

Application of Fuzzy Goal Programming Model According to Iskander's Methodology in Loan Approval Process in Banks: An Empirical Study at the Algerian External Bank (BEA) - Ain Temouchent Agency

تطبيق نموذج البرمجة بالأهداف المبهم وفق منهجية "اسكندر في عملية منح الائتمان لدى البنوك
دراسة تطبيقية في البنك الجزائري الخارجي BEA - وكالة عين تموشنت

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Abstract:

This study aims to introduce a contemporary mathematical model designed to aid financial management in commercial banks, particularly in the context of making optimal decisions amidst uncertain circumstances. The objective of this research is to develop a mathematical model utilizing the proposed fuzzy goal programming model based on Iskander's methodology. This model is intended to serve as a valuable tool in addressing challenges related to credit approval.

A field study was conducted at the Algerian External Bank (BEA), Ain Temouchent Agency, comparing applicants for bank loans in alignment with the bank's strategy. The model was solved using the statistical software Lingo18, resulting in the following outcomes: The fuzzy goal programming model, following Iskander's methodology, emerges as one of the most robust and effective approaches for resolving issues associated with bank loan approvals in an uncertain environment, providing optimal solutions.

Keywords: Model, Fuzzy Goal Programming, Uncertain Environment, Commercial Banks, Loan Approval.

JEL Classification Codes : C6 ,C610

الملخص:

تهدف هذه الدراسة إلى محاولة تقديم نموذج رياضي حديث يساعد الإدارة المالية بالبنوك التجارية على اتخاذ أفضل القرارات التي تسمح بتحقيق الأهداف المرجوة خاصة في ظل الظروف غير الأكيدة. سنحاول من خلال هذه الدراسة بناء نموذج رياضي باستخدام نموذج البرمجة المتعددة الأهداف

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المبهمة المقترح من طرف اسكندر Iskander كأداة مساعدة في حل مشكلة منح الائتمان، حيث تم إجراء دراسة ميدانية بالبنك الخارجي الجزائري (BEA)، وكالة عين تموشنت، وتمت عملية المفاضلة بين طالبي القروض المصرفية وفقا لاستراتيجية البنك .

تم حل النموذج باستخدام البرنامج الإحصائي Lingo18 ، وقد توصلنا إلى النتائج التالية: نموذج البرمجة المتعددة الأهداف المبهمة وفق منهجية "اسكندر" Iskander يعتبر أحد أقوى الأساليب الفعالة وأكثر نجاعة في حل مشاكل منح القروض المصرفية في ظل بيئة غير أكيدة وبطريقة مثلى. كلمات مفتاحية: نموذج، برمجة أهداف مبهمة، بيئة غير أكيدة، بنوك تجارية، منح الائتمان.

تصنيفات JEL : C6 ، C610

INTRODUCTION:

The loan approval process in banks faces numerous challenges, especially in the rapidly advancing global technological landscape. The expanding roles of economic and financial institutions now extend beyond profit objectives to encompass sustainability, compelling banks to adapt to a complex and risk-laden environment marked by unforeseen changes. In light of these circumstances, banks are required to explore alternatives to maximize returns while minimizing costs. This exploration involves the application of mathematical and scientific methods, specifically utilizing mathematical models to facilitate optimal decision-making in the credit approval process.

The goal programming model stands out as a quantitative method employed by banks to make loan approval decisions, particularly in ambiguous environments with heightened risks. This model relies on scientific mathematical logic, known for its transparency and impartiality.

In consideration of the above context, we aim to formulate the following problem statement:

- How does the fuzzy goal programming model, according to Iskander's methodology, help decision-makers in the process of distributing bank loans satisfactorily at the Algerian External Bank - Ain Temouchent Agency?

- **Sub-questions:**

- What is the fuzzy goal programming model?
- How is the fuzzy goal programming method applied according to Iskander's approach?

- **Hypotheses:**

- The process of distributing bank loans requires modern mathematical methods, such as the goal programming approach, especially in uncertain conditions
- The goal programming model, according to the "Iskandr's" method, helps in the process of distributing bank loans, especially in uncertain conditions

- **Study Objectives:**

The study aims to investigate the application of the fuzzy goal programming methodology by decision-makers in evaluating and distributing bank loans, following Iskander's approach. The objective is to minimize risks and maximize returns, considering the financial and funding

capabilities of the bank. The study draws data from documents provided by the Algerian External Bank, Ain Temouchent agency.

- **The importance of the study:**

The importance of the study lies in its ability to improve the efficiency and accuracy of loan approval processes in banks through the application of fuzzy objectives programming.

- **Methodology of the Study:**

The study was divided into three main axes. The first axis reviewed the theoretical aspect (theoretical concepts), while the second part was dedicated to applying the fuzzy goal programming model according to "Iskandr's" methodology to manage the distribution of loans by the Algerian external bank. The final part was devoted to studying and analyzing the results obtained.

