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ARTICLES

AN APPLICATION OF A MULTICRITERIA RANKING APPROACH TO ASSESSING THE PERFORMANCE OF THE DOMINANT MEXICAN ECONOMIC SECTORS

Juan Carlos Leyva López[1*], Jesús Jaime Solano Noriega[2] and Martín León Santiesteban[3]

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ABSTRACT. This paper proposes a multicriteria model for ranking the functioning of the dominant economic sectors of the Mexican economy. The paper presents a real case study dealing with comparing economic sectors. It includes the problem situation, a suitable problem formulation, and a detailed version of the multicriteria evaluation model. The model considers the multiple dimensions involved in the evaluation. Eighty-nine dominant economic sectors of Mexico represent the alternatives to be considered in the evaluation model. The problem statement is a relative economic comparison of such sectors under a multicriteria ranking purpose from the 2019 Economic Census data. The study found that the model could determine the degree of the overall appeal of an economic sector in contrast to others.

Keywords: multicriteria decision analysis, economic sectors, multiobjective evolutionary algorithms.

1 INTRODUCTION

Planning economic development in developing countries is a fundamental task. Countries should adequately promote the various economic sectors and contribute to solving social and economic problems. However, the pace of progress is often controlled by the available resources, which means that not all sectors can be equally stimulated. Therefore, a correct development scheme to support the competent sectors is essential to achieve the projected development goals (Sudaryanto, 2003).

*Corresponding author
[1]Universidad Autónoma de Occidente, Department of Economic and Management Sciences, Culiacán, México – E-mail: juan.leyva@uadeo.mx – https://orcid.org/0000-0002-4821-6324
[2]Universidad Autónoma de Occidente, Department of Economic and Management Sciences, Los Mochis, México – E-mail: jaime.solano@uadeo.mx – https://orcid.org/0000-0002-8762-1453
[3]Universidad Autónoma de Occidente, Department of Economic and Management Sciences, Culiacán, México – E-mail: martin.leon@uadeo.mx – http://orcid.org/0000-0002-8632-3833

The transfer of capital within and outside a country's economy involves important elements such as internal sectors that produce and consume output, households, governments that utilize output, and foreign entities that import and export goods and services. The Input-Output (I-O) matrix is associated with the intermediate sectors of an economy and the output segments that other sectors consume as input. A fundamental component of an I-O model is a matrix that displays resource flows between sectors over a specific duration (Leontief, 1986). I-O matrices depict how an economy is structured and the interrelated connections between its sectors.

Mexican investors and policymakers must consider the global economic environment (Leyva et al., 2016). The Mexican economy is the fifteenth in the world and the second in Latin America (World Bank, 2022). Mexico ranks eleventh among the countries with the largest population on earth, with 126.7 million inhabitants (INEGI, 2023). In addition, economic growth is supported by its trade openness, a solid manufacturing export base connected to global value chains integrated with the United States, and a stable macroeconomic framework (World Bank, 2022).

According to Augusto et al. (2005), different methodological approaches can be used to evaluate the performance of economic sectors. For example, a multidimensional statistical approach has been attempted to identify the factors that affect various economic sectors in a city and determine the extent of their impact (Wolin, 2000).

Input-output analysis has some significant limitations when analyzing the sectors of a country's economy. These include focusing on economic transactions and production processes, neglecting important factors like employment and capital formation. The traditional methods may not easily accommodate diverse evaluation metrics or changing priorities and overlook qualitative aspects, potentially excluding broader stakeholder input. Additionally, input-output analysis can be less adaptable to exploring alternative scenarios or providing a ranking mechanism for sector prioritization.

On the contrary, Multicriteria Decision Analysis (MCDA) (Figueira et al., 2013) provides some benefits for examining a country's economic sectors. It allows for the simultaneous evaluation of economic sectors based on multiple criteria, offering a comprehensive analysis. MCDA is flexible and can integrate various criteria tailored to specific objectives or stakeholder preferences. It enables the assignment of weights to different criteria based on their relative importance, reflecting stakeholder priorities and policy objectives. Additionally, MCDA integrates qualitative and quantitative data, encourages stakeholder participation in the decision-making process, and provides clear rankings of economic sectors based on their overall performance across multiple criteria, aiding in prioritization and policymaking.

MCDA is a broad classification of methods that permits alternatives to be assessed according to different, often contradictory, and incommensurable criteria. Therefore, MCDA is appropriate for this application, where the sectors operate as decision alternatives. The variables under the study of the 2019 economic census of Mexico act as criteria for evaluating alternatives.

MCDA techniques have been widely employed to tackle various decision-making challenges encountered in areas such as finance, education, transportation, services, water management, en-

vironmental issues, and more (Figueira et al., 2013; Govindan & Jepsen, 2016). In the past few years, MCDA methods have been employed to evaluate significant economic sectors, influencing decision-making and problem-solving processes. Nevertheless, such uses are still reduced in number and extent. Augusto et al. (2005), Baležentis et al. (2012), and Sudaryanto (2003) applied a multicriteria method to evaluate the performance of economic sectors in Portugal, Lithuania, and Indonesia, respectively. Díaz et al. (2006) demonstrated a clustering methodology to identify the economic sectors of Spain.

MCDA has been used to measure the performance of economic sectors, sometimes in combination with the input-output approach. Most notably, Kananen et al. (1990) evaluated the response to economic and political shocks propagating through the input-output structure of the Finnish economy regarding emergency management techniques. Also, Shmelev & Brook (2021) described a comparative sustainability evaluation procedure using environmentally extended input-output and MCDA. The product used symmetric input-output matrices, sectoral CO2 emissions, and computed linkage coefficients for 163 sectors in six countries.

The authors Luptáčik & Böhm (1994) used a multiobjective model to minimize factor costs of producing Gross National Product. In Shmelev & Rodriguez-Labajos (2009), a work that assessed intertemporal macro sustainability in Austria over 25 years is described, while the United Nations Sustainability Development Framework of Indicators was used to evaluate macro sustainability progress over time in Russia by implementing MCDA methods in Shmelev (2011). The economic condition in Indonesia during the COVID-19 Pandemic was analyzed by applying teaching learning-based Fuzzy Geodemographic Clustering by Nasution & Siregar (2022). A tool for making decisions in tourism and recreational engineering was created by Vladykina & Kazanskaya (2016) to automate data processing. Its purpose is to identify problem areas and potential areas for growth in a specific location.

A well-known decision-aiding method under the MCDA approach is the ELECTRE (*ELimination Et Choice Translating REality*) method. This family of methods is an alternative to the functional paradigm, which can handle ordinal and qualitative information and threshold effects without involving the constant tradeoff rate. ELECTRE methods can choose the best alternative, rank alternatives, or categorize them into pre-defined and ordered categories. Several traditional ELECTRE methods have been developed to handle incomplete knowledge using discriminatory thresholds achieved through pseudo-criteria.

The ELECTRE III method is part of the ELECTRE family. This method and the other ELECTRE methods build an outranking relation S using the concordance and non-discordance tests.

The ELECTRE III method can handle imperfect knowledge arising from uncertain, imprecise, and poorly defined criteria in real-world decision-making situations in a non-compensatory form. The method uses indifference and preference thresholds that act as technical discrimination thresholds, comparing alternatives based on each criterion to address this. The method also considers the possibility of veto power for discordant criteria against the hypothesis that the outranking relation is valid. The weights assigned to each criterion in ELECTRE III are thought

coefficients of relative importance and can be considered votes for each criterion. The weights and thresholds are used to calculate the Concordance index. This index aims to measure the reliability of the outranking relation for a finite set of alternatives.

These methods have been expanded to include interactive criteria in Figueira et al. (2009), hierarchical criteria structures in Corrente et al. (2013), and hierarchical evaluations of performance based on interactive criteria in Corrente et al. (2017). Leyva et al. (2022) presented an evolutionary approach that fully operationalizes the hierarchical ELECTRE III method. Leyva et al. (2023) also exploited a hierarchical version of the ELECTRE III method but in the context of public security in the capital cities of the Mexican Republic's states.

This paper aims to apply the ELECTRE III method (Roy, 1996) for the comparative assessment of the dominant economic sectors of the Mexican economy, that is, to group them according to their level of attractiveness using the variables under the study of the 2019 economic census of Mexico (INEGI, 2023). Furthermore, RP^2-NSGA II+H (Leyva et al., 2021), a heuristic based on multiobjective genetic algorithms, exploits the fuzzy outranking relation constructed with ELECTRE III to derive a solution to the ranking problem of the sectors of the Mexican economy.

The rest of the document is organized as follows. The second section presents material and methods, incorporating the procedure for ranking the dominant Mexican economic sectors. The third section explains the study and emphasizes the process and approach used. Also, a sensitivity analysis of the proposed recommendation using the multicriteria method is presented. Section four presents the results and discusses them. The last section shows concluding comments.

2 MATERIALS AND METHODS

In this section, we will use the ELECTRE III method, a procedure created by Roy (1990) to solve multicriteria ranking problems and develop multicriteria decision models. We will also apply the RP^2-NSGA II+H algorithm, a multiobjective evolutionary algorithm, to derive a ranking utilizing a fuzzy outranking relation.

The straightforward implementation of the ELECTRE III method is effective for a few alternatives. However, its performance degrades rapidly as the number of alternatives increases. This is mainly because the distillation ranking procedure of ELECTRE III lacks an effective mechanism to detect groups of preferentially indifferent alternatives or to minimize the pairwise rank reversal effect (Mareschal et al., 2008). Contrasting with the distillation procedure of the ELECTRE III method, the RP^2-NSGA II+H algorithm, a multiobjective evolutionary algorithm, offers significant advantages. It exploits a fuzzy outranking relation to enhance the ranking of a large set of alternatives, mainly when there are implicitly subsets of preferentially indifferent alternatives to each other. The primary goal of this method is to recommend a partial order of classes of alternatives that aligns most closely with the aggregation model of the preferences of the decision maker (DM).

The ELECTRE III method and the RP^2-NSGA II+H algorithm are integrated into the SADGAGE software (Leyva et al., 2017), a web-based multicriteria decision support system designed to

facilitate ranking a set of alternatives with evaluations in terms of several criteria in decreasing order of preferences.

2.1 The ELECTRE III method

The ELECTRE III method is an essential method of MCDA. It is based on a pairwise comparison of the alternatives to fuzzy preference degrees (Roy, 1996). ELECTRE III includes realistic decision-making parameters for different criteria scores, precisely indifference, preference, and veto thresholds (Costa et al., 2022; de Araújo Costa et al., 2021; Figueira et al., 2013).

