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A Novel MCDM Approach Based on OPA-WINGS for Policy Making in Undergraduate Elective Courses

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Abstract: This research develops a novel MCDM approach that combines the ordinal priority approach (OPA) and a weighted influence nonlinear gauge system (WINGS), for policy making about undergraduate programs and specifically elective courses. We interviewed eight professors at the School of Engineering, Universidad Catolica del Norte, who are highly engaged in organizing elective courses to obtain their prioritization criteria for offering them to undergraduate students. We proposed and applied an MCDM approach based on OPA-WINGS to rank criteria that make the process of planning future electives courses to offer more straightforward. We found that scientific thinking, Industries' needs, and the School's research lines are the main criteria for designing a new elective class. We conducted a sensitivity analysis to demonstrate de robustness of the suggested measures. This work illustrates how OPA-WINGS can improve decision-making for offering elective courses. The results indicate that Industries' needs and School's research lines strongly impact undergraduate programs' direction.

Keywords: multiple-criteria decision making (MCDM); ordinal priority approach (OPA); weighted influence nonlinear gauge system (WINGS); policy making; undergraduate program

MSC: 90B50; 97B10; 97B70

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1. Introduction and Problem Statement

In elective courses, students can study specialized areas of interest are not included in the required course curriculum. While doing this, elective courses strengthen the mandatory courses in specific skill areas students want or need to improve. As a result, students gain more knowledge and skills for future research or job positions [1]. The vital point in elective courses is choosing the right path and improving their quality constantly to provide the arising requirements for job and research positions. Therefore, evaluating the essential criteria that impact the route and quality of elective courses for future policy making is required. Previous studies are examined to identify the research gap and establish a study to improve the quality of policy making for undergraduate elective courses. Akyol et al. [2] developed an MCDM framework using the AHP method to select the best course for graduate studies based on four criteria. Kecek and Soylemez [3] used AHP and TOPSIS to evaluate eight criteria and eleven courses for postgraduate studies in the business department of the Graduate School of Social Sciences at Dumlupinar University. Adali et al. [1] implemented TODIM to evaluate elective courses for undergraduate studies. They considered ability, scheduling time of the course, lecturer of the course, the applicability of the course content for their future career, and feedback as the main criteria to assess six courses. Onay et al. [4] utilized fuzzy AHP to prioritize elective accounting courses in undergraduate and graduate studies. Burcu Doğanalp and Serkan Doğanalp [5] implemented the hierarchical fuzzy TOPSIS method to prioritize three courses in undergraduate studies.

As is clear, few researchers have investigated the critical factors and their dynamics in the policy making for undergraduate elective courses. They mainly used pairwise comparison as the primary tool to rank the criteria, while criteria interactions and experts' knowledge about the problem were neglected. In response, this research implements the ordinal priority approach (OPA), a mathematical programming approach, to consider experts' backgrounds in their statements for criteria prioritization; the field had not implemented optimization-based techniques such as OPA to obtain criteria importance. Furthermore, the weighted influence nonlinear gauge system (WINGS) is utilized to assess the dynamics of the mentioned problem in this research. Compared with the DEMATEL method, WINGS considers the internal strengths or weight of the criteria to assess their impacts on the system. This research uses a comprehensive literature review and experts' statements to identify new, solid, critical criteria in policy making for undergraduate elective courses. In order to describe the problem and determine influential criteria, this research consults professors from the school of engineering of the Universidad Católica del Norte.

The School of Engineering was founded in 2009. The dean of the Faculty of Engineering and Geological Sciences presented the project to the Universidad Católica del Norte authorities in Antofagasta. In 2009 the project was approved, and construction began in Coquimbo for the Department of Basic Science Education and the School of Engineering buildings.

The elective courses in the School of Engineering began to be taught in 2014. Its priority has always been the link with the environment that professionals come to impart their experience to students, so much so that under the Capstone Project degree, companies have been given the possibility to create professional electives to evaluate and then select the best-evaluated students so that the following semester, the company can work with them on a Capstone project. Although this modality gave results at the time in that sometimes those high-achieving good students were later hired by companies as professionals, the School of Engineering has grown in complexity in recent years. Students' interest is not only to work in an organization but to create their own companies (business entrepreneurship) and to deepen their studies through graduate programs, which has led to the need for professional electives to have an articulating role for those students between undergraduate and graduate studies.

Since 2016, the professional electives taught in the School of Engineering have been diversifying. The arrival of new academics, the professional development of the disciplines, and master's degree programs have led to a greater variety of courses to offer based on the needs of students and professors. Often, researchers propose that offering professional electives to students could net a few interested students when the line of research is very tight or the offer is extensive. Professional electives are valuable courses in the professional development of students, as they can provide new tools, deepen topics of interest, and help students evaluate if they like research, among others. Incorporating student and faculty preferences is difficult for the teaching secretary and career managers considering many factors. At this point, decision support tools become essential to improving the process. In response, this project proposes a new structure based on multiple-criteria decision making to evaluate and rank crucial factors that impact undergraduate elective course quality identified by multiple stakeholders and literature. Figure 1 shows the proposed approach flow diagram.

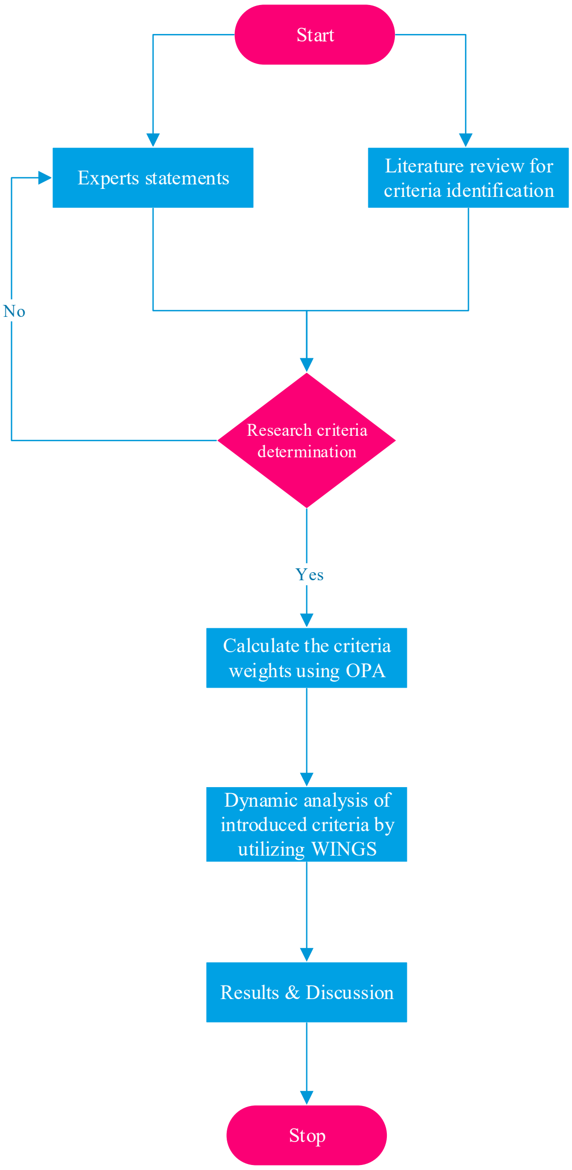

Figure 1. Research flow diagram.

The remaining parts of this research are organized as follows: Section 2 describes the literature review of two implemented MCDM methods. The research methodology is explained in Section 3. Section 4 includes the application of the research methodology and preliminary results. Research validation experiments are provided in Section 5. Finally, managerial implications and research conclusions are given in Sections 6 and 7, respectively.

2. Literature Review

2.1. OPA-Based Studies

Ataei and his colleagues [6] introduced a novel MADM method that can evaluate experts, criteria, and alternatives' weights at the same time. The OPA does not require a primary decision matrix, normalization approaches, or averaging methods (in the case of group decision making). OPA implements a mathematical model that uses the ranks and priorities of experts, criteria, and alternatives as initial data to obtain the final weights. OPA also functions well when users are unsure of the criteria or options. In other words, OPA gives experts a chance only to rank the criteria or alternatives they are completely aware of [6]. Table 1 shows recent research that utilized OPA as a MADM tool to solve various decision-making problems.

Table 1. OPA literature.

