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AN INVENTORY MODEL FOR OPTIMAL CASH MANAGEMENT FOR FINANCIAL INSTITUTIONS: A CASE STUDY (*)

by N. K. KWAK ⁽¹⁾ and Michael D. RENFRO ⁽²⁾

Abstract. — *This paper deals with determining the optimal cash maintenance level at a financial institution by utilizing traditional inventory control concepts. Using the conceptual framework of the economic order quantity (EOQ) model, this paper demonstrates that cash, properly controlled by a financial institution, can generate additional revenue and reduce employee time and costs.*

Keywords : Inventory Modelling; Banking; Financial Management.

Résumé. — *Cet article traite de la façon dont on peut déterminer le niveau optimal de maintien des liquidités pour une institution financière, en utilisant le concept traditionnel du contrôle d'inventaire. A partir du cadre conceptuel fourni par le modèle de quantité de l'ordre économique, cet article montre que les liquidités, correctement contrôlées par une institution financière, peuvent générer des revenus supplémentaires, et réduire le temps de travail ainsi que les coûts.*

Mots clés : Modélisation inventaire; Banque; Gestion financière.

1. INTRODUCTION

Because of the dynamic and competitive nature of today's financial markets, many financial institutions are keenly concerned about increased competitive pressure and are constantly searching for new methods to improve their service and internal operations.

One very important aspect of financial institution management is the minimization of non-earning assets. One such asset, cash in the hands of tellers and maintained in the vault, has often been overlooked in the past as an area for cost reduction or income generation. However, financial institution managers everywhere are now recognizing this as an untapped resource and are beginning to look at cash as inventory that can be controlled by using operations research techniques.

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The purpose of this study is to analyze and determine the optimal cash-level maintenance at a financial institution by utilizing an economic order quantity (EOQ) model, thereby reducing the opportunity costs of holding excess cash to meet customer demand. The data for this study is obtained from one sample location of a large metropolitan bank ⁽¹⁾ in St. Louis, Missouri.

There are certain limitations in determining the optimum cash level at a particular financial institution location. For example, the Federal Reserve Bank requires that a certain percentage of deposits be maintained as cash reserves. Since the reserve amount varies every two weeks based on deposit variance and the calculation method dictated by the Federal Reserve, the fluctuating reserve adds a degree of uncertainty to our approach.

Another limiting factor is the impact of peak periods on the average daily cash usage calculation. For example, cash usage may be extremely high during the Christmas shopping season or in an area where small businesses which rely heavily on cash sales (grocery stores, movie theatres, parking lots, etc.) are located.

In order to demonstrate the application of an EOQ model, the paper will focus on several key elements such as average usage, average shipments, average cash-on-hand, safety stock, and holding costs.

2. CASH MANAGEMENT AND ITS FINANCIAL IMPACT

Today, every financial institution in the United States is facing the task of increasing earnings and reducing costs in order to reduce the threats of narrowing interest margins and increased deregulation and competition.

Much of the literature on the subject of cash management is devoted to quantitative methods of controlling and managing cash reserves (Zanakis *et al.*, listed 164 publications of OR/MIS applications in banking[11]). In an earlier study, Baumol applied cash holdings by firms to the classical "lot size" model of inventory management[2]. A number of inventory theoretic models have also appeared for cash management problems [3, 5, 6, 9, 10]. However, these models have not been adopted as solutions to bank cash

⁽¹⁾ At the request of bank management, the name of the bank is withheld to ensure corporate security. The bank under study was merged with a regional bank with a few branches at the time of gathering numerical data. Again, a merger with another bank is proposed. Although each branch location has similar operating characteristics, information in totality is not available to us.

management problems because bank cash outlays are controllable to a certain degree and are not stochastic as often assumed in the existing inventory models. Anvari [1] presented an application of inventory models to cash collection examining a cash-transfer procedure that uses depository transfer checks. The optimal transfer policy was characterized by a simple (s, S) policy.

In spite of the existence of these models, cash levels have often been established by management's comfort level at many financial institutions. As a consequence, cash balances have often exceeded customer needs as well as reserve requirements. Higher than necessary cash levels result in lower amounts available for earning assets. Thus, potential earnings from additional investment are lost.

As it will become clear, cash controlled by a financial institution possesses many of the same characteristics as inventory in a manufacturing concern. The term inventory is a general one denoting those resources of an organization which are stored in anticipation of fulfilling demands. Since the banking industry is a service industry which supplies cash as one of its services, cash should be regarded as inventory when assessing profit improvement potentials. The main objective is to free excess cash funds so that they may be utilized as earning assets.

