International Journal of Applied Operational Research
Vol. 14, No. 4, pp. 39-61, Autumn 2026

Journal homepage: ijorlu.liau.ac.ir

A system dynamics–based evaluation of fiscal regimes in mining projects using fuzzy cognitive mapping: Evidence from Iranian state-owned mines

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Received: 13 April 2026; **Accepted:** 7 September 2026

Abstract Current study aims to simulate and evaluate fiscal regimes in state-owned mining projects under the Iranian Mines and Mining Industries Development and Renovation Organization (IMIDRO), employing an integrated framework of fuzzy decision-making models and system dynamics simulation. First, a comprehensive set of indicators influencing mining fiscal regimes was identified through reviewing theoretical literature, tax regulations, and empirical studies. Subsequently, using the fuzzy Delphi method and expert opinions in mineral economics, 20 key indicators were confirmed out of an initial list of 38. Next, the Fuzzy Cognitive Mapping (FCM) technique was used to determine the strength and direction of interrelations among indicators. The variables "metal reserves before taxation" and "net project return" were identified as the most strategic drivers of the system. In the final stage, in order to analyze the dynamic behavior of financial and technical variables over time, a System Dynamics (SD) model was developed and simulated using Vensim PLE software. The simulation results revealed that increasing tax rates and royalty fees, although leading to higher short-term government revenue, ultimately causes a decline in investment, productivity, and economic returns of mining projects in and Renovation Organization (IMIDRO), employing an integrated framework of fuzzy decision-making models and system dynamics simulation. Conversely, intelligent adjustment of tax rates and achieving a balance between government revenue and investment attractiveness can ensure the economic sustainability of the mining sector. By integrating the fuzzy Delphi, FCM, and system dynamics methodologies, this research provides a scientific and dynamic framework for evaluating and optimizing fiscal regimes in the mining industry. The proposed framework can serve as a decision-support tool for IMIDRO and other policymaking institutions in formulating fiscal policies, designing optimal taxation models, and enhancing the economic sustainability of national mining projects.

Keywords: Fiscal Regime, Mining Projects, Fuzzy Delphi, Fuzzy Cognitive Mapping (FCM), System Dynamics (SD).

1 Introduction

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[DOI: 10.71885/ijorlu-2026-4-724]

The evaluation of fiscal systems in mining projects is a multifaceted and critical issue that is directly linked to countries' economic growth and natural resource management. One of the key aspects of this issue is the analysis and simulation of the performance of different fiscal systems under varying economic and political conditions [1]. Such simulations help clarify how fiscal and non-fiscal instruments affect mining projects and enable the prediction of their financial outcomes [2]. Moreover, the application of simulation in the evaluation of mining projects considering changes in mineral prices, fluctuations in tax policies, costs, and investment levels can support more accurate decision-making regarding project value and risk [3]. Risk assessment and sensitivity analysis of mining projects are also of great importance, as factors such as changes in fiscal systems, price volatility, regulatory and legal amendments, and market conditions all significantly influence project performance [4].

Iran's mineral reserves represent one of the country's major economic potentials, widely distributed across diverse geographical regions [5]. Currently, Iran possesses more than 68 types of non-oil mineral resources, with estimated reserves of approximately 43 billion tons, ranking among the top 15 countries worldwide in terms of metallic and non-metallic minerals [6]. The substantial potential of the mining sector in Iran has elevated this sector to a strategic priority, and according to Article 2 of the Sixth Five-Year Economic, Social, and Cultural Development Plan, it has been identified as one of the country's core development pillars. Effective utilization of this latent capacity can increase national income and reduce the country's dependence on oil revenues [7]. Furthermore, since mines supply essential raw materials for numerous industries, the development of the mining sector can decrease reliance on imported inputs and contribute to industrial self-sufficiency [8]. The role of mining in the national economy is not limited to increasing national income and economic growth; it also has significant potential to generate employment and reduce unemployment and poverty [9]. The mining sector and mineral industries increase household incomes not only through direct employment but also indirectly through backward and forward linkages with other economic sectors such as transportation, manufacturing, construction, and food industries thereby stimulating production and employment in these sectors [10]. The geographical distribution of mines further highlights the sector's capacity to contribute to economic development, as many mining operations are located in underdeveloped and less-privileged regions [11]. Consequently, the mining sector can play a crucial role in promoting balanced regional development by strengthening local economies, creating job opportunities in deprived areas, reducing excessive migration, and fostering regional equity [12]. Another important economic function of the mining sector is its contribution to government revenues [13]. Taxes and royalties constitute two major sources of public revenue derived from the extraction and production of mineral resources [14]. In addition, export and import taxes on mineral products, as well as corporate income taxes on mining companies, represent other significant revenue streams for governments in mineral-producing countries [15]. Therefore, the expansion of mining and mineral-processing activities can provide a stable and sustainable source of government income [16].

The central issue addressed in this research is that, despite the high profitability potential of mining projects, they are exposed to substantial risks that must be managed through an appropriate fiscal system. Selecting an optimal fiscal regime that simultaneously increases government revenue and preserves investment incentives is one of the main challenges faced by policymakers. An overly lenient fiscal system may undermine public interests, whereas an excessively stringent regime may discourage investors from participating in mining activities; both scenarios can lead to adverse economic consequences. Furthermore, many existing

[DOI: 10.71885/ijorlu-2026-4-724]

models used to evaluate fiscal systems are static in nature and lack the capability to analyze dynamic changes in project behavior and environmental conditions over time. Continuously evolving economic, political, and global market conditions necessitate a dynamic and adaptive modeling approach. Additionally, factors such as business culture, legal and regulatory frameworks, interest rates, and inflation also influence fiscal systems but are not adequately captured in traditional models. The objective of this study is to design and develop a comprehensive model capable of thoroughly evaluating the impacts of different fiscal regimes on state-owned mining projects under the Iranian Mines and Mining Industries Development and Renovation Organization (IMIDRO). The proposed model is able to analyze technical and economic variables over time and calculate key financial indicators such as net present value, effective tax rate, and other relevant performance measures. In this way, the study offers an alternative to existing static models that are limited in long-term analysis. Ultimately, this research seeks to provide a practical decision-making framework that enables managers and policymakers to better understand the effects of various fiscal policies and to propose strategies for improving performance and mitigating risks in mining projects.

The remainder of the paper is organized as follows. Section 2 presents a review of the existing literature to identify the research gap. Section 3 describes the proposed research methodology. Section 4 reports and discusses the research findings. Finally, Section 5 provides the conclusions along with suggestions for future research.

2 Literature review

Huang et al. [9] predicted the peak particle velocity (PPV) caused by blasting in mines. The study was carried out in two stages. In the first stage, the Fuzzy Delphi method was used to identify the most influential input variables affecting PPV based on expert opinions. In the second stage, the identified parameters were employed in hybrid artificial neural network–based models, including GA-ANN, PSO-ANN, ICA-ANN, ABC-ANN, and FA-ANN, to predict PPV. The results indicated that all hybrid models had predictive capability; however, the FA-ANN model demonstrated the best performance in terms of prediction accuracy. This study showed that combining the fuzzy Delphi method with hybrid neural network models can be an effective tool for managing and controlling blast-induced vibrations in mines. Al-shahrani et al. [4] presented a study for develop a hybrid multi-criteria fuzzy framework for identifying key barriers to the implementation of sustainable I-Based cloud systems in the information technology industry. The aim of current research was to identified the key barriers to developing a sustainable artificial intelligence–based cloud system in IT businesses. For this purpose, integrated hybrid multi-criteria decision-making (MCDM) model was applied. Kanokfanovich et al. [9] presented a new model for a sustainable healthcare supply chain with a patient safety priority using the fuzzy Delphi method to identify healthcare workers' perspectives. For this purpose, a systematic literature review was used to identify 35 potential attributes. Subsequently, by applying the Fuzzy Delphi Method (FDM) and involving 13 healthcare experts, appropriate and consensual attributes were identified, resulting in the selection of 22 attributes. The findings indicated that integrating the technological dimension with the three traditional pillars of sustainability can contribute to the strategic design of a sustainable healthcare supply chain and improve safety in healthcare environments. Han et al. [7] investigated the factors influencing miners' psychological dilemmas in response to the rapid transition toward a low-carbon economy in China. For this

