



An intelligent Multi-criteria Decision-making Model for Sustainable Higher Education Strategy Selection

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Abstract

This study provides a means for institutions and administrations to develop plans while taking into consideration the strategic linkages. Making strategic decisions on their programming may benefit institutions and governments when relevant material is examined and talks with higher education specialists are held (HE). To handle disagreement and different criteria, multi-criteria decision-making (MCDM) models are utilized. The most effective solution was evaluated using the new multi-criteria technique known as MABAC (Multi-Attributive Border Approximation area Comparison). Following the computation of the criterion weights, the MABAC is used to rank the options. The recommended approach may be used by institutions as well as central planners (usually the government) in higher education policy.

Keywords: Intelligent Education; MABAC; Strategy; MCDM; Sustainability; Universities

1. Introduction

Understanding the relationships between universities, companies, and governments have grown more crucial in recent decades as technology has developed at such a fast pace. In this century. Research results in new possibilities for economic growth at the national level.

For most countries, universities are the primary providers of knowledge generation. In order to comprehend the government–university policy interaction, as [1] said, it is necessary to examine the multi-level and multi-actor settings in which HE institutions and governments function and establish their policies. Research and development, university cooperation, and teaching all have a direct impact on the formulation of university plans.

Universities and governments may use this study's framework MCDM technique to help them make strategic decisions. A few research in the HE research has made use of either MCDM approaches or both at the same time. For example, [2]–[5] have looked at the application of MCDM techniques in the development of an institutional plan for higher education [6]–[9]. Government investments in HE were made using the MCDM methodology [10]. There has been no research to our knowledge that uses game-theoretic methods to analyze the process of institutional and governmental strategy selection in HE. As an alternative, [11] has argued that a game ecology viewpoint might explain the impact of state and federal regulations on university behavior and HE administration overall, as well as how these policies affect the behavior of universities in specific. MCDM and game-theoretic approaches are used in our work for the selection of HE strategies on the institutional and governmental levels.

To come up with a complete framework, past research examining government and university initiatives for HE must be carefully examined. The government has a long history of imposing regulations on institutions that have a direct impact on their strategic plans. In the United States, for example, state and federal funds for higher education (HE) were cut in the 1980s. In the United

States, these policies encouraged public colleges to go nearer to the industry to get more financing and stimulate cooperation. [12]The University Grants Council (UGC) in the United Kingdom served as an intermediary between both the government and academic institutions in the allocation of research grants. As a result of government policy and financing, Australian institutions have implemented a variety of strategic change strategies[13]. While HE funding was cut, [14]said that Japan's government mandated that all other resources be used for technology, research, and market-related fields. Policy in the 1990s was perceived as steering colleges toward financial goals, forcing them to boost productivity to be responsible and receptive to businesses, as well as the state, in a study [15]. A new foreign education policy was unveiled by the Canadian government in 2014[16]. It was found that universities in Canada had to make organizational adjustments as a result of the government's initiatives[1].

According to HEFCE 1997, the "Learning and Teaching Framework for Higher Education" was issued in 1997[17]. The major concept in this plan was the utilization of financing and other designed to promote universities to design and execute comprehensive teaching and learning methodologies said the author. Educators in England were encouraged to develop learning and teaching methodologies by the Dearing Report[18]. For most institutions, by the middle of 1998, it was evident that they had to create a comprehensive plan for improving student learning and teaching across the board.

Generally speaking, universities create their credentials as either research- or teaching-focused institutions. Research and teaching are often seen as being inextricably linked in academia. that Japan's universities have traditionally eschewed efforts to enhance instruction in favor of a research-oriented academic culture reinforced the widely held view that research and education have a beneficial connection. Strong research-teaching nexus may benefit student learning, according to several studies (e.g. [19], [20]). Researchers [21] and [22] found that students valued research-based instruction and were motivated to study by their professors' interest in the subject.

Governments have an important role in encouraging research and development, as noted above. Developing and improving local creativity and regional growth capacity is critical to universities' research efforts (see [23]). Governments promote university-industry relationships in addition to measures aimed at improving "learning and teaching" and "research and development." Modernization and entrepreneurial skills are equally important to universities, in addition to their traditional roles as centers of learning and discovery. HE research is becoming increasingly technoscience-oriented and responsive to infrastructure investment and intellectual property tactics as a result of globalization practices [24]. This process of turning academic research into commercial goods has increased in recent years among universities, especially big research institutions. [25]Universities are being compelled to diversify their income streams, improve efficiency, and move resources toward a greater emphasis on commercializing research as government support shrinks[26]. As a result, plans for university-industry partnerships are being formulated. Institutional structures including TTOs, incubators, entrepreneurship centers, and internal seed funds are increasingly widely used by universities to boost the monetization of research[27]. TTOs facilitate the transfer of universities' intellectual property to external partners in a productive atmosphere[28].

