OC10006 - A comparison of classic time series models and artificial neural networks in anticipation of cash requirements of banks: A case study in Iran

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Abstract
Correct anticipation and cash management in financial institutions, especially banks, is a vital affair. Neural network is a new anticipation technique which provides a lot of capabilities for anticipation in financial fields by inspiration of brain's neuron structure.
The goal of this research is to compare anticipation power of artificial neural networks with other anticipation methods used for cash anticipation of banks. So, after identification and classification of bank cash items, classic models of time series including moving average, Holtz model, ARIMA model, and multilayer Perspetron artificial Neural networks are used to anticipate the cash items. The results show that neural network model had minimum anticipation error for the first months of 2007. Therefore, this model is suggested as premier model in comparison with classic ones.

Keywords: cash requirements, anticipation, artificial neural networks, time series models.

1. Introduction

Cash is not an abstract concept but is a function of time and cost. It means that although most assets of a financial institution are converted to cash on deadline, but the speed of this conversion has costs. In other words, although all assets can be converted to cash by selling, but lost (cost) of this selling depends on which asset is sold with what speed (up to deadline). If cash cost is high, it means losing profitability of the asset.

Unsuccessfulness in this field may endanger public confidence to banks. One of the most important duties of a bank's cash management is to have near relations with great depositor and great borrowers of the bank and to know when they will withdraw their cash, then to keep enough available cash.

Cash supplying cost by borrowing will increase by interest rate. If the loaner knows that bank's risk has increased, bank has to pay more interest rate. Then, some of loaners do not pay their loan.

In this study, we investigate theoretical fundamentals of cash management in financial institutions and propose an anticipation model for artificial Neural networks. We compare this model with classic time series models including moving average, Holtz model, and ARIMA model. Accordingly, we selected cash data of one of Iranian banks for a 3 years period, from 21/3/2004 to 20/3/2006.

2. Theoretic fundamentals and Background

2.1. Theoretic fundamentals of study

2.1.1. Bank's cash risk

"Nikomaram," "Rahnama Roodposhti," and "Heybati" (2005) have suggested that cash moneys are important items in current assets of companies and benefit-units operation process. So, this problem has increased the importance of cash management. There is a meaningful relation between cash management quality and cash risk, and cash sufficiency is an effective factor in this relation. Cash sufficiency is an everlasting problem of a bank manager, and alternatively is a source for plenty of profitability. When interest rate increases, some of the depositors may withdraw their deposit to gain higher efficiency; many loan-requesters may delay their new requests or search loans with fewer interest rate. Therefore, interest rate changes affects either on loan requests or deposit requests that each one has a potential effect on bank's cash situation.

"Peter Ross" (1999) believes that one of the most important duties of a bank manager is to guarantee cash sufficiency. If a bank has the ability to rapidly access to cash moneys with rational cost and favorite time, then it will be recognized as a bank with high cash ability. In the other hand, cash insufficiency is a sign of financial problems that increases bank's cash risk.

In better words, we can say that cash management causes interest rate changes risk (interest rate risk) and unavailability risk to needed moneys in a certain time (availability risk). If interest rate increases, then financial assets that bank is going to sell them to obtain cash money will decrease their value, and may be sold by lost. Then, not only bank encounters with a decrease in assets value, but also the income resulted from these assets would be lost.

Cash dimensions

"Koch T.W." (2003) suggested that cash is not an abstract concept, but it is a function of time and cost. It means that although most assets of a financial institution are converted to cash on deadline, but the speed of this conversion has costs. In other words, although all assets can be converted to cash by selling, but lost (cost) of this selling depends on which asset is sold with what speed (up to deadline). If cash cost is high, it means losing profitability of the asset.

A financial institution can periodically borrow some moneys to reply cash. But interest rate of this borrowing will be high, especially when other financial institutions are demander of cash. In other words, cost of providing little cashes may be equal to their borrowing cost, but supplying large cashes which is done by selling the assets, is accompanied by profitability opportunity cost of those assets.

Most of financial institutions maintain higher importance for cash and cash management, and manage their cash so there is rarely weakness in cash affairs.

Thus, cost and time are two factors that may challenge cash dimensions, and cash programs are affected by these two factors.