[DOI: 10.71885/ijorlu-2026-4-724]

purpose, factors influence one another were analyzed using integrated interpretive structural modeling (ISM) and the MICMAC method. Banda [5], presented a system dynamics model for evaluating the impact of tax regimes on mining projects, for investigating the role of taxation systems in the mining sector. Ghasemi et al. [6] identified the key barriers to implementing sustainable practices in Pakistan's mining industry. For this purpose, 11 major barriers were first identified through a systematic literature review and by incorporating stakeholders' opinions. Then, using Interpretive Structural Modeling (ISM), the hierarchical structure of these barriers was mapped across four levels of influence, and the relationships among them were analyzed. Subsequently, through MICMAC analysis, the barriers were classified into four groups based on their driving power and dependence. Mohammadfam et al. [13], analyzed of factors affecting human fatigue reliability in mining process design using the fuzzy delphi and DEMATEL methods, focused on identifying and analyzing factors influencing human errors in the design of surface mining processes in Iran. For this purpose, used the Fuzzy Delphi method, expert consensus on the importance of each factor was obtained, and 19 factors with an impact score higher than 0.7 were selected. To analyze causal relationships among these factors, then Fuzzy DEMATEL method was applied. Tirovolas and Stylios [17] introduced a fuzzy cognitive map for predicting engine health status. Improved predictive maintenance (PdM) forecasting and the estimation of the remaining useful life (RUL) of engines. Fuzzy Cognitive Maps (FCMs) were proposed as a method for predicting the engine Health Index (HI). To design the FCM model, four different learning algorithms were applied and tested to determine the optimal model parameters and achieve the highest prediction accuracy. Khaba et al. [13] identified and examined the contextual relationships among key lean enablers in the Indian coal industry. Initially, through a literature review and expert opinions, an ISM-based conceptual model was developed and hierarchical relationships among the factors were identified. Subsequently, MICMAC analysis was employed to classify the factors into different groups, and the ISM model was validated using Structural Equation Modeling (SEM). Menon et al. [12] identified and analyzed the main barriers to implementing a sustainable supply chain in India's electronics industry. Through a review of the literature and expert opinions, 11 major barriers were identified and classified into three categories: policy-making, human resources, and technology. The hierarchical structure and the relationships among these barriers were determined using the Interpretive Structural Modeling (ISM) method.

A review of the existing literature reveals that a wide range of studies have employed fuzzy-based methods, system dynamics (SD), and structural modeling techniques to address complex decision-making and sustainability-related challenges across various domains, including mining, healthcare, information technology, and supply chain management. For instance, fuzzy Delphi, DEMATEL, ISM, MICMAC, and fuzzy cognitive mapping (FCM) have been extensively used to identify critical factors, analyze causal relationships, and prioritize barriers or risks in different industrial contexts. In the mining sector, prior studies have primarily focused on technical, operational, human, and environmental issues, such as blast-induced vibrations, human fatigue, safety risks, sustainability barriers, and psychological challenges faced by miners. Although Banda [6] applied a system dynamics approach to evaluate the impact of tax regimes on mining projects, the study did not incorporate fuzzy-based causal modeling techniques to capture uncertainty, expert judgment, and complex feedback relationships among fiscal, operational, and institutional factors. Moreover, existing studies that employ FCM have largely concentrated on identifying barriers, risks, or enablers in areas such as sustainability, safety, and technology adoption, rather than on the comprehensive evaluation of fiscal regimes in mining projects. More

[DOI: 10.71885/ijorlu-2026-4-724]

importantly, the literature lacks an integrated framework that simultaneously combines system dynamics and fuzzy cognitive mapping to evaluate fiscal regimes in mining projects. Such integration is crucial for modeling the dynamic interactions, feedback loops, and hierarchical causal structures that characterize fiscal policies, especially in the context of state-owned mining enterprises, where government intervention, regulatory complexity, and long-term economic objectives play a dominant role. In addition, empirical evidence from Iranian state-owned mines remains scarce, despite the strategic importance of the mining sector in Iran's resource-dependent economy.

3 Methods

The present study is applied in terms of its objective, as its results can be utilized in the financial and managerial policymaking of state-owned mining operations. Based on the above classification, this research is categorized as analytical–mathematical in terms of its analytical approach and as a case study in terms of its empirical nature. While standard System Dynamics nomenclature conceptually distinguishes between stocks (accumulations) and flows (rates), the simulation model implemented in this study was intentionally parameterized as a dynamic algebraic and interconnected auxiliary-variable network to capture monthly policy-feedback mechanisms without imposing unnecessary differential stock lags. The conceptual references in the methodology section have been refined to clarify that core fiscal components such as cumulative revenues, effective tax burdens, and annual royalties operate as time-dependent dynamic auxiliary formulations governed by recursive algebraic relationships in Vensim PLE. This formulation directly reflects the statutory and contractual nature of state mining concessions, resolving any apparent ambiguity between conceptual stock-flow classification and the executed operational model. The stages of conducting this research are as follows:

Step 1: Identification of Indicators

In the first stage, the objective was to identify a set of indicators influencing the evaluation of fiscal regimes in mining projects. To this end, library research, analysis of organizational documents from IMIDRO, review of national tax regulations, and examination of domestic and international studies related to fiscal policies in the mining sector were employed.

At this stage, 38 initial indicators were identified through a review of validate scientific sources and interviews with experts, covering technical, economic, fiscal, managerial, and investment dimensions. These indicators include, but are not limited to:

- Metal reserves before taxation
- Pre-tax cash flow under both regimes
- Metal reserves after taxation
- Post-tax cash flow under both regimes
- Metal reserves under Tax Regimes 1 and 2
- Taxable income under Regime 2
- Corporate income tax rate
- Corporate tax payable under Regime 2
- Inactive metal reserves (in tonnes) before and after taxation
- Dollar value of inactive reserves under Regimes 1 and 2
- Payable mining royalty
- Total taxes payable under both regimes

[DOI: 10.71885/ijorlu-2026-4-724]

- Difference in the value of inactive reserves between the two regimes
- Average metal grade before and after taxation
- Net Present Value (NPV) of post-tax cash flows under both regimes
- Minimum economically mineable grade under both regimes, before and after taxation
- Metal price
- Net Present Value (NPV) of government revenue under both regimes
- Metal recovery from mineral reserves
- Average Effective Tax Rate (AETR) under both regimes
- Marginal Effective Tax Rate (METR) under both regimes
- Mining revenue before taxation
- Net Present Value (NPV) of the mining company
- Dilution (presence of non-metallic material in the extraction process)
- Fiscal period
- Initial investment
- Total final taxes payable
- Timing of initial investment
- Initial Net Present Value under both regimes
- Total marginal cost under Regimes 1 and 2
- Discount rate
- Unit operating cost including Mineral Resource Tax (MRT) and Corporate Income Tax (CIT)
- Unit operating cost excluding mining royalties and taxes
- Interest rate
- Production profile
- Internal Rate of Return (IRR) before taxation under both regimes
- Months and years (as the time unit)
- Internal Rate of Return (IRR) after taxation under both regimes

Step 2: Screening of Indicators Using the Fuzzy Delphi Method

Since not all identified indicators had equal importance, the Fuzzy Delphi Method was used at this stage to confirm, eliminate, or combine indicators. In the Fuzzy Delphi method, instead of using crisp numerical values, linguistic variables and fuzzy membership functions are employed to reduce ambiguity in human judgments. At this stage: A questionnaire was designed and distributed among 20 experts in mining economics and fiscal policymaking. Each indicator was evaluated using a linguistic scale ranging from *"very low"* to *"very high."* The data were converted into triangular fuzzy numbers, and the fuzzy mean was calculated. Indicators with a defuzzified value greater than 0.7 were retained. Finally, 20 key indicators were selected as inputs for the subsequent stages.