Several issues need to be addressed when it comes to government and university policies. University-industry partnerships and teaching are the other two. Governments and institutions alike want to see more people enroll in higher education because it's good for building human capital. There are four key areas where administrations and universities build their plans, all of which revolve around growing HE capability.

Universities may benefit from a shift in the allocation of government funding. Using game theory, it is possible to analyze the strategic interplay between governments and universities. Because various factors must be taken into account when making choices on where resources should be allocated, MCDM approaches may also be utilized by governments and universities to find the most effective strategies

The rest of the paper is organized as follows: In the next part, we'll explain the methods we followed. In section 3, the framework for developing and selecting HE strategies is described in detail Step-by-step implementation of the framework is shown, and the last part sums up the conclusion and suggests future study prospects.

2. The MCDM MABAC Method

Using the MABAC technique, the strategies in higher education are evaluated. It was created in 2015 by Pamuar and irovi [29] for the choosing of forklifts. The distance between the border approximation region and each option is a key component of the MABAC approach. It is the specification of the criteria function's distance from the border approximation region that lies at the heart of the MABAC technique.

The following are some of the benefits of the MABAC method:

- I. Due to the method's straightforward implementation, it may be put into practice quickly and easily.
- II. To produce complete results, this strategy takes into consideration both profits and losses.
- III. Independent indicator concerns may be addressed with this strategy.
- IV. MABAC may be used in conjunction with other methods.

There have been several studies using different MCDM methodologies and approaches using the MABAC method, even though it was just recently invented. For the first time, Peng and Dai [30] described the MABAC method's cautious use. The steps of the proposed model are shown in figure 1.

Step 1: The linguistic scale is used by DMs to assess the options

Step 2: Convert the linguistic variables to numbers from 1 to 9.

Step 3: Build the decision matrix by the DM

The basic choice matrix is created (X). In the first stage, n criteria are used to assess the m choices. Vectors serve as a visual representation of the choices.

$$X = \begin{pmatrix} y_{11} & \cdots & y_{1n} \\ \vdots & \ddots & \vdots \\ y_{m1} & \cdots & y_{mn} \end{pmatrix} \quad (1)$$

Where m refers to the number of alternatives and n refers to the number of criteria.

$$i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

Step 4: Normalize the decision matrix as

$$N = [n_{ij}]_{m \times n} \quad (2)$$

$$n_{ij} = \frac{y_{ij} - y_i^-}{y_i^+ - y_i^-}; \text{ benefit criteria} \quad (3)$$

$$n_{ij} = \frac{y_i^+ - y_{ij}}{y_i^+ - y_i^-}; \text{ cost criteria} \quad (4)$$

$$y_i^+ = \max_j y_{ij} \quad (5)$$

According to the options, y_i^+ represents the greatest value of the observable criteria.

$$y_i^- = \min_j y_{ij} \quad (6)$$

According to the options, y_i^- represents the greatest value of the observable criteria.

$$N = \begin{pmatrix} n_{11} & \cdots & n_{1n} \\ \vdots & \ddots & \vdots \\ n_{m1} & \cdots & n_{mn} \end{pmatrix} \quad (7)$$

Step 5: Compute the weighted normalized decision matrix

$$W = [w_{ij}]_{m \times n} \quad (8)$$

$$w_{ij} = w_i + w_i * n_{ij} \quad (9)$$

$$W = \begin{pmatrix} w_{11} & \cdots & w_{1n} \\ \vdots & \ddots & \vdots \\ w_{m1} & \cdots & w_{mn} \end{pmatrix} \quad (10)$$

Step 6: Compute the border approximation area matrix

$$D = \prod_{j=1}^m W_{ij}^{1/m} \quad (11)$$

Where m refers to the number of alternatives

Step 7: For each alternative, the distance is computed from the border approximation area

$$I = W - D \quad (12)$$

Step 8: Rank the alternatives according to the largest value of each total row of I