2.1.2. Research Background

"Petros Rose" suggested some approaches for cash structure and resources and consumption in order to financial institutions management. These approaches try to provide some patterns for cash management by studying input and output cash flow features of banks.

"Halbert White" suggested utilizing Neural networks in economic anticipations by trying to explore the hidden discipline in historical prices of capital assets. Statistical perception methods and learning methods of Neural networks have been suggested in these researches.

"Chavoshi" (2002) in his MA thesis titled "Investigation of stocks prices behavior in Tehran's Securities Bourse" in Imam Sadegh University, has investigated anticipation of stocks profitability behavior in Tehran's Securities Bourse by factorial linear model and Neural networks.

"Hamid Khaluzadeh" (1998) in his book titled "A nonlinear structure model and anticipation of stocks prices behavior in Iran's bourse market" has studied anticipation discussion of prices, and has used three-layer Neural network with 1.15.5 design to anticipate the next day price of productivity and index of bourse.

"Hossein Panhian" (2000) in his PhD thesis titled "Using Neural networks to anticipate the trend of stocks prices index in Tehran's Securities Bourse" in Islamic Azad University, has used three-layer Perspetron Neural network in order to anticipate price index in bourse.

2.1.3. Transformations of cash management strategies

Upon researches on historical works of "Koach" (2003) various strategies about cash management have been designed, which are introduced in the following theories:

Commercial Loan Theory
Historically, cash management was initially concentrated on assets management and was mixed by credit policies. Before 1930, banks only granted short-term and cash loans, and so they place themselves in a suitable cash position. Deadlines of these loans were simultaneous with deposits, and payments of deposits were accompanied by loan granting.

Shiftability Theory
Shiftability theory suggests cash management concept in so manner that, upon this theory, every cash asset can be used to reply cash requirements. In fact, bank could be ready to reply cash needs and deposit withdrawals by keeping some cash assets (like governmental securities) and selling them in market. Applying this theory was accompanied with development of governmental securities after 1930.

Anticipated Income Theory
About 1950, banks moved toward Anticipated Income Theory. This theory suggests that cash requirements and loans repayment are supplied from anticipated incomes of loans. Again banks were encouraged to capitalize in cash assets, but this time it had a structured form in so manner that loan deposit deadlines were simultaneous.
First principle in this theory was based on input and output flow features of cash and loan assets. This theory caused increasing amortization period of loans and increasing deadline of banks' portfolios.

Liability Management Theory
Recently, banks have also concentrated on loans. Upon Liability Management Theory, banks borrow from money and capital market to supply their cash requirements. In fact, when a bank encounters an immediate need, it goes to borrow than to sell assets.

Balanced Asset Liability Management
Today banks use either assets or loan to supply their cash requirements. They first manage all dimensions of input and output cash flows about deposits and loans. Then they decide about cash moneys supply via assets selling or borrowing. The important point is saving suitable cash assets and having strong capital structure to minimize cash needs.

2.1.4. Anticipation techniques used in companies
In financial texts of companies they usually point to some anticipation models for optimum cash residue. The most important of these are Bamul, Brank, Miler-Ure, and Stone models. Each of these models has its special features that determine its application. Table 1 shows a comparison of the most important assumptions and features of these models.

Table 1: A comparison of anticipation models in companies

Model / Feature	Bamul	Brank	Miler-Ure	Stone
Assumptions	- Regular and constant cash flow - Constant interest rate - Constant transaction cost	- Gradually receiving cash - Cash payment at once	- Irregular cash flows - Random and independent cash flows	Independent and random cash flows
Goal	Minimizing cost	Obtaining premium number of transactions and each time capitalization	Cash regression point	Minimizing transactions
Limits	- Reserve residue is not considered - Payments and receives are irregular	- Payments and receives are regular - No attention to risk and incertitude	Lower control limit should be determined by management view or anticipation techniques	To determine lower and higher control limits
Abilities	Increase in residue cost of cash	Maximum productivity for companies with regular cash flows	For companies with irregular cash flows	A procedure to decide for cash management

2.1.5. Anticipation techniques used in commercial banks

This study attempts to evaluate and compare anticipation power of time series models. Chart 1 illustrates a classification of the suggested anticipation techniques.