We briefly present the core of the ELECTRE III method. Let $A = \{a_1, a_2, ..., a_m\}$ be the set of actions or alternatives and suppose there are stated criteria $g_k,\ k = 1, 2, ..., r$. For each pair $(a_i, a_j) \in A \times A$, we can calculate a concordance measure $C(a_i, a_j)$ and a discordance measure $d_k(a_i, a_j)$. $C(a_i, a_j)$ measures the degree to which we agree with the statement that a_i is at least as good as a_j, while $d_k(a_i, a_j)$ measures the discordance related to this statement. The aggregation model of preferences S_A^σ joins these two indices to measure the degree of outranking, that is, a credibility index $\sigma(a_i, a_j)$, $(0 \leq \sigma(a_i, a_j) \leq 1)$ that evaluates the intensity of the assertion that "a_i is at least as good as a_j, $a_i S a_j$".The credibility degree for each pair $(a_i, a_j) \in A \times A$ is expressed as follows:

$$\sigma(a_i, a_j) = \begin{cases} C(a_i, a_j), & \text{if } K(a_i, a_j) = \varphi \\ C(a_i, a_j) \quad \bullet \prod\limits_{k \in K(a_i, a_j)} \dfrac{1 - d_k(a_i, a_j)}{1 - C(a_i, a_j)} & \text{if } K(a_i, a_j) \neq \varphi \end{cases} \tag{1}$$

where $K(a_i, a_j)$ is the set of criteria such that $d_k(a_i, a_j) > C(a_i, a_j)$.

Hence, the first stage of the ELECTRE III method constructs a fuzzy outranking relation S_A^σ defined on $A \times A$; this means that the method links with each ordered pair $(a_i, a_j) \in A \times A$ a real number $\sigma(a_i, a_j)$, $(0 \leq \sigma(a_i, a_j) \leq 1)$ that indicates the degree of strength of the arguments favoring the crisp outranking $a_i S a_j$.

The exploitation of S_A^σ is carried out in the second phase of ELECTRE III to derive a ranking of the alternatives. We use the multiobjective evolutionary algorithm RP^2-NSGA II+H of Leyva et al. (2021) to exploit a fuzzy outranking relation S_A^σ and to derive a partial pre-order of alternatives.

2.2 The Multiobjective problem and the multiobjective evolutionary algorithm

For the multicriteria ranking problem, each potential solution in the multiobjective evolutionary algorithm ranks the set of alternatives (dominant economic sectors in our application problem). To make the most of a fuzzy outranking relation S_A^σ and establish a ranking of alternatives that closely align with the preferences of the decision maker represented by S_A^σ, we approach it as a multiobjective optimization problem, identifying three objective functions as follows:

2.2.1 Objective functions

2.2.1.1 Maximum Cut Level Objective Each potential solution relates to a $\lambda - cut$, linked with a credibility level of a crisp outranking relation S_A^σ defined on a set of alternatives A. It is appropriate to have potential solutions with a credibility level λ close to 1. This denotes that the ranking obtained from the decoded potential is more credible. This objective is referred to as the *Maximum Cut Level* objective.

The multiobjective problem model includes an additional constraint for the credibility level λ. This constraint is based on a function f which prevents λ values from being close to one because it increases the number of incomparabilities between the alternatives. The quality of a solution improves as the value of f decreases. In this scenario, we are interested in individuals whose f values are close to zero or equal to zero. This condition enhances the comparability of the credibility index.

2.2.1.2 The MinCut objective To maximize the number of indifferences within classes, the alternatives within a particular class must be as indifferent to each other as possible. This objective penalizes pairs of alternatives that are not indifferent within a class.

2.2.1.3 The Minimum Pairwise Disagreement objective The quality of the final crisp outranking relation $S^*_{P_K(A)}$ should be evaluated by considering the discrepancies and concordances between S_A^σ and S_A^λ. $P_K(A)$ represents a partition of the set of alternatives A.

To address this, a n_V function counts the number of pairwise disagreements based on preferences. This function measures the number of disagreements between alternatives in terms of preferences. This is referred to as the *Minimum Pairwise Disagreement objective*.

2.2.2 The multiobjective optimization problem

Based on the defined objectives, the multiobjective optimization problem that the multiobjective evolutionary algorithm tries to solve is the next one:

$$\begin{aligned} & Min(MinCut(\widetilde{p})), \quad Min(n_V(\widetilde{p})), \quad Max(\lambda(\widetilde{p})) \\ & \textit{Subject to}: \\ & \widetilde{p} \in \Omega \\ & f(\widetilde{p}) \geq \varepsilon_f \\ & \lambda \in [0,1], \quad \lambda \geq \lambda_0 \end{aligned} \tag{2}$$

where:

Ω is the set of antisymmetric crisp outranking relations of classes of alternatives of A.

$\widetilde{p}$ is an antisymmetric crisp outranking relations of classes of A.

$f(\widetilde{p})$ is the number of incomparabilities between pairs of alternatives (a,b) in the individual $\widetilde{p}$, in the sense of the relation S_A^{λ}.

ε_f is an objective value.

λ_0 is a minimum credibility level.

Usually, in this optimization task, there is no single best solution; instead, a set of solutions that form an optimal Pareto front is obtained. For more information, please review the study conducted by Leyva et al. (2021).

Figure 1 schematically indicates the diagram of the ELECTRE-III-RP^2-NSGA II+H methodology. The methodology is iterative and not sequential, i.e., the DM can revisit and repeat any step.

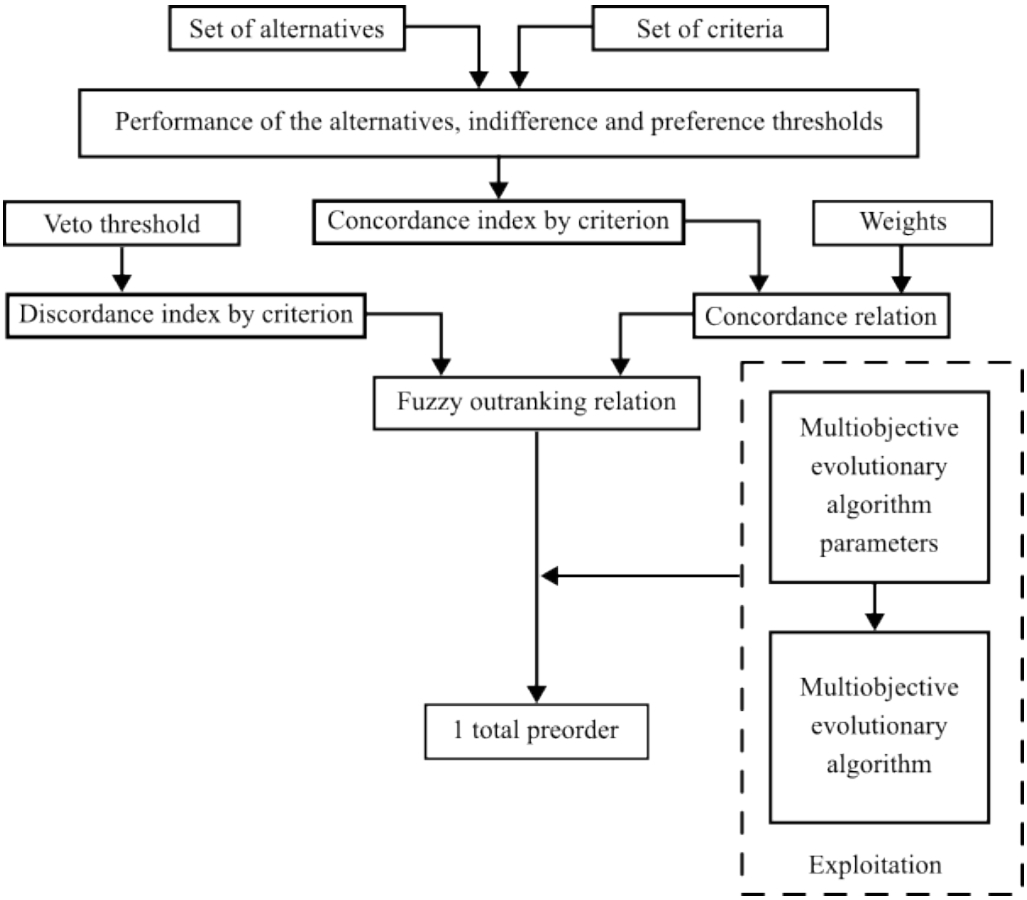

Figure 1 – General scheme of the ELECTRE -III–RP^2-NSGA II+H method.

Source: Own based on (Leyva et al., 2016).

2.3 Structured procedure to select a subset of economic variables to use as decision criteria for the multicriteria ranking of the dominant Mexican economic sectors

To select a subset of economic variables to use as a consistent family of criteria for a multicriteria ranking of the economic sectors from the 2019 Mexican Economic Census, we follow this structured procedure:

Step 1: Define the Objective and Scope: To rank dominant Mexican economic sectors based on their performance using a subset of key economic variables from the 2019 Mexican Economic Census.

Step 2: Identify potential economic variables: From a universe of 21 economic general variables

Step 3: Criteria Selection Methodology: Use a systematic approach to select the most relevant variables.

In this study, we use the methodology proposed by Bouyssou (1990) to construct a consistent family of criteria in the multicriteria decision analysis approach to solve a multicriteria ranking problem.

In the decision-making process, constructing a consistent family of criteria comes after an initial phase that defines the set of alternatives, the problem being studied, and the intervention strategy. In our study, we aimed to create a consistent family of criteria based on the perspectives of economic experts to identify the most impactful economic variables.

We aim for our family of criteria to have two important qualities:

1. “Legibility” means it should contain a small number of criteria to serve as a basis for discussion, allowing the analyst to assess the necessary inter-criteria information for implementing an aggregation procedure.

2. “Operationality” – meaning the family of criteria should be considered a reliable basis for all involved parties’ continuation of the decision-aid study.

We also aim for the family of criteria to possess technical properties such as exhaustiveness, monotonicity, and minimality.

