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An Evaluation System for University–Industry Partnership Sustainability: Enhancing Options for Entrepreneurial Universities

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Abstract: The concept of university-industry partnership sustainability (UIPS) stands for well-adjusted progress among key players from universities and industry by sustaining their welfare, both in the present and in the future. This paper sought to develop an evaluation system for UIPS. The need for such a system is justified at three levels: the micro level (i.e., research and innovation performance, transfer and absorptive capability, and technology development), the meso level (i.e., institutional arrangements, communication networks, and local and indigenous rules) and the macro level (i.e., supply and demand, regulations, financing, taxes, culture, traditions, market, climate, politics, demographics, and technology). The UIPS evaluation system developed in this study offers the possibility of calculating a fair value of UIPS and providing recommendations for improving university–industry (U–I) partnerships. This can be of great importance for entrepreneurial universities that would like to strengthen their corporate links and/or reduce/reverse the "hollowing effect" of globalisation in disadvantaged regions. Additionally, this paper also contains discussions on the advantages, limitations, and managerial implications of this proposal.

Keywords: entrepreneurial universities; university–industry partnership sustainability; multiple criteria decision analysis; micro, meso, and macro environments

1. Introduction

Analyses of university–industry partnership sustainability (UIPS) have been discussed from different perspectives over the years [1–9]. This phenomenon is influenced by different integrated macro-level contexts (e.g., supply and demand, regulations, financing, taxes, culture, tradition, market, climate, political, demographics, and technology). It also depends on various factors on the micro level (e.g., research and innovation performance, transfer and absorptive capability, and technology development) and the meso level (e.g., institutional arrangements, communication networks, and local and indigenous rules) [10–16]. Salleh and Omar [17] present a review of various models that focus on collaboration management, the formation of a knowledge integration community, and research

collaboration activities between academia and industry. Plewa et al. [18] analysed the evolution of university industry linkage phases: pre-linkage that leads to an agreement to work together, establishment that leads to a contract, engagement that leads to the delivery of a project, advancement that leads to an ongoing partnership as well as word of mouth, and the latent phase that means potential future cooperation should a suitable project arise, with continuing personal linkage. Ankrah and Al-Tabbaa [19] employed a systematic procedure to review the literature on university–industry (U–I) collaboration. Ankrah and Al-Tabbaa [19] examined three main phases in U–I collaboration: formation (identifying partners, making contact, assessing partners, negotiation, agreement signing), organisational forms (informal and formal personal relationships, third party, targeted and untargeted formal agreements, focussed structures), and operational phase activities (meetings, communication, trainings, personal mobility, employment, other activities).

The effort to make the life cycle of U–I partnerships and their components more sustainable involved the development of a wide range of different databases, evaluation techniques and intelligent systems (i.e., expert, knowledge, fuzzy, embedded, and decision support mechanisms) [20–23]. The U–I interface system and the interactive academic–industry partnership database enable academic investigators and industry to match up their needs based on complementary knowledge, initiate contact, and work to develop effective partnerships [24].

U–I partnership approaches (e.g., multidisciplinary, linear, market-led, bottom–up, top–down, and cross-disciplinary, among many others) have limitations in terms of results, generalisations and practical impacts on the community [11,15,25]. The present study sought to address this gap by analysing some of the existing multiple criteria decision analysis (MCDA) methods and identifying possibilities for improving the effectiveness of the approaches towards UIPS evaluation. Specifically, the literature review suggests that the methods and systems currently available offer no possibility to calculate a fair UIPS value, and provide recommendations for improving U–I partnerships. Furthermore, the available techniques and software packages are unable to optimise the selected criteria, which might otherwise generate an opportunity for further developments.

The INvestment Value Assessments along with Recommendation provisions (INVAR) method [26] can be used for assessing a U–I partnership by using the same data as other MCDA methods. However, by applying the INVAR method, it is additionally possible to determine the fair value of a U–I partnership under consideration, optimise the parameters and composite parts of mutual cooperation, and provide well-informed recommendations for improving cooperative work. This means that the INVAR method can support the evaluation of U–I partnerships in a new form, thereby adding to the extant literature on U–I collaboration, entrepreneurship, and operational research.

The structure of the remainder of this paper is as follows. Section 2 presents a review of related work. Section 3 presents the methodology and the INVAR method along with sketches of the components of the multiple criteria assessment system developed for UIPS. Section 4 presents a practical application of the developed UIPS system, and discusses its impact for entrepreneurial universities. Section 5 concludes the paper and lays the groundwork for future research.

2. Related Work

U–I collaborations have increased in number and variety over the past few decades [20,21,27–29]. These involve a wide range of UIPS variables, including databases and knowledge tools (e.g., software, expert, fuzzy, embedded, and decision support mechanisms). Figure 1 presents some of these elements, which are considered of extreme importance for increasing the entrepreneurial activity of universities [10,13,30].