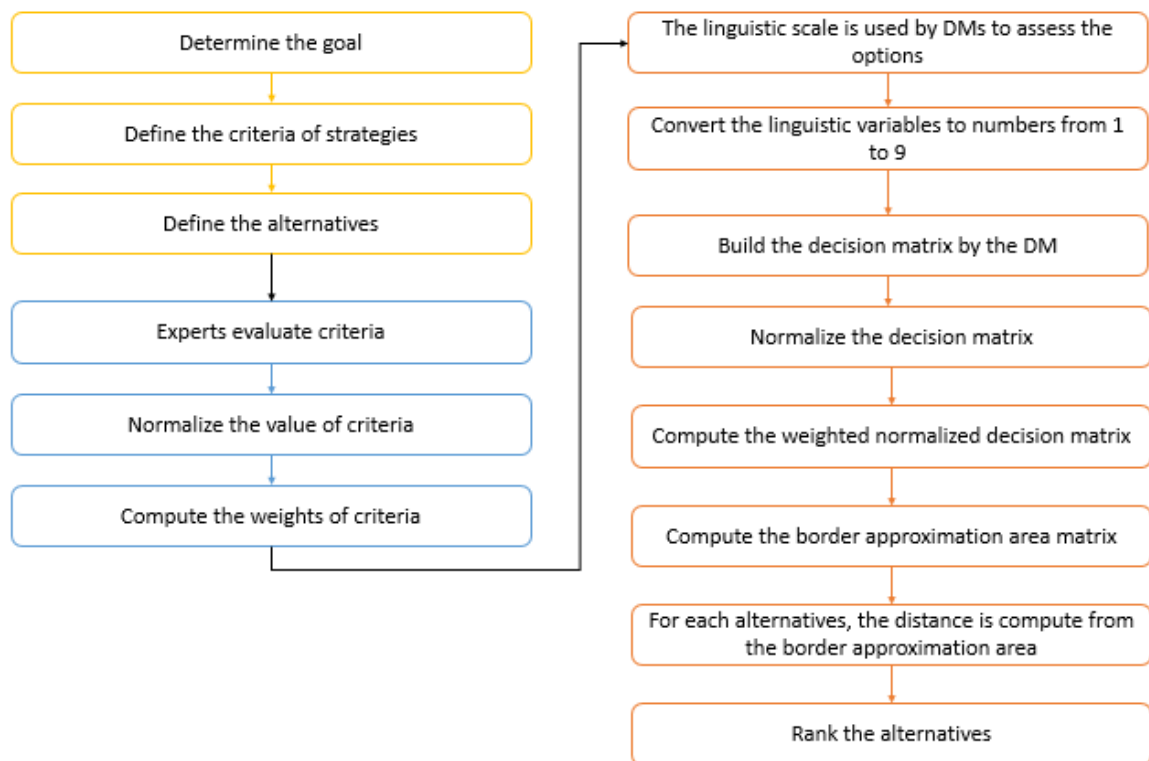


Figure 1: The steps of this paper.

3. Application and Results

This part walks you through the process of putting the framework that was introduced in Section 3 into action. For academics and practitioners, the findings are summarised and explained.

By examining the relevant literature and reviewing it with specialists in higher education, institutions and governments may come up with shared policies. Because of this, the university and country chose the following methods, respectively.

Institutional strategies include:

- 1) Increasing infrastructure expenditures and developing procedures to encourage superior learning research. HEA1
- 2) Enhancing the quality of education through increasing the number of students from both the United States and abroad, as well as improving infrastructural and capacity expenditures. HEA2
- 3) Improving laws, evaluation systems and incentives for teaching excellence at universities are among the government's plans. HEA3
- 4) Enhancing university capability in certain areas via the creation of government incentives. HEA4
- 5) Strengthening government incentive structures to encourage high-quality academic study and increase academic achievement. HEA5
- 6) Create incentive mechanisms at the state level to encourage university-industry partnerships and promote hands-on learning experiences. HEA6
- 7) Improving university-industry cooperation and fostering a climate that encourages hands-on, real-world learning. HEA7
- 8) Use language that your audience understands. SEO experts recommend using long-tail keywords. HEA8
- 9) University marketing departments are finally realizing the need of updating their logos to make them compatible with mobile devices. HEA9
- 10) Stafford Global, a supplier of online education, increased web leads by 50% thanks to HubSpot. HEA10

Governments and universities may have different priorities when it comes to deciding which tactics to use. The following are the criteria, which were arrived at after consulting with a variety of HE administrators and academics:

- 1) The quality of education and instruction HEC1
- 2) University graduates HEC2
- 3) Research quality HEC3
- 4) Collaboration between academia and business HEC4

The weights of the criteria are computed using the opinions of experts. Then convert their opinions to numbers between 1-9. Then normalize the criteria value. Then compute the weights of the criteria. Figure 2 shows the weights of the criteria.