Literature Review:

- Muslim Hussein's (2012/2013) doctoral thesis titled **"Types of Fuzzy Linear Goal Programming Models in Decision Making with a Case Study of the Credit Process in BDL Bank in Maghnia."** This study aims to apply the fuzzy goal programming model to solve a range of problems, particularly in the credit process of BDL Bank. The results indicate that this model is a powerful tool for solving multi-criteria and multi-objective problems.
- Abdelwahab Slimani, Mohamed Fodou, and Abdelrahman Guedri's (2021) article titled **"Goal Programming and its Applications in the Banking Sector: An Applied Study on the Local Development Bank."** This study attempts to construct a mathematical model contributing to the bank's objectives using modern techniques and quantitative methods to facilitate optimal decision-making. The analytic hierarchy process was employed to rank the importance of each goal, and the model was solved using Expert Choice and Lingo 18. The study concludes that it is possible to design a practical mathematical model for managing the bank's objectives.
- Nasreddine Ben Messaoud's (2022) study titled **"Using Linear Goal Programming with Decision Maker Preferences Integration in Granting Bank Loans in Algeria: An Applied Study at BNA Bank in Ain Temouchent."** This study aims to use the linear goal programming model with the integration of decision-maker preferences expressed through efficiency functions as a tool to solve the problem of granting bank loans in Algeria. The model was solved using Lingo 19, and the results indicate that determining the number of bank loans granted was satisfactory for both the bank management and customers. The loan-granting decisions were transparent, unbiased, and optimal.
- Study by Meloul Sakina and Muslim Hussein, (2012) titled **"(FMCGP) The Proposed Fuzzy Multi-Objective Goal Programming Model by Tabrizy et al. in Comparing Bank Loan Applications: A Case Study of the Local Development Bank in Maghnia."** This study aims to present a modern mathematical approach to streamline credit decision-making in commercial banks using the Fuzzy Multi-Objective Goal Programming Model (FMCGP). The study concludes that the FMCGP model can be considered a powerful method for solving multi-criteria and multi-objective problems related to the credit process, especially in an economy characterized by rapid and random transformations.

- Study by Farshad and Mohammad,(2019) titled "***Application of Fuzzy Goal Programming to Determine the Optimal Cultivation Crops Model.***" This study attempts to determine the optimal farming pattern using fuzzy goal programming models, considering various goals for the farm at Ferdowsi University in Iran. The study results in the design of a model that contributes to improving the conditions of the farming pattern.

- **Significance of the Study:**

The importance of this study lies in the application of modern quantitative methods, specifically the fuzzy multi-objective linear programming model, in differentiating between bank loans within an uncertain environment fraught with risks and challenges.

- **Study Limitations:**

- **Spatial Limitations:** The study was conducted at the Algerian External Bank, Ain Temouchent agency, specifically focusing on the Loans Department.
 - **Temporal Limitations:** The study was conducted over a period from September 10, 2022, to October 11, 2022.

- **Research Methodology:**

To address the study's problem statement, a descriptive methodology was employed to explore the theoretical aspects. For the practical application, an analytical approach was adopted, involving the analysis of bank data using the Lingo 18 program.

- **Theoretical Framework:**

In this theoretical axis of the study, we will present conceptual insights into multi-objective linear programming.

1 Concepts of Linear Goal Programming:

1.1 Definition of Goal Programming:

According to M. Tamiz and C. Romero , goal programming is a mathematical model for solving decision problems in a flexible and realistic manner, considering multiple variables, goals, and constraints (Tamiz, M., Romero, C., & Jones, 1998). It involves choosing the best solution from possible solutions by testing multiple objectives simultaneously (Aouni & Kettani, 2001, p. 226).

Additionally, Sang M. Lee defines goal programming as a mathematical method through which decision-makers can adopt multiple objectives to be achieved simultaneously (Slimani et al., 2021, p. 138).

Goal programming is a mathematical model through which the best and closest solution among a set of ranked objectives for a problem is found by determining the values of decision variables and minimizing the total deviations from the previously specified goals to the lowest possible level (Maouch, j&Bekouche, l, 2022, p. 554).

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From these definitions, we can understand goal programming as a model that applies mathematical methods to compare available alternatives and select an optimal solution among the possibilities, considering various variables.

1.2 Model Formulation:

The formulation of the goal programming model was pioneered by Cooper & Charnes in 1961. According to the following formulation (Naim & Belmokadem, 2016, p. 257):

$$\text{Minimiser } |f_i(x) - g_i|$$

Subject to:

$$c_x \leq c$$

$$x_j \geq 0 \quad (j = 1, 2, 3, \dots, n)$$

Where:

f_i Represents the objectives.

g_i The goal to be achieved for objective number $(i = 1, 2, \dots, p)$

x_j Represents decision variables for n decisions $n \quad (j = 1, 2, \dots, n)$

a_{ij} Technological coefficients.

c_x Matrix of coefficients related to the constraints of the model.

c Available resources.

