

Exponential Membership Functions in Credit Allocation. Case Study of BDL Bank Tlemcen

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Article Information

Article history

Received: 2 March 2026

Accepted: 29 June 2026

Published: 30 June 2026

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Suggested Citation

NAIM, I. (2026). Exponential Membership Functions in Credit Allocation. Case Study of BDL Bank Tlemcen, Finance and Business Economics Review, Vol. 10, No. 2, pp. 84-97. DOI : 10.58205/fber.v10i2.2107

Abstract: This study underscores the critical role of quantitative methods in BDL Bank's credit allocation process in Tlemcen. To address the inherent uncertainty in decision-making, Fuzzy Goal Programming (FGP) was applied using exponential membership functions. The proposed framework modeled key factors influencing loan approval, structured around criteria aligned with the bank's lending methodology. The findings demonstrate that quantitative modeling acts as a rigorous scientific tool, significantly enhancing the efficiency and reliability of decisions in competitive, dynamic financial environments. The study confirms the feasibility of identifying an acceptable loan portfolio under multiple, sometimes conflicting, criteria. To achieve this, the problem was formulated as a mathematical model and solved using LINGO optimization software.

Keywords: Fuzzy goal programming, linear membership function, exponential membership function, decision making, credit allocation.

1. Introduction

In recent years, modern technologies, particularly those powered by artificial intelligence, have profoundly transformed human lifestyles, leading to significant shifts in consumption patterns for goods and services compared to previous decades. The growing reliance on the Internet in daily life has forced institutions to adapt their production and operational processes to address multiple, often competing, criteria simultaneously. This evolution has made institutional decision-making increasingly complex, presenting major challenges for managers, especially amid information shortages.

Moreover, the accelerated pace of economic transactions, particularly in the banking sector, demands rigorous scientific methodologies to support timely, informed decisions. Among the most critical banking operations examined in this study is the credit allocation process, which plays a pivotal role in stimulating investment activities and enhancing overall banking performance.

In this context, contemporary strategies and analytical procedures for credit evaluation are essential for identifying loan applications likely to generate profitable returns while avoiding unprofitable investments. To this end, we propose a goal programming approach incorporating the membership function framework introduced by Zimmermann, which accommodates ambiguous and uncertain goal levels. This method has gained considerable traction among researchers across disciplines, including finance.

We argue that this approach provides a rational, structured mechanism for optimizing credit decisions, enabling banks to select loan portfolios that deliver satisfactory outcomes while

aligning with institutional lending policies.

Research Problematic:

Accordingly, the central research question of this study is: To what extent can goal programming models effectively support credit allocation decisions in uncertain conditions ?

Research hypotheses

This study is guided by the following hypotheses:

It is feasible to represent the credit granting process through a mathematical modeling framework.

The fuzzy goal programming model facilitates the identification of loan applications that meet approval criteria while adhering to the lending policies of the banking institution under investigation.

Research Aims

The primary objective of this research is to highlight the critical role of quantitative methodologies, particularly multi-criteria decision-making techniques, in supporting managerial decisions in banking operations. By doing so, the study aims to raise awareness among decision-makers of the strategic value these tools offer in enhancing institutional performance and promoting more rational, data-driven management practices.

Research methodology

This study employed a descriptive-analytical approach, first presenting and examining key concepts before applying them to the case of BDL bank.

Previous studies

Li and Es (1991) introduced an exponential membership function within the framework of fuzzy multi-objective linear programming. Their aim was to enhance the representation of decision-makers' preferences under uncertainty, offering a more flexible alternative to linear and hyperbolic membership functions. The study demonstrated that the exponential function enables finer weighting of deviations from target objectives, yielding more realistic solutions aligned with subjective preferences—a key methodological advance in fuzzy multi-objective optimization.

Building on this line of research, Bari and Gupta (2014) examined the fuzzy multi-objective capacitated transportation problem with mixed constraints. They applied different membership functions—linear, exponential, and hyperbolic—to capture decision-makers' preferences and illustrated their approach with a numerical example. Their results demonstrated that fuzzy modeling provides more effective handling of uncertainty and complexity in transportation problems, yielding practical and adaptable compromise solutions.