Figure 2: The weights of criteria.

The decision matrix is built on the opinions of experts. In this study, we used four experts to evaluate criteria and alternatives. There are four decision matrices between criteria and alternatives. So, we need to combine these matrices into one matrix. The resulting matrix is called the combined decision matrix as shown in table 1.

Step 1: Evaluated criteria and alternatives by the opinion of experts.

Step 2: Replace their opinions with numbers between 1,3,5,7,9.

Step 3: Using Eq. (1) to obtain the decision matrix between four criteria and ten alternatives

Step 4: Normalize the decision matrix by using Eqs. (2,3,4). The normalization matrix is computed by the positive and negative criteria. the positive criteria computed by the maximum value and negative criteria computed by the minimum value by using Eqs. (4,5,6). Then build the normalization matrix by using Eq. (7).

Step 5: Compute the weighted normalized decision matrix by using Eqs. (8,9,10) as shown in table 2.

Step 6: Compute the border approximation area matrix by using Eq. (11)

Step 7: For each alternative, the distance is computed from the border approximation area by using Eq. (12) as shown in table 3.

Step 8: Rank the alternatives according to the largest value of each total row of I . The HEA7 is the best alternative and HEA4 is the worst alternative. Figure 3 shows the rank of alternatives.

Table 1: The combined decision matrix.

	HEC1	HEC2	HEC3	HEC4
HEA1	0.646	0.458	0.675	0.721
HEA2	0.554	0.508	0.608	0.463
HEA3	0.646	0.600	0.637	0.525
HEA4	0.471	0.721	0.471	0.350
HEA5	0.554	0.388	0.600	0.417
HEA6	0.546	0.433	0.750	0.433
HEA7	0.675	0.721	0.508	0.683
HEA8	0.517	0.517	0.592	0.600
HEA9	0.637	0.442	0.646	0.683
HEA10	0.646	0.562	0.525	0.583

Table 2: The weighted normalized decision matrix

	HEC1	HEC2	HEC3	HEC4
HEA1	0.567	0.303	0.481	0.333
HEA2	0.430	0.341	0.415	0.217
HEA3	0.567	0.409	0.444	0.245
HEA4	0.306	0.500	0.278	0.167
HEA5	0.430	0.250	0.406	0.197
HEA6	0.418	0.284	0.556	0.204
HEA7	0.611	0.500	0.315	0.316
HEA8	0.374	0.347	0.398	0.279
HEA9	0.555	0.291	0.452	0.316
HEA10	0.567	0.381	0.332	0.272

Table 3: The distance from the border area.

	HEC1	HEC2	HEC3	HEC4
HEA1	-0.603	-0.834	-0.670	-0.765
HEA2	-0.740	-0.796	-0.736	-0.881
HEA3	-0.603	-0.727	-0.707	-0.853
HEA4	-0.865	-0.637	-0.873	-0.931
HEA5	-0.740	-0.887	-0.745	-0.901
HEA6	-0.753	-0.852	-0.595	-0.894
HEA7	-0.559	-0.637	-0.836	-0.782
HEA8	-0.796	-0.790	-0.753	-0.819
HEA9	-0.615	-0.846	-0.699	-0.782
HEA10	-0.603	-0.756	-0.819	-0.826