Step 4: Finalize the Subset of Variables

Based on the criteria selection process, we find a manageable subset of variables that adequately represent the economic performance of sectors. The final subset includes:

- Number of employees
- Remunerations
- Total gross production
- Intermediate consumption
- Gross fixed capital formation

- Gross value added
- Total fixed assets

Conclusion

Following this structured procedure, we effectively choose a subset of economic variables, which we can use as decision criteria for the multicriteria ranking of the dominant economic sectors from the 2019 Mexican Economic Census. This approach ensures a thorough and objective comparison of sector performance.

3 THE CASE STUDY

This part of the document presents the pertinence of the proposed multicriteria ranking approach in a real case study: ranking the Mexican economy's dominant sectors by their attraction level. The case study presented here addresses the problem as a multicriteria ranking problem using the economic indicators handled by INEGI (INEGI, 2023) as the evaluation criteria.

3.1 Research Framework

In this case study, we adopt the MCDA framework to rank the dominant sectors of the Mexican economy. Due to the difficulty involved in analyzing a medium-sized set of economic sectors, we follow the methodology presented in the second section, taking advantage of the rationality of the ELECTRE III method (Roy, 1996) and the RP^2-NSGA II+H algorithm (Leyva et al., 2021) to resolve the multicriteria ranking problem.

In the suggested outranking approach, the complete preferences model is a system of preferences that can bring response elements to specific questions (Roy, 1990). In this study, an authority official acted as a stakeholder, and the study authors served as analysts.

3.2 Data Source

The data is part of the 2019 Mexican Economic Census (INEGI, 2023). The census aims to obtain fundamental statistical data about companies that manufacture goods, market merchandise, and provide services to create specific geographic, sectoral, and thematic economic indicators for Mexico. The census reports almost all the economic activities that take place in Mexico. The classification used for the census is the North American Industry Classification System (NAICS) 2007.

The census provides geographically detailed data for over 950 activities classified under the North American Industry Classification System (NAICS), enabling public economic policy planning and academic and market research activities. Table 1 reports the dominant economic sectors in Mexico (INEGI, 2023).

Table 1 – Dominant economic sectors in Mexico.

Code	Economic sector name	Code	Economic sector name
A_1	112 Breeding and exploitation of animals (only aquaculture)	A_{46}	467 Trade to the retail hardware, hardware store, and glasses
A_2	114 Fishing, hunting, and capture (fishing only)	A_{47}	468 Trade to the retail of motor vehicles, spare parts, fuel, and lubricants
A_3	115 Services related to agricultural and forestry activities	A_{48}	469 Trade to the retail exclusively over the Internet, and printed catalogs, TV, and the like
A_4	211 Oil and gas extraction	A_{49}	481 Air transport
A_5	212 Metallic and non-metallic minerals, except petroleum and gas mining	A_{50}	482 Railway transport
A_6	213 Mining-related services	A_{51}	483 Water transport
A_7	221 Generation, transmission, and distribution of electric power	A_{52}	484 Trucking
A_8	222 Water supply and gas supply pipeline to the final consumer	A_{53}	485 Road transport of passengers, except for railway
A_9	236 Edification	A_{54}	486 Pipeline transport
A_{10}	237 Construction of civil engineering works	A_{55}	487 Tourist transport
A_{11}	238 Specialized construction work	A_{56}	488 Transport-related services
A_{12}	311 Food industry	A_{57}	491 Postal services
A_{13}	312 Beverages and tobacco industry	A_{58}	492 Courier and parcel services
A_{14}	313 Manufacture of textile inputs and finishing of textiles	A_{59}	493 Storage services
A_{15}	314 Manufacture of textile products, except apparel	A_{60}	511 Edition of newspapers, magazines, books, software, and other materials, and integrated with the print edition of these publications
A_{16}	315 Manufacture of garments	A_{61}	512 Industry film and video, and sound industry
A_{17}	316 Tanning and finishing of leather and fur, and manufacture of leather products, leather, and substitutes materials	A_{62}	515 Radio and television
A_{18}	321 Wood industry	A_{63}	517 Other telecommunications
A_{19}	322 Paper industry	A_{64}	518 Electronic processing of information, accommodation, and other related services
A_{20}	323 Printing and allied industries	A_{65}	519 Other information services
A_{21}	324 Manufacture of products of petroleum and coal	A_{66}	521 Central bank
A_{22}	325 Chemistry industry	A_{67}	522 No brokerage credit and financial institutions
A_{23}	326 Plastic and rubber industry	A_{68}	523 Stock, foreign exchange, and financial investment activities
A_{24}	327 Manufacture of non-metallic mineral products	A_{69}	524 Bonding, insurance, and pensions
A_{25}	331 Basic metal industries	A_{70}	531 Real Estate Services
A_{26}	332 Manufacture of metal products	A_{71}	532 Movable property rental services
A_{27}	333 Manufacture of machinery and equipment	A_{72}	533 Rental of trademarks, patents, and franchises
A_{28}	334 Manufacture of computer, communication, measurement, and other equipment, components, and electronic accessories	A_{73}	541 Professional, scientific, and technical services

Table 1 – Continuation.

Code	Economic sector name	Code	Economic sector name
A_{29}	335 Accessories, electrical appliances, and electric power generation equipment manufacturing	A_{74}	551 Corporate
A_{30}	336 Manufacture of transport equipment	A_{75}	561 Business support services
A_{31}	337 Manufacture of furniture, mattresses, and blinds	A_{76}	562 Management of wastes and remediation services
A_{32}	339 Other manufacturing industries	A_{77}	611 Educational services
A_{33}	431 Trade to the wholesale grocery, food, drinks, ice, and tobacco	A_{78}	621 Medical services of external consultation and related services
A_{34}	432 Trade to the wholesale textile products and footwear	A_{79}	622 Hospitals
A_{35}	433 Trade to the wholesale of pharmaceuticals, perfumery, minor appliances for recreation, and appliances of the white line	A_{80}	623 Social assistance and healthcare residences
A_{36}	434 Trade to the wholesale of raw agricultural and forestry, for the industry, and material waste	A_{81}	624 Other welfare services
A_{37}	435 Trade to the wholesale of machinery, equipment, and furniture for agricultural, industrial, services, and commercial activities, and other machinery and equipment for general use	A_{82}	711 Artistic, cultural, and sporting services and other related services
A_{38}	436 Trade to the wholesale trucks and parts and new parts for cars, vans, and trucks	A_{83}	712 Museums, historic sites, zoos, and similar
A_{39}	437 Intermediation of trade to the wholesale	A_{84}	713 Entertainment recreational facilities and other recreational services
A_{40}	461 Trade to the retail grocery, food, drinks, ice, and tobacco	A_{85}	721 Temporary accommodation services
A_{41}	462 Trade to the retail supermarkets and departmental	A_{86}	722 Food and beverage preparation services
A_{42}	463 Trade to the retail of textiles, jewelry, accessories, clothing, and footwear	A_{87}	811 Repair and maintenance services
A_{43}	464 Trade to the retail healthcare	A_{88}	812 Personal services
A_{44}	465 Trade to the retail stationery, for recreation and other articles of personal use	A_{89}	813 Associations and organizations
A_{45}	466 Trade to the retail of home appliances, computers, and interior decoration items and used items		

Source: (INEGI, 2023).

3.3 Decision Criteria

The criteria used in this study are part of the economic census as evaluation variables. They were carefully selected using the structured procedure of section 2.3 and defined to represent the various aspects of economic sector performance adequately; an approach that considered their multidimensional nature was required. All the criteria are oriented to maximize, as described in Table 2.

Table 2 – Description of the criteria.

Code	Elementary criterion name	Description
NE	Number of employees	Includes all persons who worked during the reference period depending contractually or not on the economic unit, subject to its direction and control.
R	Remunerations	Includes all persons who worked during the reference period under contractual dependence on the economic unit, subject to its direction and control, in exchange for fixed and periodic remuneration.
TGP	Total gross production	It is the value of all the goods and services produced or marketed by the economic unit as a result of the exercise of its activities, including the value of the processed products.
IC	Intermediate consumption	It is the number of goods and services consumed by the economic unit to carry out its activities, both the materials that were physically integrated into the products obtained (goods and services).
GFCF	Gross fixed capital formation	It is the value of the fixed assets acquired by the economic unit (domestic or imported, new or used) minus the value of fixed asset sales.
GVA	Gross value added	It is the production value that is added during the work process by the creative and transforming activity of employed personnel, capital, and organization (factors of production).
TFA	Total fixed assets	It is the updated value of all those goods owned by the economic unit whose useful life is more significant than one year.

Source: Own elaboration.

The performance matrix underscores the differences among the economic sectors based on the criteria in Table 3.

Table 3 – Assessing the criteria for each economic sector (performance matrix).

Sector code	Economic sub-sector	Number of employees	Remunerations (paid employees)	Total gross production (millions of Mexican pesos)	Intermediate consumption (millions of Mexican pesos)	Gross fixed capital formation (millions of Mexican pesos)	Gross value added (millions of Mexican pesos)	Total fixed assets (millions of Mexican pesos)
A_1	112 Breeding and exploitation of animals (only aquaculture)	33,768	18,249	12,010	7,045	241	4,966	56.44
A_2	114 Fishing, hunting, and capture (fishing only)	179,478	68,763	22,364	13,217	247	9,147	23.689
A_3	115 Services related to agricultural and forestry activities	19,273	14,876	9,403	4,148	235	5,254	13.706
A_4	211 Oil and gas extraction	48,923	48,884	901,988	124,781	104,396	777,207	0
A_5	212 Metallic and non-metallic minerals, except petroleum and gas mining	8,562	7,228	11,020	6,780	670	4,240	12.791
A_6	213 Mining-related services	22,468	9,185	26,883	18,972	642	7,911	10.557
A_7	221 Generation, transmission, and distribution of electric power	91,639	4,567	561,968	401,747	54,217	160,221	7.868
A_8	222 Water supply and gas supply pipeline to the final consumer	171,896	143,062	107,727	72,100	251	35,628	49.997
A_9	236 Edification	67,027	47,262	73,567	49,174	345	24,393	7.082
A_{10}	237 Construction of civil engineering works	19,917	16,280	10,189	6,491	75	3,699	0.983
A_{11}	238 Specialized construction work	31,447	18,061	169,907	128,885	1,949	41,022	0.584
A_{12}	311 Food industry	185,573	105,925	409,246	231,751	7,441	177,495	25.401
A_{13}	312 Beverages and tobacco industry	42,405	13,080	19,728	12,006	318	7,722	45.719
A_{14}	313 Manufacture of textile inputs and finishing of textiles	24,161	16,596	13,760	9,038	271	4,722	1.685
A_{15}	314 Manufacture of textile products, except apparel	29,108	20,976	17,921	12,214	197	5,707	0.212
A_{16}	315 Manufacture of garments	22,591	17,850	20,981	12,935	191	8,046	1.113
A_{17}	316 Tanning and finishing of leather and fur, and manufacture of leather products, leather, and substitutes materials	10,354	8,813	4,677	3,024	56	1,653	3.062
A_{18}	321 Wood industry	30,053	19,127	93,488	66,343	2,611	27,146	31.206
A_{19}	322 Paper industry	127,616	87,710	76,170	50,477	1,548	25,693	22.195
A_{20}	323 Printing and allied industries	31,031	28,230	915,155	842,317	27,226	72,837	1.069
A_{21}	324 Manufacture of products of petroleum and coal	38,098	30,815	312,083	290,938	4,783	21,144	37.592
A_{22}	325 Chemistry industry	315,924	225,122	389,015	281,816	12,412	107,199	207.097
A_{23}	326 Plastic and rubber industry	100,482	42,555	53,674	30,512	2,506	23,162	66.648
A_{24}	327 Manufacture of non-metallic mineral products	26,932	14,263	216,961	157,472	3,955	59,489	1676.019
A_{25}	331 Basic metal industries	22,489	16,371	24,403	16,244	399	8,159	0.241
A_{26}	332 Manufacture of metal products	29,304	25,859	58,319	43,810	635	14,509	3.316
A_{27}	333 Manufacture of machinery and equipment	40,919	31,185	25,020	14,221	680	10,799	0.04
A_{28}	334 Manufacture of computer, communication, measurement, and other equipment, components, and electronic accessories	19,813	18,181	13,247	7,060	391	6,187	0.223
A_{29}	335 Accessories, electrical appliances, and electric power generation equipment manufacturing	106,907	86,178	1,676,338	1,225,350	11,559	450,988	71.561