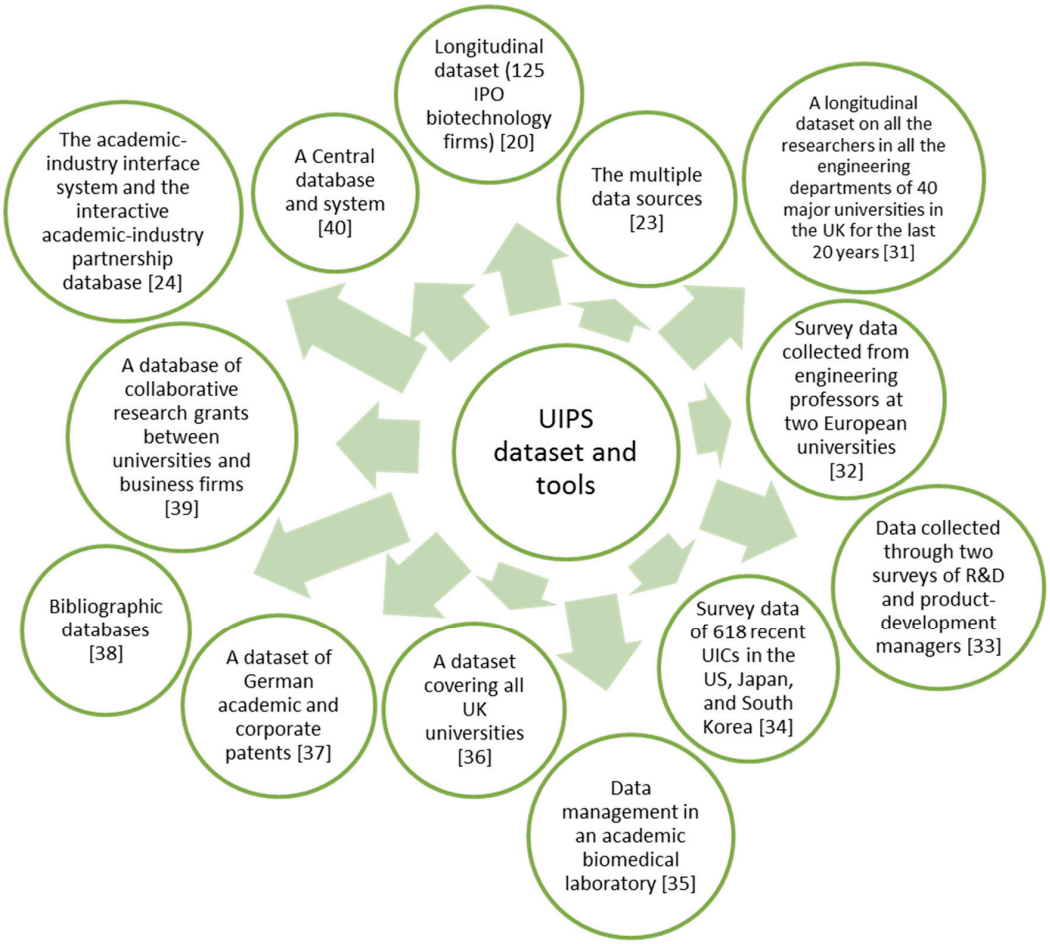

Figure 1. Databases and datasets of university–industry partnership sustainability (UIPS) [31–40].

Garousi et al. [21] identify a significant number of themes and best practices in a U–I partnership by thematic analysis. These are namely: (1) holding regular workshops and seminars with industry; (2) assuring continuous learning from industry and academia; (3) ensuring management engagement basing research on real-world problems and showing explicit benefits to an industry partner; (4) exhibiting agility during a collaboration; and (5) co-locating the researcher on the industry side.

Several studies about entrepreneurial universities in high-impact journals from the Scopus database were analysed in order to identify research gaps and highlight forthcoming research. UIPS data and software are at the heart of an examination of an entrepreneurial university. However, it is worth noting that the level of U–I collaborations in software engineering is still relatively low compared with the amount of activity in each of the two communities separately [18,21,41]. Indeed, the analysis of prior research included Chen and Lin [20], Banal-Estañol et al. [31], Callaert et al. [32], Fuentes, Dutrénit [33], Hemmert et al. [34], Myneni et al. [35] and Perkmann et al. [36]. These papers suggest that the methods and systems currently available offer no possibilities to calculate a UIPS fair value, and provide recommendations for improving U–I partnerships. Furthermore, the currently available techniques and software packages are unable to optimise the selected criteria [23,37,38,42,43]. In other words, this means that the current methods and systems are not able to calculate the fair value of a UIPS under deliberation (for further discussion, also see [21,22,24,39,40,44–48]). This study aims to contribute to this under-researched area. These limitations can be resolved by applying the INVAR method. Following this method, the present study sought to develop an UIPS evaluation system and outline the possibilities for applying the system in real settings.

3. Methodology and System Development

3.1. Methodological Processes

Johnson [49,50] investigated a U–I partnership spanning five stages. These are: (1) awareness, which includes career fairs and interviews; (2) involvement, which is related to industry affiliates, advisory programs, research grants, internships, and software grants; (3) support, which has to do with student consultancy, hardware grants, curriculum development, workshops and seminars, student organisation sponsorships, philanthropic support, and guest speaking/lectures; (4) sponsorship, which relates to university initiative sponsorships, undergraduate research program support, graduate fellowships, collaborative research programs, outreach programs, and support for education proposals; and (5) strategic partners, which involves executive sponsorships, joint partnerships, state education lobbying, major gifts, and business development. The author's proposal was later adapted by Kaklauskas [26], Zavadskas and Kaklauskas [51], Kanapeckienė et al. [52] and Urbanavičienė et al. [53]. This allowed a sequence of methodological procedures to be followed in order to address some of the limitations of the current UIPS evaluation systems. Figure 2 presents this sequence of methodological procedures specifically.

