

## Research Article

# Lexicographic Goal Programming Model for Bank's Performance Management

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Any bank's financial management is essential to preparing the assets and liabilities for multiple goals. In this paper, we develop an optimal bank model for the financial management department in the Kingdom of Saudi Arabia. The lexicographic goal programming model was used to formulate the banks' performance management. In this study, the six goals of one of the leading banks in Saudi Arabia, namely, maximize asset, minimize liability, maximize equity, maximize operating income, maximize net income, and maximizing total goal achievements in the financial statement, were studied. To illustrate the model, we have focused on Al Rajhi Bank's financial statements as a case study. The data was obtained from the banks' financial statements. The outcomes of the study exhibited that all goals were accomplished. This proposed model is dynamic because it will help examine the banks' financial strengths located in the kingdom. As a result, the proposed model can guide banking firms in making decisions and developing strategies to deal with numerous monetary circumstances.

## 1. Introduction

Asset and liability management is a critical element in balancing a company's assets and liabilities.

Asset and liability management is primarily concerned with liquidity and interest rates. In addition, in order to achieve a satisfactory result, the bank must consider a variety of objectives. Following that, a goal programming approach can be used to solve the multiobjective decision-making problem.

The primary goal of this research is to optimize the profitable structure of the Al Rajhi Bank in the Kingdom of Saudi Arabia. Al Rajhi Bank, founded in 1957, is one of the world's largest banks, with total assets of SR 411 billion (US\$ 125 billion), a paid-up capital of SR 25 billion (US\$ 6.67 billion), and a workforce of over 9600 associates. In 1957, the first branch was established in Aldirah. Al Rajhi Bank, headquartered in Riyadh, Saudi Arabia, has a vast network of over 543 branches, 142 dedicated ladies' branches, more than 5210 ATMs, and 204549 POS terminals installed

with merchant's extensive consumer base of any bank in the Kingdom [1].

The research's specific objectives are as follows:

- (a) To optimize the total assets
- (b) To optimize the total liabilities
- (c) To optimize the total equity
- (d) To optimize the total operating income
- (e) To optimize the total net income
- (f) To optimize the total goal achievements

Ref. [2] studied on mathematical modeling for "asset-liability optimal management" for the bank. Ref. [3] deliberated on the bank financial statement management using a goal programming approach. Ref. [4] developed an optimization development procedure for bank asset liability management.

Ref. [5] used a GPA to plan bank balance sheet management. Ref. [6] established an ideal appraisal of decision-making reward by LPP. The authors of [7] were among the first to develop a deterministic linear programming model for assets and liabilities.

In their model, the optimal portfolio for an individual bank over some periods was determined by considering the requirements of bank examiners.

Furthermore, in some managerial challenges, decision-makers expressed many criteria; thus, the linear programming model is unable to incorporate all of the criteria at the same time. As a result, in order to solve multiobjective issues, the goal programming technique was established. Ref. [8] introduced a goal programming approach for analyzing numerous conflicting goals while considering the decision-maker's limits and preferences. Later, Ref. [9] created generalized goal programming, a valuable and reliable technique for multiobjective mathematical programming. This study presented the approach's underlying concept and the specific subclass of models and methods that make up the overall approach. Ref. [10] developed a mixed integer goal programming model to aid in the proper management of the paper recycling logistics system. The model looked at how a recycled paper delivery network's numerous purposes interacted. Ref. [11] investigated a multichoice multiobjective transportation problem in which at least one of the objectives has many ambition levels to meet and the supply and demand factors are unpredictably random variables.

Goal programming techniques have now been applied to a variety of fields, including banking financial management [12–14], rubber production [3], scheduling [15], and tourism management [16].

The authors of [17] have designed a mathematical model of asset and liability management using a goal programming approach. Ref. [18] described developing and implementing a goal programming model at the Commercial Bank of Greece that considers the most critical institutional, financial, legal, and bank policy concerns. Tanwar et al. [19] used goal programming to optimize the assets and liabilities of an Indian bank, and the results demonstrated that goal programming could help achieve optimization and increase profitability. Furthermore, Ref. [20] suggested a number of goal programming methods for calculating firm performance measure weights using constrained regression. The significant advancements in the field of goal programming, including algorithms, applications, normalization techniques, and utility modeling methodologies, were evaluated by [21]. The study by [22] was crucial since it aids in determining the possibility for each bank to enhance total liability, profit, earnings, and total goal attainment in order to meet the benchmark target value for future development. Ref. [23] created a multiobjective model for liquidity management based on a goal programming approach.