Step 3: Fuzzy Cognitive Map (FCM) Analysis

In the fourth stage, the Fuzzy Cognitive Map (FCM) method was employed to determine the strength and direction of relationships among the indicators. This method is a semi-quantitative, graph-based modeling approach that is highly suitable for analyzing complex systems characterized by nonlinear relationships. In this stage: Experts were asked to specify the degree of influence of each indicator on other indicators using the values +1 (positive relationship), 0 (no relationship), and −1 (negative relationship). The data were organized in the form of a cross-impact matrix and entered into MATLAB software. Key indicators were then identified by calculating three main measures:

[DOI: 10.71885/ijorlu-2026-4-724]

- Outdegree (Driving influence)
- Indegree (Dependence)
- Centrality

Step 4: System Dynamics Simulation

In the final stage, **a** system dynamics model was developed and simulated using the outputs obtained from the ISM and FCM analyses. The system dynamics approach was applied to analyze the behavior of key variables over time under different fiscal policy conditions. This method is grounded in feedback theory and the interactive nature of variables.

The simulation process was carried out in four steps:

Definition of the Causal Loop Structure (Causal Loop Diagram):

- Identification of positive (reinforcing) and negative (balancing) feedback loops.
- Establishment of relationships among fiscal variables, production, investment, profit, and reserves.

Identification of Stock and Flow Variables (Stock and Flow Diagram):

- Stock variables: mineral reserves, capital, net revenue.
- Flow variables: extraction rate, taxes paid, investment expenditures.

Specification of Mathematical Relationships among Variables:

- Application of dynamic relationships derived from real data from state-owned mines.

Model Simulation Using Vensim PLE Software:

- Running the model over a multi-year time horizon to analyze system behavior under different scenarios involving changes in tax rates, royalty levels, and investment.

4 Results

4.1 Delphi method results

At this stage, a questionnaire comprising 38 influential criteria affecting the evaluation of fiscal regimes in mining projects was distributed to the expert panel, and they were asked to express their opinions on each criterion using the linguistic variables specified in the questionnaire. The preliminary results of the experts' opinions are presented in Table 1.

Table 1 Importance level of criteria affecting the evaluation of mining project fiscal regimes

No.	Criterion	Very Low	Low	Medium	High	Very High
1	Amount of metal reserves before taxation	0	2	5	13	14
2	Pre-tax cash flow under both regimes	3	11	17	2	1
3	Amount of metal reserves after taxation	0	1	6	14	13
4	Post-tax cash flow under both regimes	22	11	1	0	0
5	Amount of metal reserves under tax regimes 1 and 2	0	0	2	16	16
6	Taxable income under regime 2	12	8	13	1	0
7	Corporate income tax rate	7	6	11	9	1
8	Corporate tax payable under regime 2	1	1	21	7	4
9	Inactive metal reserves (tons) before and after tax	0	1	2	14	17
10	Dollar value of inactive reserves under regimes 1 and 2	0	0	1	11	22
11	Mineral royalty payable	12	6	6	8	2
12	Total taxes payable under both regimes	1	1	9	16	7
13	Difference in the value of inactive reserves between the two regimes	0	1	3	17	13
14	Average metal grade before and after tax	0	0	4	5	25
15	Net Present Value (NPV) of post-tax cash flows under	10	6	7	8	3

[DOI: 10.71885/ijorlu-2026-4-724]

	both regimes					
16	Cut-off grade under both regimes before and after tax	1	1	6	17	9
17	Metal price	0	2	6	9	17
18	Net Present Value of government revenue under both regimes	1	0	12	11	10
19	Metal recovery from mineral reserves	0	2	5	16	11
20	Average Effective Tax Rate (AETR) under both regimes	2	5	6	14	7
21	Marginal Effective Tax Rate (METR) under both regimes	1	5	8	15	5
22	Pre-tax mining revenue	5	3	12	8	6
23	Net Present Value of the mining company	1	4	16	5	8
24	Dilution (presence of non-metallic materials in the extraction process)	1	1	8	11	13
25	Fiscal period	1	2	1	15	15
26	Initial investment	0	2	8	8	16
27	Total final taxes payable	1	9	9	8	7
28	Timing of initial investment	0	1	4	17	12
29	Initial Net Present Value under both regimes	1	4	17	12	0
30	Total marginal cost under regimes 1 and 2	0	2	5	11	16
31	Discount rate	13	6	9	4	2
32	Unit operating cost including Mineral Resource Tax (MRT) and Corporate Income Tax (CIT)	2	2	0	9	21
33	Unit operating cost excluding mineral royalty and taxes	0	4	4	17	9
34	Interest rate	14	14	5	1	0
35	Production profile	0	0	0	18	16
36	Pre-tax Internal Rate of Return (IRR) under both regimes	0	0	0	15	19
37	Months and years (as time units)	0	1	17	14	2
38	Post-tax Internal Rate of Return (IRR) under both regimes	1	4	0	11	

The frequency of experts' opinions on the research indicators is presented in Table 1. To fuzzify the numerical values, the scores are first converted into fuzzy numbers based on the scale shown in Table 3-1. Then, the fuzzy mean of the assigned scores is calculated using Equations (3-2) to (3-4), and subsequently, the fuzzy mean is defuzzified into a crisp value using Equation (4-5). The results of all fuzzy Delphi calculations are presented in Table 4-2. As an example, the fuzzy Delphi calculations for the criterion in Row 1 are as follows. 0 experts assigned a *very low* score, 2 experts assigned a *low* score, 5 experts assigned a *medium* score, 13 experts assigned a *high* score, and 14 experts assigned a *very high* score. Therefore, the fuzzy and non-fuzzy (crisp) scores are obtained as follows:

$$Score_{fuzzy} = \frac{0 \times (0,0,0.25) + 2 \times (0,0.25,0.5) + 5 \times (0.25,0.5,0.75) + 13 \times (0.5,0.75,1) + 14 \times (0.75,1,1)}{34} = (0.537,0.787,0.934) \tag{1}$$

$$Score_{fuzzy} = \frac{0.537 + 0.787 + 0.934}{3} = 0.752$$

In current study, a threshold value of 0.7 is considered. The results indicate the confirmation of 20 indicators and the elimination of 18 indicators, as presented in Table 2.

Table 2 Delphi method results

No.	Criterion	Fuzzy Score	Defuzzified Score	Status
1	Amount of metal reserves before taxation	(0.537,0.787,0.934)	0.752	Accepted

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2	Pre-tax cash flow under both regimes	(0.176,0.404,0.647)	0.409	Rejected
3	Amount of metal reserves after taxation	(0.537,0.787,0.941)	0.755	Accepted
4	Post-tax cash flow under both regimes	(0.007,0.096,0.346)	0.15	Rejected
5	Amount of metal reserves under tax regimes 1 and 2	(0.603,0.853,0.985)	0.814	Accepted
6	Taxable income under regime 2	(0.110,0.272,0.522)	0.301	Rejected
7	Corporate income tax rate	(0.235,0.434,0.676)	0.449	Rejected
8	Corporate tax payable under regime 2	(0.346,0.588,0.809)	0.581	Rejected
9	Inactive metal reserves (tons) before and after tax	(0.596,0.846,0.971)	0.804	Accepted
10	Dollar value of inactive reserves under regimes 1 and 2	(0.654,0.904,0.993)	0.85	Accepted
11	Mineral royalty payable	(0.206,0.368,0.603)	0.392	Rejected
12	Total taxes payable under both regimes	(0.456,0.699,0.897)	0.684	Rejected
13	Difference in the value of inactive reserves between the two regimes	(0.559,0.809,0.963)	0.777	Accepted
14	Average metal grade before and after tax	(0.654,0.904,0.971)	0.843	Accepted
15	Net Present Value (NPV) of post-tax cash flows under both regimes	(0.235,0.412,0.640)	0.429	Rejected
16	Cut-off grade under both regimes before and after tax	(0.493,0.735,0.919)	0.716	Accepted
17	Metal price	(0.551,0.801,0.926)	0.76	Accepted
18	Net Present Value of government revenue under both regimes	(0.471,0.713,0.890)	0.691	Rejected
19	Metal recovery from mineral reserves	(0.515,0.765,0.934)	0.738	Accepted
20	Average Effective Tax Rate (AETR) under both regimes	(0.404,0.640,0.838)	0.627	Rejected
21	Marginal Effective Tax Rate (METR) under both regimes	(0.390,0.632,0.846)	0.623	Rejected
22	Pre-tax mining revenue	(0.338,0.551,0.757)	0.549	Rejected
23	Net Present Value of the mining company	(0.368,0.610,0.801)	0.593	Rejected
24	Dilution (presence of non-metallic materials in the extraction process)	(0.507,0.750,0.904)	0.721	Accepted
25	Fiscal period	(0.559,0.801,0.941)	0.767	Accepted
26	Initial investment	(0.529,0.779,0.912)	0.74	Accepted
27	Total final taxes payable	(0.338,0.581,0.779)	0.566	Rejected
28	Timing of initial investment	(0.544,0.794,0.956)	0.765	Accepted
29	Initial Net Present Value under both regimes	(0.301,0.544,0.794)	0.547	Rejected
30	Total marginal cost under regimes 1 and 2	(0.551,0.801,0.934)	0.762	Accepted
31	Discount rate	(0.169,0.324,0.559)	0.35	Rejected
32	Unit operating cost including Mineral Resource Tax (MRT) and Corporate Income Tax (CIT)	(0.596,0.831,0.926)	0.784	Accepted
33	Unit operating cost excluding mineral royalty and taxes	(0.478,0.728,0.912)	0.706	Accepted
34	Interest rate	(0.051,0.199,0.449)	0.233	Rejected
35	Production profile	(0.618,0.868,1.000)	0.828	Accepted
36	Pre-tax Internal Rate of Return (IRR) under both regimes	(0.640,0.890,1.000)	0.843	Accepted
37	Months and years (as time units)	(0.375,0.625,0.860)	0.62	Rejected
38	Post-tax Internal Rate of Return (IRR) under both regimes	(0.559,0.801,0.919)	0.76	Accepted