2. Definition of Decision Making

Decision-making has been conceptualized and defined in various ways across the academic literature. This section presents selected definitions that reflect its complexity and relevance in organizational contexts.

According to M. A. Hitt et al., decision-making is a structured process involving the identification of an existing problem or opportunity and the selection of the most suitable alternative from available options. This process aims to resolve issues or capitalize on

opportunities in ways that support strategic objectives and enhance organizational effectiveness (Mulyono H. P., 2020)

As to Trewatha and Newport, the decision-making process entails selecting a specific course of action from multiple available alternatives to resolve a particular problem. (Jadhav, 2019)

Drucker conceptualizes a decision as an individual's conclusion regarding a specific situation, emphasizing that effective business decisions are instrumental to organizational success. (Katarzyna Kozioł-Nadolna, 2021).

R. C. Davis views management as fundamentally a decision-making process. This intellectual process involves selecting a single course of action from multiple possible alternatives. Once made, a decision is typically followed by planning—the second key function of management—along with subsequent functions such as organizing, directing, coordinating, controlling, and motivating, all of which ensure effective implementation within an organization. (Suraj Panpatte, 2019).

Based on the preceding definitions, decision-making can be understood as the process of selecting one option from a set of alternatives, guided by information gathered by the decision-maker (or decision-making group), to identify an optimal solution that satisfactorily addresses their objectives.

3. Purpose of Decision Making

The decision-making process serves not only to identify and implement the most suitable course of action but also to diagnose and uncover structural or operational gaps within an organization. As such, its various stages function as a diagnostic and analytical framework, enabling the identification of secondary issues and the formulation of solutions that may not have been initially apparent. We present these objectives, as outlined by (Mulyono H. P., 2020) as follows :

Generating Optimal Outcomes: This strategy involves selecting the most suitable option from a set of identified alternatives. Its effectiveness depends on several factors, including the problem's significance, time constraints, resource availability, opportunity costs, and the decision-maker's psychological condition.

Achieving Satisfactory Outcomes: Rather than seeking the optimal alternative, this approach focuses on identifying the first option that meets acceptable criteria. The term "satisficing" combines "satisfying" and "sufficient," implying that when both conditions are met, the chosen decision can be regarded as most appropriate under the circumstances.

Maximax Strategy : This optimistic strategy aims to maximize the best possible outcome by evaluating all available alternatives and selecting the one offering the highest potential gain.

Maximin Strategy : This conservative approach seeks to maximize the minimum possible outcome. It involves evaluating the worst-case scenarios for each alternative and selecting the one with the highest minimum payoff. This strategy is particularly relevant in situations where the cost of failure is high and unacceptable.

4. Type of Decision Making

4.1. Strategic Decision Making

Strategic decisions involve long-term planning, typically spanning two to five years. At this level, they are characterized by their high-level nature and are often difficult to reverse due to their broad impact and long-term implications. (Farahanim Misni, 2017). Strategic

decisions are closely aligned with the organization's overarching policies and are typically made by senior management. These decisions often entail substantial financial commitments, and even minor errors in judgment can have serious consequences for the enterprise. (Maiti, 2020)

4.2. Tactical Decision

Tactical decisions are typically made over medium- to long-term timeframes, such as monthly, quarterly, or annual periods. In logistics, common examples include production planning, transportation planning, and resource allocation. These decisions are generally made by middle management or logistics engineers and often rely on disaggregated data for detailed, operationally focused analysis. (Seifi, 2011)

4.3. Operational Decision

Operational decisions are routine, repeatable choices made within daily business activities. They are executed in real time as processes unfold, guiding immediate next steps or determining task outcomes. Due to their time-sensitive nature and structured format, they require little deliberation and, unlike strategic decisions, are well-suited for automation. (Steve Craggs, 2013)

5. Principal Elements Shaping Decision Outcomes

The key factors influencing decision making include the following (Gupta, 2022) :

What is the necessity of this decision, and who stands to benefit or be adversely affected by it ?

FBER

87

How urgent is the decision, and can it be postponed without compromising organizational priorities ?

What are the immediate and long-term objectives associated with the decision, and what are its probabilistic or stochastic implications for other organizational functions and future goals?