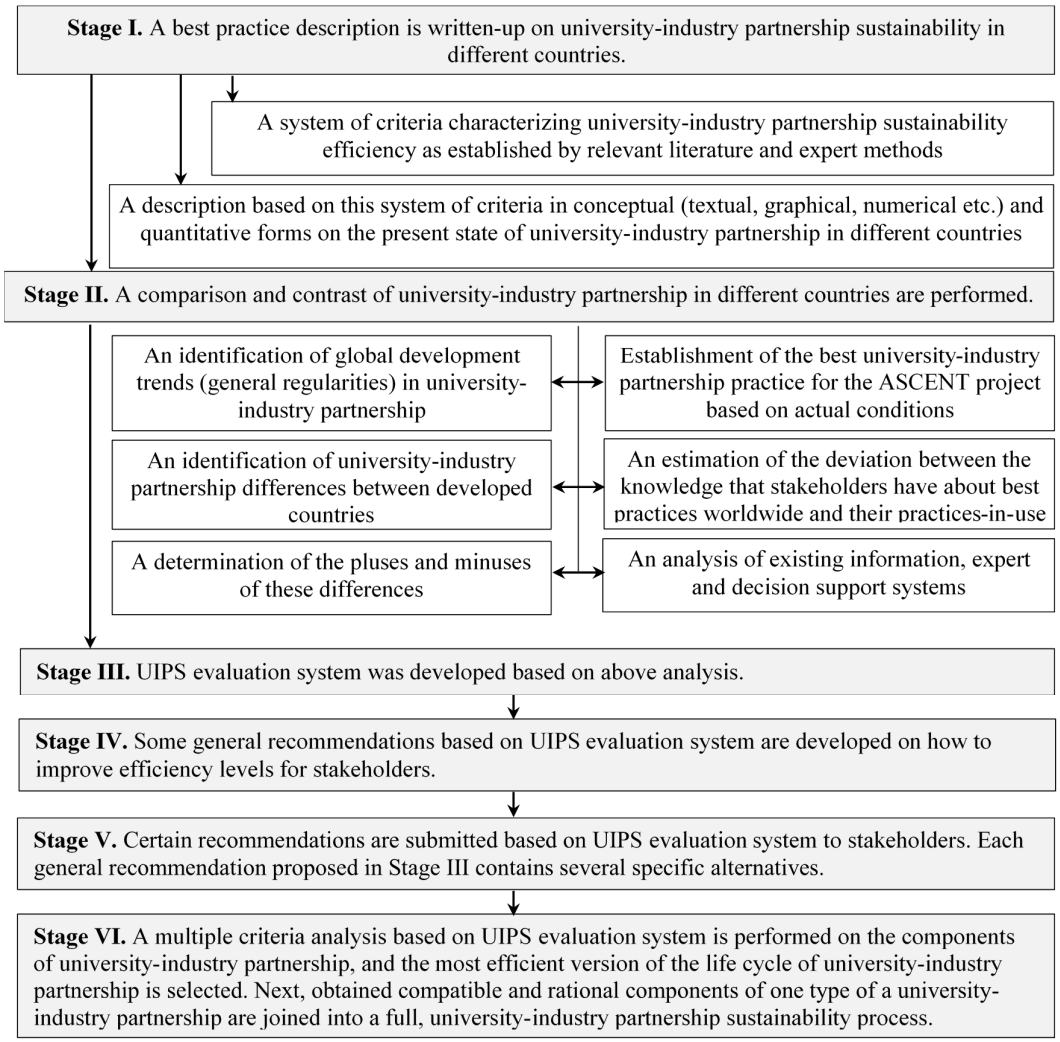

Figure 2. Sequence of methodological procedures adopted in this study.

A wide range of different MCDA methods have been applied for analysing UIPS alternatives. For example, Karsak and Dursun [54] use a fuzzy multi-criteria group decision making approach. Chithambaranathan et al. [55] employ the ELimination Et Choix Traduisant la REalité (ELECTRE) (in English, ELimination and Choice Expressing Reality) and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) (in English, Multiple criteria optimisation and compromise solution) approaches. Prakash and Barua [56] utilise the fuzzy Analytic Hierarchy Process (fuzzy AHP) and VIKOR methods. Deveci et al. [57] use the interval type-2 and fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods. Büyüközkan et al. [58] integrate the fuzzy Axiomatic Design (fuzzy AD) and fuzzy AHP techniques, and the group decision making (GDM) approach. Yazdani et al. [59] exploit the COmplex PRoportional ASsessment (COPRAS) method. According to Mendoza and Prabhu [60], widespread use of these methods is due to a number of reasons, including the possibility of quantifying complex phenomena and supporting decision-makers in situations where multiple—and possibly conflicting—criteria and alternatives need to be regarded.

Frequently different results are obtained using different multiple criteria decision-making (MCDM) methods when solving the same problem with identical criteria, the same values, and the same weights. The determination of the best multiple criteria analysis method always caused many disagreements and endless discussions. There is always an array of competing methods. It is usually very difficult to ascertain whether the answer obtained by the application of some specific multiple criteria analysis method is correct or incorrect. The COPRAS method has been applied sufficiently broadly in scientific research worldwide, and it has been compared to other methods many times [61–65], etc. These scientific studies have shown that the COPRAS method is reliable.

However, it is worth noting that an application of the different functions of the INVAR method can expand the possibilities inherent in all of these methods (i.e., calculation of fair value, optimisation of different criteria, and provision of digital recommendations). The INVAR method has been applied in this study to strengthen the internal coherence of this evaluation system.

The main steps of the INVAR method are shown in Figure 3.

The significances and priorities of the alternatives under deliberation are calculated in the first four stages based on data from the decision matrix (alternatives, criteria values, and weights). In the third stage, the significance/effectiveness (Q_j) is established for each variant under comparison, whereas in the fourth stage, the priority of an alternative is established instead. The greater the Q_j, the greater the effectiveness (priority) of an alternative. The generalised criterion Q_j depends directly and proportionately on the values x_{ij} and weights q_i of the criteria under comparison.

In the fifth stage, the calculated utility degrees (U_j) of the variants under comparison directly depend on the criteria system, values, and weights defining them. The effort to determine the investment value of an object under assessment that would make it equally competitive on the market involved comprehensively assessing all of the positive and negative features of the objects under deliberation, which led to the recommended sixth stage for determining investment value. This stage involves calculating the investment value $x_{1j\ (cycle\ e)}$ by e cycles based on the decision matrix data (alternatives, criteria values and weights) and the utility degrees (U_j) of the alternatives, until the alternative a_j under deliberation becomes equally competitive on the market with the candidate alternatives (a_1–a_n).

