety of environments. Specifically, vast research has concentrated on investments in RFID technology in an inventory to optimize the total cost alone by solving in a manual manner. Annual order frequency and cycle time are essential in order to maintain effective stock management and balance inventory expenses. Optimizing these metrics helps businesses avoid overstocking, minimize ordering costs, and reduce the risk of stockouts. This balance ensures timely product availability and increased customer satisfaction while controlling overall operational expenses. Therefore, research on inventory management to optimize the annual order frequency and cycle time is also required to increase the sales revenue of an organization. This highlights a research gap, as there has been no exploration of solving these issues using the C programming language. So in this study, an integrated inventory model is developed that incorporates Radio Frequency Identification (RFID) technology investment within an inventory system to optimize annual order frequency, total costs, and cycle time, using a C programming approach to solve and address these challenges.

2 Methodology

The assessment method of expense on RFID is based on the traditional economic order quantity approach with a scheduled shortfall which is utilized for managing inventories. In this study, we assume an EOQ method with scheduled shortfall is used and there was a warehouse to keep the things that were produced in the manufacturing process, as well as a distribution hub for delivering items to the customers. The stock level in the storehouse is replenished when there is a supply shortfall in a distribution center is optimal. RFID development focuses on increasing distribution network efficiency in a variety of ways. As a result, the total supply chain RFID investment is made up of ordering and storing costs and shortage costs. Here we consider the expenditure of RFID in Ordering and Just-In-Time efficiencies in order to lower overall costs and obtain the best possible quantity of orders, and enhance in managing inventories. The ordering process can be made more efficient by cutting out any inefficiency. For instance, RFID automates and simplifies enumerating, and labor inaccuracy is reduced to a minimum. Efficiency of JIT ensures that inventory levels are kept to a bare minimum and modifying the layout in order to save money on storage. RFID improves "Monitoring" in their warehouses, so they can keep an eye on their stock levels in real-time and assist them in Managing inventory levels and rapidly relocating machines from one location to another one usage to another, and cutting the delivery time down of an order, by the cause of JIT efficiency.

Consider the following:

i) Non-RFID technology: We examine the EOQ investment assessment model with scheduled shortages in the absence of RFID.

ii) RFID investment in both ordering and JIT efficiency: We provide a great solution in which RFID invests in placing an order and JIT efficiencies in the inventory system at the same time. We also created this model, which depends on an EOQ method with a scheduled shortfall. This method has the advantage of simultaneously reflecting the mutual dependence of the two investment options. The motivation for making multiple investments at the same time is to examine the synergistic impact between the purchasing and storing costs. It is obvious from the analysis that achieving both ordering and JIT efficiencies simultaneously is possible. The goal of simultaneous RFID investment decisions is to further reduce investment costs by simultaneously evaluating both efficiencies.

Following that, we explain a model construction and introduce the notations we will use throughout this paper.

2.1 Notations

- d - yearly demand rate
- h - storage cost
- c - operating cost
- o - order cost
- q - manufacturing order quantity
- r - ordering efficiency
- r1 - ordering efficiency under RFID
- i - JIT (just-in-time) efficiency
- i1 - JIT (just-in-time) efficiency under RFID
- j - efficiency of functioning
- j1 - efficiency of functioning under RFID
- k - the amount of investment for order efficiency
- k1 - the amount of investment for order efficiency under RFID
- v - amount of investment for JIT efficiency
- v1 - amount of investment for JIT efficiency under RFID
- x - level of investment for operational efficiency
- x1 - level of investment for operational efficiency under RFID
- tc - total cost of the inventory
- tc1 - total cost under RFID
- t - cycle time
- t1 - cycle time under RFID
- o1 - number of orders per year
- o2 - number of orders per year under RFID
- imp - improvement of this method

2.2 Mathematical Formulation

The following are the mathematical formulas for the methods indicated above.

(i) The ordering efficiency function is formally stated as,

$$r = n + (m - n)e^{-(b*k)}$$

where m denotes the minimal ordering efficacy that can be achieved without investing in RFID technology, and n is the maximal ordering efficacy that is obtained by investing in k. Keep in mind that the value of a higher ordering efficiency equates to a lower ordering efficiency.