4.2 Fuzzy cognitive method results

In this section of the study, the research questionnaire was developed based on the qualitative findings. Accordingly, 20 × 20 matrix was designed in which the rows and columns represent the criteria for evaluating fiscal regimes of mining projects, and it was administered

[DOI: 10.71885/ijorlu-2026-4-724]

to the sample members. Using a three-point scale (–1, 0, and +1), the respondents assessed the extent to which each component influences another and assigned scores to the components. Specifically, a score of –1 indicates an inverse relationship, 0 indicates no relationship, and +1 indicates a positive relationship between the variables.

After collecting the questionnaires, a 20 × 20 matrix representing the relationship matrix was constructed in accordance with Table 3. Once the relationship matrix was established, the indicators of dependence power, driving power, and the centrality index were calculated for each component.

The dependence power index represents the sum of incoming edges to each node (i.e., the sum of the elements in the corresponding column of the relationship matrix). Among the factors affecting the evaluation of mining project fiscal regimes, the amount of metal reserves before taxation (C1), the amount of metal reserves after taxation (C2), inactive metal reserves per ton before and after taxation (C4), operating cost including mineral resource tax (C16), production profile (C18), internal rate of return before taxation (C19), and internal rate of return after taxation (C20) exhibit the highest dependence power, with a value of 18. Figure 1 illustrates a bar chart of the dependence power for each factor.

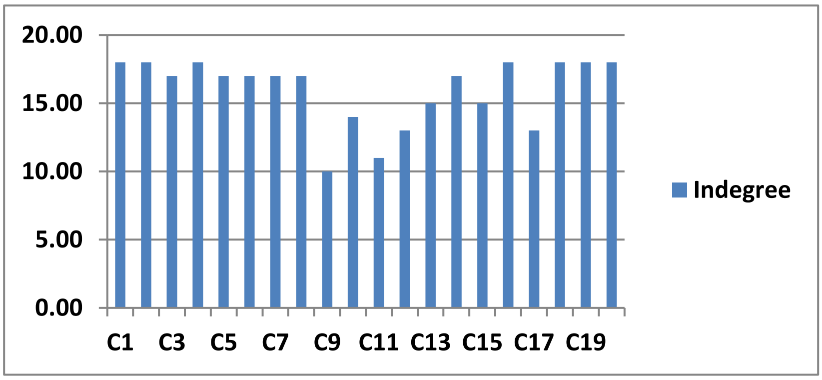

Fig.1 Bar chart of the impact level of criteria affecting the evaluation of fiscal regimes in mining projects

The impact index shows the degree of influence by a factor. In other words, it shows the sum of the edges exiting each node (the sum of the horizontal elements corresponding to each node in the relationship matrix). Here, among the factors for evaluating fiscal regimes in mining projects, the amount of metal reserves before tax (C1) and the difference in the value of inactive reserves between the two regimes (C6) have the highest influence with an influence of 19. Figure 2 shows a bar chart of the influence of each factor.

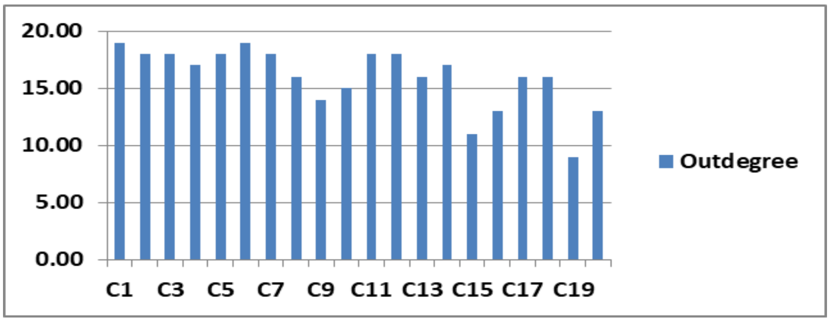

Fig.2 Bar chart of the level of influence of criteria affecting the evaluation of fiscal regimes for mining projects

[DOI: 10.71885/ijorlu-2026-4-724]

Table 3 Impact matrix of criteria for evaluating fiscal regimes for mining projects

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
C1	0.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C2	1.00	0.00	1.00	-1.00	-1.00	-1.00	-1.00	1.00	0.00	-1.00	1.00	-1.00	1.00	-1.00	1.00	1.00	1.00	-1.00	1.00	1.00
C3	1.00	-1.00	0.00	1.00	1.00	-1.00	-1.00	1.00	-1.00	1.00	0.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	1.00	1.00
C4	1.00	-1.00	-1.00	0.00	1.00	-1.00	1.00	1.00	1.00	0.00	-1.00	0.00	-1.00	1.00	-1.00	1.00	1.00	1.00	1.00	1.00
C5	1.00	-1.00	-1.00	-1.00	0.00	1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00
C6	-1.00	1.00	1.00	-1.00	1.00	0.00	1.00	-1.00	1.00	1.00	-1.00	1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00
C7	-1.00	1.00	1.00	1.00	-1.00	1.00	0.00	-1.00	0.00	1.00	1.00	-1.00	1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00
C8	-1.00	1.00	1.00	1.00	-1.00	1.00	1.00	0.00	-1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	1.00
C9	0.00	0.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	0.00	0.00	1.00	0.00	1.00	-1.00	0.00	1.00	-1.00	1.00	1.00	1.00
C10	1.00	1.00	-1.00	0.00	-1.00	-1.00	-1.00	-1.00	0.00	0.00	1.00	-1.00	0.00	1.00	-1.00	1.00	0.00	1.00	1.00	1.00
C11	1.00	1.00	-1.00	1.00	1.00	1.00	-1.00	1.00	1.00	0.00	0.00	1.00	-1.00	1.00	1.00	1.00	-1.00	1.00	1.00	1.00
C12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00
C13	1.00	1.00	1.00	-1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	-1.00	1.00	-1.00	0.00	1.00	-1.00	-1.00
C14	-1.00	-1.00	1.00	-1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.00	-1.00	1.00	0.00	1.00	-1.00	-1.00	1.00	1.00	-1.00
C15	-1.00	-1.00	0.00	1.00	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00
C16	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	1.00	1.00	0.00
C17	1.00	1.00	1.00	-1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	-1.00	1.00	-1.00	0.00	1.00	1.00	1.00
C18	-1.00	-1.00	1.00	-1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.00	-1.00	1.00	0.00	1.00	-1.00	-1.00	0.00	-1.00	1.00
C19	-1.00	-1.00	0.00	1.00	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	1.00	0.00	0.00	1.00
C20	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	1.00	1.00	0.00

The sum of the two preceding factors influence and dependence constitutes the dominance index. Any factor with a higher degree of centrality, in fact, possesses either a greater dependence capacity or a stronger influencing power; therefore, it is regarded as an important factor and should receive special attention. As shown in Table 4-16, among the factors used to evaluate the fiscal regimes of mining projects, the factor amount of metal reserves before tax (C1) has been identified with a capacity of 37. Figure 3 illustrates a bar chart of the level of influence of each factor.