Multiobjective optimization methods like lexicographic goal programming (LGP) are better suited for problem-solving in complex decision-making scenarios. The LGP is an extension of linear programming (LP), which was first presented by [24] and has since been presented by [8, 9,

25] among others. This technique was created to deal with multicriteria situations within the context of LP.

Some other methods used for evaluating the bank's performance management except goal programming are enlisted here. For instance, Jun et al. [26] suggested a dynamically reduced step size gradient boosting regression tree algorithm for bank performance evaluation. They used extending regression trees to study the prediction of multidimensional factors on commercial bank performance. Furthermore, Ref. [27] investigated the literature for balanced scorecard practices. The findings demonstrate that preparing a balanced scorecard for banks is more advantageous than reporting financial performance just in evaluating performance holistically. Besides, Ref. [27] investigated the literature for balanced scorecard practices. The findings demonstrate that preparing a balanced scorecard for banks is more advantageous than reporting financial performance just in evaluating performance holistically. In addition, Ref. [28] conducted a three-year study of twenty-five Indonesian banks, using multivariate regression analysis to test their hypothesis. Their study indicated that bank features play a vital influence in determining how well a bank performs.

In this study, we present a lexicographic goal programming (LGP) model for the optimal performance management of Al Rajhi Bank for the financial management department. In this study, the six goals were studied. In addition, we have used the observed data from the Al Rajhi Bank's financial statements to demonstrate the model.

## 2. Materials and Methods

**2.1. Goal Programming.** Goal programming is a method for examining several aspects of an organization's performance, such as costs, revenue, productivity, and profitability. In this paper, the goal programming model is developed to find an optimal solution for six goals. The several goals' accomplishment currently has exposed the importance of completing numerous objectives simultaneously. Hereafter, there is required a mathematical model to resolve these difficulties in order to find an optimal result. A goal programming approach is widely used in solving multiple objective problems simultaneously to achieve all objectives. Subsequently, the bank has to attain contradict goals like maximizing assets while minimizing liability; in this regard, goal programming approach is the preeminent method to resolve the problem ([29, 30] and others).

**2.2. Mathematical Formulation as Lexicographic Goal Programming (LGP) Model.** Goal programming, particularly lexicographic goal programming (i.e., goal programming with non-Archimedean weights or within an as such "preemptive priority" design), has become one of the most popular methodologies for multiobjective mathematical programming.

In general, the goals can be prioritized by the problem-solver. That is, a priority factor,  $\rho_i$  ( $i = 1, 2, \dots, n$ ), is assigned to the deviational variables associated with the goals. This is referred to as "lexicographic ordering." The lexicographic

goal programming (LGP) model, as defined by [9], can be addressed as

$$\text{Min } \sum_{i=1}^n \rho_i (\delta_i^- + \delta_i^+) \quad (1)$$

subject to

$$\sum_{j=1}^m (\alpha_{ij} x_j + \delta_i^- - \delta_i^+) = \tau_i, \quad (2)$$

$$x_j, \delta_i^-, \delta_i^+ \geq 0, \quad \forall i, j; i = 1, 2, \dots, n, j = 1, 2, \dots, m. \quad (3)$$

Because both under- and overachievement of the goal are not feasible at the same time, at least one of the deviational variables must be zero. To put it another way,

$$\delta_i^- \cdot \delta_i^+ = 0. \quad (4)$$

Here,  $n$  represents number of goal constraints,  $\tau_i$  represents the target level of the  $i^{\text{th}}$  goal,  $x_j$  represents the vector of  $m$ -decision variables,  $\alpha_{ij}$  represents the coefficients of decision variables, and  $\delta_i^-$  &  $\delta_i^+$  indicate the under- and over-deviational variables, respectively. As a goal is unsatisfied or oversatisfied, the deviations  $\delta_i^-$  and  $\delta_i^+$  are added to the constraints. Finally, the deviation variables are used to determine whether each goal is underachieved or overachieved [31].

