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Developing of an asset/liability allocation model for banks

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Abstract: Asset-liability management is one of the solutions for implementing banking policies in the economy. This study is aimed to determine the parameters, variables, and constraints of multi-objective modelling for asset-liability management of banks. Therefore, the standard balance sheet of Bank A (as research variables), which is one of the branches of a state-owned bank in Iran, was reviewed at the end of its fiscal year in 2017. Using the Delphi technique, a linear multi-objective model was presented, the most significant feature of which was the inclusion of new constraints and strategic goals, such as increasing joint income, increasing the share of low-cost deposits, and increasing productive assets. To solve that model, Microsoft Excel was used through the lexicography method. By solving the model, the optimal values of balance sheet variables were calculated for Bank A.

Keywords: bank; asset/liability management; ALM; multi-objective linear model; lexicography method.

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1 Introduction

One of the main duties of financial management of banks is the assets/liabilities management (ALM), aimed at creating more value through maximising returns and minimising risks due to the necessity for complying with specific regulations (El-Sood and El-Ansary, 2017). ALM seeks to find a combination of the assets and liabilities in the balance sheet to increase the net wealth of the banks; however, it tries to quantify the related risks, liquidity management, and other requirements (Kobayashi, 2013). The scope of the optimal ALM process model can be divided into liquidity risk management, market risk management, credit risk management, resource management, investment and profit planning, and growth and development (Ferstl and Weissensteiner, 2011). These techniques target the volume, composition, maturity, rate of sensitivity, quality, and liquidity of assets and liabilities to achieve a predetermined value for the ratio of risk to return (Chakroun and Abid, 2013).

By its nature, ALM is also called the management of balance sheets. Therefore, the components of the financial statements of the institution should be identified. Furthermore, the relationship between these components and other components of the financial statements should be fully explained; hence, banks should pay attention to the optimisation of assets and liabilities with due supervision (Gülpinar and Pachamanova, 2013). With an integrated simultaneous look at assets and liabilities, ALM combines them with the factors affecting them and applies an organised and systematic management approach that realises targeted goals in terms of profitability or risk reduction (Jahera, 2018). Therefore, as one of their main duties of financial management, including ALM, the banks are required to increase their profitability by monitoring risk to minimise losses arising from their transactions using ALM techniques (Chen et al., 2017). As a result, for optimal management of resources and expenditures, the use of scientific techniques in conjunction with the managers' art is necessary for financial institutions. In general, ALM techniques, used by most of the world's financial institutions today, will cause financial institutions pay the lowest cost on attracting the existing resources by controlling internal factors and creating scenarios against external factors, and while their profitability increases, their risks are controlled as well (Horvath et al., 2018).

One of the ultimate objectives of liquidity management is to maintain the balance between assets and liabilities. To properly manage liquidity, it is necessary to identify the appropriate tools and effective factors (Ismal, 2010). On the other hand, ALM is one of the key factors in explaining the financial sustainability of the banking sector and the economy (Jaiswal, 2010).

On the other hand, it is evident that one of the key factors for the survival of organisations, such as banks, is attracting more financial resources, or in other words, attracting various deposits, including sight deposits, savings, short-term and long-term deposits, and optimal use of these resources in services, and in commercial, industrial, and infrastructural affairs of the society, in which both the banks and their customers will take advantage, and the national economy will start a boom period.

Since banks are formed with little capital, or in any case, have limited financial resources, and are considered a safe and secure place to keep and safeguard people's cash, they seek to attract financial resources through deposits, and then, using the resources provided by clients, they take the necessary measures to lend their money on a large scale.

In the mobilisation of financial resources, the banks' financial resources include operational resources and non-operational resources. Operational resources are all monetary and quasi-monetary funds raised by the establishment of mutual relations between the bank and depositors, such as different types of deposits. Non-operating resources also result from the internal activities, items, and consumptions of banks, such as added value, the result of earnings and expenses, capital, other debts, etc. in the financial balance sheet of banks. Operating resources represent the bank's liabilities to owners of different accounts and are reflected in the balance sheet of each bank along with the debt items (Sadeghi et al., 2012). In addition, since banks grant a great part of customer deposits in the form of facilities, in case the facilities are not repaid on time, they will face a sudden decrease in resources, and in pessimistic circumstances, it may even lead to their bankruptcy (Branco, 2015).

Given the mentioned objectives, the use of some techniques to cover all these objectives to balance the assets and liabilities of the bank in the form of a balance sheet seems necessary. This research seeks to provide a mathematical model for asset-liability management (balance sheet) of banks to help them achieve their strategic goals. The advantages of the model presented in this research are paying attention to strategic goals, such as attracting inexpensive resources, increasing non-joint profits, and increasing productive assets in Iranian banks, which are not found in the previous models. Achieving these goals leads to increased profitability of Iranian banks and helps them give up acting as real estate agents and melt their frozen and unproductive assets.

Providing an asset and liability allocation system, which can optimise balance sheet items, will reduce the risk of banks to invest and opt for investors, which will increase joint profit for financial institutions and banks. Therefore, it is necessary to optimise balance sheet items as an optimised asset allocation and liability system.

2 A review of the literature and research background

Asset and liability management models can be definitive or probabilistic (Kosmidou and Zopounidis, 2004). Assuming specific values for random events, definitive models use

linear programming and can be computed for a wide range of problems. The banking industry has accepted these models as a useful and principled tool (Cohen and Hammer, 1967). Probabilistic models include applying stochastic constraint programming, stochastic dynamic programming, sequential decision-making theory, and probabilistic linear programming under uncertainty, which demand problematic and intensive calculations.

In the literature of asset-liability management, one can find some examples of planning models based on mathematical principles to coordinate with asset and liability management programs and the use of ideal decision-making solutions. These models have had one or more objectives, among which some are algebraic, and some are random. Algebraic models have become more popular because users have not been fully acquainted with random models and have encountered computational problems. Operational models are based on the assumption that banks seek to maximise the benefits of the constraints they face. Various investigations have been conducted in the field of optimising the structure of assets and liabilities of banks, some of which will be discussed in the following. Most studies can be categorised into two general groups:

The first group is those studies that seek to provide a solution by defining the bank's goals concerning the balance sheet and also considering the relationships between its components. In such studies, while introducing the variables affecting the problem and application of one of the classical mathematical models, such as linear programming or ideal programming, an attempt is made to present an optimal combination of assets and liabilities.

In the second group of studies conducted with a simpler look at the research problem, an attempt is made to search for the best balance sheet structure only through the management and optimisation of some of its major items. For example, by arguing that the issue of liquidity in the banking system is of particular importance and that the entire balance sheet structure depends on its proper management, they only examine and provide solutions for the liquidity issues of the banks (Poorzarandi and Mansoreh, 2007).

Chakroun and Abid (2013) presented a multi-objective model for managing the assets of the Tunisian bank. Mizgier and Pasia (2015) used a multi-objective model to optimise the allocation of credit capital in financial institutions.

