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Applying a Method for Measuring the Performance of University-Industry R&D Collaborations: Case Study Analysis

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Abstract

Collaborations between university and industry are possibly the most important strategic instrument used to increase the efficiency and effectiveness of industrial investments in Research and Development (R&D), and have been increasing, which assigns even more importance to the need for measuring their performance. Therefore, a method to measure university-industry R&D collaborations, named MPUIC, developed based on Design Science Research methodology (DSRM), was applied and validated through a case study. This paper firstly describes some improvements made to the previously developed MPUIC method before to its application to a large program between the University of Minho and Bosch Car Multimedia (Portugal). The MPUIC method adopted a weighted scoring approach, and is composed by 31 performance indicators, distributed through the program management life cycle. Secondly, the performance measurement of the case study program is conducted, resulting in a score of 4.4 in a scale of 1 to 5, where 5 indicates "very high" performance. Finally, a questionnaire was administered to evaluate the developed method and, from the 31 performance indicators that compose the method, 29 were evaluated as having a level of relevance above 3 in a scale of 1 to 5 and, from these, 19 were evaluated as having a level of relevance equal to or above 4.

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1. Introduction

A major topic of concern for policy makers nowadays is the cooperation in Research and Development (R&D) as a means to stimulate innovation. Most European Union and national public funding for R&D is applied at stimulating cooperation between firms and between firms and public institutions, in order to promote economic growth and improve the performance of the national system of innovation [1]. Thus, in addition to their internal R&D, organizations are progressively engaging with external sources of innovation [2, 3], namely with universities institutions that include the mission of economic and social development [4, 5] and are expected to join a coherent system, incorporating the industry and government, that is the basis of innovation and economic progress [4, 6].

R&D collaborations between universities and industries have been increasing [7] and a greater importance is being assigned to the need for monitoring and assessing the outcomes of these collaborations [8]. Still, in spite of being a subject of interest to the entities involved and policy makers, few attempts have been made in this regard [9].

It is important to distinguish between success and performance. On one hand, the success of a project can only be measured after the project is completed, while, on the other hand, the performance of a project can be measured throughout the project life cycle. Thus, a system of project metrics requires both success and performance measure, and a way to link both these measures is to assess the precision with which performance is able to predict the future success [10]. Given this difference, measuring the success of university-industry R&D collaborations requires the assessment of the program/project after its conclusion, allowing to match and compare the provided benefits with the expected ones [8], while, measuring the performance of university-industry R&D collaborations requires the assessment of the ongoing program/project, in order to enable adjustments and improvements [7].

The management of research collaborations would benefit from an answer to the need for measuring the outcomes of university-industry R&D collaborations [8], namely from a tool capable of measuring the performance of these collaborations during their occurrence and the success after their conclusion. Accordingly, a first effort to measure the performance of university-industry R&D collaborations has been made and an initial measurement method was developed in a previous research [11]. This previous research focuses solely on the design and development of the stated method [11] but does not include any practical demonstration. Therefore, it gives the opportunity for the present research emerges in order to test the application of the method in a university-industry R&D collaboration case study in order to obtain the validation of this method. The method is henceforth denominated as the MPUIC (Measuring the Performance of University-Industry Collaboration) method. The method adopted a weighted scoring approach and was applied in a university-industry R&D collaboration between University of Minho and Bosch Car Multimedia in Portugal.

The following paper presents a commonly used structure. In Section 2 a brief theoretical background regarding the topic is discussed. Section 3 defines the applied research methodology. Section 4 presents the design and development of the MPUIC method itself, while Section 5 demonstrates its application. An overall discussion occurs in Section 6 and, lastly, Section 7 provides the main conclusions of the paper.

2. Theoretical background

The universities' role is facing ongoing changes [12] and these traditionally educational institutions are contributing to industrial change through knowledge transfer in distinct areas, such as spin-offs, licensing and patenting, collaborative research, consultancy, and mobility of graduates and researchers [13]. As a result, firms are progressively establishing collaborative relationships with universities [12]. In a business environment that is continuously changing, performance measurement is increasingly drawing attention over the last decades and organizations are recognizing its importance [14]. Performance measurement is considered an essential principle of management, since it identifies gaps between current and expected performance, which allows adjustments to close these gaps [15]. University and industry are no exception and are seeking to improve the management of their research collaborations [16], which can be financed by government funds or by the industrial partner of the collaboration [17]. An important feature to reach this improvement is the development of effective performance metrics [18].

The concept of performance measurement implies the identification of performance metrics and the corresponding criteria for their calculation and, thus, performance measurement has a significant function in ensuring the success of a project [19]. Moreover, performance measurement informs about the activities state, continuously, thus easing the final achievement of the customer expectations and strategic objectives [20].

Given the objective of university-industry collaborations to produce innovation outcomes, the development and use of systems of indicators to evaluate these collaborations is a difficult endeavor. Innovation, as a complex and multidimensional concept, does not adjust to traditional metrics and requires a wide variety of indicators to be evaluated [21]. Additionally, the complexity of innovation increases proportionally to the heterogeneity of the parties involved and university-industry collaborations highly reflect such heterogeneity [12]. The primary studies concerning the subject of measuring the performance of projects executed in university-industry collaborations date back to the early 90's. Measuring the performance allows a university-industry collaboration to develop in an efficient and effective manner. Additionally, it can also allow to perceive when adjustments to the organization and/or the objectives of the collaboration are required.