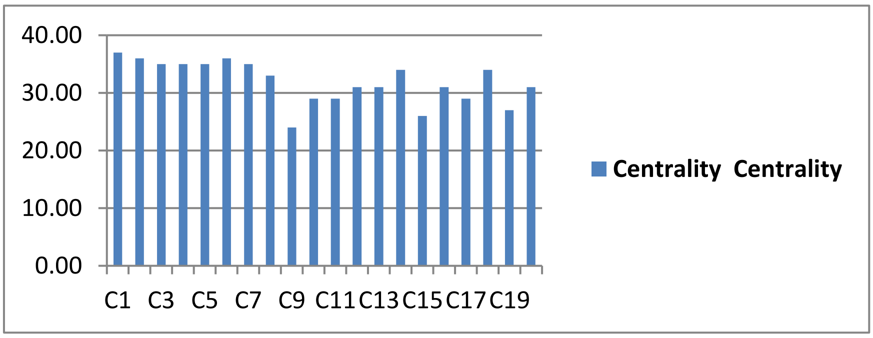

Fig.3 Bar chart of the level of centrality of criteria affecting the evaluation of fiscal regimes for mining projects

4.3 System dynamic results

In this section, system dynamics modeling is employed to evaluate fiscal regimes in mining projects. The system dynamics approach seeks to identify closed feedback loops in order to examine the functioning of the system. A feedback loop essentially consists of a closed chain

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of causal relationships in which a change affects the initial variable. Feedback loops include positive feedback loops, also known as reinforcing loops, as well as negative feedback loops, or so-called balancing loops. These loops are such that if one component changes in a particular direction, the loop reinforces the changes in that direction. Accordingly, a negative feedback loop can be described as a loop in which, if a component changes in a certain direction, the loop resists the change of that component in that direction. In summary, a negative loop plays a neutralizing role and opposes change. It should be noted that all loop relationships are considered positive in this study, since all identified factors, as criteria, influence the evaluation of fiscal regimes in mining projects.

A mining financial regime can be considered as a system comprising fiscal and non-fiscal elements that affect the economics of a mining project. The developed system dynamics model presented in this section is capable of evaluating these impacts over time. This system consists of technical and economic sub-models. The technical subsystem explains the engineering variables of the mine model and includes several variables such as: the amount of metal reserves before taxation; the amount of metal reserves after taxation; the amount of metal reserves under tax regimes 1 and 2; inactive metal reserves (in tons) before and after tax; average metal grade before and after tax; minimum extractable cut-off grade in both regimes before and after tax; metal recovery from mineral reserves; and dilution (the presence of non-metallic materials in the extraction process), which are among the most important variables in the technical subsystem. On the other hand, the economic subsystem describes financial, fiscal, and macroeconomic data. These include: the internal rate of return (IRR) before tax under both regimes; the internal rate of return (IRR) after tax under both regimes; the dollar value of inactive reserves under regimes 1 and 2; the difference in the value of inactive reserves between the two regimes; fiscal period; initial investment; timing of the initial investment; total marginal cost under regimes 1 and 2; unit operating cost including the mineral resource tax (MRT) and corporate income tax; unit operating cost excluding mineral royalties and taxes; and metal price, which are among the most important variables in the economic subsystem. It should be noted that the technical and economic subsystems continuously interact with each other throughout the life of the mine to produce various outputs. The generated results greatly assist the decision-making process. The proposed framework has been developed inspired by the model proposed by Benda [6]. For the final modeling stage, it is first necessary to identify the state variables, flow variables, and auxiliary variables; therefore, this section is devoted to introducing them.

The computational structure and functional equations governing the auxiliary variables in the System Dynamics model (detailed in Table 4) are formulated based on standardized corporate financial accounting and mineral economic appraisal frameworks. The functional notations (e.g., F1, F3, F4) denote explicit mathematical formulations such as compound amortization curves, tax-deductible royalty algorithms, and discounted cash flow routines derived directly from Iranian mining tax statutes and IMIDRO operational guidelines. All variables are assigned standard measurement units (e.g., monetary values in Million USD, metal grades in percentages, and temporal intervals in months), and the associated functional coefficients were parameterized through expert consensus and baseline project cost sheets, ensuring complete mathematical traceability and structural transparency.

Table 4 Introduction of problem variables and their operational definition in the system dynamics model

Row	Vaiables	Variables type	Equation
1	Amount of metal reserves before taxation	Flow	$IF\ THEN\ ELSE(human\ resource \geq 0.1, 0.4, IF\ THEN\ ELSE(human\ resource - es \geq 0.09, 0, 0.2))$

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	(C1)		
2	Amount of metal reserves after taxation (C2)	Decision	$Skilled\ human\ resources/30$
3	Amount of metal reserves under tax regimes 1 and 2 (C3)	Decision	$SMOOTH\ (human\ resources \times 0.21)$
4	Inactive metal reserves (tons) before and after taxation (C4)	Decision	$F3(training)$
5	Dollar value of inactive reserves under tax regimes 1 and 2 (C5)	Flow	$(SMOOTH\ (Change\ in\ the\ rate\ of\ orders, 10))$
6	Difference in the value of inactive reserves between the two regimes (C6)	Decision	$F1(Media\ support)$
7	Average metal grade before and after taxation (C7)	Decision	$SMOOTH\ (human\ resources, 10)$
8	Minimum extractable (cut-off) grade under both regimes before and after taxation (C8)	Decision	$F4\ (Supervision\ over\ implementation\ of\ Laws\ and\ regulations)$
9	Metal price (C9)	Decision	$F3(training)$
10	Metal recovery from mineral reserves (C10)	Decision	$(SMOOTH\ (Change\ in\ the\ rate\ of\ orders, 10))$
11	Dilution (presence of non-metallic materials in the extraction process) (C11)	Decision	$F1(Media\ support)$
12	Fiscal period (C12)	Decision	Skilled human resources/30
13	Initial investment (C13)	Decision	0.4/Skilled human resource
14	Timing of initial investment (C14)	Decision	$(SMOOTH\ (Change\ in\ the\ rate\ of\ orders, 10))$
15	Total marginal cost under tax regimes 1 and 2 (C15)	Decision	$F4\ (Supervision\ over\ implementation\ of\ Laws\ and\ regulations)$
16	Unit operating cost including Mineral Resource Tax (MRT) and Corporate	Decision	$SMOOTH\ (human\ resources, 2)$

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	Income Tax (CIT) (C16)		
17	Unit operating cost excluding mineral royalty and taxes (C17)	Decision	$F3(training)$
18	Production profile (C18)	Decision	$F3(training)$
19	Pre-tax Internal Rate of Return (IRR) under both regimes (C19)	Decision	$F3(training)$
20	Post-tax Internal Rate of Return (IRR) under both regimes (C20)	Decision	$F3(training)$

Figure 4 illustrates the inputs and outputs of the system dynamics model. On the other hand, Figure 5 shows the developed prototype model in the Vensim simulation software. As can be inferred from this figure, the model does not include stocks and flows; rather, it consists solely of technical and economic auxiliary variables. The auxiliary variables, along with their computational formulas, are presented in Table 4-17. The strength of the model lies in the fact that it can evaluate the dynamic behavior of mining fiscal policies over time. Although the model was primarily developed in Vensim, it can also be implemented in other system dynamics software platforms such as Stella, Powersim, AnyLogic, and others.