Table 3 – Continuation.

Sector code	Economic sub-sector	Number of employees	Remunerations (paid employees)	Total gross production (millions of Mexican pesos)	Intermediate consumption (millions of Mexican pesos)	Gross fixed capital formation (millions of Mexican pesos)	Gross value added (millions of Mexican pesos)	Total fixed assets (millions of Mexican pesos)
A_{30}	336 Manufacture of transport equipment	133,878	86,314	49,509	28,276	570	21,233	23.431
A_{31}	337 Manufacture of furniture, mattresses, and blinds	172,298	161,285	66,968	28,641	1,580	38,326	1.107
A_{32}	339 Other manufacturing industries	432,761	286,485	245,012	83,498	1,828	161,514	68.192
A_{33}	431 Trade to the wholesale grocery, food, drinks, ice, and tobacco	43,673	27,935	23,313	8,078	465	15,235	3.472
A_{34}	432 Trade to the wholesale textile products and footwear	48,464	32,500	46,522	14,723	488	31,799	1.871
A_{35}	433 Trade to the wholesale of pharmaceuticals, perfumery, minor appliances for recreation, and appliances of the white line	79,861	42,680	41,416	13,450	8,342	27,966	22.163
A_{36}	434 Trade to the wholesale of raw agricultural and forestry, for the industry, and material waste	21,943	15,748	17,440	4,626	88	12,814	3.651
A_{37}	435 Trade to the wholesale of machinery, equipment, and furniture for agricultural, industrial, services, and commercial activities, and other machinery and equipment for general use	40,512	30,606	23,535	7,531	440	16,004	11.398
A_{38}	436 Trade to the wholesale trucks and parts and new parts for cars, vans, and trucks	2,899	1,259	1,481	480	6	1,001	0.726
A_{39}	437 Intermediation of trade to the wholesale	1,763,515	401,027	223,374	48,842	3,684	174,532	289.49
A_{40}	461 Trade to the retail grocery, food, drinks, ice, and tobacco	739,519	277,542	450,771	126,179	2,926	324,592	29.506
A_{41}	462 Trade to the retail supermarkets and departmental	72,299	42,481	14,442	4,428	289	10,014	3.933
A_{42}	463 Trade to the retail of textiles, jewelry, accessories, clothing, and footwear	336,713	219,732	92,559	25,204	1,372	67,355	35.323
A_{43}	464 Trade to the retail healthcare	91,084	42,087	20,044	7,955	723	12,089	9.303
A_{44}	465 Trade to the retail stationery, for recreation and other articles of personal use	146,892	74,474	78,454	23,636	3,369	54,819	25.838
A_{45}	466 Trade to the retail of home appliances, computers, and interior decoration items and used items	410,331	233,107	126,833	34,747	2,168	92,086	122.932
A_{46}	467 Trade to the retail hardware, hardware store, and glasses	150,166	66,008	112,042	42,194	1,558	69,848	21.295
A_{47}	468 Trade to the retail of motor vehicles, spare parts, fuel, and lubricants	5,470	1,536	4,617	1,324	18	3,293	0.007
A_{48}	469 Trade to the retail exclusively over the Internet, and printed catalogs, TV, and the like	30,314	21,292	120,584	85,916	509	34,669	0
A_{49}	481 Air transport	15,673	11,287	44,309	23,993	3,529	20,316	291.343
A_{50}	482 Railway transport	10,262	6,778	16,311	5,513	2,446	10,799	0
A_{51}	483 Water transport	172,061	149,060	114,434	71,450	809	42,984	38.865
A_{52}	484 Trucking	157,487	134,758	56,891	32,057	3,842	24,834	8.241

Table 3 – Continuation.

Sector code	Economic sub-sector	Number of employees	Remunerations (paid employees)	Total gross production (millions of Mexican pesos)	Intermediate consumption (millions of Mexican pesos)	Gross fixed capital formation (millions of Mexican pesos)	Gross value added (millions of Mexican pesos)	Total fixed assets (millions of Mexican pesos)
A_{53}	485 Road transport of passengers, except for railway	5,387	4,633	12,210	5,190	864	7,020	0.156
A_{54}	486 Pipeline transport	8,501	5,901	3,035	1,640	189	1,395	0.135
A_{55}	487 Tourist transport	37,577	18,785	20,584	9,702	339	10,882	5.51
A_{56}	488 Transport-related services	14,618	14,618	5,156	1,269	-13	3,887	0
A_{57}	491 Postal services	42,658	26,354	20,606	11,474	433	9,132	8.219
A_{58}	492 Courier and parcel services	33,410	21,438	20,883	11,710	362	9,173	0
A_{59}	493 Storage services	39,307	28,032	22,283	11,503	70	10,780	0.228
A_{60}	511 Edition of newspapers, magazines, books, software, and other materials, and integrated with the print edition of these publications	47,956	31,419	57,312	28,436	1,734	28,876	3.092
A_{61}	512 Industry film and video, and sound industry	43,130	17,323	53,295	26,389	1,219	26,906	3.327
A_{62}	515 Radio and television	172,051	95,673	453,861	344,108	136,191	109,754	2543.444
A_{63}	517 Other telecommunications	22,026	17,053	13,132	5,001	108	8,130	0.611
A_{64}	518 Electronic processing of information, accommodation, and other related services	3,977	2,551	2,522	1,226	19	1,296	0.726
A_{65}	519 Other information services	3,403	3,403	80,106	12,679	3,080	67,427	0
A_{66}	521 Central bank	303,536	168,100	611,624	226,304	10,780	385,321	0
A_{67}	522 No brokerage credit and financial institutions	12,720	9,142	27,792	10,491	200	17,300	0.597
A_{68}	523 Stock, foreign exchange, and financial investment activities	58,934	29,865	199,737	29,839	1,105	169,898	0
A_{69}	524 Bonding, insurance, and pensions	96,323	38,433	35,956	15,422	1,762	20,534	40.451
A_{70}	531 Real Estate Services	17,407	8,845	17,879	10,815	546	7,064	3.637
A_{71}	532 Movable property rental services	755	360	1,371	507	50	864	0.298
A_{72}	533 Rental of trademarks, patents, and franchises	130,468	73,889	35,859	12,773	591	23,086	31.372
A_{73}	541 Professional, scientific, and technical services	138,987	124,025	498,741	97,256	6,530	401,485	0.672
A_{74}	551 Corporate	281,345	265,204	123,945	40,953	842	82,991	3.844
A_{75}	561 Business support services	14,244	10,266	11,476	6,129	164	5,346	5.174
A_{76}	562 Management of wastes and remediation services	456,778	397,586	89,103	24,403	1,923	64,700	96.414
A_{77}	611 Educational services	138,623	58,577	26,400	12,007	1,081	14,393	57.01
A_{78}	621 Medical services of external consultation and related services	113,636	68,353	69,146	43,289	1,411	25,857	9.694
A_{79}	622 Hospitals	1,693	675	163	82	2	81	0
A_{80}	623 Social assistance and healthcare residences	107,492	6,431	1,558	1,027	33	531	3.258
A_{81}	624 Other welfare services	19,990	8,725	1,649	747	42	902	1.122
A_{82}	711 Artistic, cultural, and sporting services and other related services	11,075	6,116	4,584	2,768	116	1,816	8.514

Table 3 – Continuation.

Sector code	Economic sub-sector	Number of employees	Remunerations (paid employees)	Total gross production (millions of Mexican pesos)	Intermediate consumption (millions of Mexican pesos)	Gross fixed capital formation (millions of Mexican pesos)	Gross value added (millions of Mexican pesos)	Total fixed assets (millions of Mexican pesos)
A_{83}	712 Museums, historic sites, zoos, and similar	39,518	19,754	13,537	5,609	181	7,928	31.092
A_{84}	713 Entertainment recreational facilities and other recreational services	484,011	247,681	230,579	128,835	7,726	101,743	107.879
A_{85}	721 Temporary accommodation services	49,444	38,887	12,438	6,504	96	5,935	1.262
A_{86}	722 Food and beverage preparation services	542,568	226,015	93,234	45,805	1,951	47,429	252.662
A_{87}	811 Repair and maintenance services	334,398	81,319	36,097	17,118	745	18,980	52.388
A_{88}	812 Personal services	99,455	58,836	13,590	6,958	484	6,632	8.251
A_{89}	813 Associations and organizations	33,768	18,249	12,010	7,045	241	4,966	56.44

Source: (INEGI, 2023).