2.1.6. Approaches for cash anticipation in banks

The most important approaches of cash anticipation include Resources and Consumption Approach and Moneys Structure Approach (Ibid, p. 234).

Resources and Consumption Approach

This approach begins with two realities:

1. Bank's cash increases when increasing deposits or decreasing loans.
2. Bank's cash decreases when decreasing deposits or increasing loans.

When money resources and consumptions are not coincided, bank has a cash interval that equals to the difference between money resources and consumptions. When money resources are more than its consumptions, then we will have positive cash interval. When money resources are less than its consumptions, then we will have negative cash intervals.

The basic steps in Resources and Consumption Approach are in the following order:

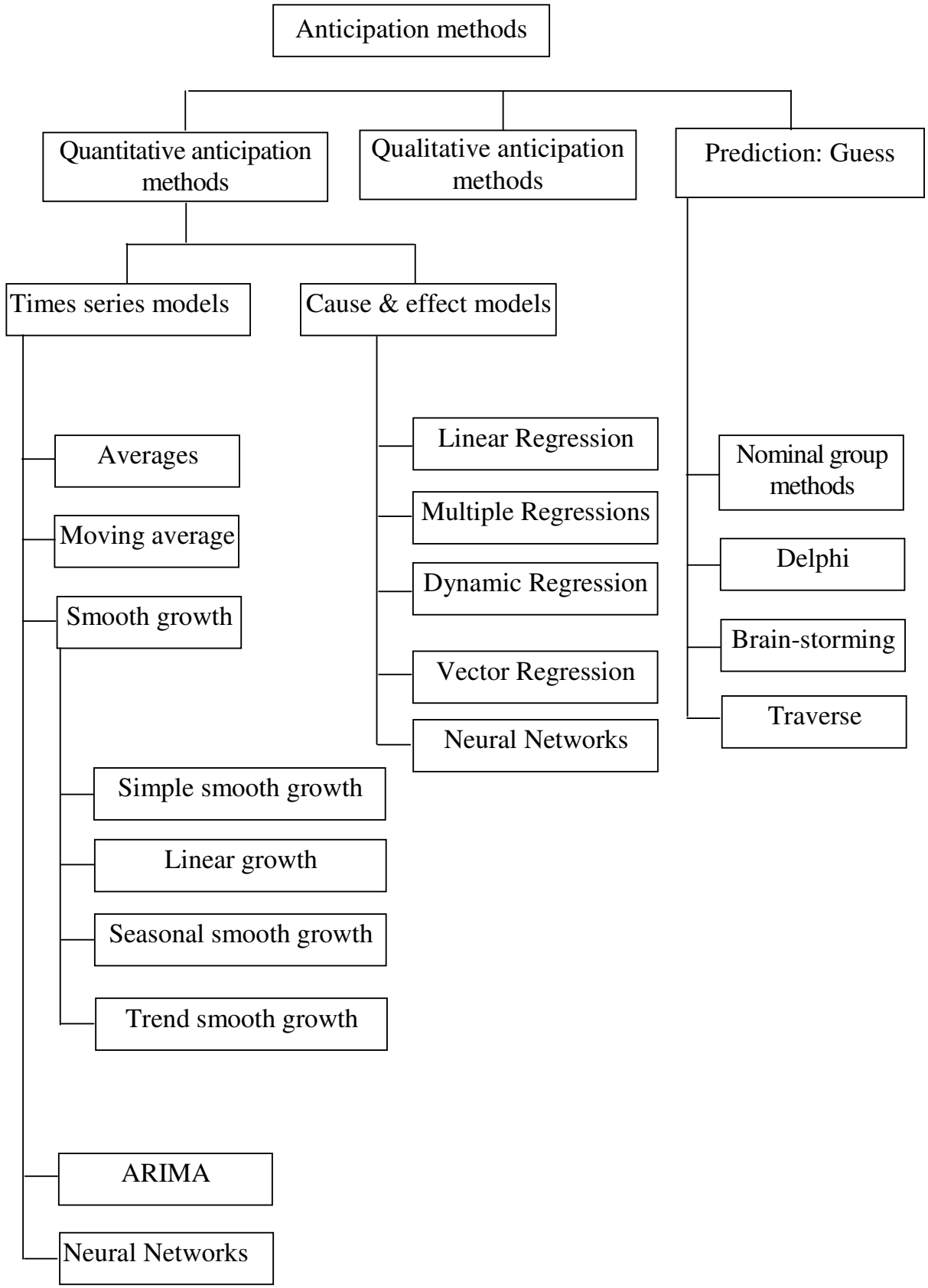

Chart 1: Anticipation Techniques.