(ii) Consider the operational effectiveness, j, to be an exponential function with base e,

$$j = e + (a - e)\, e^{-(sci*x)}$$

where a indicates lower processing efficacy attained without investing in RFID technology, and e indicates higher processing efficacy attained by investing in x.

(iii) JIT (just in time) is stated as follows,

$$i,\ where\ 0 \le i \le 1$$

(iv) The optimum order quantity is given by,

$$q = \sqrt{(2*((o*d)/h))}$$

(v) The Mathematical formula for the total cost of the EOQ system is estimated by,

$$tc = o*((r*d)/q) + h*((i*q)/2) + j*(c*d)$$

(vi) The cycle time is expressed as follows,

$$t = \frac{o*((r*d)/q) + h*((i*q)/2) + j*(c*d)}{d} = \frac{q}{d}$$

(vii) The annual number of orders is expressed as follows,

$$o1 = \frac{d}{o*((r*d)/q) + h*((i*q)/2) + j*(c*d)} = \frac{d}{q}$$

(viii) The optimum order quantity under RFID is determined by

$$q1 = -pi + \sqrt{(pi*pi) + (2*((o*d)*n))/(h*l)}$$

where $pi = (b - lam)/(((lam*l)*h)*b)$

(ix) The RFID's Ordering Efficacy is stated as follows,

$$r1 = (q1 + (be*((o*d)*n)))/(be*(o*d))$$

(x) The JIT efficiency under RFID is expressed as follows,

$$i1 = (2 + (lam*((h*q1)*l)))/(lam*(h*q1))$$

(xi) The RFID's Operating Efficacy is given by,

$$j1 = (1/((c*d)*sci)) + e$$

(xii) The amount of money required to make RFID-enabled ordering operate is given by,

$$k1 = log((r1 - n)/(m - n))/(-b)$$

(xiii) The level of investment required for RFID-enabled JIT efficacy is determined by,

$$v1 = log((i1 - l)/(u - l))/(-lam)$$

(xiv) The Investment level for Operating efficacy under RFID is given by,

$$x1 = log(1/(((c*(d*sci))*(a - e))))/(-sci)$$

(xv) Considering the operational, JIT, and ordering efficiencies for the decisions of expenditure on RFID, the investment expenses, k, v, x are included in the total cost. Hence the total cost under RFID is determined by,

$$tc1 = o*((r1*d)/q1) + h*((i1*q1)/2) + j1*(c*d) + k1 + v1 + x1$$

(xvi) Cycle time under RFID is given by

$$t1 = \frac{-pi + \sqrt{(pi*pi) + (2*((o*d)*n))/(h*l)}}{d} = \frac{q1}{d}$$

(xvii) The number of orders per year under RFID is given by,

$$o2 = \frac{d}{-pi + \sqrt{(pi*pi) + (2*((o*d)*n))/(h*l)}} = \frac{d}{q1}$$

(xviii) The improvement of this method is given by,

$$imp = tc - tc1$$

3 Result and discussion

The existing research has primarily focused on utilizing RFID technology investments in inventory systems to manually optimize total costs. However, effective stock management also requires optimizing key factors such as annual order frequency and cycle time to balance inventory expenses. Despite the importance of these aspects, there is a noticeable research gap in applying computational methods, particularly using the C programming language, to address these challenges. Hence, this study aims to fill the gap by developing an integrated inventory model that incorporates RFID technology investments, focusing on optimizing annual order frequency, total costs, and cycle time using a C programming approach to provide a novel solution for enhancing sales revenue and improving inventory management.

d - yearly demand rate: 100000, h - storage cost: 1000, c - operating cost: 2000, o - order cost: 1500, m=1.0, n=0.3, k=0, b=0.00002, a=1.0, e=0.5, sci=0.00002, lam=0.00001, l=0.2, u=1.0