3.4 Computations with the ELECTRE III-RP^2-NSGA II+H Methodology

The ELECTRE-III method is used here to evaluate the performance of the economic sectors in Mexico because it can be handled as a multicriteria ranking problem. The ELECTRE methods use indifference and preference thresholds to integrate the fuzzy nature of the decision-making procedure, a feature of the current problem. Furthermore, since balancing out a loss in one area with a gain in another may not be satisfactory for the decision maker, the non-compensatory characteristics of the ELECTRE III method are desirable in some situations (Figueira et al., 2005). In addition, the ELECTRE models allow for incomparability between alternatives. Finally, the selection of ELECTRE III was also caused by previous practical applications of the approach (see Govindan & Jepsen (2016) for a catalog of successful applications of ELECTRE).

Threshold selection is closely concerned with whether a specific preference relation holds. In this case study, the criteria's indifference and preference thresholds are presented in Table 4. The criteria weights were obtained using the deck of cards technique (Corrente et al., 2017).

Table 4 – Weights (w), Indifference (q), and preference (p) threshold values.

Code	Criterion (g_j)	Weights (w)	Indifference (q_j)	Preference (p_j)
NE	Number of employees	0.107	9000	18000
R	Remunerations	0.179	6000	12000
TGP	Total gross production	0.071	7000	15000
IC	Intermediate consumption	0.214	5000	12000
GFCF	Gross fixed capital formation	0.036	200	400
GVA	Gross value added	0.143	4000	8000
TFA	Total fixed assets	0.250	4	9

Source: Own-made.

Calculations have been performed on the performance matrix (Table 3) and information about the DM's preferences (Table 4) to build a valued outranking relation S_A^σ that represents the aggregation model of the DM's preferences. For space reasons, we omit the presentation of this relation.

The next phase is to mathematically process the preference relation S_A^σ and derive a final partial order of classes of alternatives. Our means of exploitation involves using the multiobjective evolutionary algorithm RP^2-NSGA II+H (Leyva et al., 2021).

Due to the stochastic nature of RP^2-NSGA II+H, the solutions found from different algorithm runs may vary in quality. Because of this, the RP^2-NSGA II+H algorithm was executed ten times, with the parameters set to include 5000 generations, 40 individuals in the population, a crossover probability of 0.9, and a range of lambda values [0.50, 0.60]. The mutation probability is automatically derived from the mutation operator.

Table 5 presents the ten best solutions with the lowest number of inconsistencies in the restricted Pareto front found in all the runs. Since all the solutions on this front are mathematically equivalent, the DM's preferences must be incorporated into the selection process to determine the final solution. Here, solution no. 1 was selected because it showed fewer inconsistencies.

Table 5 – Objective values and overall inconsistencies of the top ten solutions with fewer inconsistencies returned by all algorithm's runs at termination.

Lambda	Obj. 1	Obj. 2	Overall Inconsistencies
0.596	36	268	304
0.594	35	271	306
0.599	35	272	307
0.600	34	274	308
0.599	36	273	309
0.595	34	276	310
0.600	36	274	310
0.600	36	275	311
0.596	40	271	311
0.595	33	278	311

Source: Own-made.

Figure 2 presents the decoded representation of the partial order of classes associated with solution #1, along with a table indicating the determined belonging class for each alternative of the multiobjective evolutionary algorithm (MOEA), as a recommendation made by the analyst to the DM.

Economic sectors were grouped into forty-nine different ordered classes: $C_1, C_2, \ldots, C_{49}$. The attractiveness of economic sectors differs from one another when compared within classes, as can be observed in Fig. 2. For example, economic sectors in the "C_{17}", "C_{22}", "C_{24}", "C_{35}", "C_1 " and "C_4" classes show lower levels of attractiveness compared to the higher-ranked classes: 'C_{18}", "C_{25}", "C_{36}", "C_{26}", "C_{14}" and "C_{37}". Economic sectors in the same class represent a similar level of attractiveness. A suitable granularity in the classes permits us to differentiate better the appropriate attractiveness level between two economic sectors, which is appreciated for many state and federal government economic policy agendas.

The results recommend that A_{29}: Accessories, electrical appliances, and electric power generation equipment manufacturing, A_{39}: Intermediation of trade to the wholesale, A_{62}: Radio and television, A_{40}: Trade to the retail grocery, food, drinks, ice, and tobacco, A_{22}: Chemistry industry, and A_{66}: Central Bank are the economic sectors best evaluated according to the economic information presented in the decision criteria. We can notice the RP^2-NSGA-II+H's facility to detect classes of alternatives indifferent to each other. The results could be used by an economic analyst, stakeholder, or specialist to gain an accurate understanding and realistic depiction of the relative level of attractiveness among Mexico's economic sectors.

Alternative	Class	Alternative	Class
A_1	1	A_9	7
A_3	1	A_{11}	8
A_6	1	A_{12}	9
A_{13}	1	A_{18}	10
A_{14}	1	A_{19}	11
A_{15}	1	A_{20}	12
A_{16}	1	A_{21}	13
A_{25}	1	A_{22}	14
A_{27}	1	A_{23}	15
A_{28}	1	A_{24}	16
A_{33}	1	A_{26}	17
A_{36}	1	A_{29}	18
A_{41}	1	A_{30}	19
A_{55}	1	A_{31}	20
A_{57}	1	A_{32}	21
A_{58}	1	A_{34}	22
A_{59}	1	A_{35}	23
A_{63}	1	A_{37}	24
A_{65}	1	A_{43}	24
A_{67}	1	A_{88}	24
A_{70}	1	A_{39}	25
A_{83}	1	A_{40}	26
A_{85}	1	A_{42}	27
A_{89}	1	A_{44}	28
A_2	2	A_{45}	29
A_4	3	A_{46}	30
A_5	4	A_{48}	31
A_{10}	4	A_{49}	32
A_{17}	4	A_{52}	33
A_{38}	4	A_{60}	34
A_{47}	4	A_{61}	35
A_{50}	4	A_{62}	36
A_{53}	4	A_{66}	37
A_{54}	4	A_{68}	38
A_{56}	4	A_{69}	39
A_{64}	4	A_{72}	40
A_{71}	4	A_{73}	41
A_{75}	4	A_{74}	42
A_{79}	4	A_{76}	43
A_{80}	4	A_{77}	44
A_{81}	4	A_{78}	45
A_{82}	4	A_{84}	46
A_7	5	A_{86}	47
A_8	6	A_{87}	48
A_{51}	6		

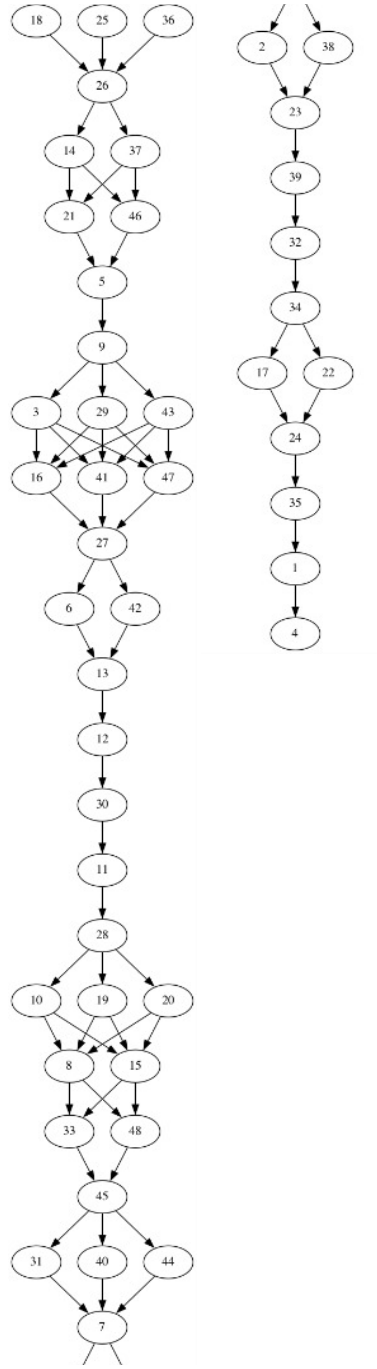

Figure 2 – Left: Table specifying each economic sector's class according to the MOEA and its label. Right: Decoded representation as a partial order of classes of alternatives of the associated individual of solution #1.

Source: Own-made.

3.5 Sensitivity Analysis of the Recommendation

Usually, in MCDA, a sensibility analysis is required after the DM takes the recommendation proposed by the analyst. Sensitivity analysis allows one to analyze the effect of changing some given parameter values on the obtained results regarding the DM's preferences.

When conducting sensitivity analysis, changes in the values of the criteria weights (w) for multiple criteria are considered simultaneously, as are changes in the values of the indifference and strict preference thresholds for one or more criteria. Tables A1 and A2, shown in Appendix 1, contain the findings of the sensitivity analysis (the original parameters are found in Table 4).

From the ten variations made in the sensitivity analysis, the resulting rankings retained most of the estimations presented in Figure 2 on the level of the relative attractiveness of the economic sectors in Mexico. Therefore, the sensitivity of the proposed result was judged irrelevant. However, based on the sensitivity analysis results of Tables A1 and A2, rankings slightly different from those presented in Figure 2 can be observed. In most instances, the rankings of economic sectors change within the categories, and, in some cases – less frequently – they move from one class to another immediately higher or lower.

Operatively, the decision support method ends with the performance of the sensitivity analysis. However, the DM is the actor who makes the final evaluation and declares which elements are consistent with their beliefs, such as accepting the final result and the consistency between the final result and their preferences.

4 RESULTS AND DISCUSSION

This paper describes the methodology and variables used in the survey to collect information to analyze the 2019 economic Mexican census (INEGI, 2023). It was interesting to comprehensively study the economic characteristics of the dominant economic sectors in Mexico because it can lead to the design of public policies that allow establishment actions for those economic sectors of interest that show a high or low economic lag. Therefore, we chose a representative set of economic indicators defined based on variables used in the 2019 economic census. Seven indicators in this work have the role of decision criteria. We evaluated the eighty-nine economic sectors on each of these criteria.

The SADGAGE software described in Leyva et al. (2017) was used to facilitate the calculations of the method used to compare the economic sectors. First, the relative importance and thresholds of the criteria were defined, and from this, a partial pre-order of the economic sectors was derived. The SADGAGE system has computationally systematized the ELECTRE III—RP^2-NSGA II+H methodology. The system recommends a partial pre-order of the sectors in decreasing order of attractiveness.