Decisions without financial implications are generally easier to make. However, for complex, high-stakes decisions—particularly those involving significant financial commitments—the final choice is often guided by the intuition of experienced decision-makers with proven track records. While logical reasoning, supported by mathematical or statistical models and brainstorming techniques, helps objectively identify alternatives and evaluate risks, intuition frequently plays a decisive role in the final judgment.

In practice, the ultimate decision often diverges significantly from initially proposed options—or, in some cases, no decision is made at all. Such postponement or deferral constitutes a decision in itself, reflecting the inherent uncertainty and complexity of the decision-making environment.

6. Steps of Decision Outcome

6.1. Problem Identification

One of the most challenging aspects of the decision-making process is accurately defining the underlying problem. Executives often face unsatisfactory situations where the precise nature of the issue remains unclear, complicating the path to effective resolution. (Obi, 2014) Consequently, thorough analysis and diagnosis of the issue are essential to accurately identify the core problem requiring attention, along with its relevant aspects and dimensions.

6.2. *Gathering Relevant Information*

After determining the decision to be made, it is essential to gather pertinent information to support the process. Following problem identification and analysis, the next phase involves generating alternative solutions. The primary objective of this step is to identify the most effective course of action among available options. During this process, managers often encounter innovative or unconventional approaches that may offer valuable solutions to the issue at hand (Suraj Panpatte, 2019).

6.3. *Identifying alternatives*

Identifying alternatives involves exploring various strategies to transform the current situation into the desired outcome. Whether pre-existing or developed during the decision-making process, each must satisfy established criteria. When alternatives are finite, each can be evaluated individually for feasibility; non-viable options are eliminated, yielding a clear list of contenders. For infinite sets, mathematical constraints guide selection by defining conditions each solution must meet (Al-Tarawneh, 2012).

6.4. *Developing alternative solutions*

The third stage involves evaluating potential solutions based on established decision criteria. These criteria should align with the organization's objectives to ensure consistency and relevance. Once identified, they enable structured comparison of alternatives, supporting informed decision-making (Mulyono H. P., 2020)

6.5. *Implementation of the Decision*

Once a decision has been made, it must be effectively implemented. This stage typically requires allocating resources to support the chosen course of action. Successful implementation is critical, as even a well-informed, strategic decision can fail if not executed properly (Ejekwu, 2018).

6.6. *Taking Action*

Following the decision-making process, the chosen option must be translated into concrete actions. This involves developing a structured plan outlining the steps required for effective implementation. Tools such as Lucidchart can visually map project components and workflows. Once established, the plan requires delegating responsibilities and mobilizing the team to execute tasks and achieve the desired outcome. (Suraj Panpatte, 2019)

6.7. *Evaluating Results*

The final stage of the decision-making process involves evaluating the outcomes of the implemented decision. This requires gathering relevant data to analyze how well the chosen solution achieved its intended objectives. Establishing clear goals and measurable success indicators beforehand enables a critical assessment of effectiveness and provides insights for future decisions. (Mulyono H. P., 2020)

7. **The Role of Multi Criteria Analysis in Decision Making**

In today's increasingly complex and volatile decision-making environment, multi-criteria analysis (MCA) methods have become essential. This need stems from dual challenges of uncertainty and randomness, alongside global disruptions such as geopolitical conflicts, most notably the Russia-Ukraine war, that have significantly impacted the global economy. Climate change continues to pressure national economies, while rapid technological advancements

have transformed consumer behavior and lifestyles, positioning technology as a central driver of economic activity.

Given these dynamics, adopting modern scientific approaches to decision-making, including advanced tools such as computer programs and AI-based software, is imperative. These systems enable institutions to manage diverse processes, regardless of complexity. MCA has attracted considerable researcher attention for its ability to address complex problems by integrating diverse information sources into mathematical models of simplified elements, facilitating clearer understanding and analysis of the issues at hand.

The integration of computer-based tools has further accelerated MCA adoption by enabling efficient handling of multi-variable problems, thereby saving time and effort in decision-making. Moreover, MCA reduces subjective bias, enhances transparency, and provides a more rational basis for evaluating options. It also supports ranking and prioritizing alternatives, guiding decision-makers toward optimal solutions.