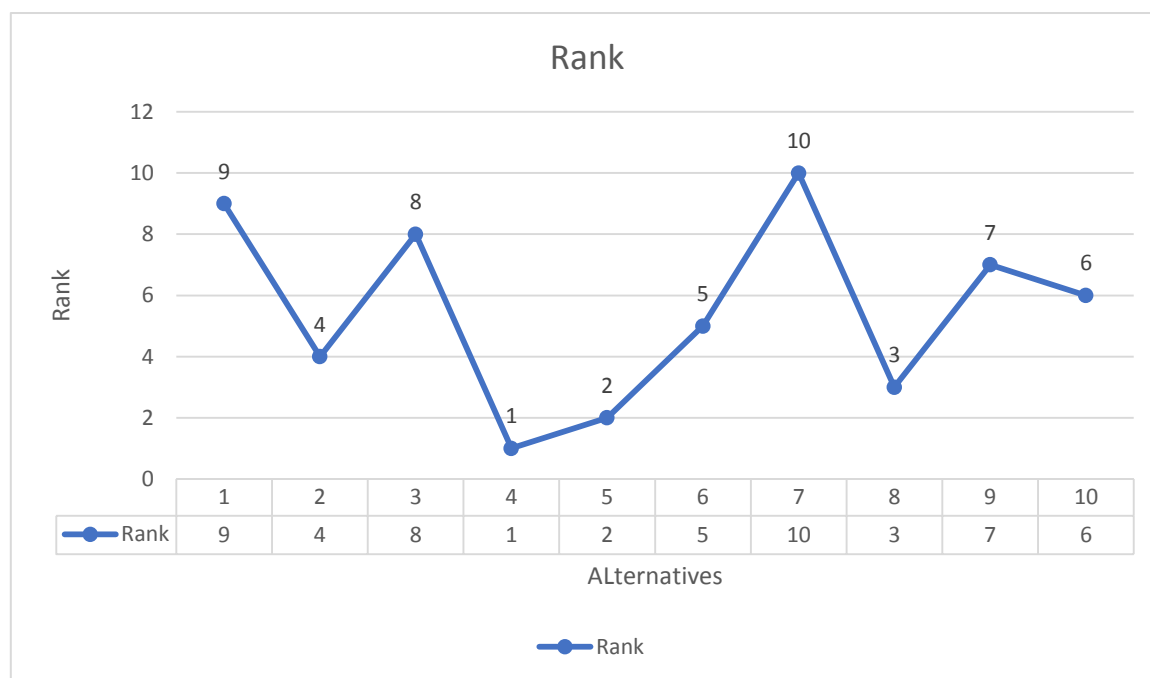


Figure 3: The rank of alternatives

4. Conclusion

Academic institutions, such as universities, are crucial for advancing human knowledge and stimulating economic development across the world. Rapid technical advancement is facilitated by university-industry collaborations. Human capital is important to technological advancement and high-quality HE produces it. This process relies solely on government policies that promote R&D incentives, high-quality HE, and robust university-industry partnerships. This research provides a framework for governments and institutions to use when deciding on the best course of action in such a difficult situation. Under a variety of factors, including strategic interaction, universities and governments must make difficult decisions. We developed a strategy selection framework by using the MCDM MABAC methodology. We used four decision-makers to evaluate criteria and alternatives. We used four criteria and ten alternatives. The MABAC is the better MCDM technique to deal with conflict criteria. The weights of the criteria are obtained. Then the MABAC is used to rank the alternatives.

References

- [1] R. Trilokekar and A. El Masri, "Canada's international education strategy: Implications of a new policy landscape for synergy between government policy and institutional strategy," *Higher Education Policy*, vol. 29, no. 4, pp. 539–563, 2016.
- [2] J.-K. Chen and I.-S. Chen, "Using a novel conjunctive MCDM approach based on DEMATEL, fuzzy ANP, and TOPSIS as an innovation support system for Taiwanese higher education," *Expert Systems with Applications*, vol. 37, no. 3, pp. 1981–1990, 2010.
- [3] S. Hashemkhani Zolfani and A. Safaei Ghadikolaei, "Application of MCDM methods in short-term planning for private universities based on balanced scorecard: a case study from Iran," *International Journal of Productivity and Quality Management*, vol. 10, no. 2, pp. 250–266, 2012.
- [4] A. Labib, M. Read, C. Gladstone-Millar, R. Tonge, and D. Smith, "Formulation of higher education institutional strategy using operational research approaches," *Studies in Higher Education*, vol. 39, no. 5, pp. 885–904, 2014.
- [5] A. Özdemir and F. Tüysüz, "An integrated fuzzy DEMATEL and fuzzy ANP based balanced scorecard approach: application in Turkish higher education institutions," *Journal of Multiple-Valued Logic & Soft Computing*, vol. 28, 2017.
- [6] H.-Y. Wu, J.-K. Chen, I.-S. Chen, and H.-H. Zhuo, "Ranking universities based on performance evaluation by a hybrid MCDM model," *Measurement*, vol. 45, no. 5, pp. 856–880, 2012.