4.1 Analysis of the Results Obtained in the Context of the Economic Problem

The following economic sectors are part of the categories that are considered the most attractive in relative terms. A_{29}: Accessories, electrical appliances, and electric power generation equipment manufacturing, A_{39}: Intermediation of trade to the wholesale, A_{62}: Radio and television, A_{40}: Trade to the retail grocery, food, drinks, ice, and tobacco, A_{22}: Chemistry industry, and A_{66}: Central bank. This is because they perform better in the most important decision criteria. Most of these economic sectors are categorized by presenting values in all criteria above the average (see Table 6).

In contrast, the findings indicate that the economic sectors: A_5: Metallic and non-metallic minerals except petroleum and gas mining, A_{10}: Construction of civil engineering works, A_{50}: Railway transport, A_{53}: Road transport of passengers, except for railway, A_{54}: Pipeline transport, A_{56}: Transport-related services, A_{64}: Electronic processing of information, accommodation, and other related services, A_{71}: Movable property rental services, A_{75}: Business support services, A_{79}: Hospitals, A_{82}: Artistic, cultural, and sporting services belong to the class with the worst level of attractiveness. The common distinctive of these economic sectors is the low evaluation achieved by the sectors within the criteria that the DM deems most important, such as intermediate consumption and total fixed assets. Consequently, they report, in this class, values below the means, as shown in Table 7. Based on these findings, it can be confirmed that the economic sectors with these features belong to the class with lower levels of attractiveness.

The findings from applying multicriteria decision analysis to rank economic sectors in Mexico offer valuable insights for decision-makers and stakeholders. Here are the key points regarding the findings and any novelty observed in the results:

- In contrast to traditional methods that use composite indicators for sector comparison, the multicriteria approach used in this study provides a more comprehensive evaluation of economic sectors. Multiple criteria, such as the number of employees, remunerations, total gross production, and others, are considered to achieve a more nuanced and detailed sector performance assessment.
- The study ranks the dominant economic sectors in Mexico based on their attractiveness levels. This ranking is crucial for policymakers, financiers, entrepreneurs, trade unions, customers, and providers to make informed decisions about investments, policies, and risk management strategies.
- Applying the ELECTRE III method in the multicriteria ranking of economic sectors in Mexico presents a novel approach to evaluating sector performance. By utilizing a systematic and structured method, the study offers a formal procedure for assessing the attractiveness of economic sectors, which can benefit decision-makers in the public and private sectors.

Table 6 – Partial analysis of results (economic sectors with highest relative attractiveness).

Sector code	Economic sub-sector	Number of employees	Remunera-tions (paid employees)	Total gross production (millions of Mexican pesos)	Intermediate consumption (millions of Mexican pesos)	Gross fixed capital formation (millions of Mexican pesos)	Gross value added (millions of Mexican pesos)	Total fixed assets (millions of Mexican pesos)
A_{22}	325 Chemistry industry	315,924	225,122	389,015	281,816	12,412	107,199	207.097
A_{29}	335 Accessories, electrical appliances, and electric power generation equipment manufacturing	106,907	86,178	1,676,338	1,225,350	11,559	450,988	71.561
A_{39}	437 Intermediation of trade to the wholesale	1,763,515	401,027	223,374	48,842	3,684	174,532	289.49
A_{40}	461 Trade to the retail grocery, food, drinks, ice, and tobacco	739,519	277,542	450,771	126,179	2,926	324,592	29.506
A_{62}	515 Radio and television	172,051	95,673	453,861	344,108	136,191	109,754	2543.444
A_{66}	521 Central bank	303,536	168,100	611,624	226,304	10,780	385,321	0
	Average	**123,904.93**	**65,971.60**	**126,812.65**	**69,086.10**	**5,277.85**	**57,726.54**	**75.81**
	Weight	**0.107**	**0.179**	**0.071**	**0.214**	**0.036**	**0.143**	**0.250**

Source: own-made.

Table 7 – Partial analysis of the findings (economic sectors with lowest relative attractiveness).

Sector code	Economic sub-sector	Number of employees	Remunerations (paid employees)	Total gross production (millions of Mexican pesos)	Intermediate consumption (millions of Mexican pesos)	Gross fixed capital formation (millions of Mexican pesos)	Gross value added (millions of Mexican pesos)	Total fixed assets (millions of Mexican pesos)
A_5	212 Metallic and non-metallic minerals, except petroleum and gas mining	8,562	7,228	11,020	6,780	670	4,240	12.791
A_{10}	237 Construction of civil engineering works	19,917	16,280	10,189	6,491	75	3,699	0.983
A_{50}	482 Railway transport	10,262	6,778	16,311	5,513	2,446	10,799	0
A_{53}	485 Road transport of passengers, except for railway	5,387	4,633	12,210	5,190	864	7,020	0.156
A_{54}	486 Pipeline transport	8,501	5,901	3,035	1,640	189	1,395	0.135
A_{56}	488 Transport-related services	14,618	14,618	5,156	1,269	13	3,887	0
A_{64}	518 Electronic processing of information, accommodation, and other related services	3,977	2,551	2,522	1,226	19	1,296	0.726
A_{71}	532 Movable property rental services	755	360	1,371	507	50	864	0.298
A_{75}	561 Business support services	14,244	10,266	11,476	6,129	164	5,346	5.174
A_{79}	622 Hospitals	1,693	675	163	82	2	81	0
A_{82}	711 Artistic, cultural, and sporting services and other related services	11,075	6,116	4,584	2,768	116	1,816	8.514
	Average	**123,904.93**	**65,971.60**	**126,812.65**	**69,086.10**	**5,277.85**	**57,726.54**	**75.81**
	Weight	**0.107**	**0.179**	**0.071**	**0.214**	**0.036**	**0.143**	**0.250**

Source: own-made.

In conclusion, the results of applying multicriteria decision analysis to rank economic sectors in Mexico provide a systematic and objective way to assess sector performance, offering valuable insights for stakeholders and decision-makers. The novelty lies in the comprehensive evaluation approach and the potential for future research to refine further and enhance the methodology for evaluating economic sectors.

5 CONCLUDING COMMENTS

Public policies and decision-making processes include conflicts and tensions since a group of actors is participating at the political level, power relations are involved, and economic interests are in dispute, issues that affect regional development. However, DMs must rely on tools that offer information scenarios and their technical feasibility. Therefore, Cabrero & Gil (2010) recommend systematic support from technical and professional commissions, which contribute to executing more rigorous and informed decision-making processes.

MCDA methodologies for solving complex decision-making problems are linked to government tasks. Therefore, this work proposes a support model based on the ELECTRE III method for the multicriteria ranking problem. Furthermore, this model works as a formal procedure that supports the assessment of the degree of attractiveness of Mexico's economic sectors.

The goal of this research work was to present a structured method for the comprehensive comparison and ranking of the attractiveness of the dominant economic sectors in Mexico and thus select, for example, the most lagging economic sectors for the application of specific public policies and programs for their strengthening and consolidation. An additional objective is to educate the political and academic spheres in the region about the differences in this phenomenon across various economic sectors. Finally, our interest is to present evidence that allows public sector planners involved in issues that affect the population of Mexico to consider it when carrying out their planning exercises.

Traditionally, economic sectors are marginally compared using a composite indicator. However, in this paper, we comprehensively compare economic sectors. We use the respective data and representative economic indicators in the literature based on the variables used in the 2019 Mexican economic census.

The recommended multicriteria assessment approach for ranking the dominant economic sectors in the Mexican economy can be helpful for policymakers, financiers and entrepreneurs, trade unions, customers, and providers of specific economic sectors. Tax authorities can oblige complementary tax charges for the best-positioned sectors, namely accessories, electrical appliances, and electric power generation equipment manufacturing sector, intermediation of trade to the wholesale sector, radio and television sector, and chemistry industry sector, among others. Financiers can decide to invest in the long term in uncompetitive sectors, that is, the construction of civil engineering works, railway transportation, oil pipelines, and the hospital sector, among others, and take advantage of efficient sectors to make short-term investments. Finally, if customers and suppliers encounter incompetent economic sectors, they may wish to explore alternative risk

management strategies, such as credit insurance. Therefore, a thorough evaluation of sector activities can enhance decision-making for all stakeholders and mitigate associated risks to some extent.

In future work, we will compare the attractiveness levels in Mexico's economic sectors over time.

Other interesting future research lines are related to this work's limitations. One of them is eliciting the parameter values that best suit the system of preferences of the DM. As it is well known, ELECTRE-based models require the definition of many parameters, and the direct estimates of their values may not represent the DM's preferences. Furthermore, the problem addressed in this work can be naturally represented by a hierarchical structure of the criteria; thus, a detailed analysis should be performed to assess Mexico's economic sectors using an approach that appropriately models such structures.

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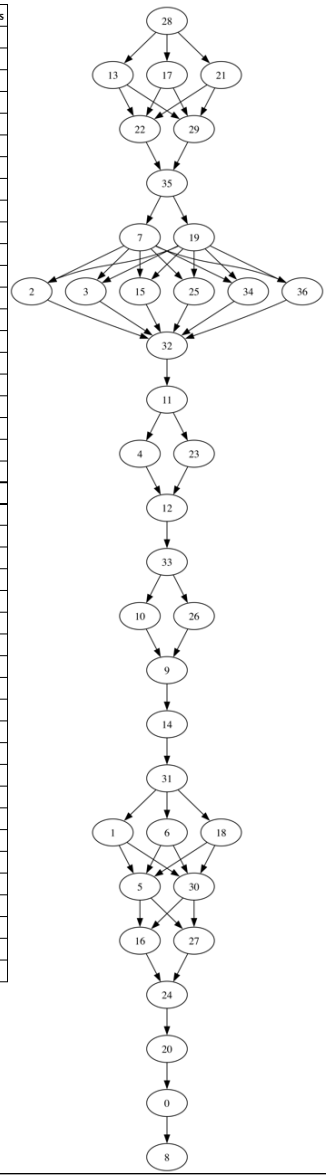
APPENDIX 1

Table A1 – Effect of modifications in criteria weights and alterations in the values of the recommendation. Modifications of relative importance (weights) values (w) for two or more criteria at the same time.