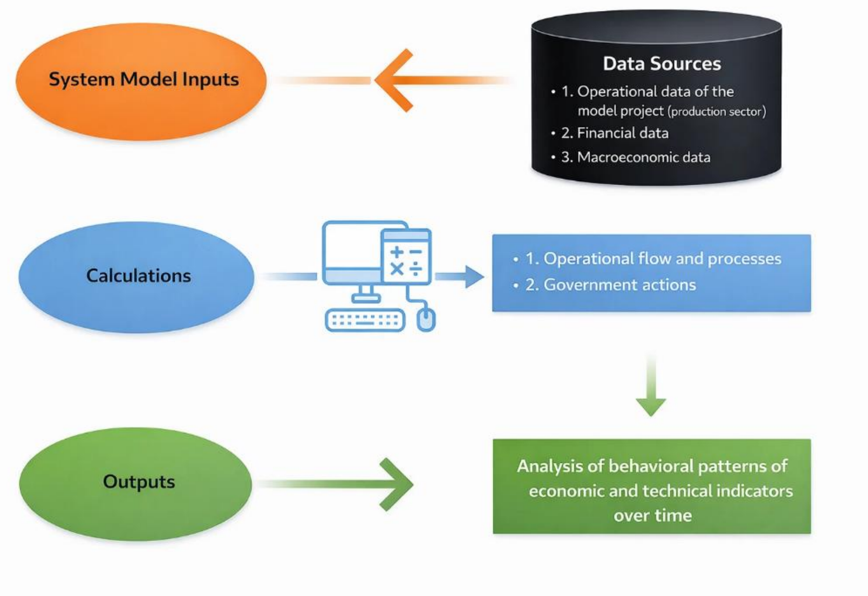

Fig. 4 Inputs, outputs, and calculations of the dynamic model

The circular relationships of the factors are shown in Figure 5. This model is designed based on the interpretive structure determined using the ISM method presented in this study.

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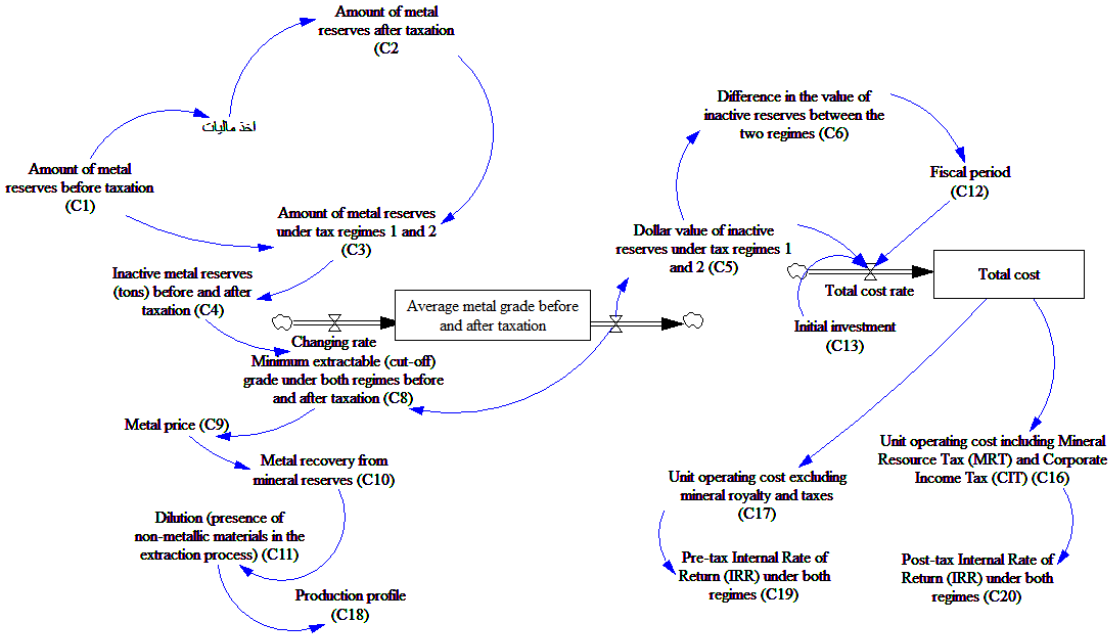

Fig. 5 Loop model for simulating the evaluation of the financial regime in mining projects

Figure 5 illustrates the simulation of revenue generated from improvements in the financial regime of mining projects. Based on the results obtained from the collected data, the revenue resulting from improvements in fiscal regimes considering the influencing factors shows an increasing trend over a 100-month period, indicating the logical behavior of the model.

4.3.1 Validation of the system dynamics model

One of the most important stages of modeling is model validation. Since a system dynamics model usually represents the real operation of actual systems in certain aspects, the closeness of the model to the real world is essential and critical for its validation.

To ensure empirical credibility and robust grounding, the model parameters and causal loops were informed by a structured panel of 20 senior experts comprising mining economists, fiscal policy analysts, and project managers from IMIDRO and affiliated state organizations, each possessing over a decade of operational and policy experience. The System Dynamics (SD) simulation model underwent a multi-stage verification and validation protocol following standard structural and behavioral assessment guidelines. Specifically, structural confirmation, dimensional consistency checks, and extreme condition testing (simulating drastic shifts in tax rates, price volatility, and investment cutoffs) were executed in Vensim PLE alongside sensitivity analyses on critical parameters. As demonstrated by the plausible system trajectories and the boundary tests illustrated in Section 4.4, the model outputs consistently mirrored systemic economic behaviors, confirming that the framework offers high operational validity and structural robustness for policy experimentation.

To ensure the validity of the model's performance, the following tests were conducted, the results of which are described below:

Extreme Condition Test:

In this method, some model variables are subjected to sudden changes and extreme conditions, and the model's behavior is examined. As shown in Figure 6, in the absence of

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improvement in fiscal regimes through an increase in costs revenue experiences a significant decline. Conversely, with the introduction of improvements, revenue increases again.

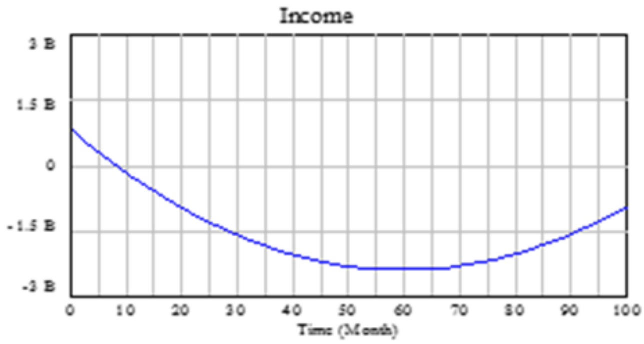

Fig. 6 Limit test for applying and not applying fiscal regimes

Behavior reproduction test:

The purpose of conducting the behavior reproduction test is to compare the simulation results with real-world data in order to ensure the validity of the model's behavioral performance. In this test, the simulated behavior of the model is reproduced and compared with actual data. For this purpose, the absence of financial policy implementation over time has been examined. Considering the influential factors, as the non-implementation of financial policies intensifies over time, costs increase, which indicates the logical behavior of the model.

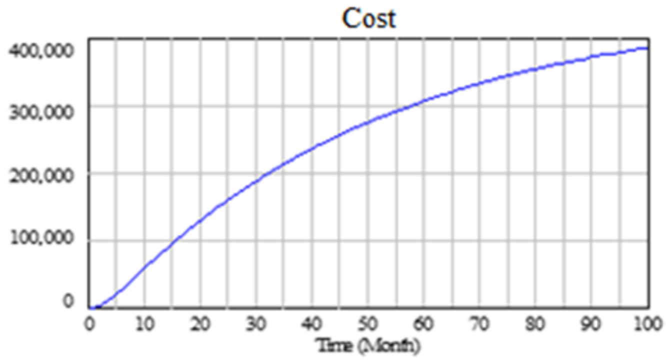

Fig. 7 Material shortage rate over time

4.3.2 Proposed scenarios

In order to achieve the most important objective of system dynamics modeling, it is necessary to examine various potential policies aimed at strengthening and improving the performance of fiscal regimes in mining projects. Among the proposed scenarios (i.e., policies), the policy that yields the best outcomes is selected by managers for implementation in the target system. Therefore, after validating the model and once consensus is reached among the research experts, the results obtained from scenario analysis can be used by mining managers to evaluate different policies for improving the system.