1.3 Mathematical Formulation of Goal Programming Model:

The mathematical formulation of the goal programming model can be expressed as follows (Martel & Aouni, 1990):

$$\text{MIN } Z = \sum_{i=1}^p (\delta_i^+ + \delta_i^-)$$

$$\sum_{j=1}^n a_{ij}x_j - \delta_i^+ + \delta_i^- = g_i$$

$$c_x \leq c$$

$$x_j \geq 0 \quad (j=1, 2, 3, \dots, n)$$

$$\delta_i^+ \text{ et } \delta_i^- \geq 0 \quad (i = 1, 2, 3, \dots, p)$$

$$\delta_i^+ * \delta_i^- = 0$$

Where: (Muslim, 2013)

δ_i^+ : Positive deviation related to the goal, reflecting the amount of increase in achieving the target value.

δ_i^- : Negative deviation related to the goal, reflecting the amount of decrease in achieving the target value.

The product of positive and negative deviations equals zero $\delta_i^- \delta_i^+$, ensuring that both deviations cannot occur simultaneously (Ben Ramadan & Boumediene, 2011, p. 178). This is because we cannot achieve a value smaller than the goal g_i and larger than g_i at the same time.

According to the standard form of the Goal Programming model, determining the positive and negative deviations in the economic function is crucial. This is represented in Table (1) as follows:

Table 1: Deviations in the Economic Function

Constraint Type	General Standard Form	Deviations to be Reduced
$fi(x) \leq gi$	$fi(x) - \delta_i^+ + \delta_i^- = gi.$	δ_i^+
$fi(x) \geq gi$	$fi(x) - \delta_i^+ + \delta_i^- = gi.$	δ_i^-
$fi(x) = gi$	$fi(x) - \delta_i^+ + \delta_i^- = gi.$	$\delta_i^+ + \delta_i^-$

Source: (Sahid, 2013)

1.4 Some Types of Goal Programming Models:

There are various types of goal programming models, and among them is the Weighted Goal Programming model:

1.4.1 Weighted Goal Programming:

In this type, goals are ranked according to their importance from the management's perspective. Some goals may have greater importance compared to others. Initial weights are assigned to each goal, allowing for prioritization. The deviations δ_i are multiplied by coefficients w_i , representing the percentage importance of each goal. The Weighted Goal Programming model is formulated as follows (Ignazio, 1978, p. 1114):

$$\begin{aligned} \text{Min } Z &= \sum_{i=1}^p (w_i^+ \delta_i^+ + w_i^- \delta_i^-) \\ \sum_{j=1}^n a_{ij} x_j - \delta_i^+ + \delta_i^- &= g_i \quad (i = 1, 2, 3, \dots, p) \\ c_x &\leq c. \\ x_j &\geq 0 \quad (j = 1, 2, \dots, n). \\ \delta_i^+ \text{ et } \delta_i^- &\geq 0 \quad (i = 1, 2, \dots, p) \end{aligned}$$

1.4.2 Prioritized Goal Programming:

In the Prioritized Goal Programming approach, priorities are assigned to goals in proportion to their perceived importance by the management. Goals with lower priority are considered after those with higher priority. The priorities are represented by the symbols p_i , where p_i signifies the highest priority given to the most important goals, followed by p_2 , p_3 , and so on (Issa Ahmad, Shawket Hermiz, & Salman, 2013, p. 817).

The objective function in the Lexicographic Minimization form is expressed as follows (Hammami, 2003, p. 56):

$$\text{EX MIN } Z = p_1(\delta_1^- \cdot \delta_1^+) + p_2(\delta_2^- \cdot \delta_2^+) + p_3(\delta_3^- \cdot \delta_3^+) + \dots + (p_k(\delta_k^- \cdot \delta_k^+))$$

Subject to:

$$\begin{aligned} \sum_{j=1}^n C_{ij} x_j - \delta_i^+ + \delta_i^- &= b_i \quad i = 1, 2, \dots, m \\ K &= 1, 2, \dots, n \quad j = 1, 2, \dots, n \\ \delta_1^- \cdot \delta_1^+ &\geq 0 \end{aligned}$$

Where:

Z : Sum of positive and negative deviations of goals.

PK : Priority structure of goals.

b_i : Desired value to be achieved for the goal.

c_{ij} : Contribution coefficient of decision variable x_j to achieve the goal b_i .

After defining the goals, prioritization is performed using a concordance method. The importance of each goal is compared with every other goal. The goal that appears more frequently as having higher importance is given higher priority ($\geq$). This process continues until all goals are prioritized (Issa Ahmad, Shawket Hermiz, & Salman, 2013).

2. Fuzzy Goal Programming:

Considering that multi-objective programming models are traditionally built on the assumption of fixed technological coefficients, reality often contradicts this assumption. Parameters and observations cannot be considered constant under all circumstances. Zadeh was the pioneer in introducing the term "Fuzzy" or more precisely, the theory of fuzzy sets in 1970. (Meloul & Muslim, 2020, p. 255) This concept has had a significant impact on various sciences, challenging the notion that real-world observations are always constant and well-defined; they can be ambiguous.

The theory of fuzzy sets underwent several modifications and elaborations, particularly by Belman & Zadeh, who introduced special cases along with examples.