Bighdeli and Mehreghan (2011) presented an optimal asset management model for banks using fuzzy hierarchical analysis and goal programming. Omrani and Azimi (2016) studied a fuzzy goal programming model with fuzzy constraints. Using stochastic programming, Giandomenico (2011) presented an optimal asset/liability model that led to maximised bank profits. Gülpinar and Pachamanova (2013) provided a robust way for ALM under variable investment opportunities promptly using stochastic programming. Kobayashi (2013) designed a cross-network portfolio structure in financial systems for bank assets by sharing specific assets using a network model. Alhumaidah (2015) presented a model of ALM for stocks under liquidity constraints in Saudi Arabia.

Lofberg (2012) analysed the relationship between assets, liabilities, and income management with liquidity risk in banks using a statistical model. Xiang and Shamsuddin (2013) analysed the banks' productivity that led to the financial crisis in Australian, Canadian, and British banks via a statistical model. Anjum (2015) analysed the market orientation, balance sheet, and risk of Islamic banks using statistical methods. Faruk and Alam (2014) presented an optimal model of ALM for banks using economic-mathematical models. Sukmana and Kholid (2013) used statistical models of liquidity policies assessment concerning Islamic and conventional banks in Indonesia and

compared them. Umme Hanna et al. (2014) analysed and compared inappropriate ALM in Bangladesh banks. Chen et al. (2017) presented a goal programming model for optimising the ALM system at the Berhad bank of Malaysia. Tee (2017) studied the impact of ALM on banks' profits in Ghana through multiple linear regressions. Horvath et al. (2018) analysed a dynamic ALM problem with an uncertainty model in a market.

By examining previous research, it was found that a comprehensive math model with minimum parameters and strategic and managerial goals (except for main and repeated goals) and the constraints related to the main financial and accounting ratios were not presented. Therefore, this research focuses on determining the optimal number of variables related to the assets and liabilities of the bank balance sheet (public sector) by specifying the constraints related to that bank and considering certain constraints, such as financial ratios. Also, three specific strategic objectives have been highlighted, including increasing joint profitability, increasing low-cost deposits, and increasing productive assets that so far have not been taken into account in previous studies. The current model will also have the ability to analyse the sensitivity of the model to the effective parameters to select the best values for managers.

In Table 1, the features of the new model have also been presented, along with the reviews of ten outstanding models for ALM in banks, which have been presented by the previous researchers so far.

Table 1 Comparative comparison of the new model with previous models

		Bighdeli and Mehreghan (2011)	*Chen et al. (2017)*	*Chakroun and Abid et al. (2013)*	*Jahera (2018)*	*Mizgier and Pasia (2015)*	*El-Sood and El-Ansary (2017)*	*Faruk and Alam (2014)*	*Tee (2017)*	*Alhumaidah (2015)*	*Omrani and Azimi (2016)*	*New model*
Variable												
1	Cash	√	√	√	√	√	√	–	–	√	√	√
2	Claims from the central bank	√	√	√	√	√	√	–	–	√	√	√
3	Claims from banks and credit institutions	√	√	√	√	√	√	–	–	√	√	√
4	Claims from the government (state)	√	√	√	–	–	√	–	–	√	√	√
5	Given facilities and claims from the public sector.	√	√	√	√	√	√	–	–	√	√	√
6	Given facilities and claims from the non-governmental sector	√	√	√	√	√	√	–	–	√	√	√

Table 1 Comparative comparison of the new model with previous models (continued)

		Bighdeli and Mehreghan (2011)	*Chen et al. (2017)*	*Chakroun and Abid et al. (2013)*	*Jahera (2018)*	*Mizgier and Pasia (2015)*	*El-Sood and El-Ansary (2017)*	*Faruk and Alam (2014)*	*Tee (2017)*	*Alhumaidah (2015)*	*Omrani and Azimi (2016)*	*New model*
Variable												
7	Debtors for L/C and long-term currency drafts	√	√	√	–	–	√	√	√	√	√	√
8	Bonds and other similar papers	√	√	√	√	√	√	√	√	√	√	√
9	Investments and Contributions	√	√	√	√	√	√	√	√	√	√	√
10	Fixed assets	√	√	√	√	√	√	√	√	√	√	√
11	Other assets	√	√	√	√	√	√	√	√	√	√	√
12	Liabilities of clients for L/C	√	–	√	–	–	√	√	√	√	√	√
13	Customer obligations for Warranties	√	–	√	–	–	√	√	√	√	√	√
14	Parties to other obligations	√	–	–	–	–	√	√	–	√	√	√
15	Funds managed and other similar cases	√	–	–	–	–	√	√	–	√	√	√
16	Debt to the central bank	√	√	√	√	√	√	√	√	√	√	√
17	Debts to banks and credit institutions	√	√	√	√	√	√	√	√	√	√	√
18	Sight deposit	√	√	√	√	√	√	√	√	√	√	√
19	Saving deposits	√	√	√	√	√	√	√	√	√	√	√
20	Long-term investment deposits	√	√	√	√	√	√	√	√	√	√	√
21	Other deposits	√	√	√	√	√	√	√	√	√	√	√
22	The bank's debt for a long-term currency draft	√	–	–	–	–	√	√	√	√	√	√
23	Reserves and other liabilities	√	√	√	√	√	√	√	√	√	√	√

Table 1 Comparative comparison of the new model with previous models (continued)

		Bighdeli and Mehreghan (2011)	*Chen et al. (2017)*	*Chakroun and Abid et al. (2013)*	*Jahera (2018)*	*Mizgier and Pasia (2015)*	*El-Sood and El-Ansary (2017)*	*Faruk and Alam (2014)*	*Tee (2017)*	*Alhumaidah (2015)*	*Omrani and Azimi (2016)*	*New model*
24	Savings for employees end of service reward	√	–	–	–	–	√	√	√	√	√	√
25	Shareholders' equity	√	√	√	√	–	√	√	√	√	√	√
26	Reserves	√	√	√	√	–	√	√	√	√	√	√
27	The result of the changes due to the legal equality of the currency rate	√	–	–	–	–	√	√	√	√	√	√
28	Profit from the exchange of foreign currency assets and liabilities	√	–	–	–	–	–	√	√	√	√	√
29	Accumulated profit (Loss)	√	√	√	–	√	–	√	√	√	√	√
30	Liabilities of the bank for L/C	√	–	√	–	–	–	√	√	√	√	√
31	Bank's obligations for warranties	√	–	√	–	–	–	√	√	√	√	√
32	Other obligations	√	–	–	–	–	–	√	√	√	√	√
33	Funds managed and similar cases	√	–	–	–	–	–	√		√	√	√
Constraint												
1	Equality of assets with liabilities and shareholders' equity	√	√	√	√	√	√	√	√	√	√	√
2	Liquidity ceiling	√	√	√	√	–	–	–	√	√	√	√
3	Claims from the central bank (legal deposit)	√	√	√	√	–	–	–	√	–	√	√
4	Claims from banks and credit institutions	√	–	–	–	–	–	–	√	–	√	√
5	Given facilities and claims from the non-governmental sector.	√	√	–	√	–	–	–	√	–	√	√