1. Deposits and loans for planning period should be anticipated.
2. Changes in deposits and loans for planning period should be estimated.
3. Pure cash moneys for planning period should be estimated. This can be done by comparison of estimated changes of deposits and estimated changes of loans.

Cash Money Structure Approach

The other approach to estimate a bank's cash requirements is financial resources structure method. In the first step, deposits and other bank's capital resources are divided into sections according to elimination and withdrawal probability. Deposited and non-deposited debts of a bank can be divided into three parts:

1. **Hot (active) funds:** includes those deposits and debts that are sensible toward interest rate and manager is sure that they will be withdrawn during current period.
2. **Vulnerable funds:** includes those constant deposits of customers and the constant part of deposits (probably 25-30%) that are probable to be withdrawn during current period.
3. **Stable funds:** that is called central or basic deposits and their withdrawal is improbable unless a trivial percent of total deposits.

In the second step, cash flow manager should determine his cash fund according to favorite operational rules for each of above funds. For example, manager may consider cash reserve for 95% of hot funds. This cash reserve can include payable deposits plus bank capitalization in governmental bonds and repayment contract.

The thumbnail rule for vulnerable funds is considering a constant value of total deposits, for example, 30% of vulnerable funds will be reserved.

For constant financial resources, bank considers a lower ratio, for example, 15% or lower. Therefore, cash reserve of funds is:

Cash reserve of funds = 0.95 (hot deposited and non-deposited resources – legal reserve)
+ 0.3 (vulnerable deposited and non-deposited resources – legal reserve)
+ 0.15 (constant deposited and non-deposited resources – legal reserve)

About loaning, banks should always be ready to grant suitable loans, namely, legal requirements of the customers which are proportional to bank's standards should be supplied. Loan customers generate new deposits and they naturally are basic resources for interest and commission incomes.

Resources coefficients can be determined by experiment or by historical behavior. Coefficients of Holtz's time series can be used for this purpose. One way to estimate stability of funds is drawing a chart. A line for stable funds is drawn by finding points and drawing all deposits during the time. Hot fund is the difference of available and basic deposits. Curviness of basic deposits shows their little growth. A sample chart is shown from "Koch Timothy W. & Scott S. Macdonald, op. cit. p. 583) in figure 1.