Author(s)	Method(s)	Application
Quartey-Papafio et al. [7]	OPA	Supplier selection for health centers is based on four criteria (delivery performance, cost, quality, and service level)
Sadeghi et al. [8]	OPA	Assessing the barriers that confront the utilization of blockchain in the sustainability of the construction industry
Dorado Chaparro et al. [9]	OPA	Evaluating at-home rehabilitation approaches
Li et al. [10]	OPA	Assessing the environmental needs of age-friendly communities
Abdel-Basset et al. [11]	Neutrosophic OPA	Selecing of a suitable robot
Mahmoudi & Javed [12]	OPA-based Relative Performance Index	Evaluating subcontractors' performance in the construction industry
Mahmoudi et al. [13]	Robust OPA	Portfolio project selection based on an organizational resilience strategy
Elkadeem et al. [14]	OPA & weighted linear combination (WLC)	Assessing the economic and technical potential of solar photovoltaic and onshore wind turbine power plants from a geographical, technological, and economic perspective.
Mahmoudi et al. [15]	OPA-TOPSIS	Project selection based on big and incomplete data
Bah & Tulkinov [16]	OPA-TOPSIS	Analysis of suppliers in the automotive parts industry
Irvanizam et al. [17]	TraFNN MULTIMOORA-OPA-CCSD	Assessing low-income families during the Covid-19 pandemic for assigning social aid
Mahmoudi et al. [18]	DEA-OPA	Performance evaluation of suppliers
Mahmoudi et al. [19]	Fuzzy OPA	Post-COVID-19 appropriate supplier selection in the green-resilient supply chain under disruptions
Mahmoudi et al. [20]	Fuzzy OPA	Construction supplier performance assessment based on agility, localization, and digitalization
Sadeghi et al. [21]	Fuzzy OPA	Risk evaluation of blockchain technology implementation in construction companies
Sadeghi et al. [22]	Fuzzy OPA	Ranking blockchain technology utilization necessities in construction supply chains under uncertainty
Le et al. [23]	OPA-Fuzzy EDAS	Evaluating post-COVID-19 production strategies of the manufacturing industry in Vietnam
Deveci et al. [24]	Q-Rung Orthopair Fuzzy Sets Based OPA-RAFSI	Assessing the autonomous vehicle technology implementation in the metaverse
Pamucar et al. [25]	OPA under picture fuzzy sets	Achieving zero-carbon emissions for freight companies through transportation planning
Islam [26]	Grey OPA	Prioritizing low-carbon sustainable technologies in the agriculture industry
Mahmoudi et al. [27]	Grey OPA	Selecting sustainable supplier in megaprojects
Candra [28]	Grey OPA	Assessing the barriers facing electric vehicle adoption in Indonesia
Pamucar et al. [29]	Rough Aczel–Alsa (RAA)Function & OPA	Metaverse evaluation model toward sustainable transportation

2.2. WINGS Literature

WINGS is a structural-based model that originated from DEMATEL to assess the interactions among system elements based on their influence and strength factors [30]. WINGS benefits from graphs to show the interactions among the systems' components. Moreover, it considers the weight or internal strength of each element in computation steps that DEMATEL neglected. At the same time, try to keep the calculations simple [30].

Table 2 illustrates the application of the WINGS method in overcoming different decision-making problems.

Table 2. WINGS literature.

Author(s)	Method(s)	Application
Kashi & Franek [31]	ANP-WINGS-ENTROPY	Assessing the important business process criteria based on the balanced scorecard approach
Rego Mello & Gomes [32]	WINGS	Industry risk evaluation in Brazil
Michnik & Adamus-Matuszyńska [33]	WINGS	Determining the appropriate public relations strategy
Kashi [34]	AHP-WINGS	Proposing an employee training and development framework in an automotive company
Radziszewska-Zielina & Śladowski [35]	Fuzzy WINGS	Selecting a variant of historical building adaptation
Michnick [36]	WINGS-BOCR based	Selecting innovation projects
Salum et al. [37]	DEMATEL-TOPSIS-WINGS	Categorizing multimarket investment funds
Salum et al. [38]	TOPSIS-WINGS	Ranking stock investment funds
Banaś & Michnik [39]	Dynamic WINGS	Assessing the impact of strategic offers on company conditions
Adamus-Matuszyńska et al. [40]	Dynamic WINGS	Boosting the city image of Katowice city
Kaviani et al. [41]	BWM-WINGS	Identifying barriers to logistics success in the automotive industry
Michnik & Grabowski [42]	Interval arithmetic WINGS	Strategic decision making in health care organizations/ Supporting sports
Wang et al. [43]	RBF-WINGS	Assessing the factors affecting the development of green buildings in China
Tavana et al. [44]	Fuzzy WINGS	Evaluating advanced technology projects at NASA
Tavana et al. [45]	WINGS-optimization model	Partner selection in public–private partnership projects in the tourism industry
Chen [46]	SOM-MOEA-WINGS	Social network analysis
Zhang & Zu [47]	fuzzy WINGS-G1	Identifying key risk factors in medical and health care integration projects
Marsili et al. [48]	Interval arithmetic WINGS	Evaluating aging levees' vulnerability
Šmidovnik [49]	Finite sum of WINGS influences—FSI WINGS	Assessing advanced technology projects at NASA (Tavana et al. [44] case study)
Govindan et al. [50]	WINGS	Evaluating blockchain technology adoption in health care sectors
Tavana et al. [51]	BWM-WINGS-TOPSIS	Developing a sustainable partnership selection model for green public-private partnerships

2.3. Research Gap

As mentioned, elective courses are one of the essential ways to strengthen the skills and quality of a specific field of knowledge in undergraduate programs. Previous research had not considered the macro criteria involved in determining elective courses' future policies. Therefore, systemic research that considers the literature and the opinions of skilled experts is needed.

According to methodology literature, OPA was not used to determine the internal strength of criteria and evaluate their dynamics. The WINGS method is only integrated with techniques such as ANP, AHP, and BWM to obtain the inner strength of the criteria. Therefore, the integration of OPA and WINGS, which is for the first time, has the following advantages:

- Since the weights are based on experts' opinions, the OPA method incorporates experts' experience in determining weights, which leads to weighing accuracy. This issue was not considered in other studies.
- The implementation of OPA based on mathematical modeling confirms the convergence towards more accurate weights.
- WINGS considers the weights of criteria in determining their impacts and roles, leading to more accurate policy making.

3. Methodology

A novel three-stage MCDM approach is introduced in this research to map the factors that affect undergraduate elective courses. In the first stage, solid criteria are presented based on reviewing the literature and experts who are practically engaged in this issue at Universidad Católica del Norte Norte, School of Engineering. The second stage consists of the ordinal priority approach procedure for prioritizing the experts based on their experiences and obtain criteria strengths (weights). WINGS is utilized in stage three to assess the dynamics of the proposed criteria and determine their roles and impacts.

3.1. Ordinal Priority Approach (OPA)

OPA is an optimization-based technique that can evaluate experts, criteria, and alternatives' importance in an MCDM problem. The OPA steps in this research are as follows:

Step 1. Criteria based on experts' statements and literature review need to be identified to evaluate undergraduate elective courses. First, literature is surveyed to extract appropriate measures. Then experts from Universidad Catolica del Norte, School of Engineering are asked, "What criteria do you consider important about elective courses if students want to continue as a researcher in graduate programs?"

The answers are as follows:

- Utilize professors, hopefully from the same career, who are professionals successful in their practice and models of how to become in time.
- Provide depth of knowledge (industry 4.0), articulation with the MCII (advanced simulation), regional industry demand (decision making in tourism, agriculture, aquaculture, and mining), national and international industry demand (data science), lack of courses in the current curriculum of school (engineering systems, market research, marketing, etc.).
- Depth of content.
- Applicability in the short term.
- Development of teamwork.
- Provide knowledge and skills that respond to emerging needs of the professional market, the latest that are being demanded. In its generic part, self-learning and hours of work.
- Elective courses should offer cutting-edge knowledge.
- Provide schools' lines of research.
- Educate students on lean, critical, agile, and innovative thinking.

In the next step, experts were asked to verify each statement for future consideration of criteria. Criteria that were mentioned in the literature briefly (C_4, C_6, C_7) were considered as experts' suggestions for future policy making

Descriptive and transparent results are shown in Table 3. It presents seven solid criteria that are vital in instructing undergraduate elective courses.

Table 3. Research criteria.