The data from the decision matrix and the utility degrees (U_j) of the alternatives serve as the basis for performing the seventh and tenth stages, correspondingly as follows:

- the optimisation of value x_{ij} for any criteria during e approximations;
- the calculation by approximation e cycle to determine what the value $x_{ij\ (cycle\ e)}$ should be for the alternative a_j to become the best among all of the candidate alternatives.

The criteria values and weights serve as the basis for calculating the minimising attributes S_{-j} and the maximising attributes S_{+j} that define the j variant. These serve as the basis for providing the quantitative recommendations in Stage 8 and Stage 9.

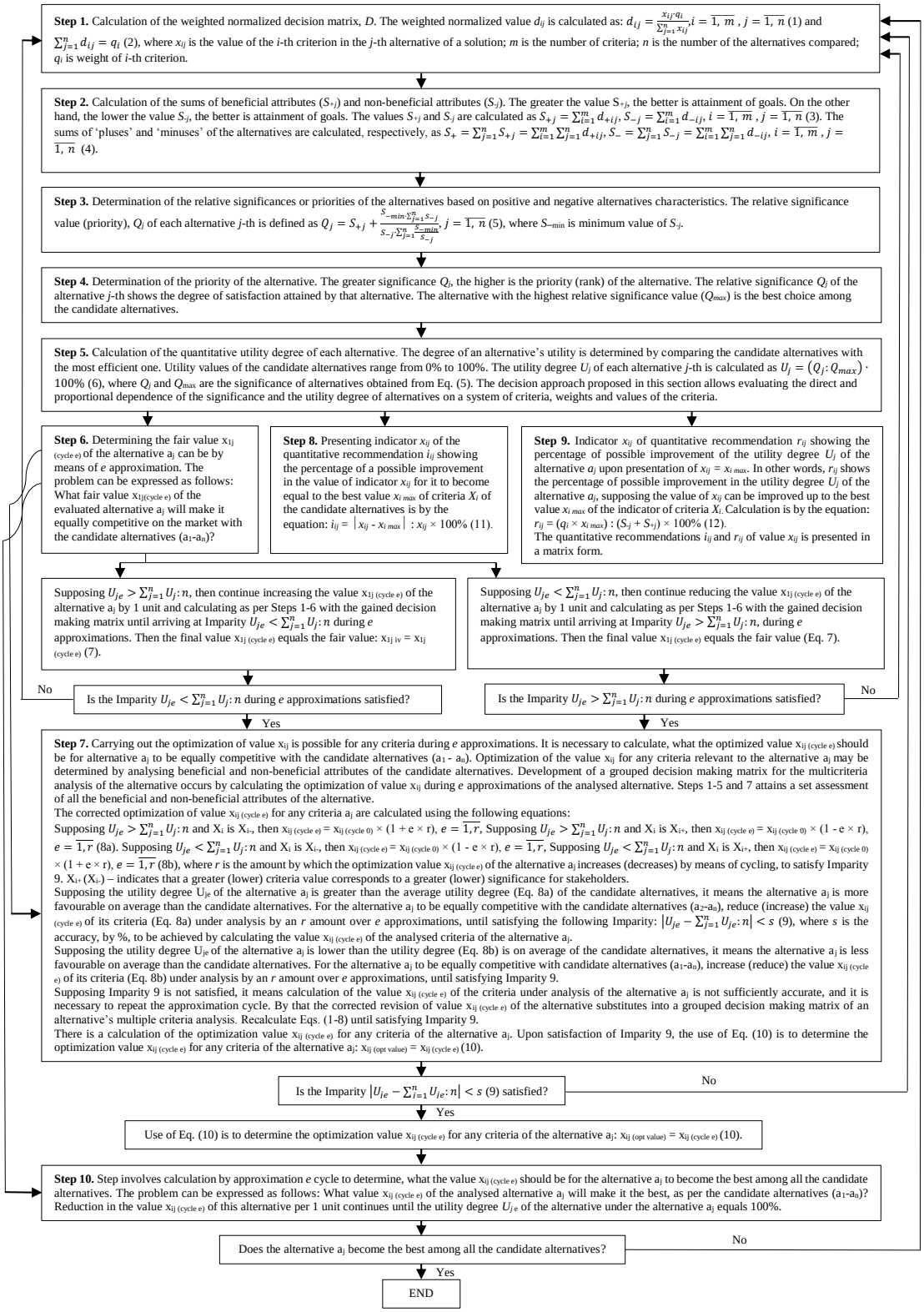

Figure 3. Key steps of the INvestment Value Assessments along with Recommendation provisions (INVAR) method [26].

One of the most important stages of an MCDA application involves the establishment of a system of criteria describing the alternatives, measurement units, weights, and values. U–I partnerships relate directly to the quantitative and qualitative data of these alternatives by comprehensively describing

the alternatives under consideration. The system captures criteria X_1–X_t along with the information describing them (measuring units of the criteria [m_1–m_t], values [x_{11}–x_{tn}], and weights [q_1–q_t]) from the U–I partnership database (see Table 1).

Table 1. Decision matrix [66].