Algorithm

Step 1: Start
Step 2: Declare the variables d, h, c, o, q11, m, n, k, b, value, result, r, a, e, x,
sci, value1, result1, j, i, u, q, tc, lam, l, pi, q12, q1, r1, i1, j1, k1, v1,
x1, tc1, t, t1, o1, o2, imp
Step 3: Get the values of d, h, c, o
Step 4: Set m=1.0; n=0.3; k=0; b=0.00002
Step 5: Compute value=-b*k and result=exp(value)
Step 6: Print the exponential term
Step 7: Compute r=n+(m-n)*result and print the value of r
Step 8: Assign the values a=1.0; e=0.5; x=0; sci=0.00002;
Step 9: Calculate value1=-sci*x; result1=exp(value1) and print the result1
Step 10: Compute j=e+(a-e)*result1 and display the value of j
Step 11: Set i=1.0
Step 12: Compute q=sqrt(2*((o*d)/h)) and display the value of q
Step 13: Calculate tc=o*((r*d)/q)+h*((i*q)/2)+j*(c*d) and print the value of tc
Step 14: Compute t=q/d; o1=d/q and print their values
Step 15: Assign the values lam=0.00001;l=0.2
Step 16: Compute pi=(be-lam)/(((lam*l)*h)*b)
q11=(pi*pi)+(2*((o*d)*n))/(h*l)
q12=sqrt(q11)
q1=-pi+q12and print the value of q1
Step 17: Calculate r1=(q1+(b*((o*d)*n)))/(b*(o*d)) and display the value of
r1
Step 18: Determine i1=(2+(lam*((h*q1)*l)))/(lam*(h*q1)) and display the value
of i1
Step 19: Set e=0.5. Compute j1=(1/((c*d)*sci))+e and print the value of j1
Step 20: Compute k1=log((r1-n)/(m-n))/(-b) and display the k1 term
Step 21: Set u=1.0. Determine v1=log((i1-l)/(u-l))/(-lam) and print the v1 term
Step 22: Compute x1=log(1/(((c*(d*sci))*(a-e))))/(-sci)
tc1=o*((r1*d)/q1)+h*((i1*q1)/2)+j1*(c*d)+k1+v1+x1
and display their terms
Step 23: Calculate t1=q1/d; o2=d/q1 and print their values
Step 24: Determine imp=tc-tc1 and display the value of imp
Step 24: End program

Program

```
#include<stdio.h>
#include<conio.h>
```

```
#include<math.h>
void main()
{
longint d,h,c,o,q11;
float m,n,k,value,result,r,a,e,x,sci,value1,result1,j,i,u;
double q,tc,b,lam,l,pi,q12,q1,r1,i1,j1,k1,v1,x1,tc1,t,t1,o1,o2,imp;
clrscr();
printf("\n Enter the Annual demand d:");
scanf("%ld",&d);
printf("\n Enter the holding cost h:");
scanf("%ld",&h);
printf("\n Enter the operating cost c:");
scanf("%ld",&c);
printf("\n Enter the order cost o:");
scanf("%ld",&o);
m=1.0;n=0.3;k=0;b=0.00002;
value=-b*k;
Result=exp(value);
printf("\n The exponential of %f is %f",value,result);
r=n+(m-n)*result;
printf("\n The ordering efficiency is %f",r);
a=1.0;e=0.5;x=0;sci=0.00002;
value1=-sci*x;
Result1=exp(value1);
printf("\n The exponential of %f is %f",value1,result1);
j=e+(a-e)*result1;
printf("\n The Operating efficiency is %f",j);
i=1.0;
printf("\n The JIT efficiency is %f",i);
q=sqrt(2*((o*d)/h));
printf("\n The value of q is: %lf",q);
tc=o*((r*d)/q)+h*((i*q)/2)+j*(c*d);
printf("\n The total cost is: %lf",tc);
t=q/d;
printf("\n Cycle time is : %lf",t);
o1=d/q;
printf("\n The aggregate number of orders placed each year  is: %lf",o1);
lam=0.00001;l=0.2;
pi=(b-lam)/(((lam*l)*h)*b);
printf("\n The value of pi is: %lf",pi);
q11=(pi*pi)+(2*((o*d)*n))/(h*l);
printf("\n q11: %ld",q11);
q12=sqrt(q11);
printf("\n q12: %lf",q12);
q1=-pi+q12;
printf("\n q1: %lf",q1);
r1=(q1+(b*((o*d)*n)))/(b*(o*d));
printf("\n The RFID's Ordering Efficacy is: %lf",r1);
i1=(2+(lam*((h*q1)*l)))/(lam*(h*q1));
printf("\n The RFID-enabled JIT performance is: %lf",i1);
e=0.5;
j1=(1/((c*d)*sci))+e;
printf("\n The RFID's Operating Efficacy is: %lf",j1);
```

```
k1=log((r1-n)/(m-n))/(-b);
printf("\n The amount of money needed to get an RFID-enabled ordering system working is:%lf",k1);
u=1.0;
v1=log((i1-l)/(u-l))/(-lam);
printf("\ The amount of expenditure required to run RFID-enabled JIT functioning is: %lf",v1);
x1=log(1/(((c*(d*sci))*(a-e))))/(-sci);
printf("\n The extent of capital needed for RFID operational effectuality is: %lf",x1);
tc1=o*((r1*d)/q1)+h*((i1*q1)/2)+j1*(c*d)+k1+v1+x1;
printf("\n The total cost under RFID is: %lf",tc1);
t1=q1/d;
printf("\n Cycle time under RFID is: %lf",t1);
o2=d/q1;
printf("\n  The number of orders acquired under RFID Once per year is: %lf",o2);
imp=tc-tc1;
printf("\n The improvement is : %lf",imp);
getch();
}
```