- [7] M. Shayganmehr and G. A. Montazer, "An extended model for assessing E-services of Iranian Universities websites using Mixed MCDM method," *Education and Information Technologies*, vol. 25, no. 5, pp. 3723–3757, 2020.
- [8] M. Kabak and M. Dağdeviren, "A hybrid MCDM approach to assess the sustainability of students' preferences for university selection," *Technological and Economic Development of Economy*, vol. 20, no. 3, pp. 391–418, 2014.
- [9] M. Kiani, M. Bagheri, A. Ebrahimi, and M. Alimohammadlou, "A model for prioritizing outsourceable activities in universities through an integrated fuzzy-MCDM method," *International Journal of Construction Management*, pp. 1–17, 2019.
- [10] C. Kahraman, A. Suder, and S. Cebi, "Fuzzy multi-criteria and multi-experts evaluation of government investments in higher education: the case of Turkey," *Technological and Economic Development of Economy*, vol. 19, no. 4, pp. 549–569, 2013.
- [11] M. A. Nisar, "Higher education governance and performance based funding as an ecology of games," *Higher Education*, vol. 69, no. 2, pp. 289–302, 2015.
- [12] S. Slaughter, "Notional higher education policies in a global economy," *Universities and globalization: Critical perspectives*, pp. 45–70, 1998.
- [13] L. T. Jonathan, "Quality assurance and evaluation in African universities: developing a sustainable quality culture in a challenging environment: international perspectives," *South African Journal of Higher Education*, vol. 14, no. 2, pp. 45–49, 2000.
- [14] Y. Reiko, "University reform in the post-massification era in Japan: analysis of government education policy for the 21st century," *Higher Education Policy*, vol. 14, no. 4, pp. 277–291, 2001.
- [15] J. S. Levin, "Public policy, community colleges, and the path to globalization," *Higher Education*, vol. 42, no. 2, pp. 237–262, 2001.
- [16] S. Hurtado and A. Ruiz Alvarado, "Realizing the potential of Hispanic-serving institutions: Multiple dimensions of institutional diversity for advancing Hispanic higher education," 2012.
- [17] G. Gibbs, T. Habeshaw, and M. Yorke, "Institutional learning and teaching strategies in English higher education," *Higher Education*, vol. 40, no. 3, pp. 351–372, 2000.
- [18] N. C. of I. into H. E. (Great Britain), *Higher education in the learning society: Report of the National Committee*. The Committee, 1997.
- [19] R. M. Van der Rijst, G. J. Visser-Wijnveen, N. Verloop, and J. H. Van Driel, "Undergraduate science coursework: Teachers' goal statements and how students experience research," *Innovations in Education and Teaching International*, vol. 50, no. 2, pp. 178–190, 2013.
- [20] J. Robertson and G. Blackler, "Students' experiences of learning in a research environment," *Higher Education Research & Development*, vol. 25, no. 3, pp. 215–229, 2006.
- [21] M. Healey and A. Jenkins, *Developing undergraduate research and inquiry*. Higher Education Academy York, 2009.
- [22] Y. Hu, R. Van Der Rijst, K. Van Veen, and N. Verloop, "The role of research in teaching: A comparison of teachers from research universities and those from universities of applied sciences," *Higher Education Policy*, vol. 28, no. 4, pp. 535–554, 2015.
- [23] P. Westnes, S. Hatakenaka, M. Gjelsvik, and R. K. Lester, "The role of universities in strengthening local capabilities for innovation—A comparative case study," *Higher Education Policy*, vol. 22, no. 4, pp. 483–503, 2009.
- [24] L. A. Moncayo-Martínez, A. Ramírez-Nafarrate, and M. G. Hernández-Balderrama, "Evaluation of public HEI on teaching, research, and knowledge dissemination by Data Envelopment Analysis," *Socio-Economic Planning Sciences*, vol. 69, p. 100718, 2020.
- [25] J. B. Powers, "Commercializing academic research: Resource effects on performance of university technology transfer," *The Journal of Higher Education*, vol. 74, no. 1, pp. 26–50, 2003.
- [26] D. D. Wang, "Performance-based resource allocation for higher education institutions in China," *Socio-Economic Planning Sciences*, vol. 65, pp. 66–75, 2019.
- [27] E. Rasmussen, Ø. Moen, and M. Gulbrandsen, "Initiatives to promote commercialization of university knowledge," *Technovation*, vol. 26, no. 4, pp. 518–533, 2006.
- [28] B. Carlsson and A.-C. Fridh, "Technology transfer in United States universities," *Journal of Evolutionary Economics*, vol. 12, no. 1, pp. 199–232, 2002.
- [29] D. Pamučar and G. Čirović, "The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison (MABAC)," *Expert systems with applications*, vol. 42, no. 6, pp. 3016–3028, 2015.
- [30] X. Peng and J. Dai, "Hesitant fuzzy soft decision making methods based on WASPAS, MABAC and COPRAS with combined weights," *Journal of Intelligent & Fuzzy Systems*, vol. 33, no. 2, pp. 1313–1325, 2017.