MCA is a relatively recent methodology for evaluating and selecting projects with complex socio-economic implications. It involves separately assessing individual criteria, each measured in its appropriate dimension. Because these criteria vary in importance, they must be weighted accordingly. Assigning these weights is a critical task requiring both responsibility and expertise, as the weighting process significantly influences the final evaluation outcomes (Barfod & Leleur, 2014). Two fundamental approaches are commonly recognized for addressing multiple criteria decision-making (MCDM) problems: Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM) (Kahraman, 2008). This study distinguishes between Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM).

Table 1. Difference between MADM and MODM

MADM	MODM
MODM entails formulating the most suitable alternative by evaluating trade-offs among interrelated design constraints.	MODM assumes a theoretically infinite set of possible alternatives, with trade-offs among design criteria typically represented through continuous mathematical functions.
MADM involves selecting from various possible courses of action, each characterized by multiple, often conflicting, attributes.	Unlike predefined options, MODM establishes a mathematical framework for generating decision alternatives
The MADM framework requires choosing among predefined decision alternatives, each described by a set of attributes.	Each generated alternative is evaluated based on its alignment with one or more specified objectives
MADM problems typically assume a finite, predetermined set of alternatives.	Given the potentially vast number of alternatives, solving a MODM problem requires a selection process to identify the most suitable option(s).
Addressing a MADM problem generally involves sorting and ranking available options	

Source: Kahraman, C. (2008). p: 18

8. Fuzzy Goal Programing

Goal programming (GP) is a multi-criteria decision-making technique in operations

research, widely applied to complex decision problems. (Aneirson Francisco da Silva F. A., 2018). Goal programming (GP) can be regarded as an extension or generalization of linear programming, designed to accommodate multiple, often conflicting, objective criteria (Ryńca & Ziaean, 2021). This technique was originally introduced by Charnes and Cooper in the early 1960s. It represents a valuable approach to decision-making (DM), as it simultaneously accounts for multiple objectives to identify an optimal solution. A typical formulation of the multi-objective programming model is presented as follows: (A Charnes, 1955)

$$\begin{cases} \min |f_i(x) - g_i| \\ \text{subject to} \\ Cx \leq c \\ x_j \geq 0 \quad j = (1, 2, \dots, n) \end{cases}$$

Let g_i and $f_i(x)$ denote, respectively, the aspiration level (i.e., the target) and the actual achievement level of objective j , for $j=1,2,\dots,n$

X_j : decision variables , a_{ij} : technological coefficients

Cx : constraint coefficient matrix , c : right-hand side vector of the model

The corresponding mathematical model can be expressed as follows (Jean Maec Martel, 1990)

$$\begin{cases} \min Z = \sum_{i=1}^p (\delta_i^- + \delta_i^+) \\ \text{subject to:} \\ \sum_{j=1}^n a_{ij}x_j - \delta_i^+ + \delta_i^- = g_i \\ Cx \leq c \end{cases}$$

δ_i^+ denotes the amount by which the achievement of objective j exceeds its target level, while the latter indicates the extent to which it falls short of that goal.

9. Fuzzy Goal Programing with Linear Membership Function

The previous model proved inadequate for many contemporary decision-making scenarios. Decision-makers often face significant challenges due to the volatile nature of information associated with objectives. Moreover, in uncertain and dynamic environments, available data may be imprecise or incomplete, further complicating the process. To address these limitations, numerous researchers have introduced fuzzy goal programming (FGP), which effectively incorporates and manages uncertainty in complex decision-making contexts.

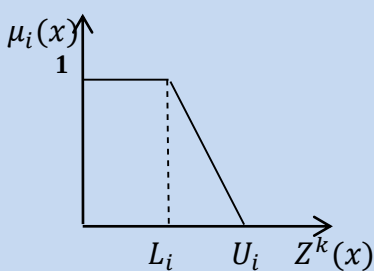
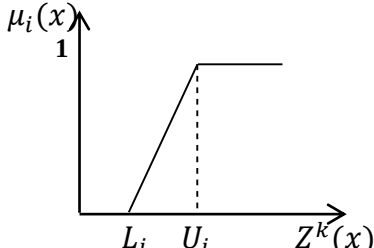
The concept of fuzzy sets was first introduced by Zadeh (1965); since this seminal work, researchers have widely adopted this framework for optimization in multi-criteria decision-making. For instance, Bellman and Zadeh (1970) explored fuzzy set applications in decision contexts, while Zimmermann (1976, 1978) developed fuzzy linear programming models for single and multiple objectives. Narasimhan (1980) proposed an FGP technique to represent imprecision in aspiration levels, and Yang et al. (1991) extended the FGP model with a nonlinear membership function. (Belaïd Aouni, 2014).