Table 1 Comparative comparison of the new model with previous models (continued)

		Bighdeli and Mehreghan (2011)	*Chen et al. (2017)*	*Chakroun and Abid et al. (2013)*	*Jahera (2018)*	*Mizgier and Pasia (2015)*	*El-Sood and El-Ansary (2017)*	*Faruk and Alam (2014)*	*Tee (2017)*	*Alhumaidah (2015)*	*Omrani and Azimi (2016)*	*New model*
Constraint												
6	Government bonds, similar bonds, investments, and partnerships.	√	–	√	–	√	–	–	√	–	√	√
7	Fixed assets	√	√	√	√	√	–	–	√	–	√	√
8	Equality of customers obligations and bank or parties to obligations.	√	–	–	–	–	–	–	–	–	√	√
9	Liquidity risk control	√	√	–	√	√	–	–	√	–	√	√
10	Capital adequacy	√	√	√	√	–	–	√	√	√	√	√
11	Resource growth	√	–	√	–	√	–	–	√	–	√	√
12	Current ratio	-	–	–	–	–	-	–	–	–	–	√
13	Total debt ratio to special value	-	–	–	–	–	-	–	–	–	–	√
14	Current debt ratio to special value	-	–	–	–	–	-	–	–	–	–	√
15	Liquidity ratio	-	–	–	–	–	-	–	–	–	–	√
16	Deposits ratio	-	–	–	–	–	-	–	–	–	–	√
Goal												
1	Increasing the margin of joint income (profit increase).	√	–	√	√	√	√	√	√	–	√	√
2	Deviation decreases of capital adequacy ratio.	√	√	√	–	√	–	–	–	–	√	√
3	Reducing deviation index of costs to resources.	√	√	–	–	√	–	–	–	–	√	√
4	Decrease in deviation of the expected growth of assets compared to last year.	√	–	√	–	√	–	–	–	–	–	√

Table 1 Comparative comparison of the new model with previous models (continued)

		Bighdeli and Mehreghan (2011)	*Chen et al. (2017)*	*Chakroun and Abid et al. (2013)*	*Jahera (2018)*	*Mizgier and Pasia (2015)*	*El-Sood and El-Ansary (2017)*	*Faruk and Alam (2014)*	*Tee (2017)*	*Alhumaidah (2015)*	*Omrani and Azimi (2016)*	*New model*
Goal												
5	Liquidity risk control	√	√	√	–	√	√	–	√	√	–	√
6	Maintaining the ratio of fixed assets to capital	√	√	√	–	√	–	–	–	–	–	√
7	The status of the deposits of foreign currency and Rial	-	√	–	–	–	–	–	–	–	–	√
Strategic goal												
1	Increasing share of low-cost deposits in relation to total deposits	-	–	–	–	–	–	–	–	–	–	√
2	Conversion of non-productive assets to productive	-	–	–	–	–	–	–	–	–	-	√
3	Achieve minimal risk	-	–	–	–	–	–	–	–	–	–	√

As Table 1 shows, some of the objective functions investigated in this study include increasing the share of low-cost deposits in relation to total deposits, converting non-productive assets into productive ones, and tracking and collecting claims. Also, some constraints related to financial ratios, such as the ratio of total debt to special value, the ratio of cash flow, etc. have not been studied in previous models.

This research does not seek to examine ALM practices but seeks to develop previously presented models and suggests a multi-objective linear model to bank managers that is a more developed version of previous models in which the optimal combination of the concerned bank's balance sheet is optimised by taking into account the objectives, such as increasing productive assets, increasing low-cost deposits, and increasing joint income margins (increasing profits), as well as new constraints, such as the ratio of total debt to special value, liquidity ratio, etc. which have not been examined in previous models. Considering the optimisation of the goal, such as increasing productive assets, the most important feature of this model for Iranian banks is their departure from acting as real estate agents and the thawing of their frozen and non-productive assets. A significant part of bank assets are fictitious and frozen. The presence of these assets reduces their lending power, and as a result, banks cannot concentrate on their core tasks. That is, one of the most important problems of Iranian banks, especially state-owned banks, is their focus on acting as real estate agents and

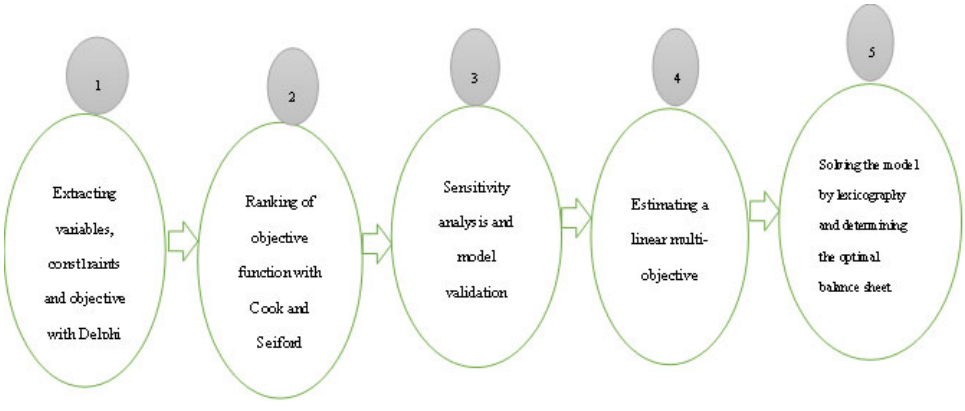
their increased non-productive assets. Given the non-optimal use of their roles as real estate agents, the impacts of which have been reflected in the destructive interferences in the real estate market, foreign trades (imports), and the domestic capital market in the last two years, the banks have made their way into 'money creation' since the last two decades. In Iran, the bank is not a 'financial intermediary' agent but serves as a 'money creator institution'. If this money-creating institution functions optimally, it can serve the economic growth of the country, but if it does not function optimally, it will become destructive. The money created in the banks becomes publicly used money, and the whole society accepts this money as a means of payment and a value estimation tool. If not properly controlled and managed, it will cause inflation in the economy. Considering the goal of increasing productive assets, the model suggested in this study seeks to solve this problem in the Iranian economy to some extent.

3 Research methodology

This research is an applied study that, using the model presented in it; one can determine the amounts of assets and liabilities in accordance with the balance sheet structure of the desired bank. Given the wide range of financial issues, it is possible to present many other variables; however, since the multiplicity of variables will complicate the model, and on the other hand, according to the findings of one part of the research, the most important influential variables are those related to the balance sheet, only the standard balance sheets of banks are considered. Using the findings of the Delphi method, the balance sheet structure of Bank A (which is one of the branches of a state-owned bank in Iran) leading to the end of the fiscal year 2017 as well as the rules and assumptions of an allocation system of asset-liability, constraints, and model objectives were extracted and using them, a linear multi-objective model was obtained. The obtained model was validated after sensitivity analysis, and then the objective functions were ranked using the Cook and Seiford method and solved via the lexicography technique.