w_{IC}= 2.04	w_R= 1.89
w_{GVA}= 1.53	w_{TFA}= 2.40

Alternative	Class	Alternative	Class
A1	1	A71	9
A3	1	A79	9
A5	1	A80	9
A6	1	A81	9
A10	1	A82	9
A13	1	A18	10
A14	1	A19	11
A15	1	A30	11
A16	1	A44	11
A25	1	A20	12
A27	1	A21	13
A28	1	A22	14
A33	1	A23	15
A36	1	A24	16
A41	1	A26	17
A50	1	A34	17
A53	1	A48	17
A55	1	A60	17
A56	1	A61	17
A57	1	A29	18
A58	1	A31	19
A59	1	A52	19
A63	1	A78	19
A65	1	A32	20
A67	1	A37	21
A70	1	A39	22
A75	1	A40	23
A83	1	A42	24
A85	1	A43	25
A89	1	A88	25
A2	2	A45	26
A4	3	A46	27
A7	4	A49	28
A8	5	A62	29
A51	5	A66	30
A9	6	A68	31
A35	6	A72	32
A69	6	A77	32
A11	7	A87	32
A12	8	A73	33
A17	9	A74	34
A38	9	A76	35
A47	9	A84	36
A54	9	A86	37
A64	9		



Alternative	Class	Alternative	Class
A1	1	A71	9
A3	1	A79	9
A5	1	A80	9
A6	1	A81	9
A10	1	A82	9
A13	1	A18	10
A14	1	A19	11
A15	1	A30	11
A16	1	A44	11
A25	1	A20	12
A27	1	A21	13
A28	1	A22	14
A33	1	A23	15
A36	1	A24	16
A41	1	A26	17
A50	1	A34	17
A53	1	A48	17
A55	1	A60	17
A56	1	A61	17
A57	1	A29	18
A58	1	A31	19
A59	1	A52	19
A63	1	A78	19
A65	1	A32	20
A67	1	A37	21
A70	1	A39	22
A75	1	A40	23
A83	1	A42	24
A85	1	A43	25
A89	1	A88	25
A2	2	A45	26
A4	3	A46	27
A7	4	A49	28
A8	5	A62	29
A51	5	A66	30
A9	6	A68	31
A35	6	A72	32
A69	6	A77	32
A11	7	A87	32
A12	8	A73	33
A17	9	A74	34
A38	9	A76	35
A47	9	A84	36
A54	9	A86	37
A64	9		

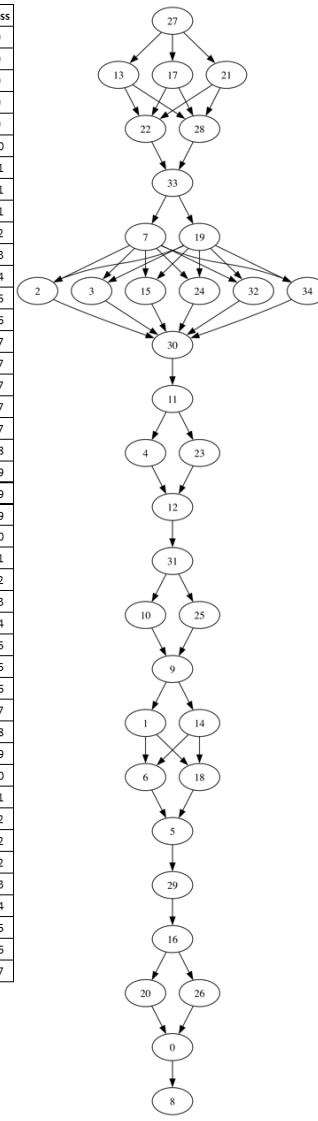
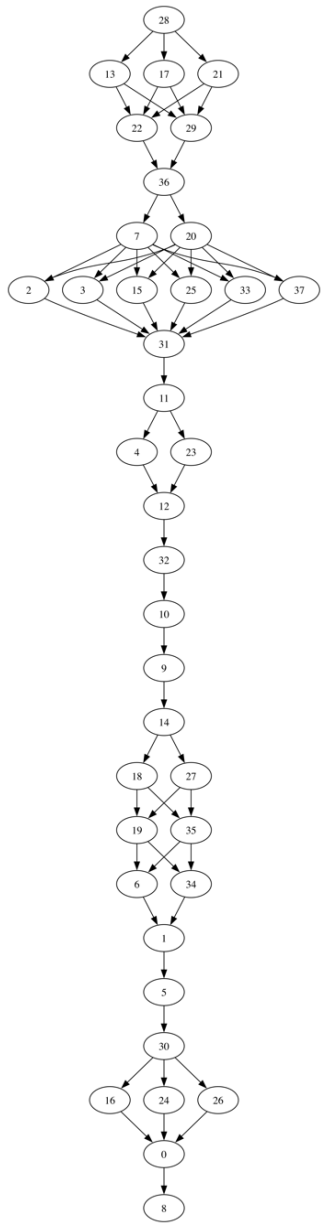


Table A1 – Continuation.

w_{NE}= 1.17	w_{GVA}=1.40
w_{IC}= 2.04	w_{TFA}=2.43, w_{GFCF}=0.46

Alternative	Class	Alternative	Class
A1	1	A71	9
A3	1	A79	9
A5	1	A80	9
A6	1	A81	9
A10	1	A82	9
A13	1	A18	10
A14	1	A19	11
A15	1	A44	11
A16	1	A46	11
A25	1	A20	12
A27	1	A21	13
A28	1	A22	14
A33	1	A23	15
A36	1	A24	16
A41	1	A26	17
A50	1	A34	17
A53	1	A37	17
A55	1	A48	17
A56	1	A60	17
A57	1	A61	17
A58	1	A29	18
A59	1	A30	19
A63	1	A72	19
A65	1	A87	19
A67	1	A31	20
A70	1	A32	21
A75	1	A39	22
A83	1	A40	23
A85	1	A42	24
A89	1	A43	25
A2	2	A88	25
A4	3	A45	26
A7	4	A49	27
A8	5	A52	28
A51	5	A62	29
A9	6	A66	30
A35	6	A68	31
A69	6	A73	32
A11	7	A74	33
A12	8	A76	34
A17	9	A77	35
A38	9	A78	36
A47	9	A84	37
A54	9	A86	38
A64	9		



Alternative	Class	Alternative	Class
A1	1	A56	9
A3	1	A64	9
A5	1	A71	9
A6	1	A79	9
A10	1	A80	9
A13	1	A81	9
A14	1	A82	9
A15	1	A18	10
A16	1	A19	11
A25	1	A30	11
A27	1	A44	11
A28	1	A20	12
A33	1	A21	13
A36	1	A22	14
A41	1	A23	15
A50	1	A24	16
A55	1	A26	17
A57	1	A34	17
A58	1	A48	17
A59	1	A60	17
A63	1	A61	17
A65	1	A29	18
A67	1	A31	19
A70	1	A52	19
A75	1	A78	19
A83	1	A32	20
A85	1	A37	21
A89	1	A39	22
A2	2	A40	23
A72	2	A42	24
A77	2	A43	25
A87	2	A88	25
A4	3	A45	26
A7	4	A46	27
A8	5	A49	28
A9	6	A51	29
A35	6	A62	30
A69	6	A66	31
A11	7	A68	32
A12	8	A73	33
A17	9	A74	34
A38	9	A76	35
A47	9	A84	36
A53	9	A86	37
A54	9		

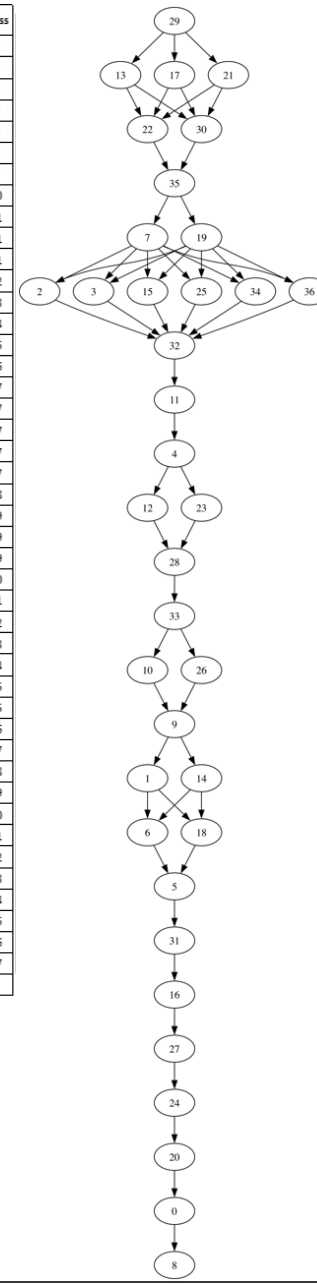


Table A1 – Continuation.

w_{TGP}=0.66

w_R=1.74, w_{IC}=2.24

Alternative	Class	Alternative	Class
A1	1	A82	3
A6	1	A85	3
A13	1	A4	4
A15	1	A7	5
A16	1	A8	6
A25	1	A9	7
A26	1	A11	8
A27	1	A12	9
A33	1	A18	10
A34	1	A19	11
A37	1	A44	11
A41	1	A46	11
A43	1	A20	12
A48	1	A21	13
A55	1	A22	14
A57	1	A23	15
A58	1	A24	16
A59	1	A29	17
A83	1	A30	18
A88	1	A31	19
A89	1	A32	20
A2	2	A35	21
A3	3	A39	22
A5	3	A40	23
A10	3	A42	24
A14	3	A45	25
A17	3	A49	26
A28	3	A51	27
A36	3	A52	28
A38	3	A60	29
A47	3	A61	30
A50	3	A62	31
A53	3	A66	32
A54	3	A68	33
A56	3	A69	34
A63	3	A72	35
A64	3	A77	35
A65	3	A87	35
A67	3	A73	36
A70	3	A74	37
A71	3	A76	38
A75	3	A78	39
A79	3	A84	40
A80	3	A86	41
A81	3		