Criteria Describing the Candidate Alternatives	*	Weight	Units	U–I Partnership Alternatives under Comparison					
				1	**2**	...	***j***	...	***n***
University–Industry Partnership Database									
X_1	−	q_1	m_1	x_{11}	x_{12}	...	x_{1j}	...	x_{1n}
X_2	+	q_2	m_2	x_{21}	x_{22}	...	x_{2j}	...	x_{2n}
...	...	...	...	...	...	...	...	...	...
X_i	+	q_i	m_i	x_{i1}	x_{i2}	...	x_{ij}	...	x_{in}
...	...	...	...	...	...	...	...	...	...
X_t	+	q_t	m_t	x_{t1}	x_{t2}	...	x_{tj}	...	x_{tn}
V_k				V_1	V_2	...	V_j	...	V_n

*: The symbol "+/−" specifies that a bigger (smaller) criterion value corresponds to a bigger (smaller) importance for a user (stakeholder).

Based on this methodology, the INVAR method examines the existing intelligent and decision support systems in order to identify the most rational alternative, allowing a UIPS evaluation system to be developed. A step-by-step description of this process is presented in the next subsection.

3.2. Development of a UIPS Evaluation System

The analysis of information systems previously used in U–I partnerships (e.g., Kaklauskas and Zavadskas [67]) and the methodology presented in Section 3.1 helped to develop a new multiple criteria analysis system for U–I partnerships. This new system differs in the use of new, original, and MCDA methods. Specifically, it involves the analysis of a U–I partnership life cycle and its components (i.e., awareness, involvement, support, sponsorship, and strategic partner, as suggested by Johnson [49,50]). Following this, a UIPS evaluation system was developed based on the analysis of existing information and with the support of expert decision systems, as described in Figures 2 and 3. This was accomplished to determine the most efficient alternatives of U–I partnerships.

4. Practical Application

4.1. Background

The Department of Construction Management and Real Estate (hereafter, CMRE) of Vilnius Gediminas Technical University (hereafter, VGTU) works in close collaboration with companies and organisations (e.g., Lithuanian Real Estate Development Association (LREDA), UAB Consultus Magnus, UAB EIKA, and Capital Experts) that operate in different fields. UAB Consultus Magnus operates in the sectors of transportation, education, social services, human resources, information technologies, environmental protections, business environments, and tourism. UAB Consultus Magnus provides consultations for preparing and implementing various projects with consideration of the needs and environmental features of specific companies, organisations, or public sector institutions. UAB EIKA is one of the largest real estate development and construction groups in Lithuania developing residential, commercial, and public sector building projects. Capital Experts assists in selling, purchasing, and leasing real estate, and offers consulting on different issues relevant to real estate. Together, the Lithuanian Real Estate Development Association (hereafter, Association), UAB EIKA, and Capital Experts participate in career fairs, where they always emphasise in their interviews the importance of CMRE-educated experts in real estate and construction management to the Lithuanian market. They also consult the CMRE Department students on different issues regarding their professional careers and other matters. Members of the Association and UAB Consultus Magnus, UAB EIKA, and Capital Experts companies participate in workshops and seminars held

by the CMRE department, deliver targeted lectures to CMRE students, take part in the Career Days held by VGTU, and engage in curriculum development studies programs of the CMRE Department. They are preparing the collaborative research program report in joint with the CMRE. Furthermore, these companies consult CMRE students and employees on business development issues.

The CMRE, the Association, UAB Consultus Magnus, UAB EIKA, and Capital Experts have jointly signed a partnership and support contract. These companies invite CMRE academics and students to conferences, seminars, and fairs that they organise in the fields of real estate and construction management and development. Each academic year, the head of the Association serves as chairperson of the defense committee that hears the oral defenses of the final projects for graduating the Property Management study program with a Bachelor's degree. Additionally, the Association, UAB Consultus Magnus, UAB EIKA, and Capital Experts support the university and the CMRE department by offering suggestions for the undergraduate research program in consideration of Lithuanian market needs. The Association promotes state education. Furthermore, the Association, UAB Consultus Magnus, UAB EIKA, and Capital Experts help provide practice positions for students.

These U–I agents have recently signed a joint partnership agreement. UAB EIKA has established the EIKA Academy earmarked for first–fourth-year students who want not only to acquire theoretical knowledge at the university, but also to apply it in practice. This is an ongoing practice, which provides students with the opportunity to try out working at jobs tailored to their expertise. The EIKA Academy partnership can last from a half-year to several years, or until graduation. The Academy organises tours of objects under construction, and introduces the latest technologies that the construction sector has been applying.

4.2. Calculation of the UIPS Utility Degree

The present study analyses four alternative U–I partnerships (i.e., a_1, a_2, a_3, and a_4). Table 2 shows the data, which sums up the details about the four organisations in question related to a sustainable VGTU–industry partnership. The system of criteria was based on the partnership chart, which is also the source that served as the basis for the system of criteria developed by Johnson [49,50].

The following groups of criteria were analysed: awareness, involvement, support, sponsorship, and strategic partner. The criteria weights were determined by means of expert methods. A five-point Likert scale was used to capture the importance, or weights, of the evaluation criteria for UIPS. Thirty-nine UIPS experts contributed to the anonymous survey. Eighteen experts were representing the Department of Construction Management and Real Estate of the VGTU's Civil Engineering faculty. Another 21 experts came from industry, representing the Lithuanian Real Estate Development Association, Consultus Magnus, UAB EIKA, and Capital Experts. For the evaluation of compared UIPS alternatives, a group of three experts was formed that consisted of university representatives (one head of department, and two professors). The group had to evaluate all criteria on a 10-point scale, where the least relevant criteria scored one point each and very important criteria scored 10 points each. The agreed integer number was used for further calculations. Table 2 enables a comparison of alternative U–I partnerships.

The information included in Table 2 (i.e., partnership evaluation criteria, as well as respective values and weights) is the basis for performing an assessment of the VGTU–industry partnership. Tables 3 and 4 present the results of the calculations conducted using INVAR.

As shown in Table 4, a_2 presents the highest utility degree (U_2 = 100%).