The research steps are presented in Figure 1 as follows:

Figure 1 Research steps (see online version for colours)



3.1 Research model

In this research, the Delphi technique was used to identify variables, constraints, and objectives. Twenty banking experts were selected independently.

According to the studies conducted in the Delphi, if the participants are homogeneous, 10 to 15 samples will suffice to conduct Delphi (Tabrizi and Gharibi 2013). Accordingly, 20 people were selected to maintain the validity of the research in case of a decrease in the number of respondents during the study.

Then, through an open structured questionnaire, data were obtained for the variables, constraints, and objectives. The questionnaire consisted of three sections: common, legal, and suggestive. In the proposed section, the experts presented suggestions based on their knowledge of the banking sector. After obtaining the results in the first round, they were analysed and organised for use in the second round. Finally, the information needed to build the model was obtained.

Table 2 Headlines mentioned in the balance sheet of banks

Assets		*Liabilities and shareholders' equity*	
Cash	X_1	Debts to the central bank	Y_1
Claims from the central bank	X_2	Debts to banks and credit institutions	Y_2
Claims from banks and credit institutions	X_3	Sight deposit	Y_3
Claims from government	X_4	Savings deposits and similar cases	Y_4
Given facilities and claims from the public sector	X_5	Long-term investment deposits	Y_5
Given facilities and claims from the non-governmental sector	X_6	Other deposits	Y_6
Debts for L/C and long-term currency drafts	X_7	The bank's debt for L/C and a long-term draft credit	Y_7
Government bonds and other similar bonds	X_8	Reserves and other debts	Y_8
Investments and contributions	X_9	Savings for employees end of service reward	Y_9
Fixed assets	X_{10}	Shareholders' equity	Y_{10}
Other assets	X_{11}	Reserves	Y_{11}
Total assets		The result of the changes due to the legal equality of the currency rate	Y_{12}
Obligations of clients for L/C	X_{12}	Profit from the exchange of foreign currency assets and liabilities	Y_{13}
Clients' obligations for warranties	X_{13}	Accumulated profit (loss)	Y_{14}
Parties to other obligations	X_{14}	Total debts and shareholder's equity	
Funds managed and similar items	X_{15}	Liabilities of the bank for L/C	Y_{15}
		Bank's obligations for warranties	Y_{16}
		Other obligations	Y_{17}
		Funds managed and similar items	Y_{18}

3.2 Model variables

The variables of this research are the ones on both sides of the bank balance sheet. Based on Delphi's results, the most comprehensive balance sheet is the standard balance sheet proposed by the Central Bank of Iran. Table 2 shows the headings in the bank balance sheet, which were used as variables in this study.

As can be seen, this model has 33 decision variables, 18 of which are related to bank resources, while 15 variables are related to the bank assets.

3.3 Model objectives

At the end of the Delphi processes, the experts introduced nine goals, among which five were common goals, and four were identified as strategic goals. Of the nine goals, three goals were eliminated because they were non-compliant with model variables, i.e., risk integration, collecting debts, and asset growth expectations. The next three goals were converted to constraints given the fact that in the text of the law, threshold values had been determined for them. These three objectives are known as liquidity risk control, costs/ resources ratio, and capital adequacy ratio. Finally, the other three were considered as model objectives, including increasing productive assets, increasing low-cost deposits, and increasing the margin of joint income (increased profits).

Objective 1 Increasing joint income

Joint revenues are part of the bank's income achieved through partnerships with individuals. It can be said that the main source of income and expenses of the bank are known as the proceeds from facilities and investments and the profits of deposits, the difference of which shows the margin of the bank's joint income. The cost of doubtful claims is also calculated and stored as equivalent to 1.5% of the remaining facilities under the Central Bank directive since 2004. On the other hand, by using the expense of money, the real rate of return on deposits can be obtained. Using calculations of previous studies, as well as the interest rate on deposits (as of 2017), the rate used to attract a current account was about 0%, about 2% for savings, 17% for long-term deposits, and other deposits 1%. Also, the interest rate received for bonds and other similar cases was 10%, for paid facilities, it was 18%, and finally, average warranty costs were about 2%.

$$Max\ Z = 0.18\sum_{i=5}^{6} X_i + 0.1X_8 + 0.02X_{13} - 0Y_3 - 0.02Y_4 - 0.17Y_5 - 0.01Y_6 - 0.015\sum_{i=5}^{6} X_i$$

Objective 2 Increasing share of low-cost deposits

Low-cost deposits include sight deposits (current accounts) and savings deposit accounts.

$$Max\ F_2 = Y_3 + Y_4 - Y_5 - Y_6$$

Objectives 3 Increasing productive assets

Productive assets are the ones held to generate business returns. Assets create business returns when they are consistent with the procedures of profit organisations. In our

model, these items include all assets like debtors for L/C and long-term credits and fixed assets, except government claims

$$Max\ F_3 = X_1 + X_2 + X_3 - X_4 + X_5 + X_6 - X_7 + X_8 + X_9 - X_{10} + X_{11}$$

3.4 Model constraints

Given that this model is related to a bank (bank A) without considering the banking network, the model constraints can be considered as the system as well as the constraints related to bank rules and regulations. On the other hand, based on the fact that the main purpose is constraints of asset control or debt, it can be divided into two categories. According to the explanation, the constraints of the model are shown in Table 3.

Table 3 Constraints of the model

A. Constraints related to assets	
Constraint 1: Equality of balance sheet	*Constraint 14: Capital adequacy ratio*
A balance sheet means that assets are equal to the sum of liabilities and shareholder's equity. $\sum_{i=1}^{11} X_i = \sum_{j=1}^{14} Y_j$	The ratio of capital adequacy, under Article 3 of the Capital Adjustment Regulations approved by the Money and Credit Council for Iranian banks, should be at least 8%. This ratio is the result of dividing the base asset into the sum of assets adjusted according to the risk factors. Rational assets are obtained from the following equation: $WA = 0.2(X_3 + X_{13}) + 0.5(X_{12} + X_{14}) + \sum_{i=6}^{7} X_i + \sum_{i=9}^{11} X_i$ The base capital of the bank is also obtained using the balance sheet capital items and through the following equation: $BC = \sum_{j=10}^{14} Y_j$ Concerning the above relations, one can obtain the constraints on capital adequacy through the general relationship as: $\frac{\sum_{j=10}^{14} Y_j}{0.2(X_3 + X_{13}) + 0.5(X_{12} + X_{14}) + \sum_{i=6}^{7} X_i + \sum_{i=9}^{11} X_i} \geq 0.8$
Constraint 2: Liquidity ceiling	*Other constraints*
According to the rules of banks in Iran, the banks' cash is at least 0.3% of total deposits and liabilities to the central bank.	