In order to accomplish this objective, this paper utilizes traditional inventory control concepts. Specifically, the classical EOQ model is modified and applied to this situation.

Determining the actual cash needs and monitoring these needs on an ongoing basis requires detailed information about the daily ending cash position and the cash shipments (incoming and outgoing) by location. In order to effectively monitor and control the cash position, a financial institution manager must accumulate the following data:

- average cash usage or receipt;
- average shipments incoming and outgoing;
- average cash-on-hand.

Once the data noted above is obtained, three other key items can also be ascertained:

- the appropriate safety stock level;
- the necessary cash shipment or ordering requirements;
- the average cost to order cash shipments.

After this data is compiled, the reorder point and the optimum level of cash-on-hand can be calculated and coupled with the income improvement opportunity of investing idle cash.

3. DATA COLLECTION METHODS AND VALIDITY

Financial background

The financial institution selected as an implementation site for this study is a large bank in the St. Louis metropolitan area (hereafter referred to as LBC). LBC is a multibank holding corporation which owns six banks in Missouri and is approaching one billion dollars in total assets. The subsidiary banks have 21 locations in the St. Louis, Kansas City and Springfield regions with 16 of the banking centers located in the St. Louis area.

Of the six banks owned, three banks are located in the St. Louis metropolitan region and are listed below with selected financial information (as of September 30, 1985).

TABLE I
Financial data (in thousands)

	St. Louis (County) (\$)	St. Charles (\$)	St. Louis (City) (\$)
Average assets.	609,313	154,783	33,674
Average deposits	539,881	137,710	28,224
Average equity	41,381	11,228	1,819

Source: LBC Finance Department, *Consolidated Financial Analysis*, September 30, 1985, Schedule 1.

Based on the above financial data, the SLC bank (one of the LBC) represents 76.4% of the total average assets in the St. Louis area. Therefore, for the purpose of this study, we have selected one of the ten banking center locations comprising the SLC as hopefully this would have a greater impact on the organization as a whole.

The SLC center selected is located in Clayton, Missouri and has been in existence for approximately one year. It presently is manned by five financial service representatives who serve as tellers and new accounts personnel. The center does not have a high volume of lobby traffic but is subject to a rather steady flow of customers. The selection of this center is appropriate for this study since customer flows and cash usage are less volatile. Many other LBC centers have higher volumes of lobby traffic and are subject to sporadic

activity and this would have perhaps affected the validity of the data which was collected over a relatively short period of time.

The following monthly average balances (in thousands) are presented for the Clayton Center. As of September 30, 1985:

— Total cash and due from banks	\$ 33,233
— Total assets	147,225
— Total deposits:	
transaction accounts	27,222
time deposits	49,628

Cash, as stated above, represents all cash held by tellers or maintained in the vault and automated teller machines (ATM). For the purposes of this study, however, ATM cash will not be considered as it has a minimal impact on total cash required at this particular location because of its recent installation of the system.

Data collection

In determining the optimum cash level, data requiring cash balances and usages was collected by utilizing data collection logs designed for this purpose (see Appendix).

Data collection logs can be used to pinpoint the daily ending cash balancing by denomination. This log tracks, on a daily basis, each denomination of bills and coins. Once completed, the banking location can ascertain their daily and weekly cash balances by denomination as well as their daily and weekly usages or receipts.

A similar log can be maintained to record cash shipments. This log will provide the daily and weekly shipment totals, both in or out, by denomination for each banking location. Both logs should be implemented for a one-to two-month period. For the purposes of this study, data was collected for a six-week period beginning September 3, 1985 and continuing through October 11, 1985.

Another element of data which should be ascertained in order to apply the EOQ model is the reserve requirement applicable to the location being analyzed. A financial institution is required to hold reserves in the form of cash or deposits with the Federal Reserve Bank equal to some percentage of its deposits as summarized in Table II.

Although the above requirements will not be fully applicable in the form stated above until November, 1988, the Federal Reserve does require a

TABLE II
Reserve requirements for financial institutions.

The first \$25 million of transaction account balances (%)	3
Transaction account balances over \$25 million (%)	12
Negotiable certificates of deposit (%)	3
Eurodollar borrowings (%)	3

financial institution to maintain reserves of cash and deposits at the Federal Reserve based on a complicated formula which represents a phase-in of the above requirements. Thus, the reserve requirement has some impact on the level of cash maintained on premises. In the following subsection, we will explore some practical constraints, however, to the applicability of the reserve requirement for this study.