In the bank's performance management, we have drawn the six goals in the financial statement. In the LGP model of the bank's performance management problem, the following notations are defined.

2.3. *Notations.*  $x_j$ : Decision variables

$\rho_i$ : The preemptive priority level is allocated to each target in order of preference

$\delta_i^-$ : Negative deviation variable (underachievement)

$\delta_i^+$ : Positive deviation variable (overachievement)

$\alpha_{ij}$ : Coefficients of decision variables

$\tau_i$ : Target levels of the  $i$ th goal.

2.4. *The Goals.* The goal programming approach is used to solve six significant goals at the same time in this study. The six major goals of bank financial management in order of importance (priority) can be defined in Table 1.

According to Equation (2),  $x_j$  (decision variables) represents the total quantity for each component in each year as shown below.

$x_1$  is the total quantity for each component in financial statement in the year 2015.

$x_2$  is the total quantity for each component in financial statement in the year 2016.

$x_3$  is the total quantity for each component in financial statement in the year 2017.

$x_4$  is the total quantity for each component in financial statement in the year 2018.

$x_5$  is the total quantity for each component in financial statement in the year 2019.

TABLE 1: Goals of bank with priority.

Goals	Priority
Maximizing total assets	$\rho_1$
Minimizing total liabilities	$\rho_2$
Maximizing total equity	$\rho_3$
Maximizing operating income	$\rho_4$
Maximizing net income	$\rho_5$
Maximizing total goal achievements	$\rho_6$

$x_6$  is the total quantity for each component in financial statement in the year 2020.

2.5. *Goal Constraints.* In order to formulate the problem in this study, the following goal constraints were examined.

2.5.1. *Total Asset Goal Constraint.*

$$\alpha_{11} x_1 + \alpha_{12} x_2 + \alpha_{13} x_3 + \alpha_{14} x_4 + \alpha_{15} x_5 + \alpha_{16} x_6 + \delta_1^- - \delta_1^+ = \tau_1. \quad (5)$$

2.5.2. *Total Liability Goal Constraint.*

$$\alpha_{21} x_1 + \alpha_{22} x_2 + \alpha_{23} x_3 + \alpha_{24} x_4 + \alpha_{25} x_5 + \alpha_{26} x_6 + \delta_2^- - \delta_2^+ = \tau_2. \quad (6)$$

2.5.3. *Total Equity Goal Constraint.*

$$\alpha_{31} x_1 + \alpha_{32} x_2 + \alpha_{33} x_3 + \alpha_{34} x_4 + \alpha_{35} x_5 + \alpha_{36} x_6 + \delta_3^- - \delta_3^+ = \tau_3. \quad (7)$$

2.5.4. *Total Operating Income Goal Constraint.*

$$\alpha_{41} x_1 + \alpha_{42} x_2 + \alpha_{43} x_3 + \alpha_{44} x_4 + \alpha_{45} x_5 + \alpha_{46} x_6 + \delta_4^- - \delta_4^+ = \tau_4. \quad (8)$$

2.5.5. *Total Net Income Goal Constraint.*

$$\alpha_{51} x_1 + \alpha_{52} x_2 + \alpha_{53} x_3 + \alpha_{54} x_4 + \alpha_{55} x_5 + \alpha_{56} x_6 + \delta_5^- - \delta_5^+ = \tau_5. \quad (9)$$

2.5.6. *Total Goal Achievement Constraint.*

$$\alpha_{61} x_1 + \alpha_{62} x_2 + \alpha_{63} x_3 + \alpha_{64} x_4 + \alpha_{65} x_5 + \alpha_{66} x_6 + \delta_6^- - \delta_6^+ = \tau_6. \quad (10)$$

In bank financial management, only liability is minimized, while all other goals are maximized. In addition, positive and negative deviational variables are added to the constraints to determine the growth or reduction of the goals because the variables have uncertain values.

TABLE 2: Financial data from the Al Rajhi Bank.