Criteria	Abbreviation	Description	References
Professional practices	C_1	Courses that researchers should teach in the core line of expected professional practice, using a mixture of technology and management engineering and developing student abilities in systems optimization, analytics, and decision making.	[52,53]
Industries' needs	C_2	The skills required by industries in researching and creating knowledge or operational activities, such as communication, problem-solving, self-management, and teamwork skills.	[52,54–56]
Application of Scientific Thinking	C_3	The strength of an elective in establishing or improving scientific thinking dimensions such as logical reasoning, means of change (inherent theories), and practical activities; also includes identifying a problem, developing a scientific hypothesis, making conclusions based on all evidence, etc.	[57–59]
Schools' lines of research	C_4	The characteristics of an elective course that can provide research fields in line with university policies in the short and long terms. This criterion is a win–win situation for students and the university. While university research ability and creating knowledge follow with more speed and power, students receive more support.	Experts
Scientific skills	C_5	The strength of an elective course in reinforcing student skills to read and understand scientific texts better, write research papers, data analysis, present their knowledge, etc.	[58,60,61]
Pre-planned activities	C_6	Clearly defined curriculum and content to meet the course's scientific objectives; contents are planned to improve students' scientific and social skills.	Experts
Provide deeper sight of an area of knowledge	C_7	Introducing new trends in a specific part of knowledge and allowing students to go deeper into that area stimulate scientific curiosity and develop skills related to research methodology, including current technologies and methods.	Experts

Step 2. The experts' prioritization. The eight experts in this research are introduced in Table 4 and ranked based on their experience concerning the issue.

Table 4. Experts introduction and prioritization.

Name	Index	Title	Rank
Dr. Jorge Alfaro Pérez	E_1	Former director and the current research secretary	1
Dr. Ariel Areyuna Santiago	E_2	Former director of the industrial engineering department on the Antofagasta campus and the current teaching secretary of the School of Engineering	4
Dr. Sarfaraz Hashemkhani Zolfani	E_3	The former head of the industrial engineering group	5
Dr. Carlos Monardes Concha	E_4	The former and first head of the industrial engineering group	3
Dr. Patricio Ramírez Correa	E_5	The current director of the School of Engineering and the former research secretary	1
Raúl Carrasco Cea	E_6	The former teaching secretary and former head of the industrial engineering group	7
José Castillo Venenciano	E_7	The current head of the industrial engineering group	8
Pedro Reyes Norambuena	E_8	The current communication secretary and the former head of the industrial engineering group	6

Step 3. Experts are asked to rank the criteria based on their preferences.
Step 4. Obtain the criteria weights by utilizing the following linear optimization model: Table 5 shows the required sets, indexes, parameters, and variables of the OPA.

Table 5. Sets, indexes, parameters, and variables of the OPA technique.

Sets	
$\boldsymbol{I}$	Set of experts $\forall i \in I$
$\boldsymbol{J}$	Set of criteria $\forall j \in J$
Indexes	
$\boldsymbol{i}$	Index of the experts $(1, \ldots, n)$
$\boldsymbol{j}$	Index of the criteria $(1, \ldots, m)$
Variables	
$\boldsymbol{Z}$	The objective function, free variable
$\boldsymbol{w_{ij}^{p}}$	Strength of jth criterion according to ith expert at pth rank
Parameters	
$\boldsymbol{i}$	The rank of expert i
$\boldsymbol{j}$	The rank of criteria j
p	Order of criteria j

$$
\begin{gathered}
Max\ Z. \\
s.t\ : \\
Z \leq i \times j \times \left(w_{ij}^{p} - w_{ij}^{p+1} \right) \quad \forall i, j, p \\
Z \leq i \times j \times \left(w_{ij}^{m} \right) \quad \forall i, j \\
\sum_{i=1}^{n} \sum_{j=1}^{m} w_{ij} = 1 \\
w_{ij} \geq 0 \ \ \forall i, j
\end{gathered}
\tag{1}
$$

By solving the mentioned model, the weights of criteria and experts can be obtained by implementing Equations (2) and (3):

$$w_i = \sum_{j=1}^{m} w_{ij} \quad \forall i \tag{2}$$

$$w_j = \sum_{i=1}^{n} w_{ij} \quad \forall j \tag{3}$$

3.2. Weighted Influence Nonlinear Gauge System (WINGS)

WINGS was introduced to assess the dynamics of a system based on the components' internal strengths and their behavior towards each other. Applying this method makes it possible to determine the importance of criteria and their role in a system. WINGS procedure is described as follows:

Step 1. Criteria identification. Seven criteria introduced in Table 3 and also assessed by OPA to obtain their internal strengths are considered.

Step 2. Present the causal map. In this step, experts are asked to identify the criteria's interactions among each other. Nodes show the criteria, and meaningful interaction is represented by the arrow from the dominant node to the affected node.

Step 3. Verbal and numerical scale determination. A five-point verbal scale including: very weak interaction, weak interaction, medium interaction, high interaction, and very high interaction is considered for the relation assessment among the criteria. Then verbal scale needs to be transformed from a qualitative to a numerical scale. In this research, very weak interaction = 1, weak interaction = 3, medium interaction = 5, high interaction = 7, very high interaction = 9. Furthermore, OPA is used to determine criteria strengths without considering verbal or numerical scales. As a result of maintaining the equality of the scales, the OPA weights are rescaled since they range between zero and one.

Step 4. Construct the direct influence–strength matrix (DIS). The direct influence strength is filled by utilizing experts' statements about criteria interactions and strengths. Criteria interactions are inserted in such a way that $i \neq j$, d_{ij} shows the impact of criterion i on criterion j. Criteria strengths are inserted into the principal diagonal of the DIS matrix, shown by d_{ii}.

Step 5. DIS matrix balancing. This step consists of defining a balancing measure (m) based on the sum of all values in the DIS matrix and dividing each value in that matrix by the balancing measure. Equations (4) and (5) show this process:

$$m = \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij} \tag{4}$$

$$M = DIS \times m^{-1} \tag{5}$$

Step 6. Compute the total influence–strength matrix T. Equation (6) is utilized to complete this step:

$$T = M + M^2 + M^3 + \ldots = \frac{M}{(I - M)} = M \times (I - M)^{-1} \tag{6}$$

Step 7. Obtain total impact (TI_i), total receptivity (TR_j), total engagement $(TI_i + TR_i)$, and role $(TI_i - TR_i)$ for each criterion. Equations (7) and (8) illustrate this procedure:

$$TI_i = \sum_{j=1}^{n} t_{ij} \tag{7}$$

$$TR_j = \sum_{i=1}^{n} t_{ij} \tag{8}$$

Step 8. Draw engagement-position map based on total engagement and role measures for final analysis.

4. Application and Discussion

After finalizing the research criteria introduced in Table 3, OPA is applied to obtain the strength of each criterion based on experts' ideas. Table 5 illustrates the experts' statements about the criteria order.

In the next step, the following optimization model is introduced to obtain the criteria strengths by utilizing the experts' rankings from Table 4 and their preferences on research criteria from Table 6.

Table 6. Criteria order based on each expert opinion.

Experts	C_1	C_2	C_3	C_4	C_5	C_6	C_7
E_1	4	2	1	7	5	6	3
E_2	2	3	1	6	4	7	5
E_3	4	1	5	6	2	7	3
E_4	2	1	3	5	4	7	6
E_5	2	5	3	1	4	7	6
E_6	7	4	6	5	3	1	2
E_7	1	2	4	5	6	7	3
E_8	3	2	1	4	6	5	7