Table 3 Constraints of the model (continued)

A. Constraints related to assets	
Constraint 2: Liquidity ceiling	*Other constraints*
$X_1 \geq 0.003\left(Y_1 + \sum_{j=3}^{6} Y_j\right)$	
Constraint 3: Minimum amount of legal deposit	*Constraint 15: Current ratio*
According to the monetary and banking law of the country, to control the amount of money, the central bank must obtain and maintain a stable ratio of bank deposits from banks. The money and credit council approves this ratio in the range of 10% to 30%.	The ratio of current assets to current liabilities should not be smaller than 2.
$X_2 \geq 0.1\sum_{j=3}^{6} Y_j$	$\frac{\sum_{i=6}^{9} X_i}{\sum_{j=1}^{7} Y_j} \geq 2$
Constraint 4: Maximum amount of legal deposit	*Constraint 16: Total debt ratio to special value*
The legal deposit with the central bank cannot exceed 30%.	The special value is the difference between total assets and total debt. The total debt ratio should not be bigger than the total value.
$X_2 \leq 0.3\sum_{j=3}^{6} Y_j$	$\frac{\sum_{i=6}^{9} Y_j}{\sum_{i=6}^{11} X_i - \sum_{j=1}^{9} Y_j} \leq 1$
Constraint 5: Claims from banks and credit institutions	*Constraint 17: Current debt ratio to special value*
These assets are used for internal bank needs, which are usually at least 3% of total deposits.	The current debt ratio to special value should not be less than 0.5.
$X_3 \geq 0.03\sum_{j=3}^{6} Y_j$	$\frac{\sum_{j=1}^{7} Y_j}{\sum_{i=6}^{11} X_i - \sum_{j=1}^{9} Y_j} \geq 0.5$
Constraint 6: Given facilities to the non-governmental sector	*Constraint 18: Cash flow ratio*
According to the law, banks are allowed to pay 70% of their deposits as facilities.	Cash flow is the sum of cash, bank balances, and net profit after tax to total current liabilities. This ratio should not be smaller than 0.4.
$X_6 \leq 0.7\left(Y_1 + \sum_{j=3}^{6} Y_j\right)$	$\frac{\sum_{i=6}^{3} X_i + Y_{14}}{\sum_{j=1}^{7} Y_j} \geq 0.4$

Table 3 Constraints of the model (continued)

A. Constraints related to assets	
Constraint 7: Investment ceiling and partnership	*Constraint 19: Resources index to costs*
Under the provisions of Article 3 of the Investment Instructions, Clause 3 of Article 34 of the monetary and banking law of the country approved by the Council for Money and Credit, the ceiling for the purchase of bonds of shares and direct/indirect investment is up to 40% of the bank's basic capital.	This indicator shows the efficient use of resources. The usual desirable rate is 85%.
$X_8 + X_9 \le 0.4\sum_{j=10}^{14} Y_j$	$X_5 + X_6 \le 0.85\sum_{j=1}^{6} Y_j$
Constraint 8: Fixed assets ceiling	*Constraint 20: The ceiling claims from the government*
Under the provisions of Article 6 of the Administrative Code, Article 34 of the monetary and banking law of the country, fixed assets are mostly up to 30% of the base capital.	Typically, according to the balance sheets of previous years, banks' claims from the government do not exceed 5% of deposits.
$X_{10} \le 0.3\sum_{j=10}^{14} Y_j$	$X_4 \le 0.05\sum_{j=1}^{6} Y_j$
Constraint 9: Equality of liabilities for L/C	*Constraint 21: Minimum claims form government*
For the items below the balance sheet, the existing structural constraints can be considered as equal to the client's obligations, the obligations of the bank, or the parties to the obligations, which are classified as four constraints. First, they refer to the equalization of liabilities for L/C.	Normally, according to the balance sheets of previous years, claims from the government are not less than 3% of deposits.
$X_{10} = Y_{15}$	$X_4 \ge 0.03\sum_{j=1}^{6} Y_j$
Constraint 10: Equality of obligations for warranties	*Constraint 22: Facilities given to the public sector*
The second structural constraint refers to the equality of client and bank obligations for guarantees.	Under the rules of banks and the opinion of the central bank, the maximum amount of facilities given to the public sector is determined according to the balance sheet of banks with an average of 3% of total deposits and liabilities held in the central bank.
$X_{13} = Y_{16}$	$X_5 \ge 0.03\left(Y_1 + \sum_{j=1}^{6} Y_j\right)$

Table 3 Constraints of the model (continued)

A. Constraints related to assets	
Constraint 11: Equality of other obligations	*Constraint 23: Long-term credits*
The third structural constraint is equal to the other obligations of the clients and the bank.	In this model, the amount of long-term credits is determined according to exchange rates and is estimated at 5% of total resources.
$X_{14} = Y_{17}$	$X_7 = 0.05\sum_{j=1}^{14} Y_j$
Constraint 12: Equity of funds managed	*Constraint 24: Other assets*
The third structural constraint refers to the equality of funds administered by customers and the bank.	Considering shareholders and capital, this model represents a maximum of 4% of total resources.
$X_{15} = Y_{18}$	$X_{11} \le 0.04\sum_{j=1}^{14} Y_j$
Constraint 13: Liquidity risk control	
To control the liquidity risk, the bank allocates 1% of total deposit resources to cash with the highest degree of liquidity.	
$X_1 \le 0.01\left(Y_1 + \sum_{j=3}^{6} Y_j\right)$	
B. Constraints related to liabilities	
In the case of debts, there should be constraints on certain items that are non-zero and adequate, and on the other hand, following accounting principles and rules, as well as policies of bank A. These items should be a percentage of total liabilities and capital resources. Therefore, according to the balance sheet of the previous year, the constraints on liabilities are defined.	
Constraint 25: Debt to the central bank	*Constraint 34: Legal equities of exchange rate*
According to the bank A policies, the debt to the central bank can be up to 5% of total bank liabilities.	According to predicted currency changes, changes due to the legal equivalents of the exchange rate should be at least equal to 2% of the bank's liabilities for long-term currency drafts.
$Y_1 \le 0.05\sum_{j=1}^{9} Y_j$	$Y_{12} \le 0.02Y_7$
Constraint 26: Debt to other banks	*Constraint 35: Exchange of foreign currency assets and liabilities*
According to bank A policies, debt to banks and financial institutions can be up to 2% of total bank liabilities.	According to forecasts made by the bank's managers, the profit from the conversion of foreign currency assets and liabilities will be equal to a maximum of 5% of the total profit of the bank.
Constraint 26: Debt to other banks	*Constraint 35: Exchange of foreign currency assets and liabilities*

Table 3 Constraints of the model (continued)