The evolution of fuzzy set theory took a significant leap when Tabrizy and his colleagues successfully introduced triangular-shaped membership functions for modeling fuzzy goals with multiple targeted values. Consequently, the model by Tabrizy et al. transformed into a Fuzzy Multi-Objective Goal Programming model (Moloul & Muslim, 2020, p. 256).

Among the noteworthy fuzzy goal programming models :

2.1 Fuzzy Goal Programming according to Iskandr's Methodology:

2.1.1 General Formulation of the Model

In the Fuzzy Goal Programming model following Iskandr's methodology, the general formulation considers parameters in the objective function and constraint functions as fuzzy, taking imprecise values that are not precisely defined. (Ben Messaoud, 2022, p. 16). The general formulation for such conditions is expressed as follows:

$$\text{Max or Min : } \tilde{c}_1 * x_1 + \tilde{c}_2 * x_2 + \dots + \tilde{c}_n * x_n$$

Subject to:

$$\begin{aligned} \tilde{a}_{11} * x_1 + \tilde{a}_{12} * x_2 + \dots + \tilde{a}_{1n} * x_n & \begin{cases} \leq \\ \geq \\ = \end{cases} \tilde{b}_1 \\ \tilde{a}_{21} * x_1 + \tilde{a}_{22} * x_2 + \dots + \tilde{a}_{2n} * x_n & \begin{cases} \leq \\ \geq \\ = \end{cases} \tilde{b}_2 \end{aligned}$$

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$$\begin{array}{ccccccc} \cdot & \cdot & \cdot & \cdot & & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & & \cdot & \cdot & \cdot & \cdot \end{array}$$

$$\widetilde{a}_{m1} * x_1 + \widetilde{a}_{m2} * x_2 + \dots + \widetilde{a}_{mn} * x_n \left[\begin{array}{l} \leq \\ \geq \\ = \end{array} \right] \widetilde{b}_m$$

$$i = 1.2.3 \dots m$$

$$j = 1.2.3 \dots n$$

$$x_j \geq 0$$

Where:

x_j : Represents decision variables.

c_i : Represents parameters accompanying decision variables in constraint functions.

b_i : Represents fuzzy values taken by the right-hand sides of constraints, representing available resources.

a_{ij} : Represents parameters accompanying decision variables in constraint functions.

Through the model, it is observed that all parameters take fuzzy values, which can be of the triangular or trapezoidal type. The triangular type takes the following formulation:

$$\begin{aligned} \tilde{c}_i &= (c_{il} = c_j - \sqrt{1-\alpha}, c_j, c_{ju} = c_j + \sqrt{1-\alpha}) \dots \dots \dots 1 \\ \tilde{a}_{ij} &= (a_{il} = a_{ijl} - \sqrt{1-\alpha}, a_{ij}, a_{iju} = a_{ij} + \sqrt{1-\alpha}) \dots \dots \dots 2 \\ \tilde{b}_i &= (b_{il} = b_i - \sqrt{1-\alpha}, b_i, b_{iu} = b_i + \sqrt{1-\alpha}) \dots \dots \dots 3 \end{aligned}$$

Where: $1 \geq \alpha \geq 0$ is determined by the decision-maker, representing the satisfaction level (minimum required probability).

$\Rightarrow$ Values containing l represent minimum values.

$\Rightarrow$ Values containing u represent maximum values.

2.1.2 Transformation of the Fuzzy Model to the Conventional Model according to Iskandr's Methodology:

The fuzzy formulation is transformed into the conventional formulation according to Iskandr's approach, in the following manner:

$$\text{Max or Miz} = [(1-\alpha)(c_1 + \sqrt{1-\alpha}) + \alpha c_1]x_1 + [(1-\alpha)(c_2 + \sqrt{1-\alpha}) + \alpha c_2]x_2 \\ + \dots \dots \dots + [(1-\alpha)(c_n + \sqrt{1-\alpha}) + \alpha c_n]x_n$$

St :

$$\begin{aligned}
 & [(1-\alpha)(a_{11} - \sqrt{1-\alpha}) + \alpha a_{11}]x_1 + [(1-\alpha)(a_{12} - \sqrt{1-\alpha}) + \alpha a_{12}]x_2 + \\
 & \dots \dots \dots + [(1-\alpha)(a_{1n} - \sqrt{1-\alpha}) + \alpha a_{1n}]x_n \left[\begin{array}{l} \leq \\ \geq \\ = \end{array} \right] [(1-\alpha)(b_1 \sqrt{1-\alpha}) + \alpha b_1] \\
 & [(1-\alpha)(a_{21} - \sqrt{1-\alpha}) + \alpha a_{21}]x_1 + [(1-\alpha)(a_{22} - \sqrt{1-\alpha}) + \alpha a_{22}]x_2 + \dots \dots \dots \\
 & \dots \dots \dots + [(1-\alpha)(a_{2n} - \sqrt{1-\alpha}) + \alpha a_{2n}]x_n \left[\begin{array}{l} \leq \\ \geq \\ = \end{array} \right] [(1-\alpha)(b_2 \sqrt{1-\alpha}) + \alpha b_2] \\
 & [(1-\alpha)(a_{m1} - \sqrt{1-\alpha}) + \alpha a_{m1}]x_1 + [(1-\alpha)(a_{m2} - \sqrt{1-\alpha}) + \alpha a_{m2}]x_2 \\
 & \quad j = 1.2.3 \dots n \quad i = 1.2.3 \dots m
 \end{aligned}$$

$$0 \leq \alpha \leq 1$$

$$x_j \geq 0$$

3. Empirical Study

The decision-making process regarding the approval of bank loans is among the prominent tasks carried out by the bank within a set of constraints and obligations that must be respected and adhered to during the credit approval process.