$$
\begin{array}{l}
Max\ Z \\
s.t\ : \\
1\times\left(1\times\left(w_{E_1C_3}-w_{E_1C_2}\right)\right)\geq Z,\ 1\times\left(2\times\left(w_{E_1C_2}-w_{E_1C_7}\right)\right)\geq Z, \\
1\times\left(3\times\left(w_{E_1C_7}-w_{E_1C_1}\right)\right)\geq Z,\ 1\times\left(4\times\left(w_{E_1C_1}-w_{E_1C_5}\right)\right)\geq Z, \\
1\times\left(5\times\left(w_{E_1C_5}-w_{E_1C_6}\right)\right)\geq Z,\ 1\times\left(6\times\left(w_{E_1C_6}-w_{E_1C_4}\right)\right)\geq Z, \\
1\times\left(7\times\left(w_{E_1C_4}\right)\right)\geq Z, \\
1\times\left(1\times\left(w_{E_5C_4}-w_{E_5C_1}\right)\right)\geq Z,\ 1\times\left(2\times\left(w_{E_5C_1}-w_{E_5C_3}\right)\right)\geq Z, \\
1\times\left(3\times\left(w_{E_5C_3}-w_{E_5C_5}\right)\right)\geq Z,\ 1\times\left(4\times\left(w_{E_5C_5}-w_{E_5C_2}\right)\right)\geq Z, \\
1\times\left(5\times\left(w_{E_5C_2}-w_{E_5C_7}\right)\right)\geq Z,\ 1\times\left(6\times\left(w_{E_5C_7}-w_{E_5C_6}\right)\right)\geq Z, \\
1\times\left(7\times\left(w_{E_5C_6}\right)\right)\geq Z, \\
3\times\left(1\times\left(w_{E_4C_2}-w_{E_4C_1}\right)\right)\geq Z,\ 3\times\left(2\times\left(w_{E_4C_1}-w_{E_4C_3}\right)\right)\geq Z, \\
3\times\left(3\times\left(w_{E_4C_3}-w_{E_4C_5}\right)\right)\geq Z,\ 3\times\left(4\times\left(w_{E_4C_5}-w_{E_4C_4}\right)\right)\geq Z, \\
3\times\left(5\times\left(w_{E_4C_4}-w_{E_4C_7}\right)\right)\geq Z,\ 3\times\left(6\times\left(w_{E_4C_7}-w_{E_4C_6}\right)\right)\geq Z, \\
3\times\left(7\times\left(w_{E_4C_6}\right)\right)\geq Z, \\
4\times\left(1\times\left(w_{E_2C_3}-w_{E_2C_1}\right)\right)\geq Z,\ 4\times\left(2\times\left(w_{E_2C_1}-w_{E_2C_2}\right)\right)\geq Z, \\
4\times\left(3\times\left(w_{E_2C_2}-w_{E_2C_5}\right)\right)\geq Z,\ 4\times\left(4\times\left(w_{E_2C_5}-w_{E_2C_7}\right)\right)\geq Z, \\
4\times\left(5\times\left(w_{E_2C_7}-w_{E_2C_4}\right)\right)\geq Z,\ 4\times\left(6\times\left(w_{E_2C_4}-w_{E_2C_6}\right)\right)\geq Z, \\
4\times\left(7\times\left(w_{E_2C_6}\right)\right)\geq Z, \\
5\times\left(1\times\left(w_{E_3C_2}-w_{E_3C_5}\right)\right)\geq Z,\ 5\times\left(2\times\left(w_{E_3C_5}-w_{E_3C_7}\right)\right)\geq Z, \\
5\times\left(3\times\left(w_{E_3C_7}-w_{E_3C_1}\right)\right)\geq Z,\ 5\times\left(4\times\left(w_{E_3C_1}-w_{E_3C_3}\right)\right)\geq Z, \\
5\times\left(5\times\left(w_{E_3C_3}-w_{E_3C_4}\right)\right)\geq Z,\ 5\times\left(6\times\left(w_{E_3C_4}-w_{E_3C_6}\right)\right)\geq Z, \\
5\times\left(7\times\left(w_{E_3C_6}\right)\right)\geq Z, \\
6\times\left(1\times\left(w_{E_8C_3}-w_{E_8C_2}\right)\right)\geq Z,\ 6\times\left(2\times\left(w_{E_8C_2}-w_{E_8C_1}\right)\right)\geq Z, \\
6\times\left(3\times\left(w_{E_8C_1}-w_{E_8C_4}\right)\right)\geq Z,\ 6\times\left(4\times\left(w_{E_8C_4}-w_{E_8C_6}\right)\right)\geq Z, \\
6\times\left(5\times\left(w_{E_8C_6}-w_{E_3C_5}\right)\right)\geq Z,\ 6\times\left(6\times\left(w_{E_8C_5}-w_{E_8C_7}\right)\right)\geq Z, \\
6\times\left(7\times\left(w_{E_8C_7}\right)\right)\geq Z,
\end{array} \tag{9}
$$

$$7 \times (1 \times (w_{E_6C_6} - w_{E_6C_7})) \geq Z,\ 7 \times (2 \times (w_{E_6C_7} - w_{E_6C_5})) \geq Z,$$
$$7 \times (3 \times (w_{E_6C_5} - w_{E_6C_2})) \geq Z,\ 7 \times (4 \times (w_{E_6C_2} - w_{E_6C_4})) \geq Z,$$
$$7 \times (5 \times (w_{E_6C_4} - w_{E_6C_3})) \geq Z,\ 7 \times (6 \times (w_{E_6C_3} - w_{E_6C_1})) \geq Z,$$
$$7 \times (7 \times (w_{E_6C_1})) \geq Z,$$
$$8 \times (1 \times (w_{E_7C_1} - w_{E_7C_2})) \geq Z,\ 8 \times (2 \times (w_{E_7C_2} - w_{E_7C_7})) \geq Z,$$
$$8 \times (3 \times (w_{E_7C_7} - w_{E_7C_3})) \geq Z,\ 8 \times (4 \times (w_{E_7C_3} - w_{E_7C_4})) \geq Z,$$
$$8 \times (5 \times (w_{E_7C_4} - w_{E_7C_5})) \geq Z,\ 8 \times (6 \times (w_{E_7C_5} - w_{E_7C_6})) \geq Z,$$
$$8 \times (7 \times (w_{E_7C_6})) \geq Z,$$
$$w_{E_1C_1} + w_{E_1C_2} + w_{E_1C_3} + w_{E_1C_4} + w_{E_1C_5} + w_{E_1C_6} + w_{E_1C_7} + w_{E_2C_1} + w_{E_2C_2} + w_{E_2C_3} + w_{E_2C_4} +$$
$$w_{E_2C_5} + w_{E_2C_6} + w_{E_2C_7} + w_{E_3C_1} + w_{E_3C_2} + w_{E_3C_3} + w_{E_3C_4} + w_{E_3C_5} + w_{E_3C_6} + w_{E_3C_7} + w_{E_4C_1} +$$
$$w_{E_4C_2} + w_{E_4C_3} + w_{E_4C_4} + w_{E_4C_5} + w_{E_4C_6} + w_{E_4C_7} + w_{E_5C_1} + w_{E_5C_2} + w_{E_5C_3} + w_{E_5C_4} + w_{E_5C_5} +$$
$$w_{E_5C_6} + w_{E_5C_7} + w_{E_6C_1} + w_{E_6C_2} + w_{E_6C_3} + w_{E_6C_4} + w_{E_6C_5} + w_{E_6C_6} + w_{E_6C_7} + w_{E_7C_1} + w_{E_7C_2} +$$
$$w_{E_7C_3} + w_{E_7C_4} + w_{E_7C_5} + w_{E_7C_6} + w_{E_7C_7} + w_{E_8C_1} + w_{E_8C_2} + w_{E_8C_3} + w_{E_8C_4} + w_{E_8C_5} + w_{E_8C_6} + w_{E_8C_7} = 1$$
$$w_{E_1C_1}, w_{E_1C_2}, w_{E_1C_3}, w_{E_1C_4}, w_{E_1C_5}, w_{E_1C_6}, w_{E_1C_7}, w_{E_2C_1}, w_{E_2C_2}, w_{E_2C_3}, w_{E_2C_4}, w_{E_2C_5}, w_{E_2C_6}, w_{E_2C_7}, w_{E_3C_1},$$
$$w_{E_3C_2}, w_{E_3C_3}, w_{E_3C_4}, w_{E_3C_5}, w_{E_3C_6}, w_{E_3C_7}, w_{E_4C_1}, w_{E_4C_2}, w_{E_4C_3}, w_{E_4C_4}, w_{E_4C_5}, w_{E_4C_6}, w_{E_4C_7}, w_{E_5C_1}, w_{E_5C_2},$$
$$w_{E_5C_3}, w_{E_5C_4}, w_{E_5C_6}, w_{E_5C_7}, w_{E_6C_1}, w_{E_6C_2}, w_{E_6C_3}, w_{E_6C_4}, w_{E_6C_5}, w_{E_6C_6}, w_{E_6C_7}, w_{E_7C_1}, w_{E_7C_2}, w_{E_7C_3}, w_{E_7C_4},$$
$$w_{E_7C_5}, w_{E_7C_6}, w_{E_7C_7}, w_{E_8C_1}, w_{E_8C_2}, w_{E_8C_3}, w_{E_8C_4}, w_{E_8C_5}, w_{E_8C_6}, w_{E_8C_7} \geq 0$$