4.3. Calculation of the VGTU–LREDA UIPS Fair Value

The calculation of the fair value of a_1 with respect to the other U–I partnerships under analysis is presented in Table 5, which shows that the imparity was inadequate for the first 120 cycles. Indeed, for the 120th approximation cycle, the results are as follows: $U_{1\,|\,120cycle}$ = 85.51%; $U_{2\,|\,120cycle}$ = 100%; $U_{3\,|\,120cycle}$ = 71.39% and $U_{4\,|\,120cycle}$ = 85.3%. At the 190th approximation cycle, the utility degree of a_1 is U_1 = 85.55%, showing that a_1 is more beneficial than a_3 and a_4.

Table 2. Initial data matrix for INVAR method calculations.

No	Evaluation Criteria for UIPS	*	Measurement Units	Weight	Compared UIPS Alternatives			
					LREDA	Consultus Magnus	EIKA	Capital Experts
					a_1	a_2	a_3	a_4
			U–I partnership costs					
1.	Costs	-	EUR	0.5	16,000	26,000	10,000	4500
			Criteria for awareness					
2.	Career fairs	+	Points	0.125	10	9	8	9
3.	Interviews	+	Points	0.1	10	9	7	8
			Criteria for involvement					
4.	Industry affiliates/advisory program	+	Points	0.02	1	7	1	1
5.	Research grants	+	Points	0.1	1	7	3	1
6.	Internship	+	Points	0.02	1	7	2	1
7.	Software grants	+	Points	0.01	1	2	1	1
			Criteria for support					
8.	Students' consultant	+	Points	0.21	10	10	5	7
9.	Hardware grants	+	Points	0.01	1	2	1	1
10.	Curriculum development	+	Points	0.2	7	10	1	2
11.	Workshops/seminars	+	Points	0.05	10	10	2	8
12.	Support contract	+	Points	0.025	9	10	5	2
13.	Students organisations' sponsorship	+	Points	0.01	1	1	3	1
14.	Guest speaking/lectures	+	Points	0.05	10	8	6	8
			Criteria for sponsorship					
15.	Undergraduate research program support	+	Points	0.1	8	10	7	5
16.	Graduate fellowships	+	Points	0.045	9	10	8	6
17.	Collaborative research program report	+	Points	0.15	6	8	5	3
18.	Support for proposal for education	+	Points	0.1	10	10	6	3
			Criteria for strategic partner					
19.	Executive sponsorship	+	Points	0.1	8	10	7	2
20.	Joint partnership	+	Points	0.25	10	10	10	10
21.	State education lobbying	+	Points	0.033	6	8	4	2
22.	Major gifts	+	Points	0.01	1	1	1	1
23.	Business development	+	Points	0.18	10	10	10	8

*: The symbol "+/−" specifies that a bigger (smaller) criterion value corresponds to a bigger (smaller) importance for a user (stakeholder); LREDA: Lithuanian Real Estate Development Association.

Table 3. Five INVAR technique steps.

Steps	Equations	Calculations
Step 1	Equation (1)	d_{11} = 0.5 × 16,000:(16,000 + 26,000 + 10,000 + 4500) = 0.1416 d_{12} = 0.5 × 26,000:(16,000 + 26,000 + 10,000 + 4500) = 0.2301 d_{13} = 0.5 × 10,000:(16,000 + 26,000 + 10,000 + 4500) = 0.0885 d_{14} = 0.5 × 45,000:(16,000 + 26,000 + 10,000 + 4500) = 0.0398
Step 1	Equation (2)	For example, q_2 = 0.0347 + 0.0312 + 0.0278 + 0.0312 = 0.125 q_4 = 0.002 + 0.014 + 0.002 + 0.002 = 0.02, etc.
Step 2	Equation (3)	S_{+1} = 0.0347 + 0.0294 + 0.2709 + 0.002 + 0.0083 + 0.0018 + 0.002 + 0.0656 + 0.002 + 0.07 + 0.0167 + 0.0087 + 0.0017 + 0.0156 + 0.0267 + 0.0123 + 0.0409 + 0.0345 + 0.0296 + 0.0625 + 0.0099 + 0.0025 + 0.0474 = 0.5248 S_{-1} = 0.1416, etc.
Step 2	Equation (4)	S_+ = 0.5248 + 0.6553 + 0.3822 + 0.3354 = 1.8977 S_- = 0.1416 + 0.2301 + 0.0885 + 0.0398 = 0.5
Step 3	Equation (5)	$Q_1 = 0.5248 + \frac{0.0398 \cdot (0.1416+0.2301+0.0885+0.0398)}{0.1416 \cdot \left(\frac{0.0398}{0.1416}+\frac{0.0398}{0.2301}+\frac{0.0398}{0.0885}+\frac{0.0398}{0.0398}\right)} = 0.5986$ etc. $Q_2 = 0.6553 + \frac{0.0398 \cdot (0.1416+0.2301+0.0885+0.0398)}{0.2301 \cdot \left(\frac{0.0398}{0.1416}+\frac{0.0398}{0.2301}+\frac{0.0398}{0.0885}+\frac{0.0398}{0.0398}\right)} = 0.7007$
Step 4		$Q_2 > Q_1 > Q_4 > Q_3$ (see Table 4: 0.7007 > 0.5986 > 0.598 > 0.5003)
Step 5	Equation (6)	U_1 = (0.5986:0.7007) × 100% = 85.43% U_2 = (0.7007:0.7007) × 100% = 100% U_3 = (0.5003:0.7007) × 100% = 71.4% U_4 = (0.598:0.7007) × 100% = 85.35%

Table 4. INVAR method calculation results.