As outlined by Zimmerman, a fuzzy goal programming (FGP) model can be formulated as follows (Zimmerman, 1978) :

$$\begin{cases} \text{opt } Z^k \cong CX \\ \text{subject to} \\ AX \preceq b_i \\ x \geq 0 \end{cases}$$

The symbol $\cong$ represents the fuzzy equivalent of the equality sign and denotes the fuzzy aspiration level.

Table 2. Types of linear membership function

Membership function	Analytical definition
	$\mu_i = \lambda = \begin{cases} 1 & \text{if } Z^k(x) \leq L_i \\ \frac{U_i - Z^k(x)}{U_i - L_i} & \text{if } L_i \leq Z^k(x) \leq U_i \\ 0 & \text{if } Z^k(x) \geq U_i \end{cases}$
	$\mu_i = \lambda = \begin{cases} 1 & \text{if } Z^k(x) \geq U_i \\ \frac{Z^k(x) - L_i}{U_i - L_i} & \text{if } L_i \leq Z^k(x) \leq U_i \\ 0 & \text{if } Z^k(x) \leq L_i \end{cases}$

FBER

91

Source: Linag-Hsuan Chen, 2001, page

U_i , L_i are the upper and lower bounds of the membership functions μ_i is the membership function where $\mu_i = \lambda$ represents the degree of satisfaction of the decision maker. $\lambda \in [0,1]$

10. Fuzzy Goal Programing with Exponential Membership Function

R. J. Li and E. Stanley Lee consider these functions among the most significant categories of nonlinear functions extensively examined by researchers, owing to two principal factors (R.J. Li, 1991). The first rationale is the relative simplicity with which such problems can be reformulated as linear models. The second concerns the inherent flexibility of these functions and the claim that exponential representations offer a more realistic framework for modeling a wide range of decision-making scenarios. Notable contributions to this area include the works of : (Sakawa, 1983), (Christer Carlsson, 1986), (Anoop Kumar Dhingra, 1991)

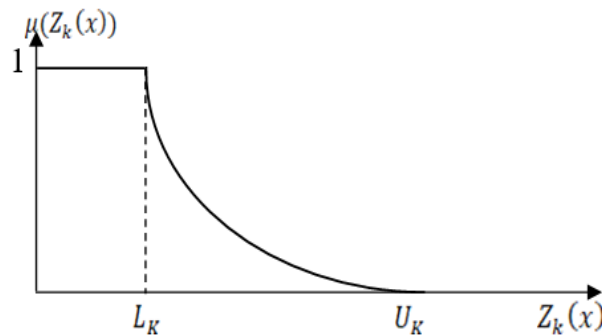
The exponential membership function employed in fuzzy goal programming models, as formulated by R. J. Li and E. Stanley Lee, is mathematically expressed as follows (R.J. Li, 1991)

$$\mu_k(Z^k(x)) = \begin{cases} 1 & \text{if } Z^k \leq Z_l^k \\ \frac{e^{\left(-\alpha \left(\frac{Z^k - Z_l^k}{Z_u^k - Z_l^k}\right)\right)} - e^{-\alpha}}{1 - e^{-\alpha}} & \text{if } Z_l^k \leq Z^k \leq Z_u^k \\ 0 & \text{if } Z^k \geq Z_u^k \end{cases}$$

The canonical form of this function, as delineated by the aforementioned researchers, is given by (Bodkhe, 2023)

$$\begin{cases} \text{Max } \lambda \\ \text{subject to:} \\ \lambda \leq \frac{e^{(-s\psi_k(x))} - e^{-s}}{1 - e^{-s}} & k = 1, 2, \dots, p \\ AX \lesseqgtr b_i \\ x_{ij} \geq 0 \end{cases}$$