After solving the above model, the following equations should be considered to obtain the final weights of criteria:

$$w_{C_1} = w_{E_1C_1} + w_{E_2C_1} + w_{E_3C_1} + w_{E_4C_1} + w_{E_5C_1} + w_{E_6C_1} + w_{E_7C_1} + w_{E_8C_1} = 0.1758$$
$$w_{C_2} = w_{E_1C_2} + w_{E_2C_2} + w_{E_3C_2} + w_{E_4C_2} + w_{E_5C_2} + w_{E_6C_2} + w_{E_7C_2} + w_{E_8C_2} = 0.1923$$
$$w_{C_3} = w_{E_1C_3} + w_{E_2C_3} + w_{E_3C_3} + w_{E_4C_3} + w_{E_5C_3} + w_{E_6C_3} + w_{E_7C_3} + w_{E_8C_3} = 0.2384$$
$$w_{C_4} = w_{E_1C_4} + w_{E_2C_4} + w_{E_3C_4} + w_{E_4C_4} + w_{E_5C_4} + w_{E_6C_4} + w_{E_7C_4} + w_{E_8C_4} = 0.1468$$
$$w_{C_5} = w_{E_1C_5} + w_{E_2C_5} + w_{E_3C_5} + w_{E_4C_5} + w_{E_5C_5} + w_{E_6C_5} + w_{E_7C_5} + w_{E_8C_5} = 0.1011$$
$$w_{C_6} = w_{E_1C_6} + w_{E_2C_6} + w_{E_3C_6} + w_{E_4C_6} + w_{E_5C_6} + w_{E_6C_6} + w_{E_7C_6} + w_{E_8C_6} = 0.0460$$
$$w_{C_7} = w_{E_1C_7} + w_{E_2C_7} + w_{E_3C_7} + w_{E_4C_7} + w_{E_5C_7} + w_{E_6C_7} + w_{E_7C_7} + w_{E_8C_7} = 0.0994$$

Table 7 describes the criteria weights and their ranks:

Table 7. Criteria weights using OPA.

Criteria	Index	Weight	Rank
Professional practices	C_1	0.1758096	3
Industries' needs	C_2	0.1922992	2
Application of Scientific Thinking	C_3	0.2384648	1
Schools' lines of research	C_4	0.1468550	4
Scientific skills	C_5	0.1010910	5
Pre-planned activities	C_6	0.0460587	7
Provide deeper sight of an area of knowledge	C_7	0.0994218	6

According to Table 7, the application of scientific thinking, industries' needs, and professional practices are the top three critical criteria in undergraduate elective courses for future planning.

OPA's weights are used as the internal strength of research criteria for WINGS. In the next step, experts were asked to evaluate how research criteria interact. Table 8 shows the average scores of interactions based on experts' statements.

Table 8. WINGS directed matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	6.61	0	4.375	4.5	4.5	4	6
C_2	5.5	7.26	4.5	6.125	4.25	4.75	4.875
C_3	6.375	0	9	6	7.5	4.125	6.375
C_4	5.875	0	7	5.52	6	4.375	5.125
C_5	3.5	0	7.25	4.5	3.81	3.625	5.125
C_6	4.5	0	5.125	0	4.125	1.74	3.625
C_7	3.5	0	3.125	4.875	3.75	3.375	3.74

Furthermore, causal map of criteria relations was drawn based on experts' ideas and shown in Figure 2.

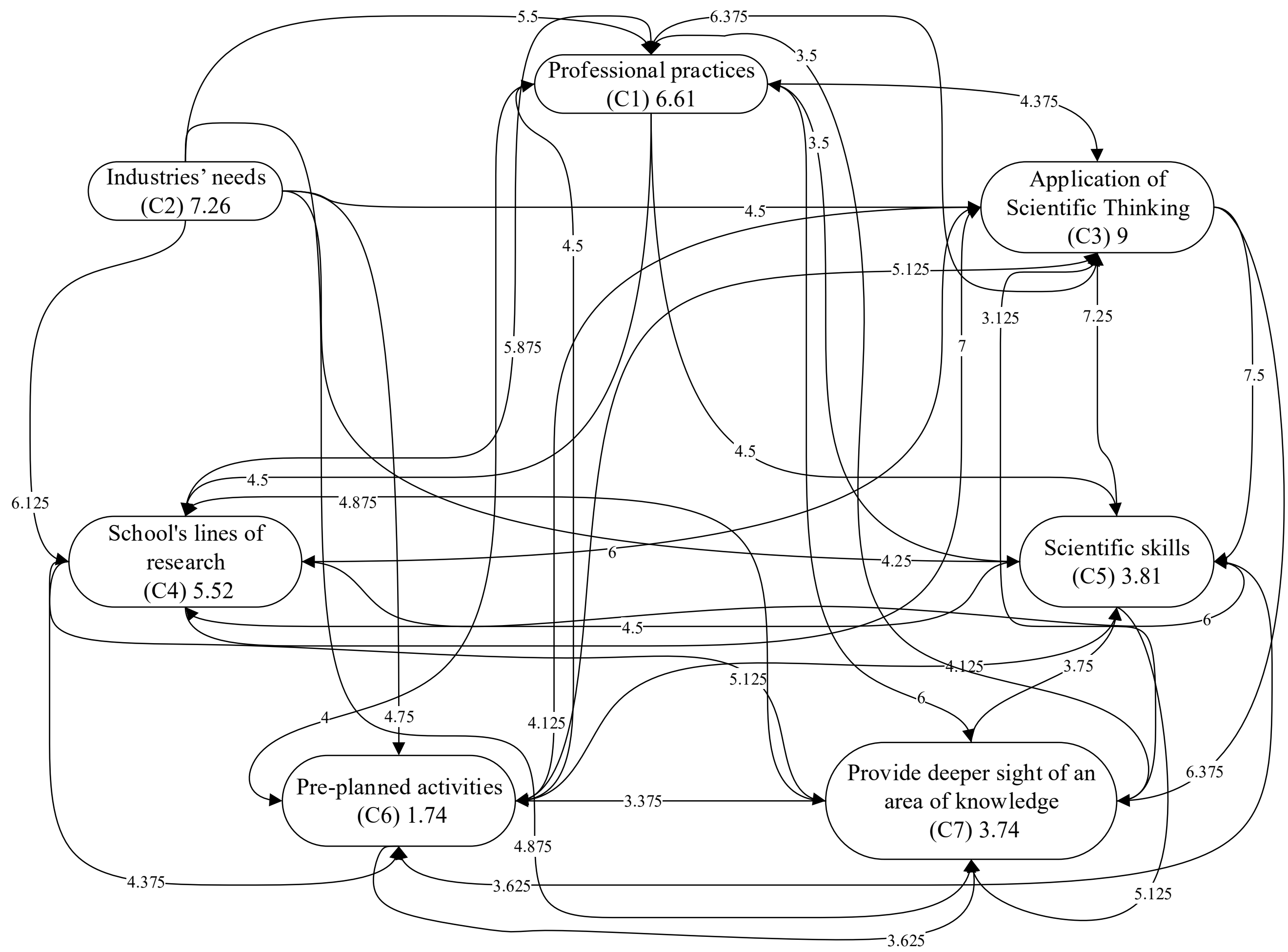

Figure 2. Criteria interaction causal map.

Table 9 shows the results obtained by completing Steps 5, 6, and 7 of the WINGS method, which is described in the Section 3 Methodology.

Table 9. WINGS results.

Criteria	Index	Total Impact	Total Receptivity	Total Engagement	Criteria Role
Professional practices	C_1	0.1655	0.1995	0.365	−0.034
Industries' needs	C_2	0.208	0.036	0.244	0.172
Application of Scientific Thinking	C_3	0.219	0.226	0.445	−0.007
Schools' lines of research	C_4	0.188	0.175	0.363	0.013
Scientific skills	C_5	0.1545	0.1895	0.344	−0.035
Pre-planned activities	C_6	0.106	0.144	0.250	−0.038
Provide deeper sight of an area of knowledge	C_7	0.1235	0.1945	0.318	−0.071

Moreover, Figure 3 illustrates the engagement-position map of research criteria.