B. Constraints related to liabilities	
$Y_2 \le 0.02\sum_{j=1}^{9} Y_j$	$Y_{13} \le 0.05Y_{14}$
Constraint 27: Total of main deposits	*Controlling constraints*
According to bank A policies, the total sum of the four main deposits should not be less than four million Rials. $\sum_{j=3}^{6} Y_j \ge 4{,}000{,}000$	To make sure that the model is correct, some controlling constraints such as the following should be added to the model to prevent some variables from becoming zero.
Constraint 28: Minimum of sight deposits	*Constraint 36: Controlling constraints for productive assets*
According to bank A policies, at least 50% of the total main deposit must be a sight deposit.	Total productive assets should not be less than non-productive assets
$Y_3 \ge 0.5\sum_{j=3}^{6} Y_j$	$X_1 + X_2 + X_3 + X_5 + X_6 + X_8 + X_9 + X_{11} \ge X_4 + X_7 + X_{10}$
Constraint 29: Balance of deposits	*Constraint 37: Controlling constraints for the combination of given facilities*
According to bank A policies, total sight deposit, and savings deposits should not be less than the sum of term deposits investment and other deposits. $Y_3 + Y_4 \ge Y_5 + Y_6$	According to the bank's policies, the size of the NGO's facilities should not be lower than the public sector. $X_6 \ge X_5$
Constraint 30: Other deposits	*Constraint 38: Controlling constraints for combining non-balance sheet variables*
According to the bank's policies, the total amount of savings deposits and term deposits investment should be higher than other deposits. $Y_4 + Y_5 \ge Y_6$	According to managers and according to the balance sheet items of the previous year, the sum of variables of client obligations for L/C, client obligations for guarantees, other obligations, managed funds, and similar cases, is 103 million Rials according to the managers of the bank. $X_{12} + X_{13} + X_{14} + X_{15} = 103{,}000{,}000$
Constraint 31: The ceiling of the L/C	*Constraint 39: Types of client obligations*
According to the bank's policies, the bank's debt for L/C and long-term drafts can be up to 10% of the total bank resources. $Y_7 \ge 0.1\sum_{j=3}^{6} Y_j$	According to managers, total client obligations for L/C and other party's obligations should not be less than the client's obligations to warranties. $X_{12} + X_{14} \ge X_{13}$

Table 3 Constraints of the model (continued)

B. Constraints related to liabilities	
Constraint 32: Reserves and other debts	*Constraint 40: Total balance sheet items*
According to the bank policies, reserves and other liabilities can be up to 5% of total debt.	According to the balance sheet of the previous year and the policies of bank A in the new year, the total assets and liabilities and the capital should be 12,000,000,000
$Y_8 \le 0.5\sum_{j=1}^{9} Y_j$	$\sum_{i=1}^{11} X_i = \sum_{j=1}^{14} Y_j = 12{,}000{,}000$
Constraint 33: Maximum legal reserves	*Constraint 41: Capital*
Under Article 14 of the Commercial Code, the legal reserves are a maximum of 5% of the company's profits.	According to the balance sheet of the previous year and policies of bank A, the capital must be at least 40% of the total debt and capital.
$Y_{11} \le 0.5Y_{10}$	$Y_{10} \ge 4{,}800{,}000$

Given the above, the final model of the problem is suggested as follows:

$$
\begin{aligned}
&Max\ F_1 = 0.18\sum_{i=5}^{6} X_i + 0.1X_8 + 0.02X_{13} \\
&\qquad -0.02Y_4 - 0.17Y_5 - 0.01Y_6 - 0.015\sum_{i=5}^{6} X_i \\
&Max\ F_2 = Y_3 + Y_4 - Y_5 - Y_6 \\
&Max\ F_3 = X_1 + X_2 + X_3 - X_4 + X_5 + X_6 - X_7 + X_8 + X_9 - X_{10} + X_{11} \\
&S.t: \\
&\sum_{i=1}^{11} X_i = \sum_{j=1}^{14} Y_j \qquad X_5 \ge 0.03\left(Y_1 + \sum_{j=1}^{6} Y_j\right) \\
&X_1 \ge 0.003\left(Y_1 + \sum_{j=3}^{6} Y_j\right) \qquad X_7 \ge 0.05\sum_{j=1}^{14} Y_j \\
&X_2 \ge 0.01\sum_{j=3}^{6} Y_j \qquad X_{11} \le 0.04\sum_{j=1}^{14} Y_j \\
&X_2 \le 0.03\sum_{j=3}^{6} Y_j \qquad Y_1 \le 0.05\sum_{j=1}^{9} Y_j \\
&X_3 \le 0.03\sum_{j=3}^{6} Y_j \qquad Y_2 \le 0.02\sum_{j=1}^{9} Y_j \\
&X_6 \le 0.07\left(Y_1 + \sum_{j=3}^{6} Y_j\right) \qquad \sum_{j=3}^{6} Y_j \ge 4{,}000{,}000 \\
&X_8 + X_9 \le 0.4\sum_{j=10}^{14} Y_j \qquad Y_3 \ge 0.5\sum_{j=3}^{6} Y_j \\
&X_{10} \le 0.3\sum_{j=10}^{14} Y_j \qquad Y_3 + Y_4 \ge Y_5 + Y_6 \\
&X_{12} = Y_{15} \qquad Y_4 + Y_5 \ge Y_6 \\
&X_{13} = Y_{16} \qquad Y_7 \ge 0.1\sum_{j=3}^{6} Y_j
\end{aligned}
\tag{1}
$$

$$X_{14} = Y_{17} \qquad Y_8 \geq 0.05\sum\nolimits_{j=1}^{9} Y_j$$

$$X_{15} = Y_{18} \qquad Y_{11} \leq 0.05Y_{10}$$

$$X_1 \leq 0.01\left(Y_1 + \sum\nolimits_{j=3}^{6} Y_j\right) \qquad Y_{12} = 0.02Y_7$$

$$\frac{\sum_{j=10}^{14} Y_j}{0.2\left(x_3 + x_{13}\right) + 0.5\left(x_{12} + x_{14}\right) + \sum_{i=6}^{7} X_i + \sum_{i=9}^{11} X_i} \qquad Y_{13} = 0.05Y_{14}$$

$$\frac{\sum_{i=6}^{9} X_i}{\sum_{j=1}^{9} Y_j} \geq 2 \qquad X_1 + X_2 + X_3 + X_6 + X_8 + X_9 + X_{11} \geq X_4 + X_7 + X_{10}$$

$$\frac{\sum_{j=1}^{9} Y_j}{\sum_{i=6}^{11} X_i - \sum_{j=1}^{9} Y_j} \leq 1 \qquad X_6 \geq X_5$$

$$\frac{\sum_{j=1}^{7} Y_j}{\sum_{i=6}^{11} X_i - \sum_{j=1}^{9} Y_j} \geq 0.5 \qquad X_{12} + X_{13} + X_{14} + X_{15} = 103,000,000$$

$$\frac{\sum_{i=6}^{3} X_i + Y_{14}}{\sum_{j=1}^{7} Y_j} \geq 0.4 \qquad X_{12} + X_{14} \geq X_{13}$$

$$X_5 + X_6 \leq 0.85\sum\nolimits_{j=1}^{6} Y_j \qquad \sum\nolimits_{i=1}^{11} X_i = \sum\nolimits_{j=1}^{14} Y_j = 12,000,000$$

$$X_4 \leq 0.05\sum\nolimits_{j=1}^{6} Y_j \qquad Y_{10} = 4,800,000$$

$$X_4 \geq 0.03\sum\nolimits_{j=1}^{6} Y_j \qquad X_i \geq 0 \quad (i = 1, 2, ..., 15)$$

$$Y_j \geq 0 \quad (j = 1, 2, ..., 18)$$

4 Solving the model

To solve the model, first, the importance of the objectives was determined using the Cook and Seiford method, and then the model was solved through the lexicography with Excel 2018. For this purpose, a problem was created and solved for the most important goal. By adding the solution from the first problem to the model and considering the goal with the second degree of importance, the new problem was created and solved. Similarly, the goal was considered to be of the third degree of significance.