Accordingly, in the present study, after confirming the validity of the model, it was employed to conduct experimental simulations, and the obtained results are presented below. In this research, three scenarios were considered, with economic outcomes namely revenue taken as the basis for scenario development.

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4.3.2.1 Scenario one: Level of metal reserves before taxation with reinforcement of factors at the sixth level

In this scenario, the level of inactive reserves between the two regimes was adjusted to an equal condition, and the model was simulated to assess income levels or economic outcomes by reinforcing the sixth-level factors. These factors include: the amount of metal reserves under the first and second tax regimes; inactive metal reserves (in tons) before and after taxation; average metal grade before and after taxation; and the minimum grade in both fiscal regimes before and after taxation.

The simulation results indicate that the desirable income level, under maximum reinforcement of these factors, is more favorable than the equal condition, and the equal condition, in turn, is more favorable than the current state. As observed in this scenario, the trend of changes from 2011 to 2019 shows no significant variation; however, from 2019 to the end of the simulation period, the trend becomes increasing and exhibits exponential growth. Therefore, through better control of these factors and the adoption of appropriate managerial policies, it is possible to prevent disruptions arising from the neglect of financial policies in project development and even achieve higher levels of revenue.

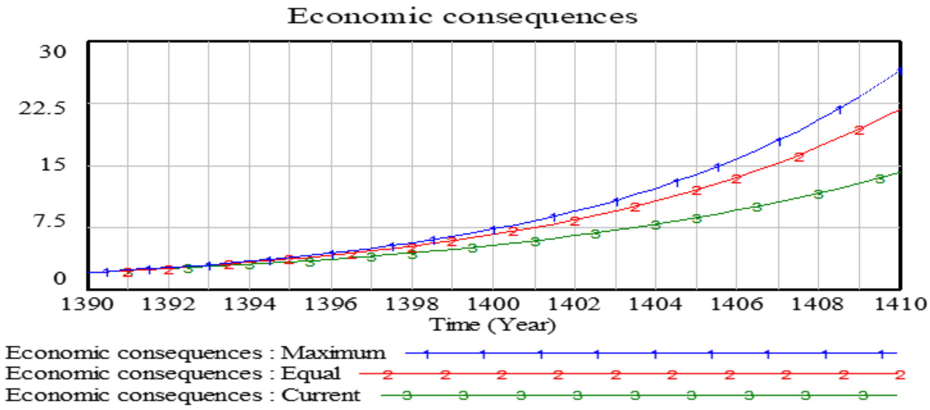

Fig. 8 Simulation of the first scenario

4.3.2.2 Second scenario: Level of metal reserves before taxation by strengthening the factors at level three

In this scenario, the model simulation regarding the value level of inactive reserves under both regimes, through the enhancement of level-three criteria, shows that the value level improves when strengthening factors such as metal price, metal recovery from mineral deposits, financial period, initial investment, *and* time of initial investment. The results indicate that the optimum value state (maximum level) performs better than the equal state, and the equal state performs better than the current situation.

It should be noted that the difference between the equal and maximum states is very small from the beginning of the simulation period up to the year (2027–2028), while from that point until the end of the simulation period, there is a noticeable and significant upward trend. Therefore, by further strengthening the application of these factors and improving the fiscal regimes of mining projects, higher revenue can be achieved throughout the simulation period.

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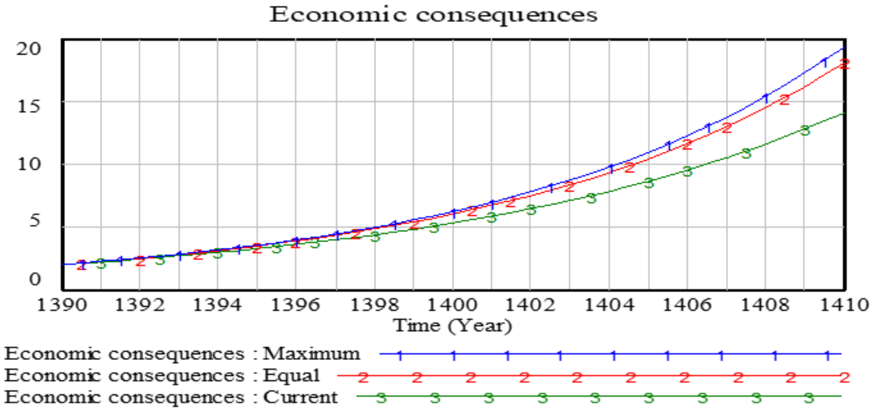

Fig. 9 Simulation of the second scenario

4.3.2.3 Third scenario: Metal reserves before tax with reinforcement of factors at level two

In this scenario, the model simulation examines the level of inactive reserve value under both fiscal regimes over time, considering factors such as unit operating cost including mineral resource taxes and corporate income taxes, unit operating cost excluding mineral royalty and taxes, production profile, and total marginal cost in the first and second regimes. The results show that the income level, given improvements in the fiscal regimes of mining projects, is higher in the maximum condition than in the equal condition, and higher in the equal condition than in the current condition. It should be noted, however, that from the beginning of the simulation period up to the year 2027, the difference between the equal and maximum conditions is very small, whereas from 2027 to the end of the period, a clearly noticeable increasing trend is observed.

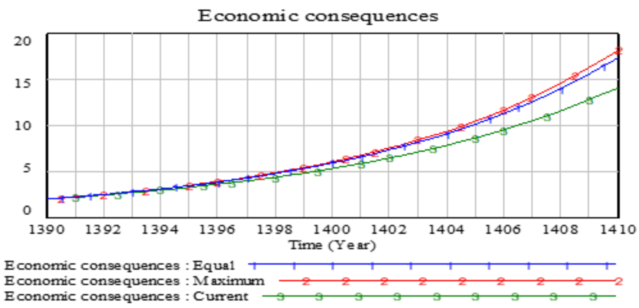

Fig. 10 Simulation of the third scenario

4.3.2.4 Scenario four: Metal reserves before taxation with strengthening of level-four factors

In this scenario, the focus is placed on level-four factors, namely capital productivity indicators and capital costs. Assuming improvements in variables such as the rate of return on investment, payback period, financing costs, and the efficiency of financial resource allocation, the simulation model indicates that post-tax income in the maximum state experiences a significant increase compared to the current state. This trend begins gradually

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from 2018 and turns into exponential growth after 2026. The results suggest that efficient capital management and the reduction of unnecessary tax-related costs can have positive effects on the financial sustainability of mining projects.

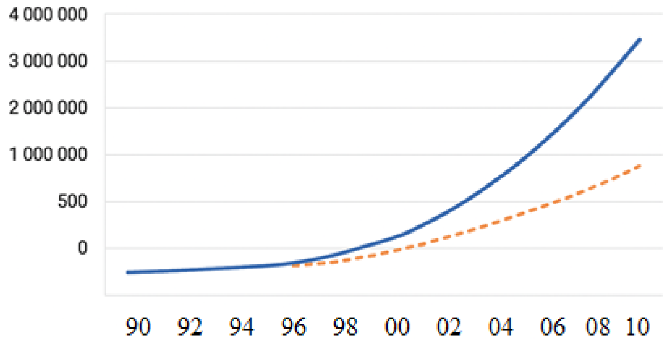

Fig. 11 Simulation of the fourth scenario

4.3.2.5 Fifth scenario: The effect of financial incentive and subsidy policies on strengthening fifth-level factors

In this scenario, the impact of financial incentive policies including reductions in interest rates on mining loans, increases in tax incentives, and the provision of subsidies for modern extraction equipment on final revenue is examined. The simulation results indicate that, under the maximum condition, revenue increases gradually from 2019 to 2025 and exhibits significant growth from 2026 onward. The difference between the equal and maximum conditions becomes significant from 2028. This demonstrates that government support policies can enhance investors' incentives to expand mining activities.