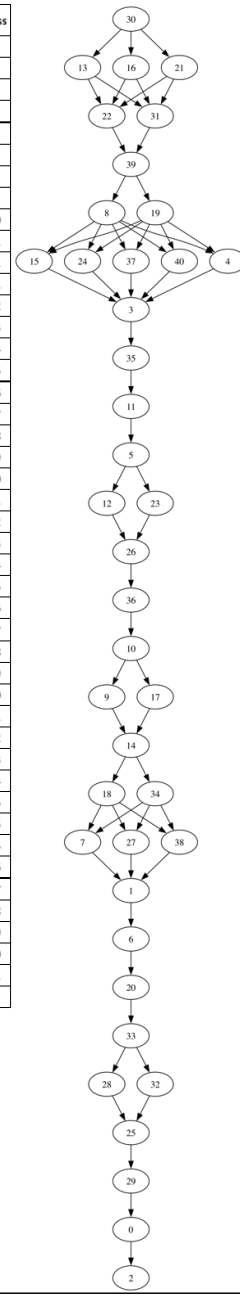
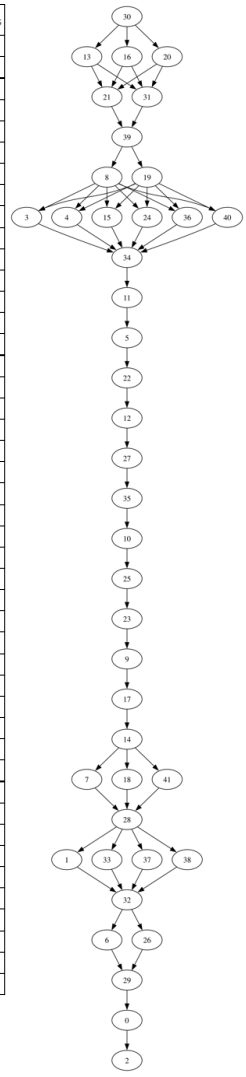


Table A2 – Effect of modifications in criteria thresholds and alterations in the values of the recommendation. Changes of values in the thresholds q and p for one, two, or three criteria simultaneously.

q_{NE}=8,800
p_{NE}=18,300

Alternative	Class	Alternative	Class
A1	1	A82	3
A6	1	A85	3
A13	1	A4	4
A15	1	A7	5
A16	1	A8	6
A25	1	A9	7
A26	1	A35	7
A27	1	A69	7
A33	1	A11	8
A34	1	A12	9
A37	1	A18	10
A41	1	A19	11
A43	1	A20	12
A48	1	A21	13
A55	1	A22	14
A57	1	A23	15
A58	1	A24	16
A59	1	A29	17
A83	1	A30	18
A88	1	A31	19
A89	1	A32	20
A2	2	A39	21
A3	3	A40	22
A5	3	A42	23
A10	3	A44	24
A14	3	A45	25
A17	3	A46	26
A28	3	A49	27
A36	3	A51	28
A38	3	A52	29
A47	3	A60	30
A50	3	A61	30
A53	3	A62	31
A54	3	A66	32
A56	3	A68	33
A63	3	A72	34
A64	3	A73	35
A65	3	A74	36
A67	3	A76	37
A70	3	A77	38
A71	3	A78	39
A75	3	A84	40
A79	3	A86	41
A80	3	A87	42
A81	3		



q_{IC}=5,150
p_{IC}=12,200

Alternative	Class	Alternative	Class
A1	1	A54	9
A3	1	A64	9
A5	1	A71	9
A6	1	A79	9
A10	1	A80	9
A13	1	A81	9
A14	1	A82	9
A15	1	A18	10
A16	1	A19	11
A25	1	A30	11
A27	1	A44	11
A28	1	A46	11
A33	1	A20	12
A36	1	A21	13
A41	1	A22	14
A50	1	A23	15
A53	1	A24	16
A55	1	A26	17
A56	1	A34	17
A57	1	A48	17
A58	1	A60	17
A59	1	A61	17
A63	1	A29	18
A65	1	A31	19
A67	1	A52	19
A70	1	A78	19
A75	1	A32	20
A83	1	A37	21
A85	1	A39	22
A89	1	A40	23
A2	2	A42	24
A72	2	A43	25
A77	2	A88	25
A87	2	A45	26
A4	3	A49	27
A7	4	A51	28
A8	5	A62	29
A9	6	A66	30
A35	6	A68	31
A69	6	A73	32
A11	7	A74	33
A12	8	A76	34
A17	9	A84	35
A38	9	A86	36
A47	9		

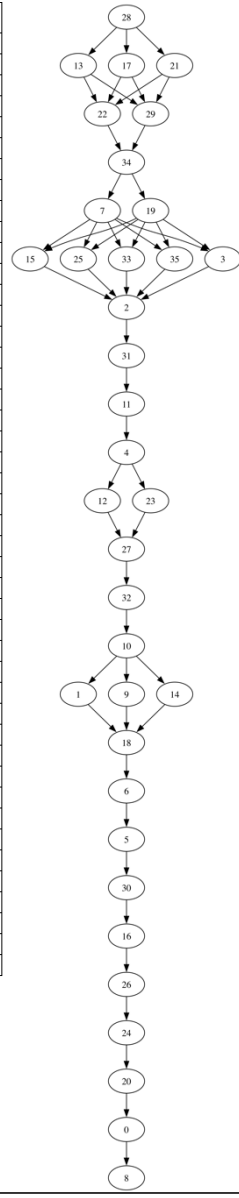
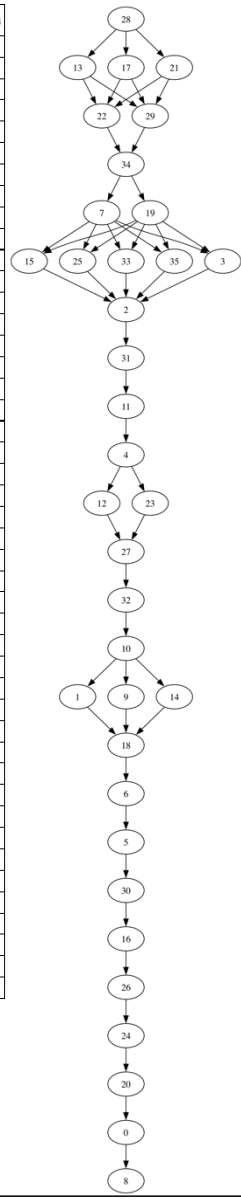


Table A2 – Continuation.

q_{GVA}=3,850
p_{GVA}=8,150

Alternative	Class	Alternative	Class
A1	1	A82	3
A6	1	A85	3
A13	1	A4	4
A15	1	A7	5
A16	1	A8	6
A25	1	A9	7
A26	1	A35	7
A27	1	A69	7
A33	1	A11	8
A34	1	A12	9
A37	1	A18	10
A41	1	A19	11
A43	1	A30	11
A48	1	A44	11
A55	1	A20	12
A57	1	A21	13
A58	1	A22	14
A59	1	A23	15
A83	1	A24	16
A88	1	A29	17
A89	1	A31	18
A2	2	A52	18
A3	3	A78	18
A5	3	A32	19
A10	3	A39	20
A14	3	A40	21
A17	3	A42	22
A28	3	A45	23
A36	3	A46	24
A38	3	A49	25
A47	3	A51	26
A50	3	A60	27
A53	3	A61	28
A54	3	A62	29
A56	3	A66	30
A63	3	A68	31
A64	3	A72	32
A65	3	A77	32
A67	3	A87	32
A70	3	A73	33
A71	3	A74	34
A75	3	A76	35
A79	3	A84	36
A80	3	A86	37
A81	3		



q_{TGP}=6,850, q_{TFA}=3.90
p_{TGP}=15,200, p_{TFA}=9.10

Alternative	Class	Alternative	Class
A1	1	A82	3
A6	1	A85	3
A13	1	A4	4
A15	1	A7	5
A16	1	A8	6
A25	1	A9	7
A26	1	A35	7
A27	1	A69	7
A33	1	A11	8
A34	1	A12	9
A37	1	A18	10
A41	1	A19	11
A43	1	A44	11
A48	1	A46	11
A55	1	A20	12
A57	1	A21	13
A58	1	A22	14
A59	1	A23	15
A83	1	A24	16
A88	1	A29	17
A89	1	A30	18
A2	2	A31	19
A3	3	A52	19
A5	3	A78	19
A10	3	A32	20
A14	3	A39	21
A17	3	A40	22
A28	3	A42	23
A36	3	A45	24
A38	3	A49	25
A47	3	A51	26
A50	3	A60	27
A53	3	A61	28
A54	3	A62	29
A56	3	A66	30
A63	3	A68	31
A64	3	A72	32
A65	3	A77	32
A67	3	A87	32
A70	3	A73	33
A71	3	A74	34
A75	3	A76	35
A79	3	A84	36
A80	3	A86	37
A81	3		

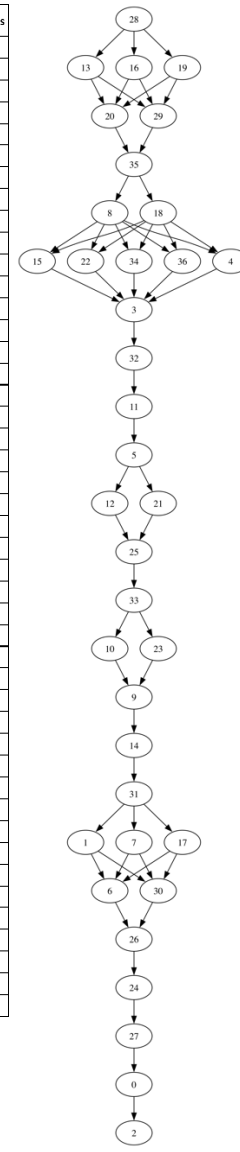


Table A2 – Continuation.

q_{GFCF}=205, q_R=6,050, q_{IC}=4,990

p_{GFCF}=405, p_R=12,050, p_{IC}=11,990

Alternative	Class	Alternative	Class
A1	1	A11	7
A3	1	A12	8
A5	1	A16	9
A6	1	A18	10
A10	1	A19	11
A13	1	A20	12
A14	1	A21	13
A15	1	A22	14
A17	1	A23	15
A25	1	A24	16
A26	1	A29	17
A27	1	A30	18
A28	1	A31	19
A33	1	A44	19
A34	1	A61	19
A36	1	A32	20
A38	1	A37	21
A41	1	A39	22
A43	1	A40	23
A47	1	A42	24
A48	1	A45	25
A50	1	A46	26
A54	1	A49	27
A55	1	A51	28
A56	1	A52	29
A57	1	A53	30
A58	1	A63	30
A59	1	A70	30
A60	1	A79	30
A64	1	A80	30
A65	1	A81	30
A67	1	A62	31
A71	1	A66	32
A75	1	A68	33
A82	1	A69	34
A83	1	A72	35
A85	1	A73	36
A88	1	A74	37
A89	1	A76	38
A2	2	A77	39
A35	2	A78	40
A4	3	A84	41
A7	4	A86	42
A8	5	A87	43
A9	6