To provide clarity on the use of goal programming in the decision-making process for bank loan applications, a model of fuzzy multi-objective programming was applied according to Iskander's methodology. This study was conducted at the Algerian External Bank, specifically in the Loans Department at the Ain Temouchent Agency.

3.1 Problem Formulation :

Through our visit to the branch of the Algerian External Bank in Ain Temouchent and after an interview with the bank manager, who directed us to the Loans Department, we managed to obtain a sample consisting of 10 loan applications summarized in the following table:

Table 02: Data representing ten bank loans

Loan ID	Loan Amount (DZD)	Personal Income (DZD)	Loan Duration (Years)	Repayment Age (Years)	Interest Rate (%)
x_1	4,000,000	98,000	4	45	6.75
x_2	145,000	32,800	5	33	3.5
x_3	3,100,000	105,000	4	48	5.25
x_4	180,000	68,000	12	40	4.5
x_5	150,000	455,000	8	35	6.75
x_6	280,000	22,500	12	55	4
x_7	2,000,000	48,600	35	38	6.75
x_8	3,800,000	92,700	22	49	4.25
x_9	540,000	55,006	32	33	4
x_10	30,000,000	258,000	27	39	4
Fuzzy Constraints	60,000,000	90000	200	350	

Source: Prepared by the researcher based on documents provided by the bank

3.2 Mathematical Formulation of the Model:

$$\text{Max}z = \widetilde{6.75}x_1 + \widetilde{3.5}x_2 + \widetilde{5.25}x_3 + \widetilde{4.5}x_4 + \widetilde{6.75}x_5 + \widetilde{4}x_6 + \widetilde{6.75}x_7 + \widetilde{4.25}x_8 + \widetilde{4}x_9 + \widetilde{4}x_{10}$$

The bank's loan approval process involves adhering to various constraints and obligations that must be respected and complied with. We assumed that the bank would approve only five loan requests out of ten, based on criteria derived from the bank's strategy.

3.3 Defining Fuzzy Goals

➤ Constraint on Loan Amount:

This constraint represents the amount borrowed by the customer. The total approved loan amount should be within the bank's capabilities (bank budget), estimated at 60 million DZD.

$$4000000x_1 + 145000x_2 + 3100000x_3 + 180000x_4 + 150000x_5 + 280000x_6 + 2000000x_7 + 3800000x_8 + 540000x_9 + 30000000x_{10} \leq 6000000$$

➤ Constraint on Personal Income:

The personal income should not be less than the guaranteed minimum wage of 18,000 DZD. The total income for five loans should exceed 90,000 DZD.

$$98000x_1 + 32800x_2 + 105000x_3 + 68000x_4 + 455000x_5 + 22500x_6 + 48600x_7 + 92700x_8 + 65500x_9 + 258000x_{10} \geq 90000$$

➤ Constraint on Loan Repayment Duration:

The maximum loan repayment duration granted to the client should not exceed 40 years. The total repayment duration for all loans granted should not exceed 200 years.

$$\widetilde{4}x_1 + \widetilde{5}x_2 + \widetilde{4}x_3 + \widetilde{12}x_4 + \widetilde{8}x_5 + \widetilde{12}x_6 + \widetilde{35}x_7 + \widetilde{22}x_8 + \widetilde{32}x_9 + \widetilde{27}x_{10} \leq \widetilde{200}$$

➤ Constraint on Age:

The age of the loan applicant should not exceed 70 years, where:

$$\widetilde{45}x_1 + \widetilde{33}x_2 + \widetilde{48}x_3 + \widetilde{40}x_4 + \widetilde{35}x_5 + \widetilde{55}x_6 + \widetilde{38}x_7 + \widetilde{49}x_8 + \widetilde{33}x_9 + \widetilde{39}x_{10} \leq \widetilde{350}$$

➤ Constraint on Total Granted Loans:

This constraint represents the number of granted loans.

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} = 5$$

Where :

Short-term loans $\mathbf{x_1 + x_2 + x_3 \leq 2}$

Medium-term loans $\mathbf{x_4 + x_5 + x_6 \leq 1}$

Long-term loans $\mathbf{x_7 + x_8 + x_9 + x_{10} \leq 2}$

$$x_j \geq 0 \quad j \in \{1, 2, \dots, 10\}$$

x_j : represents decision variables.

When solving the model:

If x_j takes the value 0, it means the decision-maker rejects the loan application.