4.1 Determining the importance of goals

Cook and Seiford (1982) proposed a ranking method for solving the research and development project selection problem in US government offices. They presented two

basic models for selecting projects. One of these methods, the ordinal intersection method, was the most appropriate method to solve this problem. Asgharpour (2001) generalised this model in a study entitled Selection of appropriate subsets of solutions in Iran Khodro Company.

The Cook and Seiford method is used to determine the final rating of m using k decision-makers.

In this research, 20 bank experts were employed as decision-makers. The features of these experts are as follows:

1 Being among the top managers of the bank.

2 Work experience over 20 years.

3 Have higher education in finance.

In this research, the judgement of each of the decision-makers was prioritised randomly. Table 4 shows the priority of the objectives according to experts. In this table, the symbol $A_i > A_j$ represents the priority of the A_i option over A_j.

Table 4 Decision-makers' preferences in selecting objective functions

		Preferences	*Number of votes*
A_1:	Increasing the margin of joint income	$A_1 > A_2 > A_3$	9
A_2:	Increasing low-cost deposits	$A_1 > A_3 > A_2$	5
A_3:	Increasing productive assets	$A_1 > A_3 > A_1$	4
		$A_2 > A_1 > A_3$	2
			20

The intervals matrix based on these views is shown as matrix 1.

- Matrix 1: experts vote intervals

$$D = \begin{matrix} A_1 \\ A_2 \\ A_3 \end{matrix} \begin{bmatrix} 22 & 15 & 18 \\ 17 & 9 & 24 \\ 23 & 11 & 16 \end{bmatrix}$$

One should consider the following points about matrix 1:

1 Initially, the judgement of each K decision-maker is obtained for n existing indicators (preferred or ranked), and then, a compromise is made by the decision-makers to rank the options for each index.

   To achieve a compromise, the authors minimised the disagreements between rankings via a metric or distance function. As a result, the rank of the possible agreement will be determined by minimising the sum of the absolute values of the distances (or disagreement).

2 It is assumed that $a_{p,i}$ stands for the rank assigned to the ith option (from the m options) by the pth decision-maker (from the k decision-maker), and a_i represents the mean (or agreed-upon rank) for that option. Then, to achieve the optimal a_i (i = 1, 2, …, m), the following absolute value (from group disagreement) must be minimised:

$$d_p = \left\{ \sum_{i=1}^{m} \left| a_{p,i} - a_i \right|,\ p = 1, ..., k(\textit{individual's disagreement with the agreed rank}) \right\}$$

Therefore, for group disagreement, we will have:

$$d_{i,r} = d_{A_1,a} = \sum_{p=1}^{20} a_{p,i} - 1$$

Each of the elements of this matrix represents the interval between each option and each rank (d_i), which is calculated as equation (2).

$$d_{i,r} = d_{A1,1} = \sum_{p=1}^{20} a_{p,i} - 1 \tag{2}$$

Hence, the following allocation problem is presented with respect to the permutation matrix *Hm** m to access a group agreement of rankings.

$$\begin{cases} \min : \sum_{i=1}^{m} \sum_{r=1}^{m} d_{i,r}.h_{i,r} \\ s.t: \\ \sum_{i=1}^{m} h_{i,r} = 1;\ r = 1, ..., m \\ \sum_{r=1}^{m} h_{i,r} = 1;\ i = 1, ..., m \\ h_{i,r} = \begin{cases} 1 \\ 0 \end{cases} \end{cases} \tag{3}$$

In the final solution, $h_{i,r} = 1$ because the t rating is assigned to the *i* option; otherwise, it is zero. Based on the interval matrix, the mix-integer linear programming problem is obtained as equation (4) for calculating the importance of the objectives by the Cook and Seiford.

$$\begin{cases} \min W = 22h_{1,1} + 15h_{1,2} + 18h_{1,3} + 17h_{2,1} + 9h_{2,2} + 24h_{2,3} + 23h_{3,1} + 11h_{3,2} + 16h_{3,3} \\ s.t: \\ h_{1,1} + h_{2,1} + h_{3,1} = 1 \\ h_{1,2} + h_{2,2} + h_{3,2} = 1 \\ h_{1,3} + h_{2,3} + h_{3,3} = 1 \\ h_{1,1} + h_{1,2} + h_{1,3} = 1 \\ h_{2,1} + h_{2,2} + h_{2,3} = 1 \\ h_{3,1} + h_{3,2} + h_{3,3} = 1 \end{cases} \tag{4}$$

By solving this model, the final and agreed on group ranking is obtained as $A_1 > A_2 > A_3$.

4.2 Solving the model by lexicography

In lexicography, various goals are ranked by the decision-maker in terms of their grade, and then optimisation proceeds with the improvement of the most important goal and process to solve the problem completely. In this research, after ranking the functions, the goal was solved using Cook's and Saif's methods and via the lexicography technique. When solving the model using lexicography, the stopping criterion is to arrive at a unique solution. In the optimisation with the first objective function, the unique solution was not obtained. Therefore, concerning the solution found for the first objective function, the constraint was added to the problem, and the optimisation was followed by the second objective function. In this case, the model achieved only one unique optimal solution. Therefore, the process of solving the model ended, and the value of the third objective function was calculated based on the values of the variables in the optimal state. Table 5 shows the final results obtained by solving the model based on all three objective functions.