Target	Fiscal year is January-December (all values in SAR' 000)						Total
	2015	2016	2017	2018	2019	2020	
Total assets	315619648	339711817	343116528	365003830	384086576	468824723	2216363122
Total liabilities	268980594	287764945	287365610	316449812	332894919	410706205	1904162085
Total equity	46639054	51946872	55750918	48554018	51191657	58118518	312201037
Total operating income	13745775	15341380	15904854	17319518	19484464	20721260	102517251
Net income	7130075	8125960	9120726	10296867	10158527	10595548	55427703
Total	652117161	702892990	711260653	757626063	797818162	968968274	4590671198



FIGURE 1: Radar chart of financial data.

2.5.7. *Objective Function.* We have now defined the objective function as follows:

$$\begin{aligned}
\text{Minimize : } & \delta_1^- \in \rho_1 : \text{Maximizing total assets +} \\
& \delta_2^+ \in \rho_2 : \text{Minimizing total liabilities +} \\
& \delta_3^- \in \rho_3 : \text{Maximizing total equity wealth +} \\
& \delta_4^- \in \rho_4 : \text{Maximizing total operating income +} \\
& \delta_5^- \in \rho_5 : \text{Maximizing total net income +} \\
& \delta_6^- \in \rho_6 : \text{Maximizing total goal achievements.}
\end{aligned} \tag{11}$$

2.5.8. *LGP Model.* In view of the above, the LGP model (12–19) is created and formulated as follows based on the established goal constraints.

$$\text{Min } \delta_1^- + \delta_2^+ + \delta_3^- + \delta_4^- + \delta_5^- + \delta_6^- \tag{12}$$

subject to

$$\alpha_{11}x_1 + \alpha_{12}x_2 + \alpha_{13}x_3 + \alpha_{14}x_4 + \alpha_{15}x_5 + \alpha_{16}x_6 + \delta_1^- - \delta_1^+ = \tau_1, \tag{13}$$

$$\alpha_{21}x_1 + \alpha_{22}x_2 + \alpha_{23}x_3 + \alpha_{24}x_4 + \alpha_{25}x_5 + \alpha_{26}x_6 + \delta_2^- - \delta_2^+ = \tau_2, \tag{14}$$

$$\alpha_{31}x_1 + \alpha_{32}x_2 + \alpha_{33}x_3 + \alpha_{34}x_4 + \alpha_{35}x_5 + \alpha_{36}x_6 + \delta_3^- - \delta_3^+ = \tau_3, \tag{15}$$

$$\alpha_{41}x_1 + \alpha_{42}x_2 + \alpha_{43}x_3 + \alpha_{44}x_4 + \alpha_{45}x_5 + \alpha_{46}x_6 + \delta_4^- - \delta_4^+ = \tau_4, \tag{16}$$

$$\alpha_{51}x_1 + \alpha_{52}x_2 + \alpha_{53}x_3 + \alpha_{54}x_4 + \alpha_{55}x_5 + \alpha_{56}x_6 + \delta_5^- - \delta_5^+ = \tau_5, \tag{17}$$

$$\alpha_{61}x_1 + \alpha_{62}x_2 + \alpha_{63}x_3 + \alpha_{64}x_4 + \alpha_{65}x_5 + \alpha_{66}x_6 + \delta_6^- - \delta_6^+ = \tau_6, \tag{18}$$

$$x_1, x_2, x_3, x_4, x_5, x_6, \delta_1^-, \delta_1^+, \delta_2^-, \delta_2^+, \delta_3^-, \delta_3^+, \delta_4^-, \delta_4^+, \delta_5^-, \delta_5^+, \delta_6^-, \delta_6^+ \geq 0. \tag{19}$$

Furthermore, the following case study has been considered to illustrate the effectiveness of the proposed LGP model.

### 3. Case Study

The Al Rajhi Bank is selected as the case study in this paper. The data of financial statement including total assets, liabilities, total equity, total operating income, and total net income are obtained from the Saudi Exchange portal from 2015 until 2020 [32]. Table 2 summarizes the details, with all six target sets depicted in Figure 1.

Table 2 shows the financial data from Al Rajhi Bank's financial statement. Table 2 is coded and converted into Table 3 for further analysis in developing a goal programming model [13].

We have now given the formulation of financial data (coded form) as a lexicographic goal programming (LGP) model.

$$\text{Min } \delta_1^- + \delta_2^+ + \delta_3^- + \delta_4^- + \delta_5^- + \delta_6^- \tag{20}$$

TABLE 3: Financial data from the Al Rajhi Bank in coded form.