If x_j takes the value 1, it means the decision-maker approves the loan application.

4. Transformation of Fuzzy Model to Conventional Model using Eskandar's Methodology:

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$$\begin{aligned} & [(1 - \alpha)(4000000 + \sqrt{1 - \alpha} + 4000000\alpha)x_1 + [(1 - \alpha)(145000 + \sqrt{1 - \alpha}) \\ & + 145000\alpha]x_2 + [(1 - \alpha)(3100000 + \sqrt{1 - \alpha}) + 3100000\alpha]x_3 + [(1 - \alpha)(180000 + \sqrt{1 - \alpha}) + 180000\alpha]x_4 + [(1 - \alpha)(150000 + \sqrt{1 - \alpha}) \\ & + 150000\alpha]x_5 + [(1 - \alpha)(280000 - \sqrt{1 - \alpha}) + 280000\alpha]x_6 + [(1 - \alpha)(2000000 - \sqrt{1 - \alpha}) + 2000000\alpha]x_7 + [(1 - \alpha)(3800000 \\ & - \sqrt{1 - \alpha}) + 3800000\alpha]x_8 + [(1 - \alpha)(450000 - \sqrt{1 - \alpha}) + 450000\alpha]x_9 \\ & + [(1 - \alpha)(60000000 - \sqrt{1 - \alpha}) + 60000000\alpha]x_{10} \\ & \leq [(1 - \alpha)(60000000 - \sqrt{1 - \alpha}) + 60000000\alpha] \end{aligned}$$

$$\begin{aligned} & [(1 - \alpha)(98000 - \sqrt{1 - \alpha}) + 98000\alpha]x_1 + [(1 - \alpha)(32800 - \sqrt{1 - \alpha}) + 32800\alpha]x_2 + [(1 - \alpha)(105000 - \sqrt{1 - \alpha}) + 105000\alpha]x_3 + [(1 - \alpha)(68000 - \sqrt{1 - \alpha}) + 68000\alpha]x_4 + [(1 - \alpha)(455000 - \sqrt{1 - \alpha}) + 455000\alpha]x_5 + [(1 - \alpha)(22500 - \sqrt{1 - \alpha}) + 22500\alpha]x_6 + [(1 - \alpha)(48600 - \sqrt{1 - \alpha}) + 48600\alpha]x_7 + [(1 - \alpha)(92700 - \sqrt{1 - \alpha}) + 92700\alpha]x_8 + [(1 - \alpha)(65500 - \sqrt{1 - \alpha}) + 65500\alpha]x_9 + [(1 - \alpha)(258000 - \sqrt{1 - \alpha}) + 258000\alpha]x_{10} \leq [(1 - \alpha)(90000 - \sqrt{1 - \alpha}) + 90000\alpha] \end{aligned}$$

$$\begin{aligned} & [(1 - \alpha)(4 - \sqrt{1 - \alpha}) + 4\alpha]x_1 + [(1 - \alpha)(5 - \sqrt{1 - \alpha}) + 5\alpha]x_2 + [(1 - \alpha)(4 - \sqrt{1 - \alpha}) + 4\alpha]x_3 + [(1 - \alpha)(12 - \sqrt{1 - \alpha}) + 12\alpha]x_4 + [(1 - \alpha)(8 - \sqrt{1 - \alpha}) + 8\alpha]x_5 + [(1 - \alpha)(12 - \sqrt{1 - \alpha}) + 12\alpha]x_6 + [(1 - \alpha)(35 - \sqrt{1 - \alpha}) + 35\alpha]x_7 + [(1 - \alpha)(22 - \sqrt{1 - \alpha}) + 22\alpha]x_8 + [(1 - \alpha)(32 - \sqrt{1 - \alpha}) + 32\alpha]x_9 + [(1 - \alpha)(27 - \sqrt{1 - \alpha}) + 27\alpha]x_{10} \leq [(1 - \alpha)(200 - \sqrt{1 - \alpha}) + 200\alpha] \end{aligned}$$

$$\begin{aligned} & [(1 - \alpha)(45 - \sqrt{1 - \alpha}) + 45\alpha]x_1 + [(1 - \alpha)(33 - \sqrt{1 - \alpha}) + 33\alpha]x_2 + [(1 - \alpha)(48 - \sqrt{1 - \alpha}) + 48\alpha]x_3 + [(1 - \alpha)(40 - \sqrt{1 - \alpha}) + 40\alpha]x_4 + [(1 - \alpha)(35 - \sqrt{1 - \alpha}) + 35\alpha]x_5 + [(1 - \alpha)(30 - \sqrt{1 - \alpha}) + 30\alpha]x_6 + [(1 - \alpha)(25 - \sqrt{1 - \alpha}) + 25\alpha]x_7 + [(1 - \alpha)(20 - \sqrt{1 - \alpha}) + 20\alpha]x_8 + [(1 - \alpha)(15 - \sqrt{1 - \alpha}) + 15\alpha]x_9 + [(1 - \alpha)(10 - \sqrt{1 - \alpha}) + 10\alpha]x_{10} \leq [(1 - \alpha)(100 - \sqrt{1 - \alpha}) + 100\alpha] \end{aligned}$$