Table 5 Output values for objective functions, variables, and constraints

Name	*Value*	*Name*	*Status*	*Slack*
Z1	1,157,863	c1	Binding	0
Z2	856,700	c3	Binding	0
Z3	10,542,919	c2	Binding	0
x1	12,511	c5	Binding	0
x2	400,000	c8	Binding	0
x3	120,000	c7	Binding	0
x4	128,541	c6	Not binding	10,996
x5	2,930,248	c10	Binding	0
x6	2,930,248	c9	Not binding	404,524.9977
x7	600,000	c13	Binding	0
x8	2,513,401	c12	Binding	0
x9	0	c14	Binding	0
x10	1,885,051	c15	Not binding	265,568
x11	480,000	c16	Not binding	5,716,498
x12	2,764,397	c22	Binding	0
y1	170,361	c19	Binding	0
y2	114,330	c24	Binding	0
y3	2,000,000	c27	Not binding	600,000
y4	428,350	c23	Not binding	85,693.81533
y5	571,650	c25	Not binding	2,805,138
y6	1,000,000	c20	Not binding	6,772,818
y7	400,000	c17	Not binding	567,003.4932
y8	285,825	c18	Not binding	1,542,940
y9	745,983	c11	Binding	0
y10	4,800,000	c28	Binding	0

Table 5 Output values for objective functions, variables, and constraints (continued)

Name	*Value*	*Name*	*Status*	*Slack*
y11	67,068	c30	Binding	0
y12	8,000	c29	Binding	0
y13	67,068	c32	Binding	0
y14	1,341,365	c33	Not binding	856700
y15	2,764,397	c31	Binding	0
y16	2,764,397	c44	Binding	0
y17	0	c47	Binding	0
y18	97,471,205	c48	Binding	0
		c46	Binding	0
		c45	Binding	0
		c41	Binding	0
		c43	Binding	0
		c42	Binding	0
		c40	Binding	0
		c33	Not binding	856700
		c4	Binding	0
		c39	Binding	0
		c34	Binding	0
		c36	Binding	0
		c38	Not binding	800000

4.3 Sensitivity analysis of the model

Solving an assets/liabilities model that has already taken can directly lead to effective responses to decision support. Another way of using the model is to analyse the sensitivity of the model. The purpose of this section is to show the sensitivity of the proposed model to change the values of some parameters and to remove some of the constraints. In the following, two key parameters and two key constraints were selected based on expert opinion. These parameters are the sum of assets (liabilities and capital) and the sum (combination) of the four major deposits. Also, the constraints are the ratio of cash flow and capital adequacy.

The selection of experts was based on the mentality that influenced the variables. They believed that the level of capital traditionally reflects the interests of the owners of the business unit. Also, the total assets and liabilities play a decisive role in the allocation of amounts to the balance sheet items. The amount and combination of the main deposits according to their impact on increasing or decreasing costs (in the amount of the profits paid to them as well as the determination of the cost of money) is the reason to the importance of this variable in decision making.

To this end, for the analysing parameter regarding the amount that was executed in the model, random values were generated in such a way that a smaller amount and a

higher value were selected and also randomly determined. The result of the sensitivity analysis of these parameters and constraints is shown in Table 6.

Table 6 Sensitivity analysis results

Parameter/constraint		*Change*	*Result*		
			Objective function 1	*Objective function 2*	*Objective function 3*
1	Total assets	20,000,000	2,026,155	0	17,724,000
		9,000,000	No solution	No solution	No solution
2	Total of main deposits	5,000,000	No solution	No solution	No solution
		3,000,000	1,203,467	1,000,000	10,605,837
3	Cash flow ratio constraints	Delete	1,164,468	800,000	10,542,695
4	Capital adequacy limit	Delete	1,775,240	875,202	14,812,998

1 According to Table 6, the increase in the total assets (liabilities) increases the value of the objective function and decreases the values of the second and the third objective functions. The decrease in the total assets will cause the model to be non-responsive. This result means that the increase in assets and liabilities will increase the joint profit and productive assets but will reduce the low-cost deposits, which is more acceptable compared to its decreasing state that causes the model to become non-responsive.

2 The increase in the total amount of main deposits will cause the model to lack the optimal solution. On the other hand, a decrease in the total amount of main deposits will increase the values of all three objective functions. The result means that the increase in the number of main deposits cannot be merely an acceptable scenario to achieve the goals because it will increase the bank's expenses and reduce the profitability of the company, low-cost deposits, and productive assets.

3 Removing the constraints regarding cash flow ratios increases the first objective function, i.e., joint income, and reduces the second and the third objective functions, i.e., low-cost deposits and productive assets, respectively. On the other hand, if this ratio is greater than or equal to 0.4 for a company, it would be in a favourable position in terms of the ability to pay short-term debts. Ultimately, the bank has to decide to increase its objective functions at the expense of the increased risk of fame.

4 Removing the capital adequacy constraint also increases the objective functions, namely, joint income, low-cost deposits, and productive assets. On the other hand, the ratio of capital adequacy is one of the ratios of the healthy performance measurement and financial stability of financial institutions and banks. Generally, banks must have sufficient capital to cover the risks arising from their activities and ensure that losses are not conveyed to depositors. For this reason, according to the rules of the International Committee of Basel, this ratio must be respected. The bank ultimately has to decide how much the increase in joint income is preferable over the reduction of low-cost deposits and productive assets and, of course, violations of the law.

5 Conclusions and discussion

This study suggested a multi-objective linear model to bank managers, which is the generalised version of the previous models, and in which the combination of the balance sheet of the bank was optimised by considering targets, such as increasing productive assets, increasing low-cost deposits, and increasing the joint income margin (increased profit) as well as by new restrictions, such as the ratio of total debt to special value, the liquidity ratio, etc. which have not been reviewed in previous models. The most important feature of this model for Iranian banks is the fact that it makes them give up acting as a real estate agent and thaw frozen and non-productive assets. As mentioned, fictitious and frozen assets constitute a key part of bank assets, as a result of which, they cannot concentrate on their core tasks. Another important feature of this model is attention to increasing joint profits for the banks, which reduces the finished cost of money as well. The model presented in this study has developed an optimised balance sheet realising the strategic goals of banks.

In this study, the asset-liability model was designed and solved according to Iranian banking rules.

About Iranian banking rules, as said in the constraints section, each country has a series of constraints in banking topics, such as capital adequacy, the ratio of awarded loan to the attracted deposits, the minimum and the maximum legal deposits of banks at the central bank, etc. which are communicated according to the instructions issued by the central bank to banks, and banks are required to comply with them.

The results of the model showed its consistency with the bank's proposed balance sheet. This proposed balance sheet could be a guide for managers to allocate assets and liabilities to different headings so that they can meet the bank's goals while complying with legal constraints. Sensitivity analysis of this model also provides valuable knowledge to the bank managers. By sensitivity analysis, the highest bounds and the lowest limit of the effective parameters of the model are determined, which reduce or increase the values of the objective functions. By recognising key parameters and their level of influence, bank managers can also apply more precision in estimating these parameters and may also be able to attempt outside the bank's boundaries to change the value of the parameters. Other valuable knowledge obtained from the sensitivity analysis of the asset-liability model is the recognition of key constraints. Managers need to know what levels of constraints should be allocated appropriately. Severe constraints that make a significant change in the optimal response should be taken seriously. Managers may want to make an effort to adjust these constraints outside the bank's borders or prefer to ignore them. For future research, it is recommended to extract the model parameter values from simulation research results in long-term intervals to include some important economic events affecting the banking system.

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