Target	Fiscal year is January-December (all values in SAR' trillion)						Total
	2015	2016	2017	2018	2019	2020	
Total assets	0.316	0.340	0.343	0.365	0.384	0.469	2.216
Total liabilities	0.269	0.288	0.287	0.316	0.333	0.411	1.904
Total equity	0.047	0.052	0.056	0.049	0.051	0.058	0.312
Total operating income	0.014	0.015	0.016	0.017	0.019	0.021	0.103
Net income	0.007	0.008	0.009	0.010	0.010	0.011	0.055
Total	0.652	0.703	0.711	0.758	0.798	0.969	4.591

subject to

$$0.316 x_1 + 0.340 x_2 + 0.343 x_3 + 0.365 x_4 + 0.384 x_5 + 0.469 x_6 + \delta_1^- - \delta_1^+ = 2.216,$$

$$0.269 x_1 + 0.288 x_2 + 0.287 x_3 + 0.316 x_4 + 0.333 x_5 + 0.411 x_6 + \delta_2^- - \delta_2^+ = 1.904,$$

$$0.047 x_1 + 0.052 x_2 + 0.056 x_3 + 0.049 x_4 + 0.051 x_5 + 0.058 x_6 + \delta_3^- - \delta_3^+ = 0.312, \tag{21}$$

$$0.014 x_1 + 0.015 x_2 + 0.016 x_3 + 0.017 x_4 + 0.019 x_5 + 0.021 x_6 + \delta_4^- - \delta_4^+ = 0.103, \tag{22}$$

$$0.007 x_1 + 0.008 x_2 + 0.009 x_3 + 0.010 x_4 + 0.010 x_5 + 0.011 x_6 + \delta_5^- - \delta_5^+ = 0.055, \tag{23}$$

$$0.652 x_1 + 0.703 x_2 + 0.711 x_3 + 0.758 x_4 + 0.798 x_5 + 0.969 x_6 + \delta_6^- - \delta_6^+ = 4.591, \tag{24}$$

$$x_1, x_2, x_3, x_4, x_5, x_6, \delta_1^-, \delta_1^+, \delta_2^-, \delta_2^+, \delta_3^-, \delta_3^+, \delta_4^-, \delta_4^+, \delta_5^-, \delta_5^+, \delta_6^-, \delta_6^+ \geq 0. \tag{25}$$

In this study, the lexicographic goal programming model (20–25) is solved with LINGO software version 18.0x64. In addition, in the following section, we will go over the outcomes of goal achievement.

### 4. Results and Discussion

The outcomes of target achievement are depicted in Table 4. All of  $\rho_i, (i = 1, 2, \dots, 6)$  is zero. As a result, all of the objectives of the bank are achieved, and the optimal solution is established. This reveals that Al Rajhi Bank's financial performance is consistently strong.

Table 5 and Figure 2 show the potential improvement on the target value based on the optimal solution of the LGP model. Among the targets, four potential improvements have been identified. First, the positive values of deviation variables can be used to detect possible increments or decrements. In the case of a maximization problem, the increment can be determined by using a positive deviation variable,

TABLE 4: Target achievement.

Target priority	Outcomes	Target achievement
$\rho_1$	$\delta_1^- = 0$	Completely attained
$\rho_2$	$\delta_2^+ = 0$	Completely attained
$\rho_3$	$\delta_3^- = 0$	Completely attained
$\rho_4$	$\delta_4^- = 0$	Completely attained
$\rho_5$	$\delta_5^- = 0$	Completely attained
$\rho_6$	$\delta_6^- = 0$	Completely attained

TABLE 5: Outcomes of deviational variables.

Target priority	Negative deviational variables ( $\delta_i^-$ )	Positive deviational variables ( $\delta_i^+$ )
$\rho_1$	0	0.023005
$\rho_2$	0	0.000000
$\rho_3$	0	0.023005
$\rho_4$	0	0.000000
$\rho_5$	0	0.001601
$\rho_6$	0	0.044967

while in the case of a minimization problem, the decrement can be determined by using a negative deviation variable.