This type of membership function is graphically depicted as follow (Bari., 2014)



$$\begin{cases} \text{Max } \lambda \\ \text{subject to:} \\ \lambda \leq \frac{e^{(-s\psi_k(x))} - e^{-s}}{1 - e^{-s}} & k = 1, 2, \dots, p \\ AX \lesseqgtr b_j \\ x_i \geq 0 \end{cases}$$

The equivalent crisp model for the fuzzy model can be formulated as follows (Bodkhe., 2023)

11. Model Implementation

We focus on the practical implementation of the fuzzy goal programming framework, with particular emphasis on Zimmermann's model, which employs linear membership functions. The objective is to demonstrate how this approach can be applied to prioritizing loan applications. An empirical study was conducted at the Tlemcen Agency of the Local Development Bank (BDL), where nine loan applications were evaluated. Ultimately, four applications were approved: two long-term loans, one medium-term loan, and one short-term loan. The dataset, presented in the following table, was obtained through collaboration with a bank staff member.

Table 1. Table title

		Rate of return (%)	Loan amount (million DA)	Repayment method	Loan duration (years)	Environment	Guarantee (million DA)	Degree of risk
Long term	Loan 1	3.5	342	4	15	1	272	1.5
	Loan 2	3.7	180	2	20	1	156	2
	Loan 3	3.5	110	4	15	2	78	0
	Loan 4	2	250	4	20	1	210	1
Medium term	Loan 5	6	40	2	6	1	40	0.5
	Loan 6	6	68	2	7	1	58	1
	Loan 7	6	162	2	6	1	118	1
Short term	Loan 8	8	60	1	1	3	38	0.5
	Loan 9	8.5	30	1	1	1	24	1.5

FBER

93

Based on the table and the collected information, the model constraints can be formulated as follows: let X_i denote the decision variable corresponding to loan application i .

The goals

The first objective concerns the total loan amount: the aggregate value of approved applications must not exceed the agency's available financial capacity (i.e., the budget at hand). Due to uncertainties noted by the bank employee regarding certain details, the aspiration level for this objective was deemed imprecise and thus determined by the decision-maker's judgment. The acceptable threshold was set in the range of 500 to 680 million dinars.

The second objective relates to the expected rate of return. The decision-maker seeks to ensure a minimum return of 24% for each loan, while rejecting any application yielding less than 18%. Given that four loans are to be approved, the cumulative return must therefore lie between 72% and 96%.

The constraints

Loan duration is influenced by economic activity and classified into three categories: short-, medium-, and long-term. The decision-maker evaluates applications in line with the bank's policy, which establishes a hierarchical framework based on the number of repayment years and corresponding interest rates.

Repayment Method

Loan repayment is structured according to the following scale

→ annual repayment , 3 → semestrial repaymen

2→ seasonal repayment , 1→ monthly repayment

The bank seeks to ensure that the guarantee value approaches 100%. Given that four loans are to be approved, the corresponding aggregate value on the right-hand side of the model is set at 400.

Environment: In this context, the ranking scale from 1 to 3 reflects the degree of a project's contribution to pollution, with higher values indicating a greater environmental impact

Total limit of the selected loans :

$$\begin{aligned}x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 &= 4 \\x_1 + x_2 + x_3 + x_4 &= 2 \\x_5 + x_6 + x_7 &= 1 \\x_8 + x_9 &= 1\end{aligned}$$

The mathematical model of these objectives and constraints is as follows:

FBER

94

$\left\{ \begin{array}{l} \text{Max } \lambda \\ \text{subject to} \\ \lambda \leq \frac{e^{(-\alpha(\frac{500-Z_1}{180}))} - e^{-\alpha}}{1 - e^{-\alpha}} \\ \lambda \geq \frac{e^{(-\alpha(\frac{Z_2-72}{24}))} - e^{-\alpha}}{1 - e^{-\alpha}} \\ \sum_{i=1}^9 d_i x_i \leq 18 \\ \sum_{i=1}^9 m_i x_i \leq 4 \\ \sum_{i=1}^9 g_i x_i \leq 400 \\ \sum_{i=1}^9 e_i x_i \leq 3 \\ \sum_{i=1}^9 x_i = 4 \\ \sum_{i=1}^4 x_i = 2 \\ \sum_{i=5}^7 x_i = 1 \\ \sum_{i=8}^9 x_i = 1 \\ 0 \leq \lambda \leq 1 \end{array} \right.$	$z_1 = \sum_{i=1}^9 a_i x_i ,$ a_i: represents the value of each loan $z_2 = \sum_{i=1}^9 r_i x_i$ r_i: represents the rate of return of each loan d_i: represents the duration of each loan m_i: represents the repayment method of each loan g_i: represents the guarantee of each loan e_i: represents the degree of pollution of each project
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The solution of this model with Lingo software is as follow:

$$\begin{aligned}x_2 = x_3 = x_5 = x_8 &= 1 \\x_1 = x_4 = x_6 = x_7 = x_9 &= 0 \\ \lambda &= 0.61\end{aligned}$$

Zimmermann's fuzzy goal programming model stands out as a versatile decision-support tool, particularly in the context of loan prioritization at the Tlemcen Agency of the Local Development Bank (BDL). By selecting applications No. 2, 3, 5, and 8 with an impressive 61.11% decision-maker satisfaction level, the model demonstrates its ability to navigate complex, multi-objective scenarios under real-world constraints. Traditional crisp optimization methods, which rely on binary yes/no decisions and precise parameters, often fail here: they demand exact budget figures, fixed return thresholds, and unambiguous priorities—inputs rarely available in practice due to economic volatility, incomplete data, or subjective risk assessments. In contrast, Zimmermann's fuzzy approach uses linear membership functions to quantify "degrees of satisfaction," allowing aspiration levels (e.g., total loan amounts between 500–680 millions dinars or returns of 72–96%) to flex within realistic ranges. This results in balanced outcomes that respect bank policies on loan durations and guarantees while maximizing overall utility.

The model's strength lies in its transparent handling of trade-offs, fostering stakeholder confidence. For instance, approving a mix of two long-term, one medium-term, and one short-term loan reflects hierarchical policy preferences without overcommitting resources. Bank staff, who provided the dataset amid noted uncertainties, can now validate results against intuition, reducing perceived risk. Quantitatively, the 61.11% satisfaction—derived from aggregated membership values—outperforms heuristic methods (e.g., simple ranking by return), which might prioritize high-risk/high-return loans at the expense of guarantees, potentially leading to defaults. Empirically, this aligns with fuzzy set theory's core tenet: decisions in ambiguous environments improve when vagueness is modeled explicitly rather than ignored.

Practically, this empowers financial institutions like BDL to operationalize fuzzy programming via accessible tools like LINGO or Excel solvers, scaling from nine-application cases to portfolio-wide analyses. It mitigates common pitfalls in credit decisions, such as over-reliance on historical data amid inflation or sector shifts in Algeria's economy.

12. Conclusion

The acquisition of managerial experience is widely recognized as a factor that facilitates decision-making and helps organizations overcome various challenges. However, in the current context, such experience alone is insufficient. The dynamic nature of today's economic environment demands precision, quality, and speed simultaneously. This requirement is largely driven by technological transformations, particularly the rise of artificial intelligence, which profoundly influence economic structures and lifestyles. Alongside these technological shifts, geopolitical developments and climate change compel us to reconsider traditional decision-making methods and adopt modern scientific approaches for organizational management.

To illustrate one such approach, this study introduces the fuzzy goal programming with exponential membership function, a well-established method for handling ambiguous objectives. The model enables the resolution of loan allocation problems involving conflicting and imprecise goals. Ambiguity in aspiration levels represents one of the most significant challenges faced by managers in contemporary business environments. The lack of clarity, or the inability to rely on precise information during the decision-making process, necessitates the development of methods adapted to the pace of economic evolution.

Moreover, the fundamental difficulty in decision-making lies in the fact that economic problems are not purely mathematical in nature; rather, they belong to the domain of the social sciences. This complexity makes the selection of an appropriate mathematical model particularly challenging, especially when both quantitative and qualitative variables are involved. For this reason, we advocate the establishment of specialized operations research

departments that integrate economics, mathematics, and computer science, thereby enabling a deeper understanding and more effective modeling of such problems. In addition, strengthening collaboration between academia and the business sector is essential to foster managerial expertise and to train organizational leaders in the application of these modern scientific methods.

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