No	Evaluation Criteria for UIPS	*	Measurement Units	Weight	Compared UIPS Alternatives			
					LREDA	Consultus Magnus	EIKA	Capital Experts
					a_1	a_2	a_3	a_4
			U–I partnership costs					
1.	Costs	−	EURO	0.5	0.1416	0.2301	0.0885	0.0398
			Criteria for awareness					
2.	Career fairs	+	Points	0.125	0.0347	0.0312	0.0278	0.0312
3.	Interviews	+	Points	0.1	0.0294	0.0265	0.0206	0.0235
			Criteria for involvement					
4.	Industry affiliates/advisory program	+	Points	0.02	0.002	0.014	0.002	0.002
5.	Research grants	+	Points	0.1	0.0083	0.0583	0.025	0.0083
6.	Internship	+	Points	0.02	0.0018	0.0127	0.0036	0.0018
7.	Software grants	+	Points	0.01	0.002	0.004	0.002	0.002

Table 4. *Cont.*

No	Evaluation Criteria for UIPS	*	Measurement Units	Weight	Compared UIPS Alternatives			
					LREDA	Consultus Magnus	EIKA	Capital Experts
					a_1	a_2	a_3	a_4
			Criteria for support					
8.	Students' consultant	+	Points	0.21	0.0656	0.0656	0.0328	0.0459
9.	Hardware grants	+	Points	0.01	0.002	0.004	0.002	0.002
10.	Curriculum development	+	Points	0.2	0.07	0.1	0.01	0.02
11.	Workshops/seminars	+	Points	0.05	0.0167	0.0167	0.0033	0.0133
12.	Support contract	+	Points	0.025	0.0087	0.0096	0.0048	0.0019
13.	Students organisations' sponsorship	+	Points	0.01	0.0017	0.0017	0.005	0.0017
14.	Guest speaking/lectures	+	Points	0.05	0.0156	0.0125	0.0094	0.0125
			Criteria for sponsorship					
15.	Undergraduate research program support	+	Points	0.1	0.0267	0.0333	0.0233	0.0167
16.	Graduate fellowships	+	Points	0.045	0.0123	0.0136	0.0109	0.0082
17.	Collaborative research program report	+	Points	0.15	0.0409	0.0545	0.0341	0.0205
18.	Support for proposal for education	+	Points	0.1	0.0345	0.0345	0.0207	0.0103
			Criteria for strategic partner					
19.	Executive sponsorship	+	Points	0.1	0.0296	0.037	0.0259	0.0074
20.	Joint partnership	+	Points	0.25	0.0625	0.0625	0.0625	0.0625
21.	State education lobbying	+	Points	0.033	0.0099	0.0132	0.0066	0.0033
22.	Major gifts	+	Points	0.01	0.0025	0.0025	0.0025	0.0025
23.	Business development	+	Points	0.18	0.0474	0.0474	0.0474	0.0379
Sums of weighted normalised maximising indices (UIPS "pluses") of the university–industry partnership sustainability continuum					0.5248	0.6553	0.3822	0.3354
Sums of weighted normalised minimising (VGTU–industry partnership continuum "minuses") indices of the university–industry partnership sustainability continuum					0.1416	0.2301	0.0885	0.0398
Significance of the university–industry partnership sustainability continuum					0.5986	0.7007	0.5003	0.598
Priority of the university–industry partnership sustainability continuum					2	1	4	3
Utility degree of the university–industry partnership sustainability continuum (%)					85.43%	100%	71.4%	85.35%

* The symbol "+/−" specifies that a bigger (smaller) criterion value corresponds to a bigger (smaller) importance for a user (stakeholder).

Table 5. Revised changes in fair value calculations for LREDA under analysis a_1.

Approximation Cycle	*	Utility Degree Change in UIPS under Analysis by Rationalising the Corrected Value $x_{11\ cycle\ e}$ of a_1				$(U_{1e} + U_{2e} + U_{3e} + + U_{4e})$:4	Imparity
		U_{1e}	U_{2e}	U_{3e}	U_{4e}		
0	16,000	85.43%	100%	71.4%	85.35%	85,55%	|−0.12%| > 0.00%
…	…	…	…	…	…	…	…
120	15,880	85.51%	100%	71.39%	85.3%	85.55%	|−0.04%| > 0.00%
…	…	…	…	…	…	…	…
190	15,810	85.55%	100%	71.39%	85.26%	85.55%	0.00 = 0.00%
…	…	…	…	…	…	…	…
1000	$x_{1j\ iv}$ = 15,000	86.08%	100%	71.27%	85.03%	85.56%	0.52 > 0.00%

* Revised changes in value and fair value $x_{11\ cycle\ e}$ (EURO) of LREDA under valuation a_1.

According to Table 5, calculations were repeated according to steps 1–6 (see Figure 2) until imparity was fulfilled in the 190th cycle.

4.4. Value Optimisation

Based on steps 1–5 and 7, the $x_{104\ cycle\ e}$ shows the UIPS value that is necessary for a_4 to be equally competitive on the market, as related to the other UIPSes (a_1, a_2, a_3) under analysis (see Table 6). The followed procedures allowed for the calculation of what the optimised curriculum development score $x_{104\ cycle\ e}$ should be for a_4.

Table 6. Value optimisation processes.

Approximation Cycle	$x_{104\ cycle\ e}$	U_{4e}	U_{1e}	U_{2e}	U_{3e}	$(U_{1e} + U_{2e} + U_{3e} + + U_{4e}) : 4$	Imparity
0	2	85.35	85.43	100	71.4	85.55	|−0.19%| > 0.01%
…	…	…	…	…	…	…	…
10	2.1	85.53	85.45	100	71.45	85.61	|−0.08%| > 0.01%
…	…	…	…	…	…	…	…
14	2.14	85.62	85.44	100	71.46	85.63	|−0.01%| = 0.01%
…	…	…	…	…	…	…	…
20	2.2	85.72	85.45	100	71.49	85.67	|0.05%| = 0.01%

As Table 6 shows, the imparity was inadequate for the first 10 cycles. The score x_{104} was increased in every cycle (from $x_{104\ cycle\ 0}$ = 2) by an amount of 0.01 until the imparity was fulfilled ($x_{104\ cycle\ 14}$ = 2.14). Scores $x_{104\ cycle\ e}$ (respectively, 2 … and 2.14) were then checked for consistency in the decision-making matrix.