Another important data input for this study is the average cash ordering lead time. This measure is usually dictated by the correspondent banking institution with whom the subject bank has contracted for cash shipments and other correspondent services. Generally, the lead time ranges from one to two days.

A final segment of data which is vital to our calculation of EOQ and optimum cash balance is the average cost to order cash. This cost is comprised of several components including the correspondent institution's order fee, the courier's fee and bank staff time to process the order. This can also be a difficult item to accurately measure if the bank is not paying for services on a fee basis but is having all services accumulated in an account analysis format for comparison to its compensating balance maintained at the correspondent institution.

Data validity and constraints

The data for this study was accumulated by analyzing existing cash balancing records prepared by tellers on a daily basis, consulting with location managers and reviewing correspondent bank contracts which provide details regarding the costs of services such as cash shipments.

The data regarding cash balances is valid since it is controlled and verified by the general ledger control accounts. However, the data regarding reserve requirements and ordering costs is subject to several limitations or assumptions which are detailed in the following paragraphs.

Since reserve requirements are subject to a fluctuating calculation method at present and are only applicable to a legal bank and cannot be applied to

just one of the bank's possible locations, we must make some assumptions regarding the reserve requirement for this study.

First of all, the location chosen for this study is not a separate legal bank but rather a facility. As such, there is no specific requirement for reserves to be maintained at this level, nor are reserves calculated at this level. Reserves are maintained, instead, on a total bank level. Therefore, due to the complexities of the reserve calculation procedure coupled with the non-bank aspect of analyzing one physical location, the following assumption was made to control the impact of the reserve requirement.

Assumption: A reserve cash balance serving as partial fulfillment of the reserve requirement will only be considered at the locations having a high volume of lobby traffic as the additional reserve will serve as a buffer against peak cash usage days. In other words, the reserve requirement will not be considered in computing the optimum cash level for the Clayton Center as the reserve will be held at other locations with higher volumes of traffic and will also be offset by controlling and monitoring the level of the Federal Reserve deposit balance. Any excess or deficiency can be accommodated by the purchase or sale of Federal funds. Furthermore, due from bank deposit balances at the Federal Reserve is only maintained for each legal bank and, thus, in practice it would be difficult to factor this into the reserve calculation on a location basis.

The other limitation on the validity of the data is in the area of ordering costs, specifically the amount charged by the correspondent bank when a cash shipment is requested. Most financial institutions charging this fee "bury" it in an account analysis statement which is designed to accumulate all fees for services and offset these fees against the earnings related to a compensating balance maintained at the correspondent institution. The exact fee could be separated from the data after performing some lengthy computations. However, for the purpose of this study any average ordering fee was obtained consulting various correspondent customers and is used in the calculations presented in Section 5.

4. ECONOMIC ORDER QUANTITY: A PRACTICAL APPROACH

The overall goals of an inventory system are to have available:

1. The right resource.
2. In the correct quantity.
3. At the right time so as to maximize profits [7].

In order to properly determine the above criteria, one must be able to quantify several costs which relate to inventory. These costs are holding costs, ordering costs and shortage costs. As shortages costs are rough estimates at best and since they may not as readily apply to a financial institution with multiple locations in close proximity, they were deleted from the EOQ calculation. In the case of a financial institution, we can classify the significant costs as follows:

Holding costs

1. Cost of capital
2. Cost of insurance
3. Risk of theft
4. Cost of storage space

Ordering costs

1. Order processing
2. Inspection costs
3. Courier's fee

Since the costs of insurance, theft and storage are minimized in a financial institution through other means, we will not include those as significant segments of the cost to hold cash in this study.

In the traditional EOQ analysis, the optimum quantity, Q^* , is found by the formula:

$$Q^* = \sqrt{2C_0D/H}.$$

(See Table III for the definition of notation.)

A more practical method which can be used for financial institutions and can be more readily understood is a derivation of the EOQ formula. It is explained in step-by-step fashion below. The following symbols are used for this analysis, as shown in Table III.