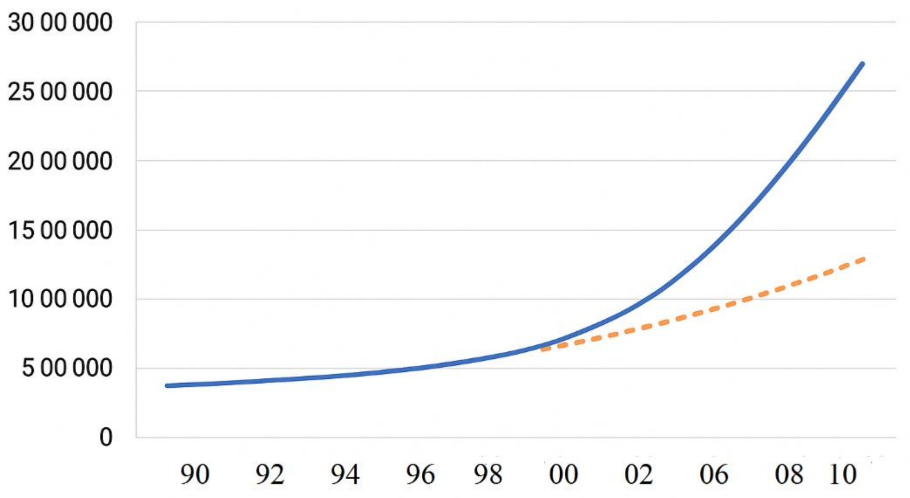

Fig.12 Simulation of the fifth scenario

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4.3.2.6 Scenario six: The impact of improvements in extraction and processing technologies on the performance of fiscal regimes

In this scenario, it is assumed that the adoption of modern extraction and mineral processing technologies leads to increased operational productivity. Factors such as the reduction of mining losses, improvement in energy efficiency, an increase in metal recovery rates, and a reduction in operating costs are strengthened in the model. The simulation results indicate that, under the second financial regime, due to its more flexible tax structure, the impact of technological advancement is more pronounced. The income level in the maximum state gradually increases from the year 2021 and, after 2029, grows at a steeper rate. Therefore, technological innovation plays a key role in enhancing the financial performance of mining projects.

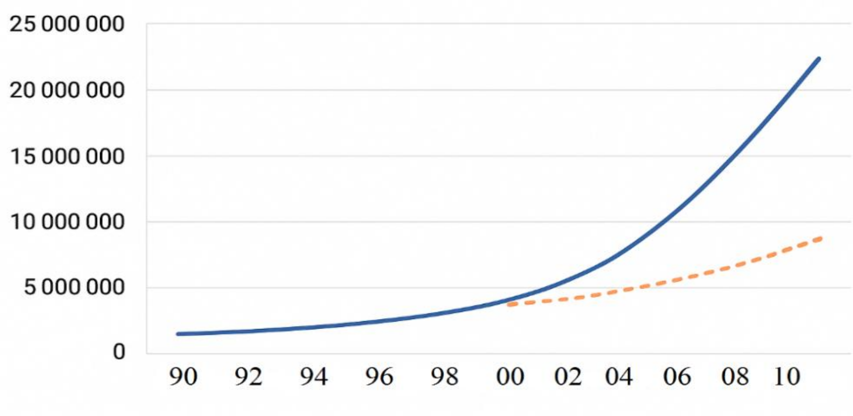

Fig. 13 Simulation of the sixth scenario

All scenarios in the "maximum" state led to a significant improvement in income compared to the current state; however, the intensity and timing of the onset of growth differ. The fourth, fifth, and sixth scenarios have the greatest impact on income growth and financial sustainability, as they are respectively related to capital management, supportive policies, and technological innovation. The turning point of exponential income growth in most scenarios is observed between the years 2026 and 2029, a period that coincides with investment maturity and the effectiveness of reform policies. Based on expert consensus, the combination of efficient fiscal policies, new technologies, and government support incentives can transform the financial structure of mining projects from an unstable condition into an optimal and sustainable financial regime.

5 Conclusion

Mining fiscal regimes are important systems for extracting revenue from the mining sector. However, fiscal regimes must balance the needs of both industry and government. A mining fiscal regime that generates low revenue creates difficulties for governments in mineral-dependent economies in fulfilling their socio-economic responsibilities. Similarly, a mining fiscal regime that is punitive toward the mining sector will drive investors out of the business, which in turn will lead to low revenue generation from this sector in the long term. Given the importance of fiscal regimes for mineral-hosting economies, their impacts on mining projects must be evaluated in order to support the formulation of mining policies. In

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this paper, a decision-making model for the financial evaluation of mining projects is proposed using multi-criteria decision-making methods and system dynamics to examine the impacts of these fiscal regimes on mining projects. For this purpose, the most important factors affecting the evaluation of mining projects were first identified through expert surveys using the Delphi method. In order to achieve the primary objective of system dynamics modeling namely, examining the impact of potential policies on improving the financial performance of mining projects six policy scenarios were designed and tested within a simulation environment. The overall simulation results indicate that, across all scenarios, the maximum condition outperforms both the equal and the current conditions in terms of revenue growth; however, the magnitude of the effect and the timing of changes vary among scenarios.

Scenario 1: Pre-tax metal reserves

- **Key factors:** Quantity of metal reserves, average metal grade, minimum mineable grade
- **Result:** After 2019, the revenue trend increases exponentially.
- **Analysis:** Precise control over reserve quality and the associated fiscal policies leads to sustained revenue growth.

Scenario 2: Value of inactive reserves

- **Key factors:** Metal price, fiscal period, initial investment, metal recovery rate
- **Result:** Up to 2027, the difference between the minimum and maximum conditions is small; thereafter, a noticeable increase is observed under the maximum condition.
- **Analysis:** Improved investment management and valuation of inactive reserves result in gradual revenue growth.

Scenario 3: Operating costs

- **Key factors:** Unit operating cost, corporate income tax, total marginal cost
- **Result:** From 2027 onward, revenue under the maximum condition increases significantly.
- **Analysis:** Controlling operating and tax-related costs leads to substantial improvements in the economic returns of mining projects.

Scenario 4: Capital productivity and capital costs

- **Key factors:** Rate of return on investment, payback period, efficiency of financial resource allocation
- **Result:** An upward trend begins in 2018 and reaches exponential growth after 2026.
- **Analysis:** Efficient capital management and the reduction of unnecessary financial costs are among the most important drivers of financial sustainability.

Scenario 5: Financial incentive and subsidy policies

- **Key factors:** Loan interest rates, tax incentives, equipment subsidies
- **Result:** Moderate growth is observed from 2019 to 2025, followed by substantial growth after 2026.
- **Analysis:** Government financial support increases investor incentives and significantly enhances mining revenues.

Scenario 6: Improvement in extraction and processing technologies

- **Key factors:** Waste reduction, improved energy efficiency, increased metal recovery rates
- **Result:** The impact of technology is more pronounced under the second fiscal regime, with rapid revenue growth observed from 2029 onward.
- **Analysis:** Technological innovation is the most important long-term driver of financial growth in the mining sector.

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In conclusion, this study demonstrates that financial simulation is an effective tool for forecasting alternative scenarios and supporting decision-making by investors and policymakers. To optimize fiscal regimes in mining projects, it is recommended to employ a combination of financial incentives, balanced tax structures, and flexible revenue models, while taking market risks and geopolitical conditions into account. This approach not only ensures project profitability but also contributes to the sustainable development of the mining sector and the broader economy. This study shows that the design of fiscal regimes should be based on a comprehensive analysis of techno-economic variables in order to ensure both project profitability and sustainable government revenues. The above recommendations can contribute to improving fiscal policies in the mining sector and attracting investment. To further develop and enhance the findings of this study, several key directions for future research are proposed. Applying Data Envelopment Analysis (DEA) methods to evaluate the efficiency of fiscal regimes, integrating environmental and social dimensions into financial models with a sustainable development approach, and examining the role of modern technologies in optimizing tax structures are among the main areas suggested. Moreover, conducting international comparative studies to benefit from successful global experiences, developing financial models tailored to small and medium-sized mines (SMEs), and utilizing artificial intelligence techniques to predict tax-related impacts can help improve fiscal policymaking and increase the efficiency and sustainability of mining projects.

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[DOI: 10.71885/ijorlu-2026-4-724]