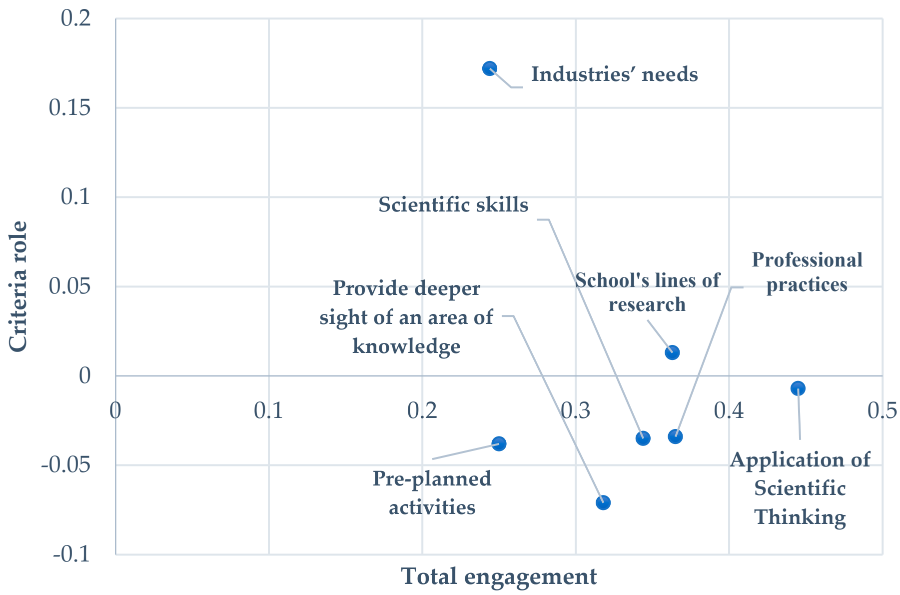

Figure 3. Engagement-position map.

According to the results in Table 9 and Figure 3, the application of scientific thinking, industries' needs, and schools' lines of research have the highest impact among the criteria, and application of scientific thinking has the highest interaction with scientific skills. This issue illustrates that by paying attention to the mentioned criteria, elective courses' efficiency will escalate. Furthermore, the application of scientific thinking, professional practices, and the schools' lines of research are highly engaged in this research, which shows their importance for future planning considering criteria roles, industries' needs, and schools' lines of research are the ones that influence the direction of undergraduate elective courses; on the other hand, providing deeper sight into an area of knowledge criterion is highly influenced by different criteria of the proposed system. Additionally, the mentioned criterion is highly affected by professional practices and the application of scientific thinking. Preplanned activities have the lowest impact in the proposed framework and also is among the influenced group.

5. Sensitivity Analysis

A vital step in each study is verifying the outcomes' robustness. Therefore, a sensitivity analysis is implemented to assess the validity of the results. As there are discrepancies in experts' ideas about the internal strengths of the high-ranked criteria, including the application of scientific thinking, industries' needs, and professional practices, three experiments were designed to assess the consequences of changing mentioned criteria' internal strengths.

5.1. Experiment 1

In the first experiment, the internal strength of the application of scientific thinking changed from 9 to 7, and the internal strength of industries' needs elevated from 7.26 to 9. Table 10 shows the results:

Table 10. Experiment 1 results.

Criteria	Index	Total Engagement	Criteria Role
Professional practices	C_1	0.365	−0.034
Industries' needs	C_2	0.263	0.172
Application of Scientific Thinking	C_3	0.421	−0.007
School's lines of research	C_4	0.363	0.013
Scientific skills	C_5	0.344	−0.035
Pre-planned activities	C_6	0.250	−0.038
Provide deeper sight of an area of knowledge	C_7	0.318	−0.071

As illustrated in Table 10, minor changes in total engagement C_3 and C_2 is observed that is negligible.

5.2. Experiment 2

In the second experiment, the internal strength of the application of scientific thinking changed from 9 to 6.61, and the internal strength of professional practices raised from 6.61 to 9. Table 11 exhibit the results:

Table 11. Experiment 2 results.

Criteria	Index	Total Engagement	Criteria Role
Professional practices	C_1	0.392	−0.034
Industries' needs	C_2	0.244	0.172
Application of Scientific Thinking	C_3	0.417	−0.007
School's lines of research	C_4	0.363	0.013
Scientific skills	C_5	0.344	−0.035
Pre-planned activities	C_6	0.250	−0.038
Provide deeper sight of an area of knowledge	C_7	0.318	−0.071

As shown in Table 11, a slight change in total engagement C_3 and C_1 is observed that is negligible.

5.3. Experiment 3

In the third experiment, the internal strength of industries' needs changed from 7.26 to 6.61, and the internal strength of professional practices raised from 6.61 to 7. Table 12 displays the results

Table 12. Experiment 3 results.

Criteria	Index	Total Engagement	Criteria Role
Professional practices	C_1	0.373	−0.034
Industries' needs	C_2	0.236	0.172
Application of Scientific Thinking	C_3	0.445	−0.007
School's lines of research	C_4	0.363	0.013
Scientific skills	C_5	0.344	−0.035
Pre-planned activities	C_6	0.250	−0.038
Provide deeper sight of an area of knowledge	C_7	0.318	−0.071

The results show minor changes in total engagement C_1 and C_2. Despite significant changes in an important factor such as internal strength, no significant differences were observed across all three experiments, and the model is reasonably robust.

5.4. Comparison with DEMATEL

In order to validate the results obtained by OPA-WINGS, DEMATEL [62] was utilized using pyDecision library and experts' statements. Table 13 shows the DEMATEL results.

Table 13. DEMATEL results.

Criteria	Index	Prominence	Relation
Professional practices	C_1	7.892	−0.827
Industries' needs	C_2	4.565	4.565
Application of Scientific Thinking	C_3	9.275	−0.308
School's lines of research	C_4	8.177	0.359
Scientific skills	C_5	8.398	−0.966
Pre-planned activities	C_6	6.382	−0.97
Provide deeper sight of an area of knowledge	C_7	7.705	−1.854

When we make the comparison between OPA-WINGS and DEMATEL results, we observe that:

- OPA-WINGS prioritization based on $r + c$ $(Total\ engagement)$ is: $C_3 > C_1 > C_4 > C_5 > C_7 > C_6 > C_2$, while DEMATEL is: $C_3 > C_5 > C_4 > C_1 > C_7 > C_6 > C_2$. The only differences in ranking is C_1 and C_5 places. This difference is because of DEMATEL defect in consideration of C_1 internal strength, as Michnik [30] mentioned in his research.
- Both OPA-WINGS and DEMATEL consider C_2 (industries' needs) and C_4 (school's lines of research) as cause elements, while the five others are considered influenced elements.
- The comparison outcomes show that OPA-WINGS and DEMATEL have almost the same results. Still, OPA-WINGS covers DEMATEL flaws in consideration of elements' internal strengths, enabling more accurate outcomes.

6. Managerial Implications

The novel OPA-WINGS approach introduced in this research allows us to assess the dynamics of planning for elective courses based on experts' experiences and interactions between the criteria. According to the engagement-position map, industries' needs play a pivotal role in elective courses; this criterion not only highly affects other measures but also is moderately engaged with the research criteria. It can be concluded that correctly identifying industries' needs can guide the course direction to qualify students with skills required for their future careers. Attention to industries' needs can pilot the research to more practical fields. Moreover, the application of scientific thinking is highly engaged in the proposed framework, which shows its potential for further investment to achieve better research quality and scientific skills. Schools' lines of research impact future studies and their quality. They have a positive role among the criteria, showing their potential to lead elective courses.

Furthermore, elective courses have the potential to absorb students in a specific area of knowledge requires professional practices to achieve this goal. Professional practices are among the substantial criteria in this research, but it is an influenced criterion that requires preprocessing. The results indicate that proper perception of industries' requirements and coordinating the school's research line with it will improve schools' achievements and prepare the students for more qualified skills and practical research abilities. Additionally, offering professional practices during elective courses by experienced instructors can improve students' scientific skills and help them better apprehend an area of knowledge.

7. Conclusions

A novel three-stage OPA-WINGS method is proposed in this research to assist in planning undergraduate elective courses to qualify students for research and future job positions. An extensive and informative questionnaire was designed for data collection and distributed among eight professors at Universidad Catolica del Norte, School of Engineering who are deeply familiar with the role of elective courses in students' preparation for their future evolution. Seven criteria were defined according to a comprehensive study on elective courses and their developing factors. Then, OPA was utilized to rank the experts and obtain the weights of the introduced criteria. The results show that applying scientific thinking, industries' needs, and professional practices are pivotal in undergraduate elective course planning and development. In the final stage, criteria weights obtained by OPA were utilized as internal strengths to initialize WINGS and assess the dynamics of the proposed system. Experts were asked to express their opinions about the mutual relation of research criteria based on WINGS. Then, the average submitted scores for each criterion were used to fill the directed matrix. The results show that industries' needs and school's lines of research have a positive role in the system and impact the other criteria. Moreover, professional practices, application of scientific thinking, school lines of research, and scientific skills are highly engaged in our introduced system, which shows their importance for elective course scheduling. A sensitivity analysis of internal strengths variations was used to validate the results in three experiments. Although the inner strengths of the criteria changed significantly, no change in outcomes was observed, which shows the robustness of our methodology. Furthermore, DEMATEL was also utilized for results comparison. The outcomes show that OPA-WINGS is more accurate than DEMATEL because of OPA-WINGS's exclusivity in the consideration of components' internal strengths.