We have now interpreted the following points based on their priority goals:

- (i) The bank's total assets should be maximized as the priority ( $\rho_1$ ). The result shows that the value for negative deviation,  $\delta_1^-$ , is zero, while the value for positive deviation  $\delta_1^+$  is 0.023005, indicating that Al Rajhi Bank can increase their total assets by SAR 0.023005 trillion to improve continuously
- (ii) The liability reduction for priority ( $\rho_2$ ) is also fully achieved because both  $\delta_2^-$  and  $\delta_2^+$  are zero, indicating that the total liabilities for six years do not change, which is equal to SAR 1.904 trillion
- (iii) The value of  $\delta_3^-$  for priority ( $\rho_3$ ) is zero, while the value of  $\delta_3^+$  is 0.023005. This demonstrates that the equity goal was fulfilled, and the bank's total equity can be increased by SAR 0.023005 trillion per year



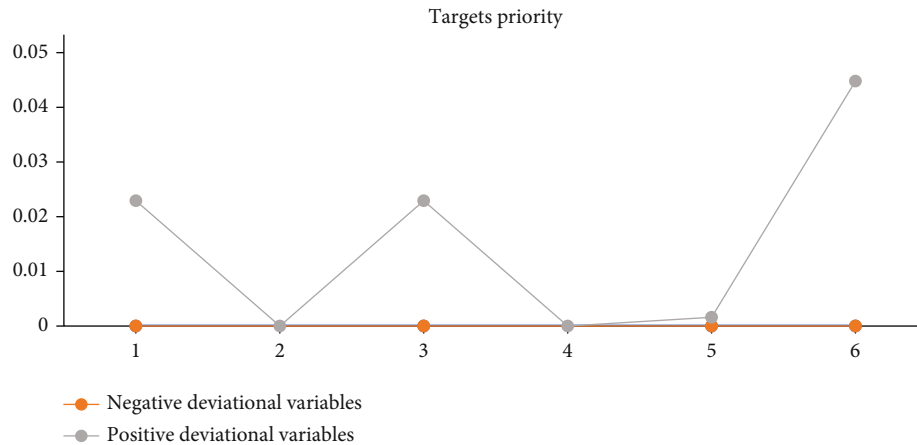


FIGURE 2: Outcomes of deviational variables.

- (iv) Similarly, because  $\delta_4^-$  and  $\delta_4^+$  are equal to zero, maximizing the total operating cost for priority ( $\rho_4$ ) is also achieved. This means that the total operating cost for the six years remains constant, equal to SAR 0.103 trillion
- (v) Furthermore, the value of  $\delta_5^-$  for priority ( $\rho_5$ ) is zero, whereas the value of  $\delta_5^+$  is 0.001601. This demonstrates that the net income goal was achieved, and the bank's total net income can be increased by SAR 0.001601 trillion per year
- (vi) Finally, because  $\delta_6^-$  is zero and  $\delta_6^+$  is 0.044967, maximizing the total goal achievements for priority ( $\rho_6$ ) is also achieved. This demonstrates that the total goal achievements in the financial statement can be increased by SAR 0.044967 trillion per year

## 5. Conclusions and Recommendations

This research intends to create a lexicographic goal programming model to analyze and optimize the performance management of Al Rajhi Bank in Saudi Arabia. Based on the optimal solution of the lexicographic goal programming model, the findings of this study show that the Al Rajhi Bank is capable of achieving all goals.

Apart from that, there are opportunities for Al Rajhi Bank to maximize its total assets, total equity, net income, and total goal achievement. As a result, this research aids in the identification of new target values for the bank's goal of continuous improvement. Banks and other financial institutions can use the proposed model to make decisions and build strategies in response to various economic circumstances.

Future studies should take a closer look at the potential consequences of financial planning, such as minimizing total liabilities while optimizing other objectives. Therefore, this research will be crucial in future efforts to solve financial difficulties. Furthermore, this study could be addressed in future studies on financial institution performance management. In addition, the primary aspect of further research will

be applying this proposed model to all Saudi banks and then to Gulf countries' banks.

## Data Availability

Previously reported financial data were used to support this study and are available at <https://www.saudiexchange.sa>. Therefore, these datasets are cited at a relevant place within the text as reference [32].

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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