Output

```
Enter the Annual demand d: 100000
Enter the holding cost h: 1000
Enter the operating cost c: 2000
Enter the order cost o: 1500
The exponential of -0.000000 is 1.000000
The ordering efficiency is 1.000000
The exponential of-0.000000 is 1.000000
The Operating efficiency is 1.000000
The JIT efficiency is1.000000
The value of q is: 547.722558
The total cost is: 200547722.557505
Cycle time is: 0.005477
The aggregate number of orders placed each year  is: 182.574186
The value of pi is: 250.000000
q11:512500
q12: 715.891053
q1:465.891053
The RFID's Ordering Efficacy is: 0.455297
The RFID-enabled JIT performance is: 0.629285
The RFID's Operating Efficacy is: 0.500250
The amount of money needed to get an RFID-enabled ordering system working is: 75287.039569
The amount of expenditure required to run RFID-enabled JIT functioning is: 62249.089744
The extent of capital needed for RFID operational effectuality is: 380045.131315
The total cost under RFID is: 100860759.476361
Cycle time under RFID is: 0.004659
The number of orders acquired under RFID Once per year is: 214.642456
The improvement is: 99686963.081144
```

Optimal solution and comparative study

The obtained optimum solutions with and without the consideration of Radio Frequency Identification technology in an inventory system by using a C programming approach are presented in Table 1 and it shows the efficiency of the suggested paradigm.

Table 1. Optimum solutions for with and without the consideration of Radio Frequency Identification technology into an inventory system by using a C programming approach

	With Radio Frequency Identification technology	Without Radio Frequency Identification technology
Total cost of the system	100860759.476361	200547722.557505
Number of orders placed each year	214.642456	182.574186
Cycle time	0.004659	0.005477

4 Conclusion

Future prospects for supply chain and inventory systems using RFID technology are promising, owing to the intelligent supply chain trend. RFID in the supply chain is now being considered as a revolutionary technology. Existing research has mainly concentrated on using RFID technology investments in inventory systems to optimize total costs. However, effective stock management also requires optimizing key factors such as annual order frequency and cycle time to balance inventory expenses. Optimizing these metrics helps businesses avoid overstocking, minimize ordering costs, and reduce the risk of stock outs. Therefore, research on inventory management to optimize the annual order frequency and cycle time is also required to increase the sales revenue of an organization. Despite the importance of these aspects, there is a noticeable research gap in applying computational methods, particularly using the C programming language, to address these challenges. An integrated investment evaluation model is established in this work and comparative study has been made to analyze the assessment model with scheduled shortages in the absence and presence of Radio Frequency Identification technology. Results shows that the total cost under non Radio Frequency Identification technology is 200547722.557505 whereas the total cost under Radio Frequency Identification technology investment is 100860759.476361. The number of orders placed each year under non Radio Frequency Identification technology and Radio Frequency Identification technology are 182 and 214 respectively. These results imply that the incorporation of Radio Frequency Identification technology in the inventory management leads to huge impact on improved efficiency and accuracy, resulting in increased profitability for an organization. This work can also be extended by considering the RFID technology in multi echelon inventory optimization and other sustainability issue parameters.

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