For the first time, in this research, OPA as a mathematical programming model and the WINGS method is combined with the increasing accuracy of problems' dynamical assessment. Additionally, this research benefits from a modified version of OPA to only obtain experts and criteria weights. From the mathematical aspect, this research presents a three-stage dynamic model for assessing the interactions among the measures of a system with high accuracy with their inner importance consideration. Future studies could consider other schools and professional experts who can highlight more criteria and subcriteria for designing elective courses using fuzzy or grey theories under uncertainty.

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References

1. Adali, E.A.; Işik, A.T.; Kundakci, N. Todim method for the selection of the elective courses. *Eur. Sci. J.* **2016**, *12*, 314–324.
2. Akyol, K.; Görgünoğlu, S.; Şen, B. Prioritization of graduate education courses with Analytic Hierarchy Process. *Glob. J. Technol.* **2014**, *5*, 18–25.
3. Kecek, G.; Söylemez, C. Course selection in postgraduate studies through analytic hierarchy process and topsis methods. *Br. J. Econ. Financ. Manag. Sci.* **2016**, *11*, 142–157.
4. Onay, A.; Karamaşa, Ç.; Saraç, B. Application of fuzzy AHP in selection of accounting elective courses in undergraduate andgraduate level. *J. Account. Financ. Audit. Stud.* **2016**, *2*, 20–42.
5. Doğanalp, B.; Doğanalp, S. Determination Of Elective Course Based On Hierarchical Fuzzy Topsis Method With Matlab Software. *Selçuk Üniver. Sos. Bilim. Enstitüsü Derg.* **2016**, *6*, 103–114.
6. Ataei, Y.; Mahmoudi, A.; Feylizadeh, M.R.; Li, D.F. Ordinal priority approach (OPA) in multiple attribute decision-making. *Appl. Soft Comput.* **2020**, *86*, 105893. [CrossRef]
7. Quartey-Papafio, T.K.; Islam, S.; Dehaghani, A.R. Evaluating suppliers for healthcare centre using ordinal priority approach. *Manag. Sci. Bus. Decis.* **2021**, *1*, 5–11. [CrossRef]
8. Sadeghi, M.; Mahmoudi, A.; Deng, X. Adopting Distributed Ledger Technology (DLT) For The Sustainable Construction Industry: Evaluating The Barriers Using Ordinal Priority Approach (OPA). *Environ. Sci. Pollut. Res.* **2021**, *29*, 10495–10520. [CrossRef]
9. Dorado Chaparro, J.; Fernández-Bermejo Ruiz, J.; Santofimia Romero, M.J.; del Toro García, X.; Cantarero Navarro, R.; Bolaños Peño, C.; López López, J.C.; Llumiguano Solano, H.C.; Villanueva Molina, F.J.; Gonçalves Silva, A. Phyx. io: Expert-Based Decision Making for the Selection of At-Home Rehabilitation Solutions for Active and Healthy Aging. *Int. J. Environ. Res. Public Health* **2022**, *19*, 5490. [CrossRef]
10. Li, J.; Dai, Y.; Wang, C.C.; Sun, J. Assessment of Environmental Demands of Age-Friendly Communities from Perspectives of Different Residential Groups: A Case of Wuhan, China. *Int. J. Environ. Res. Public Health* **2022**, *19*, 9120. [CrossRef]
11. Abdel-Basset, M.; Mohamed, M.; Abdel-Monem, A.; Elfattah, M.A. New extension of ordinal priority approach for multiple attribute decision-making problems: Design and analysis. *Complex Intell. Syst.* **2022**, *8*, 4955–4970. [CrossRef] [PubMed]
12. Mahmoudi, A.; Javed, S.A. Performance Evaluation of Construction Sub-contractors using Ordinal Priority Approach. *Eval. Program Plan.* **2022**, *91*, 102022. [CrossRef] [PubMed]
13. Mahmoudi, A.; Abbasi, M.; Deng, X. A novel project portfolio selection framework towards organizational resilience: Robust ordinal priority approach. *Expert Syst. Appl.* **2022**, *188*, 116067. [CrossRef]
14. Elkadeem, M.R.; Younes, A.; Mazzeo, D.; Jurasz, J.; Campana, P.E.; Sharshir, S.W.; Alaam, M.A. Geospatial-assisted multi-criterion analysis of solar and wind power geographical-technical-economic potential assessment. *Appl. Energy* **2022**, *322*, 119532. [CrossRef]
15. Mahmoudi, A.; Deng, X.; Javed, S.A.; Yuan, J. Large-scale multiple criteria decision-making with missing values: Project selection through TOPSIS-OPA. *J. Ambient. Intell. Humaniz. Comput.* **2021**, *12*, 9341–9362. [CrossRef]
16. Bah, M.K.; Tulkinov, S. Evaluation of Automotive Parts Suppliers through Ordinal Priority Approach and TOPSIS. *Manag. Sci. Bus. Decis.* **2022**, *2*, 5–17. [CrossRef]
17. Irvanizam, I.; Zulfan, Z.; Nasir, P.F.; Marzuki, M.; Rusdiana, S.; Salwa, N. An Extended MULTIMOORA Based on Trapezoidal Fuzzy Neutrosophic Sets and Objective Weighting Method in Group Decision-Making. *IEEE Access* **2022**, *10*, 47476–47498. [CrossRef]
18. Mahmoudi, A.; Abbasi, M.; Deng, X. Evaluating the performance of the suppliers using hybrid DEA-OPA model: A sustainable development perspective. *Group Decis. Negot.* **2022**, *31*, 335–362. [CrossRef]
19. Mahmoudi, A.; Javed, S.A.; Mardani, A. Gresilient supplier selection through fuzzy ordinal priority approach: Decision-making in post-COVID era. *Oper. Manag. Res.* **2021**, *15*, 208–232. [CrossRef]
20. Mahmoudi, A.; Sadeghi, M.; Deng, X. Performance measurement of construction suppliers under localization, agility, and digitalization criteria: Fuzzy Ordinal Priority Approach. *Environ. Dev. Sustain.* **2022**, 1–26. [CrossRef]
21. Sadeghi, M.; Mahmoudi, A.; Deng, X. Blockchain technology in construction organizations: Risk assessment using Trapezoidal Fuzzy Ordinal Priority Approach. *Eng. Constr. Archit. Manag.* 2022, *ahead-of-print*. [CrossRef]
22. Sadeghi, M.; Mahmoudi, A.; Deng, X.; Luo, X. Prioritizing requirements for implementing blockchain technology in construction supply chain based on circular economy: Fuzzy Ordinal Priority Approach. *Int. J. Environ. Sci. Technol.* **2022**, 1–22. [CrossRef]
23. Le, M.T.; Nhieu, N.L. A Novel Multi-Criteria Assessment Approach for Post-COVID-19 Production Strategies in Vietnam Manufacturing Industry: OPA–Fuzzy EDAS Model. *Sustainability* **2022**, *14*, 4732. [CrossRef]