Step 1: Determine the average usage

Calculating the average usage or receipt (\bar{U}) is achieved by adding all the daily usage or receipt total (U) then deviding by the number of days (n) being analyzed. (The daily usage or receipt is the difference between yesterday's ending cash balances and today's ending cash balance.) If that number is negative, it indicates a net usage of cash. Therefore, the formula is summarized as follows:

$$\bar{U} = \frac{\sum U}{n}. \quad (1)$$

Step 2: *Determine the average shipment*

The average cash shipment, in or out, (\bar{C}) is determined by adding the daily totals of the net shipments in or out then deviding by the number of days being analyzed.

$$\bar{C} = \frac{\Sigma C}{n} \quad (2)$$

Step 3: *Determine the average cash-on-hand*

The average cash-on-hand (\bar{K}) is calculated by adding all the daily ending balances of cash (B) and dividing the total by the number of days being analyzed.

$$\bar{K} = \frac{\Sigma B}{n} \quad (3)$$

TABLE III
List of Notation.

B	= daily ending cash balance.
\bar{B}	= average cash balance (between receiving days excluding safety stock).
C	= average cash net shipment.
\bar{C}	= average daily net cash shipment.
C_o	= average cost to order cash.
C'_o	= corresponding institutions's order fee.
D	= annual demand.
F_c	= courier's fee (armored transport).
F_r	= Fed funds rate (or equivalent cost of capital).
H	= annual holding cost per unit.
H_r	= holding cost over reorder period.
\bar{K}	= average cash on hand.
\bar{L}	= average lead time.
M^*	= optimum cash level.
n	= number of days.
Q^*	= economic order quantity.
R_p	= reorder point.
S_s	= safety stock.
T	= staff time to recover.
U	= daily cash usage or receipt.
\bar{U}	= average daily cash usage or receipt.
U_p	= peak (or highest) cash usage day of each week.
\bar{U}_p	= average peak cash usage.

Step 4: Determine the safety stock

An approximate safety stock (S_s) for financial institutions is calculated by reviewing the cash usage calculations and determining the average peak cash usage (\bar{U}_p) by focusing on the highest cash usage day for each week of the period under study. The sum of the weekly peak usages divided by the weeks analyzed will yield an average peak day usage (that is, $\bar{U}_p = \Sigma U_p/n$). This result multiplied by the average cash ordering lead time (\bar{L}) yields the safety stock amount.

$$S_s = \bar{U}_p \times \bar{L}. \quad (4)$$

Step 5: Determine the ordering cost of cash shipment

For a financial institution, the ordering cost for cash shipments (C_0) is comprised generally of the following components.

$$C_0 = C'_0 + F_c + T. \quad (5)$$

The first two components, correspondent institution's order fee (C'_0) and courier's fee (F_c), are generally quoted costs on a contract basis. The third component, staff time to process the order (T), is generally calculated by determining the average time (and, thus, salary cost) for those people processing (counting, bundling, storing, accounting) the average order amount.

With the preliminary data collected, the cash-on-hand requirements can now be analyzed. The minimum amount one would want to order is a one-day average supply or usage. The cost to hold this amount of funds in the vault for the period of time equal to the lead time would represent our cost of holding one day's usage (demand) for the two-day lead time period.

Based on the above analysis, then, the goal is to determine the break-even level where the cost of ordering one order is equal to the cost of holding that order. Holding costs would be calculated, therefore, by the following formula used on a trial basis:

$$H = \bar{B} \times F_r. \quad (6)$$

After all calculations are complete, we will be able to arrive at the optimum cash level, the amount of safety stock and the economic order quantity. Based on these findings it is then a simple matter to calculate the approximate annual savings to the financial institution. The following section provides the details regarding the resultant findings of applying this methodology to the Clayton Center location of SLC.

5. RESULTS OF THE STUDY

Based on the application of the formulas previously discussed, the following results were arrived at for the Clayton Center of SLC.

1. Average usage or receipt (\bar{U}): \$ 1,013 [29,391/29, from equation (1)].
2. Average shipments (\bar{C}): \$ 39,092 [234,550/6, from equation (2)].
3. Average cash-on-hand (\bar{K}): \$ 122,262 [3,545,585/29, from equation (3)].
4. Average peak day usage (\bar{U}_p): \$ 44,946 (269,678/6).
5. Average cash ordering lead time (\bar{L}): 2 days.
6. Safety stock (S_s): \$ 89,892 [$44,946 \times 2$, from equation (4)].
7. Average cost to order (C_o): \$ 41.89 [$8.91 + 20.00 + 12.98$, from equation (5)].
8. Economic order (Q^*): \$ 19,247 (19-day interval).