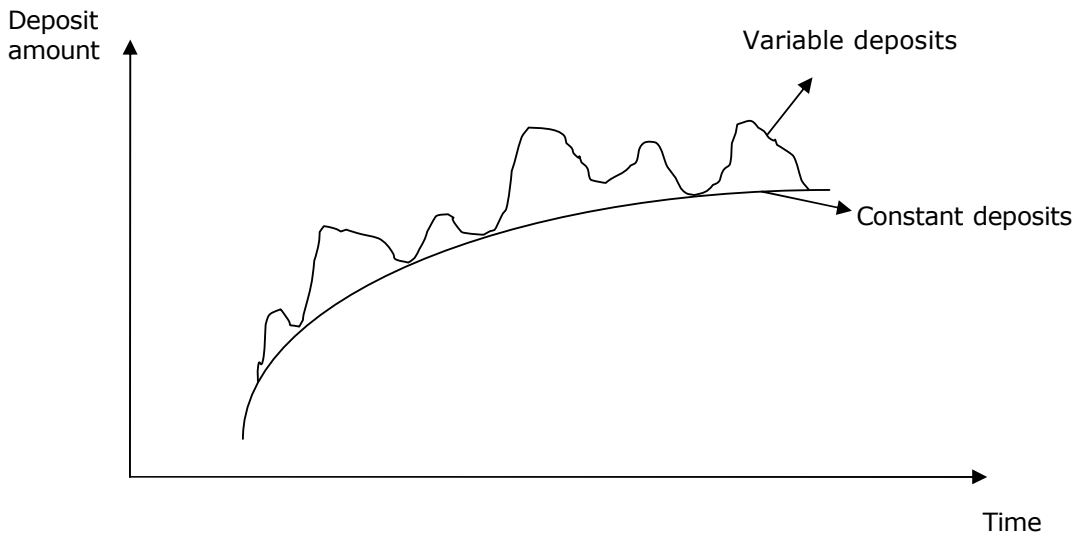

Figure 1: Constant and variable deposits.

2.3. Theoretical framework of main anticipation model

2.3.1. Introducing artificial Neural networks

"Fauseft" (1995) suggested that an artificial Neural network is an information processing system that its operational features are similar to those of biologic Neural system. Artificial Neural networks are based on generalization of mathematical models on anthropological and biological processes.

The base of calculations in artificial Neural networks is relation philosophy. This philosophy is based on a thinking that accomplishes a lot of calculations in parallel and with mutual effects. In fact, general calculation is distributed on a few calculation units which each unit accomplishes a part of calculation activity.

2.3.2. Advantages and disadvantages of utilizing artificial Neural networks

Upon researches of "J. Scholkov" (2003), since artificial Neural network is a relatively new tool in applied calculation field, it has its special advantages and disadvantages. Here we mention some of these advantages and disadvantages:

2.3.2.1. Advantages of Neural networks

1. Accomplishes calculations in parallel and extended form.
2. Faults can be ignored because of its parallel operation.
3. It may be designed in comparative form.

2.3.2.2. Disadvantages of Neural networks

1. There are not explicit rules or design guides for the specified application.
2. There is not a method to identify internal operations of the network.
3. Extra educational and learning problems of the network.

2.3.3. Function of artificial Neural networks

Upon researches of "Fausett" (1994), each artificial network consists of a set of neurons and joints between them. Each neuron has an internal situation which

is called "function level." A neuron's function level is a function of its inputs. Each neuron has an external signal that enters into many other neurons.
For example, neuron Y, which is shown in the following chart, receives input signals from three other neurons x_1, x_2, x_3. External signals of these neurons are x_1, x_2, x_3, while weights of joints of neurons x_1, x_2, x_3 are w_1, w_2, w_3. Net input of neuron y-in to neuron Y is y-in= $x_1 w_1 + x_2 w_2 + x_3 w_3$.
Activity of neuron Y depends on activity function of neuron Y. If we show output of neuron Y by y, and activity function by f(x), then we will have

y = f(y-in)

Now, if neuron Y is connected to neurons Z_3 and Z_3, and weight of joints are x_3 and x_3, then input signal to these neurons will be determined upon output of neuron Y and joints weights.

Figure 2: Function of artificial Neural network.

2.4. Research data and model tests

Research data is extracted from financial notes, documents and weekly, monthly, annually, and periodically reports and expert views of bank's financial field specialists. These data include cash items of one of the banks of country for a three-years period, from 21 March 2004 to 20 March 2006.

Bank cash items

Bank cash items	Abbreviated code of ledger
Locker	1111
In way moneys (Currency)	1112
In way moneys (Rials)	1113
Bill and foreign cash	1121
Visual current deposit in The Central Bank	1241
Visual current deposit in banks (our account)	1142

It should be mentioned that the software used to implement statistical models is MINITAB14, and MATLAB7 is used for modeling Neural network.

2.4.1. Moving average model

In this model, anticipation of a variable is done only by historical behavior of the same variable. Moving average is from simplest and the most applicable anticipation techniques in business. That is obtained by summing historical values of a variable and dividing it by number of periods, N:

where M_T is simple moving average, T is time period, and L is cash.

2.4.1.1. Holtz anticipation model

This model is a subset of moving average model, and is used when data has a trend. This model is often used when the number of anticipation data is little, and is used for short-term anticipation.

$$F_{t+1} = \alpha X_t + (1-\alpha)(F_t + T_{t)}$$
$$T_{t+1} = \beta(F_{t+1} - F_t) + (1-\beta)T_t$$

First value of anticipation can be determined by random or data average.