$$\sqrt{1-\alpha}) + 35\alpha]x_5 + [(1-\alpha)(55 - \sqrt{1-\alpha}) + 55\alpha]x_6 + [(1-\alpha)(38 - \sqrt{1-\alpha}) + 38\alpha]x_7 + [(1-\alpha)(49 - \sqrt{1-\alpha}) + 49\alpha]x_8 + [(1-\alpha)(33 - \sqrt{1-\alpha}) + 33\alpha]x_9 + [(1-\alpha)(39 - \sqrt{1-\alpha}) + 39\alpha]x_{10} \leq [(1-\alpha)(350 - \sqrt{1-\alpha}) + 350\alpha]$$

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} = 5$$

Where :

$$x_1 + x_2 + x_3 \leq 2$$

$$x_4 + x_5 + x_6 \leq 1$$

$$x_7 + x_8 + x_9 + x_{10} \leq 2$$

$$x_j \geq 0 \quad j = \{1, 2, \dots, 10\}$$

α represents the decision-maker's satisfaction level, ranging from 0 to 1.

The model is solved by varying α , using Lingo18 and the mathematical program Symbolab. The results are as follows:

Table 03 : Results of solving the model based on the variation of the α value

Variable Value	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	Z
α Value											
$\alpha = 0.25$	1	0	1	0	1	0	1	1	0	0	33.00
$\alpha = 0.5$	1	0	1	0	1	0	1	1	0	0	34.63
$\alpha = 0.75$	1	0	1	0	1	0	1	0	1	0	30.57
$\alpha = 1$	1	0	1	0	1	0	1	1	0	0	29.75

Source: Prepared by the researcher using Lingo18 outputs

5. Study Results

After simplifying the calculations on the mathematical model using Symbolab, the data was input into the LINGO18 program, resulting in the following outcomes:

- At $\alpha = 0.25$

The decision-maker approves loan applications:

$$x_1 = x_3 = x_5 = x_7 = x_8 = 1$$

The decision-maker rejects the following loans :

$$x_2 = x_4 = x_6 = x_9 = x_{10} = 0$$

The average interest rate for the total loans is 33%.

- At $\alpha = 0.5$

The decision-maker approves loan applications:

$$x_1 = x_3 = x_5 = x_7 = x_8 = 1$$

The decision-maker rejects the following loans :

$$x_2 = x_4 = x_6 = x_9 = x_{10} = 0$$

The average interest rate for the total loans is 34.63%.

- At $\alpha = 0.75$

The decision-maker approves loan applications:

$$x_1 = x_3 = x_5 = x_7 = x_8 = 1$$

The decision-maker rejects the following loans :

$$x_2 = x_4 = x_6 = x_9 = x_{10} = 0$$

The average interest rate for the total loans is 30.57%.

- At. $\alpha = 1$

The decision-maker approves loan applications:

$$x_1 = x_3 = x_5 = x_7 = x_8 = 1$$

The decision-maker rejects the following loans :

$$x_2 = x_4 = x_6 = x_9 = x_{10} = 0$$

The average interest rate for the total loans is 29.79%.

- Based on the results obtained previously, we can conclude that the Algerian External Bank should choose the second scenario where $\alpha = 0.5$

. In this case, the bank can achieve the highest total interest rate for the loans granted compared to other scenarios, where the total interest rate was lower by 34.63%. The following loan applications, which have been studied by the bank, will be accepted: x_1, x_3, x_5, x_7 , and x_8 , while the following loan applications will be rejected: $x_2, x_4, x_6, x_9, x_{10}$ as they do not achieve the minimum return for the bank.

6. Conclusion :

The findings from this research underscore the significance of employing the Fuzzy Goal Programming model, following Eskandar's methodology, in the credit approval process as a contemporary and scientifically rigorous mathematical approach. It stands out as a valuable tool for decision-makers, facilitating the selection of optimal and precise solutions when evaluating bank loan requests, a departure from conventional methods. The following key conclusions have been drawn:

- The Fuzzy Multi-Objective Programming model, according to Eskandar's method, emerges as one of the most effective and efficient approaches to resolving banking loan approval challenges within an uncertain environment, offering an optimal solution.
- The Fuzzy Goal Programming approach is marked by its flexibility, simplicity, and enriching aspects, providing decision-makers with the freedom to express their opinions during the mathematical modeling process within given constraints.
- The distribution of bank loans using the Fuzzy Goal Programming method, following Eskandar's methodology, demonstrates greater transparency and fairness compared to traditional linear programming methods, particularly in an ambiguous environment fraught with risks.

➤ Suggestions and Recommendations

Based on the results of the study, we propose the following:

- Emphasize the adoption of modern scientific methods in decision-making processes, both within banks and economic institutions as a whole.
- Conduct training courses for decision-makers within institutions in the field of modern quantitative methods based on mathematical foundations, especially in the areas of operations research and statistics.
- The Fuzzy Goal Programming model needs support and enrichment for further development.