24. Deveci, M.; Pamucar, D.; Gokasar, I.; Köppen, M.; Gupta, B.B. Personal Mobility in Metaverse With Autonomous Vehicles Using Q-Rung Orthopair Fuzzy Sets Based OPA-RAFSI Model. *IEEE Trans. Intell. Transp. Syst.* **2022**, 1–10. [CrossRef]
25. Pamucar, D.; Deveci, M.; Gokasar, I.; Martínez, L.; Köppen, M. Prioritizing Transport Planning Strategies for Freight Companies Towards Zero Carbon Emission Using Ordinal Priority Approach. *Comput. Ind. Eng.* **2022**, *169*, 108259. [CrossRef]
26. Islam, S. Evaluation of low-carbon sustainable technologies in agriculture sector through grey ordinal priority approach. *Int. J. Grey Syst.* **2021**, *1*, 5–26. [CrossRef]
27. Mahmoudi, A.; Deng, X.; Javed, S.A.; Zhang, N. Sustainable supplier selection in megaprojects: Grey ordinal priority approach. *Bus. Strategy Environ.* **2021**, *30*, 318–339. [CrossRef]
28. Candra, C.S. Evaluation of Barriers to Electric Vehicle Adoption in Indonesia through Grey Ordinal Priority Approach. *Int. J. Grey Syst.* **2022**, *2*, 38–56. [CrossRef]
29. Pamucar, D.; Deveci, M.; Gokasar, I.; Tavana, M.; Köppen, M. A metaverse assessment model for sustainable transportation using ordinal priority approach and Aczel-Alsina norms. *Technol. Forecast. Soc. Chang.* **2022**, *182*, 121778. [CrossRef]
30. Michnik, J. Weighted Influence Non-linear Gauge System (WINGS)–An analysis method for the systems of interrelated components. *Eur. J. Oper. Res.* **2013**, *228*, 536–544. [CrossRef]
31. Kashi, K.; Franek, J. Applying Group Decision Making and Multiple Attribute Decision Making Methods in Business Processes. *Appl. Mech. Mater.* **2014**, *693*, 237–242. [CrossRef]
32. Rego Mello, B.B.; Gomes, L.F.A.M. Industry risk assessment in Brazil with the WINGS method. In Proceedings of the 23rd International Conference on Multiple Criteria Decision Making MCDM, Hamburg, Germany, 2–7 August 2015.
33. Michnik, J.; Adamus-Matuszyńska, A. Structural analysis of problems in public relations. *Mult. Criteria Decis. Mak.* **2015**, *10*, 105–123.
34. Kashi, K. *Proposal of Employee Training and Development System in a Middle Size Automotive Company by Utilizing Competency Model and AHP and WINGS Methods*; SEP: Prague, Czech Republic, 2016; pp. 8–10.
35. Radziszewska-Zielina, E.; Śladowski, G. Supporting the selection of a variant of the adaptation of a historical building with the use of fuzzy modelling and structural analysis. *J. Cult. Herit.* **2017**, *26*, 53–63. [CrossRef]
36. Michnik, J. The WINGS method with multiple networks and its application to innovation projects selection. *Int. J. Appl. Manag. Sci.* **2018**, *10*, 105–126. [CrossRef]
37. Sallum, F.S.V.; Gomes, L.F.A.M.; Machado, M.A.S. A dematel-topsis-wings approach to the classification of multimarket investment funds. *Indep. J. Manag. Prod.* **2018**, *9*, 1203–1234. [CrossRef]
38. Sallum, F.S.V.; Gomes, L.F.A.M.; Machado, M.A.S. A multicriteria approach to the prioritisation of stock investment funds. *Int. J. Bus. Syst. Res.* **2019**, *13*, 120–134. [CrossRef]
39. Banaś, D.; Michnik, J. Evaluation of the impact of strategic offers on the financial and strategic health of the company—A soft system dynamics approach. *Mathematics* **2019**, *7*, 208. [CrossRef]
40. Adamus-Matuszyńska, A.; Michnik, J.; Polok, G. A Systemic Approach to City Image Building. The Case of Katowice City. *Sustainability* **2019**, *11*, 4470. [CrossRef]
41. Kaviani, M.A.; Tavana, M.; Kumar, A.; Michnik, J.; Niknam, R.; de Campos, E.A.R. An integrated framework for evaluating the barriers to successful implementation of reverse logistics in the automotive industry. *J. Clean. Prod.* **2020**, *272*, 122714. [CrossRef]
42. Michnik, J.; Grabowski, A. Modeling uncertainty in the wings method using interval arithmetic. *Int. J. Inf. Technol. Decis. Mak.* **2020**, *19*, 221–240. [CrossRef]
43. Wang, W.; Tian, Z.; Xi, W.; Tan, Y.R.; Deng, Y. The influencing factors of China's green building development: An analysis using RBF-WINGS method. *Build. Environ.* **2021**, *188*, 107425. [CrossRef]
44. Tavana, M.; Mousavi, H.; Nasr, A.K.; Mina, H. A fuzzy weighted influence non-linear gauge system with application to advanced technology assessment at NASA. *Expert Syst. Appl.* **2021**, *182*, 115274. [CrossRef]
45. Tavana, M.; Azadmanesh, A.; Nasr, A.K.; Mina, H. A multicriteria-optimization model for cultural heritage renovation projects and public-private partnerships in the hospitality industry. *Curr. Issues Tour.* **2021**, 1–26. [CrossRef]
46. Chen, Y.W. Social Network Analysis: Self-Organizing Map and WINGS by Multiple-Criteria Decision Making. In *Handbook of Research on Autopoiesis and Self-Sustaining Processes for Organizational Success*; IGI Global: Hershey, PA, USA, 2021; pp. 155–184.
47. Zhang, Y.; Xu, L. Research on risk management of medical and health care integration projects based on fuzzy WINGS-G1. *Kybernetes* 2021, *ahead-of-print*. [CrossRef]
48. Marsili, F.; Bödefeld, J.; Weber, L.; Ghadami, M. Vulnerability Assessment of Aging Levees with WINGS and Interval Arithmetic. In *International Probabilistic Workshop*; Springer: Cham, Switzerland, 2021; pp. 841–852.
49. Šmidovnik, T. New WINGS approach–WINGS of finite sum of influences. *Eng. Manag.* **2022**, *8*, 36–47.
50. Govindan, K.; Nasr, A.K.; Saeed Heidary, M.; Nosrati-Abarghooee, S.; Mina, H. Prioritizing adoption barriers of platforms based on blockchain technology from balanced scorecard perspectives in healthcare industry: A structural approach. *Int. J. Prod. Res.* **2022**, 1–15. [CrossRef]
51. Tavana, M.; Nasr, A.K.; Mina, H.; Michnik, J. A private sustainable partner selection model for green public-private partnerships and regional economic development. *Socio-Econ. Plan. Sci.* **2022**, *83*, 101189. [CrossRef]
52. Pearson, B.J.; Moore, K. Identification of industry needs and development of professional skills in students of horticulture. *HortTechnology* **2017**, *27*, 580–582. [CrossRef]
53. Edwards, A.; Daniels, H. The knowledge that matters in professional practices. *J. Educ. Work* **2012**, *25*, 39–58. [CrossRef]

54. Crawford, P.; Lang, S.; Fink, W.; Dalton, R.; Fielitz, L. Comparative Analysis of Soft Skills: What Is Important for New Graduates? Association of Public and Land-grant Universities and University-industry Consortium: Washington, DC, USA, 2011.
55. Hashim, S.A.M.; Adnan, A.; Salaudin, M.K.A. The Manufacturing Industries Needs Analysis For Manufacturing Technology Certificate Graduates. *J. STEM Educ.* **2022**, *2*, 15–25.
56. Burrus, J.; Jackson, T.; Xi, N.; Steinberg, J. Identifying the most important 21st century workforce competencies: An analysis of the Occupational Information Network (O* NET). *ETS Res. Rep. Ser.* **2013**, *2013*, i-55. [CrossRef]
57. Lehrer, R.; Schauble, L. Scientific Thinking and Science Literacy. In *Handbook of Child Psychology*; John Wiley and Sons: Hoboken, NJ, USA, 2007.
58. Janoušková, S.; Pyskatá Rathouská, L.; Žák, V.; Urválková, E.S. The scientific thinking and reasoning framework and its applicability to manufacturing and services firms in natural sciences. *Res. Sci. Technol. Educ.* **2021**, 1–22. [CrossRef]
59. Boyles, T. 21st century knowledge, skills, and abilities and entrepreneurial competencies: A model for undergraduate entrepreneurship education. *J. Entrep. Educ.* **2012**, *15*, 41–55.
60. Heikkilä, M.; Hermansen, H.; Iiskala, T.; Mikkilä-Erdmann, M.; Warinowski, A. Epistemic agency in student teachers' engagement with research skills. *Teach. High. Educ.* **2020**, 1–18. [CrossRef]
61. Murtonen, M.; Salmento, H. Broadening the theory of scientific thinking for higher education. In *Redefining Scientific Thinking for Higher Education*; Palgrave Macmillan: Cham, Switzerland, 2019; pp. 3–29.
62. Si, S.L.; You, X.Y.; Liu, H.C.; Zhang, P. DEMATEL technique: A systematic review of the state-of-the-art literature on methodologies and applications. *Math. Probl. Eng.* **2018**, *2018*, 3696457. [CrossRef]