4.5. Recommendations

The results of the INVAR application for the UIPS evaluation are presented in Table 7, where a_2 stands as the best alternative for VGTU–industry cooperation.

Table 7. Quantitative recommendations presented in a matrix form.

Criteria Describing the Candidate Alternatives	*	Measurement Units	Criterion Value (x_{ij}) Possible Improvement of the Analysed Criterion x_{ij}, by % (i_{ij}) Possible Increase in Utility Degree U_j of the Candidate Alternative a_j, by % (r_{ij})			
			a_1	a_2	a_3	a_4
5. Research grants	+	Points	1 (600%) (25.0209%)	x_{52} = 7 (0%) (0%)	x_{53} = 3 (i_{53} = 133.33%) (r_{53} = 5.5602%)	1 (600%) (25.0209%)

*: The symbol "+/−" specifies that a bigger (smaller) criterion value corresponds to a bigger (smaller) importance for a user (stakeholder).

In practice, the methodological processes that were followed for this study allowed for an integrated assessment of the U–I partnership life cycle (i.e., awareness, involvement, support, sponsorship, and strategic partner). This was conducted according to a system of criteria (i.e., innovative, economic, managerial, technical, economic, legal/regulatory, educational, social, cultural, ethical, psychological, emotional, religious, and ethnic aspects) and in conformity with the requirements and opportunities of different stakeholders. Additionally, the INVAR method allows

the strongest and weakest points of each UIPS, along with its basic components, to be established and managed. This can be extremely important for entrepreneurial universities aiming to strengthen their corporate links and/or reduce/reverse the "hollowing effect" of globalisation in some regions.

5. Conclusions

This study sought to create a neural system for a multiple criteria analysis of UIPS. An analysis of prior research [1–3] suggests that the systems available globally have offered no possibilities to execute a multi-variant design and a multiple criteria assessment of alternative iterative life cycles of U–I partnerships, calculate their market and fair value, conduct online negotiations, and select options that offer the best efficiency. Proposing a process-oriented framework that allows overcoming these limitations is the main contribution of this study to theory and practice.

A U–I partnership iterative life cycle may have many alternatives. The basis for the variants consists of an alternative's components—awareness, involvement, support, sponsorship, and strategic partners, among others. The above solutions and processes may be further considered in more detail. Thus, a wide range of U–I partnership iterative life cycle alternatives can be obtained. However, it is worth noting that the development of a potential U–I partnership is complicated, because alternatives for awareness, involvement, support, sponsorship, and strategic partners are plentiful and not continuously well matched. In this regard, the University (including its students, governing board, rector, vice-rectors, deans, chairs, teaching and research staff, and administrative and support staff) and industry stakeholders (including their top management (e.g., chairman, vice-presidents, board of directors, chief executive officer), middle management (e.g., general managers, regional managers), and first line management (e.g., supervisors, office managers, team leaders and employees)) are forced to develop and analyse alternative UIPS solutions.

This research applied the INVAR method for a UIPS evaluation. The resulting new system makes it possible to perform a multi-variant design, as well as a multiple criteria assessment of alternative U–I partnership life cycles, calculate their market and fair values, and conduct online negotiations to select the most efficient alternatives. This results in quantitative information that entrepreneurial universities can use to strengthen their corporate links and/or reduce/reverse the "hollowing effect" of globalisation in disadvantaged regions. Therefore, the UIPS evaluation system developed in this study contributes to the theory and practice of entrepreneurial universities by introducing the INVAR method and its respective framework to different classes of informational systems and decision-making problems. Naturally, it also causes managerial implications for U–I stakeholders, namely in terms of research and innovation performances.

Although the results are encouraging, the UIPS evaluation system developed in this study does have some limitations. Among them, the ones requiring highlighting are the following: (1) the number of participants in the experiment was small; (2) the processes followed require the collection of much unstructured and semi-structured data from many sources, along with their analyses to support stakeholders in decision-making; (3) stakeholders need to be aware of the broader context of decision-making, which includes lifestyle, behavioral, cognitive, social, emotional, psychological, cultural, and ethical factors that impact the success of entrepreneurial universities; and (4) the proposal is process-oriented, which can be a disadvantage during the system's implementation.

Future research is foreseen as moving in three main directions. First, the development of similar experiments that also involve the comparison of other multiple criteria decision methods (for a review, see Zavadskas and Turskis [68], Zavadskas et al. [69]), surveys of comparisons among different methods and sensitivity and robustness analyses in order to explore which method provides more robust and reliable risk assessments. Second, the existing database and the model-base under adaptation should be extended. Third, development of the opinion analytics based on the new UIPS evaluation system is expected. Opinion analytics will empower the automatic detection of opinions expressed in articles, reviews, surveys, comments, opinions, notices, papers, researches, studies, blogs, online forums, Facebook, Twitter, and other social media channels, thereby allowing for the visualisation

of the opinions held by stakeholders on issues regarding a U–I partnership. The innovativeness of opinion analytics will be primarily for automatically determining the level of sustainability of the U–I partnership, compiling numerous alternative recommendations applicable to a specific user, performing a multiple criteria analysis of these recommendations, and selecting the 10 most rational ones for that user. Advancements and updates will be of particular interest to U–I stakeholders, i.e., entrepreneurial universities in particular.

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