2.4.1.2. Winters model

Winters model is used when data has a trend and a seasonal pattern. This model is also used when the goal of anticipation is short-term or middle-term.

$$F_t = \alpha X_t / S_{t-p} + (1-\alpha)(F_{t-1} + T_{t-1})$$
$$S_t = \beta X_t / F_t + (1-\beta)S_{t-p}$$
$$T_t = \gamma(F_t - F_{t-1}) + (1-\gamma)T_{t-1}$$

2.4.2. ARIMA model

ARIMA model is an advance time series model that is generated by combination of two processes of auto-regression and moving average, and is used for middle-term and long-term anticipations. This model is like a black box and tries to identify autocorrelation pattern hidden in a random sequence. Also, when data has a trend, the suitable pattern can be identified by determination of differentiation order.
The conceptual pattern of this model is:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_p Y_{t-p} + e_t + W_1 e_{t-1} + W_2 e_{t-2} + \ldots + W_q e_{t-q}$$

In this model, Y is cash value in last periods, and e is error value or partial error.

2.4.3. Anticipation model of Neural network

The designed network has two middle layers. In input layer, five vectors for begin-residue of debt and credit of cash resources and for debt and credit of cash consumption are entered to the network. The first middle layer has seven neurons, and the second middle layer has fifteen neurons. Output layer has one neuron including end-residue that should be estimated by the network.

Network education

In order to education of Neural network, the education algorithm with error handling strategy is used. So, all cash items and cash resources and consumptions for the first two years are selected as education set.

First network weights are determined randomly and α=0.005. Goal error value in network education is goal=10^{-25}.

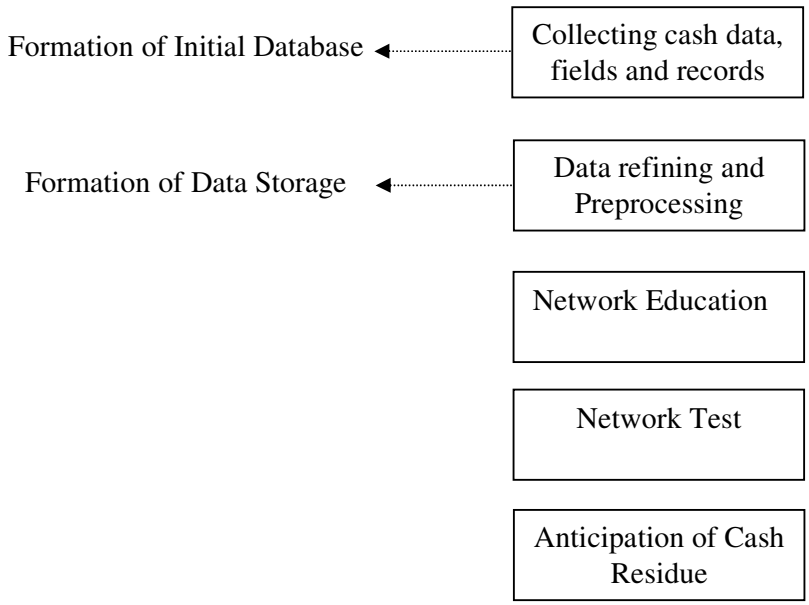

Figure 3: Anticipation process with Neural network

2.5. Data preprocessing and post-processing

Experience has shown that data preprocessing namely normalizing of input data causes rapid network convergence and stabilization. So, in this study, we first preprocess input data, then pass them through the network, and again we post-process output data.

2.5.1. Evaluation and determination of stop time

One of the problems in working with Neural network is frequency of data supply to the network. In this study, with error of goal=10^{-25}, while calculated error after weights determination is decreasing, we allow data to be supplied to the network, and when the network begins to learn the error or error is increasing, we should stop the network.

2.6. Evaluation of anticipation models

In order to evaluation of anticipation models, after presenting cash data from 21 March 2004 to 20 November 2006, each model is requested to anticipate cash value for next 3 months.