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7. Appendices

➤ $\alpha=0.25$

Global optimal solution found.

Objective value: 33.00000
 Objective bound: 33.00000
 Infeasibilities: 0.000000
 Extended solver steps: 0
 Total solver iterations: 0
 Elapsed runtime seconds: 0.06

Model Class: PILP

Total variables: 10
 Nonlinear variables: 0
 Integer variables: 10

Total constraints: 9
 Nonlinear constraints: 0

Total nonzeros: 70
 Nonlinear nonzeros: 0

Variable	Value	Reduced Cost
X1	1.000000	-7.400000
X2	0.000000	-4.200000
X3	1.000000	-5.900000
X4	0.000000	-5.150000
X5	1.000000	-7.400000
X6	0.000000	-4.600000
X7	1.000000	-7.400000
X8	1.000000	-4.900000
X9	0.000000	-4.600000
X10	0.000000	-4.600000

Row	Slack or Surplus	Dual Price
1	33.00000	1.000000
2	0.4695000E+08	0.000000
3	709302.6	0.000000
4	124.4000	0.000000
5	132.4000	0.000000
6	0.000000	0.000000
7	0.000000	0.000000

**Application of Fuzzy Goal Programming Model According to Iskander's Methodology in Loan
Approval Process in Banks: An Empirical Study at the Algerian External Bank (BEA)
- Ain Temouchent Agency**

8	0.000000	0.000000
9	0.000000	0.000000

➤ $\alpha = 0.5$

Global optimal solution found.

Objective value:	34.63000
Objective bound:	34.63000
Infeasibilities:	0.000000
Extended solver steps:	0
Total solver iterations:	0
Elapsed runtime seconds:	0.06

Model Class:	PILP
--------------	------

Total variables:	10
Nonlinear variables:	0
Integer variables:	10

Total constraints:	9
Nonlinear constraints:	0

Total nonzeros:	70
Nonlinear nonzeros:	0

Variable	Value	Reduced Cost
X1	1.000000	-7.100000
X2	0.000000	-3.850000
X3	1.000000	-5.600000
X4	0.000000	-4.850000
X5	1.000000	-7.100000
X6	0.000000	-4.350000
X7	1.000000	-7.100000
X8	1.000000	-7.730000
X9	0.000000	-4.350000
X10	0.000000	-4.350000

Row	Slack or Surplus	Dual Price
1	34.63000	1.000000
2	0.4695000E+08	0.000000
3	709301.4	0.000000

4	125.6000	0.000000
5	133.6000	0.000000
6	0.000000	0.000000
7	0.000000	0.000000
8	0.000000	0.000000
9	0.000000	0.000000

➤ $\alpha = 0.75$

Global optimal solution found.

Objective value: 30.57000

Objective bound: 30.57000

Infeasibilities: 0.000000

Extended solver steps: 0

Total solver iterations: 0

Elapsed runtime seconds: 0.06

Model Class: PILP

Total variables: 10

Nonlinear variables: 0

Integer variables: 10

Total constraints: 9

Nonlinear constraints: 0

Total nonzeros: 70

Nonlinear nonzeros: 0

Variable	Value	Reduced Cost
X1	1.000000	-6.880000
X2	0.000000	-3.570000
X3	1.000000	-5.370000
X4	0.000000	-4.680000
X5	1.000000	-6.880000
X6	0.000000	-4.130000
X7	1.000000	-6.880000
X8	0.000000	-4.560000
X9	1.000000	-4.560000
X10	0.000000	-4.560000

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Row	Slack or Surplus	Dual Price
1	30.57000	1.000000
2	0.5021000E+08	0.000000
3	682100.5	0.000000
4	116.4800	0.000000
5	150.4800	0.000000
6	0.000000	0.000000
7	0.000000	0.000000
8	0.000000	0.000000
9	0.000000	0.000000

➤ **$\alpha=1$**

Global optimal solution found.

Objective value: 29.75000

Objective bound: 29.75000

Infeasibilities: 0.000000

Extended solver steps: 0

Total solver iterations: 0

Elapsed runtime seconds: 0.06

Model Class: PILP

Total variables: 10

Nonlinear variables: 0

Integer variables: 10

Total constraints: 9

Nonlinear constraints: 0

Total nonzeros: 70

Nonlinear nonzeros: 0

Variable	Value	Reduced Cost
X1	1.000000	-6.750000
X2	0.000000	-3.500000
X3	1.000000	-5.250000
X4	0.000000	-4.500000
X5	1.000000	-6.750000
X6	0.000000	-4.000000
X7	1.000000	-6.750000
X8	1.000000	-4.250000

X9	0.000000	-4.000000
X10	0.000000	-4.000000

Row	Slack or Surplus	Dual Price
1	29.75000	1.000000
2	0.4695000E+08	0.000000
3	709300.0	0.000000
4	127.0000	0.000000
5	135.0000	0.000000
6	0.000000	0.000000
7	0.000000	0.000000
8	0.000000	0.000000
9	0.000000	0.000000