After computing the key criteria noted above, the objective is to determine the potential income improvement opportunity. This is done by comparing the present average cash-on-hand amount (historical) with the new cash-on-hand goal (calculated). The result represents a present non-earning asset which, when invested, would yield additional income to the bank. This formula is shown below utilizing the results from our study.

Present average cash-on-hand	\$ 122,262
– New cash-on-hand goal	<u>100,022</u>
= Potential reduction	\$ 22,240 (18.19%)
× Average Fed Fund rate (Sept. 1-Oct. 11, 1985)	7.91% [4], p. 7
= Annual savings.	<u>\$ 1,759</u>

As the Clayton Center is only one of ten centers comprising SLC and only one of 21 centers comprising LBC, the savings would probably be magnified if projected for the entire population as proposed by this study. In order to provide a “rough” estimate of the potential savings to the entire corporation, the following calculation (Table IV) is provided.

8. Economic order quantity (Q^*)

Since the total ordering costs must be equal to the total holding costs over the reorder period to determine the economic order quantity (Q^*), the following steps were taken:

(a) Compute average cash balances between receipts (\bar{B})—In order to arrive at the amount of holding costs over the reorder time period, we have

TABLE IV
Total corporate earnings increase projection.

	Clayton Center	SLC	All Banks
Average cash-on-hand.	\$ 122,262	\$ 4,425,059	\$ 7,237,374
Percentage reduction	18.19%	18.19%	18.19%
Potential reduction.	\$ 22,240	\$ 804,918	\$ 1,316,478
Average Fed Fund rate.	7.91%	7.91%	7.91%
Projected reduction	\$ 1,759	\$ 63,669	\$ 104,133

systematically (on a trial-and-error basis) evaluated the various reorder time periods. In our evaluation, the reorder time period began with one day setting the average daily usage amount as the minimum and increased the reorder period in order to calculate an average cash balance between receiving days.

$$\bar{B} = [(n^2 + n) \bar{U}/2]/n = \{[(19)^2 + 19](1.013)/2\}/19 = \$ 10,130.$$

(b) Compute annualized holding costs (H) — From equation (6).

$$H = \bar{B} \times F_r = 10,130 \times 7.91 = \$ 801.28.$$

(c) Compute holding costs over reorder period (H_r)

$$H_r = (H/365)n = (801.28/365)19 = \$ 41.71$$

This holding cost of \$41.71 is approximately equal to the ordering cost of \$41.89. Therefore, every 19 days, an order should be placed for \$19,247 in cash (19 days \times \$1,013 daily usage).

9. Reorder point (R_p)

$$R_p = S_s + U = 89,892 + 1,013 = \$ 90,905.$$

10. Optimum cash level (M^*)

$$M^* = S_s + B = 89,892 + 10,130 = \$ 100,022.$$

6. SUMMARY AND CONCLUSION

This paper was designed to demonstrate that, for financial institutions, cash should be viewed as inventory. As such, common inventory concepts can be applied to aid in determining optimum cash levels and thereby reducing related holding and ordering costs.

Although subject to some practical limitations, it was demonstrated that the data can be easily accumulated by banking personnel and can be applied using a practical method of the EOQ model presented in this paper.

As the need for additional operational tools increases under the umbrella for financial institution deregulation, financial managers must continue to "rethink" their business and capitalize on the benefits of applying operations research techniques such as EOQ. Such techniques will not only serve as a means to increase profits, but, in the highly competitive future, will be essential ingredients for survival.

The proposed inventory model has been presented to the LBC management and is being implemented for optimal cash management at the Clayton Center. The model seems to facilitate planning and decision making by providing management information.

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APPENDIX, CASH USAGE LOG

Week Ending-----

	Monday	Tuesday	Wednesday	Thursday	Friday	TOTAL
BILLS						
\$ 1.00	-----	-----	-----	-----	-----	-----
2.00	-----	-----	-----	-----	-----	-----
5.00	-----	-----	-----	-----	-----	-----
10.00	-----	-----	-----	-----	-----	-----
20.00	-----	-----	-----	-----	-----	-----
Large	-----	-----	-----	-----	-----	-----
Mutilated	-----	-----	-----	-----	-----	-----
COINS						
\$0.01	-----	-----	-----	-----	-----	-----
0.05	-----	-----	-----	-----	-----	-----
0.10	-----	-----	-----	-----	-----	-----
0.25	-----	-----	-----	-----	-----	-----
0.50	-----	-----	-----	-----	-----	-----
1.00	-----	-----	-----	-----	-----	-----
TOTAL	-----	-----	-----	-----	-----	-----