After comparison of anticipated value with real value, error value, error percentage, and mean square will be calculated.

$$MSD = \frac{\sum (\hat{L} - L)^2}{n}$$

2.7. Utilizing anticipation models

Identification of data pattern before utilizing time series models causes better knowledge and more suitable selection of anticipation models. So, data trend chart for three years is studied.

As it is viewed in the chart, sample data chart has a trend of seasonality.

2.7.1. Operational model of moving average

Since this model is mostly applied in static and low-harmonic data, we expect it hasn't had enough ability to identify data patterns with trends. After frequent tests, finally moving average model with order 3, which has least error, is utilized.

2.7.2.Holtz operational model

Since data has a trended pattern, Holtz model with parameter α=0.3 is selected.

2.7.3. Winters operational model

This model has three parameters to identify trended, seasonal, and level patterns. After frequent tests, finally Winters model with the following parameters, which have least anticipation errors, is selected.

2.7.4. ARIMA anticipation model

In order to determine parameters of this model, it is necessary to investigate autocorrelation and partial autocorrelation data patterns.

Autocorrelation chart can help to determine moving average order. As it is identified, this chart has a spike of 2, and so we use this order for moving average.

On the other hand, the number of spikes of partial autocorrelation chart is important to determine auto-regression order, which order 2 is more suitable regarding the above chart.

On the other hand, existing trended pattern in data shows necessity of elimination of this pattern so data will become static. Thus, using first order differentiation we will eliminate this trended data pattern, and finally, after few times try and error, ARIMA model, which has least error, is selected.

2.7.5. Neural network model

After network education and justifying joint weights, the educated network is requested to anticipate cash value of 30th end-period. The following charts indicate network convergence after various cycles, and finally network becomes successful in anticipation of cash residue.

Table 2: Network convergence.

Cash item	Anticipated value (Rials)	Real value (Rials)	Error value (Rials)	Error (%)
Locker	1,250,977,270,848	1,226,448,304,753	24,528,966,095	1.2
In way (Rials)	779,607,833,512	728,605,451,880	51,002,381,632	1.7
In way (Currency)	1649,526,163	1,527,339,040	122,187,123	8.0
Visual current deposit in The Central Bank	-3,252,794,716,598	-3,054,267,339,529	-198,527,377,069	6.5
Visual current deposit in banks (our account)	669,657,998,221	635,349,144,422	34,308,853,799	5.4

3. Evaluation of anticipation techniques

In order to evaluation of successfulness of different anticipation techniques, evaluation indexes, including error mean square, are calculated as in the following table.

As you see in the table, Neural network technique has least error in anticipation of cash residue in three months after education period, which indicates its higher ability and its applicability for anticipation.

Method	Error (%)	Error mean square
Simple moving average	13.2	3.14E+22
Holtz model	11.3	2.75E+22
Winters model	15.7	3.96E+22
ARIMA model	8.7	6.49E+21
Time series of Neural network	4.56	1.20E+20

4. Discussion and conclusion

One of the most important functions of financial institutions is generation of payment system in financial system. In order to accomplish this function, financial institutions are required to have an exact anticipation from future cash requirements and to use various techniques and modern and statistical methods.

Discussion of guaranteeing cash sufficiency is from the most important duties of a bank manager. It is an everlasting problem of a bank manager and also a profitable resource. In addition, solving cash problem is accompanied with some costs including interest and borrowed money costs, and transaction costs to achieve required cash sufficiency.

It is apparent that this cost should be managed because it increases cash risk. In addition to cost, time is another factor that challenges cash managers and planners. Therefore, cash programs are affected by two factors of cost and time.

The importance of cash managing caused cash anticipation is considered as an important process. Utilizing quantitative and mathematical models and methods is a necessity to manage cash, which from them include time series classic models and artificial Neural networks.

In this study, utilizing the above models including Neural networks as advanced models in cash management decision-making is investigated. As indicated, Neural networks are modern techniques for anticipation. The results of this study show that this method has most precision in anticipation of future

cash needs, since it had least error in anticipation of cash residue in three months after education period, which indicates it higher ability and application. After that, ARIMA model and Holtz model had most precision in anticipation. Therefore, firstly, testability of anticipation models has been approved. Secondly, positive ability of these models in cash management is tested. Thirdly, Neural networks model has more precision and less error in comparison with the other models.

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