However, in spite of the extreme importance of this measurement, a complete structured and generally accepted system of indicators to evaluate the results of these collaborations has not yet been developed [12]. Only a preliminary research attempt presented by Fernandes et al. [11] reporting initial results, based on the most significant contribution in this regard, which is the research of Perkmann et al. [7]. In this preliminary research, the authors identified four stages of the university-industry collaborations and developed a success map which explains how these collaborations work and identifies the cause and effect relationships underpinning success [7, 22]. A set of performance indicators for each stage of the collaborations was also proposed.

3. Research methodology

The research design used throughout the development of this research assumes the form of Design Science Research Methodology (DSRM). This methodology aims to solve recognized problems in organizations through the creation and evaluation of artifacts [23] that are grouped in four types, namely: constructs, models, methods, and instantiations [23, 24]. A process model consisting of six activities regarding the DSRM was proposed by Peffers et al. [25] and is illustrated in Fig. 1.

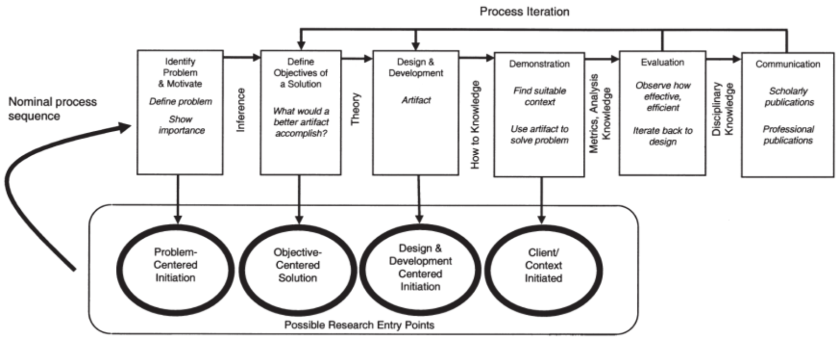

Fig. 1. DSRM process model retrieved from [25].

This research identified as a problem the nonexistence of an organized and generally accepted system of indicators able to measure the performance of university-industry R&D collaborations [12] and has the motivation of overcoming such problem. In view of the problem identified, the main objective is the development of a method capable of measuring the performance of university-industry R&D collaborations. The design and development activity is the core of the DSRM and, in this research, consists in the design and development of the artifact that is the MPUIC method; the desired functionality of the MPUIC method is established and the artifact is actually created. The demonstration activity reveals the use of the MPUIC method to provide a solution to the problem identified in the first activity, hence the application of the MPUIC method in a case study of a university-industry R&D collaboration. Furthermore, an evaluation is performed to observe and measure how the method constitutes a solution to the problem by means of a questionnaire. Regarding the last activity, communication, associated to the MPUIC method, it is performed namely through this paper, wherein the relevant issues are presented.

Data is collected through the analysis of several documents, in order to able to apply the MPUIC method to the case study, identifying the score to attribute to each performance indicator; and the conduction of a questionnaire to evaluate the developed method. Data analysis was performed through Microsoft Excel and IBM SPSS Statistics.

4. MPUIC method design and development improvement

4.1. Initial design and development

A previous research is acknowledged as the work underpinning this paper and is the initial design and development of the MPUIC method [11]. This version was achieved through a detailed review of the existing literature on the subject of performance measurement in university-industry R&D collaborations, as well as by the analysis of two R&D programs arising from the strategic partnership established between University of Minho and Bosch. The method uses the work of Perkmann, Neely, and Walsh [7] as the main theoretical foundation, due to the similarity of objectives and robustness, and the work of Seppo and Lilles [26] as the main source of performance indicators.

Since the beginning, the design of the MPUIC method derives from the need of the partnership between University of Minho and Bosch for a quantitative tool, able to measure and compare the performance of their collaborative R&D programs/projects, therefore the program and project management life cycle used by this partnership was adopted as the underlying structure for the MPUIC method [27]. The four phases of this life cycle (Program Preparation, Program Initiation, Program Benefits Delivery, and Program Closure) are linked to the four phases suggested by Perkmann et al. [7] in their work (Inputs, In-process activities, Outputs, and Impacts). Additionally, the method also considers a Post-Program phase that links to the Impacts phase defined by Perkmann et al. [7]. Fig. 2 illustrates how the phases used by each authors are closely related.

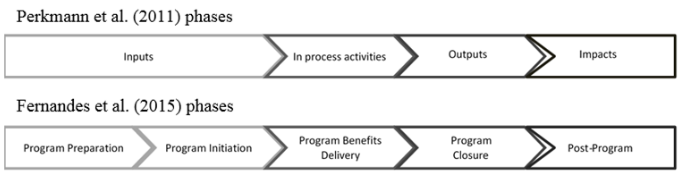

Fig. 2. Linkage between phases adapted from [27].

4.2. Difficulties in applying the initial design

The initial difficulty encountered with the initial design of the MPUIC method consists in the presence of infeasible and redundant performance indicators. This difficulty relates to the performance measures adopted, which are the metrics used to quantify the efficiency and/or effectiveness of a certain action [28].

Another difficulty perceived is centered in the application of the method, namely in the measurement of the performance indicators and in the complexity of attributing them a correspondent score, since a high degree of subjectivism characterizes some performance indicators and hinders their measurement. It is recognized that the achievement of a general agreement on the criteria to be used to measure these subjective performance indicators is a complex endeavor [11]. Altogether, these difficulties relate to the concept of performance measurement, which is the process of quantifying the efficiency and effectiveness of actions [28]. Therefore, the initial design of the MPUIC method, which is the performance measurement system as a whole, needs to be improved.

4.3. Proposed improvements

Table 1 presents the improved MPUIC method proposed from its initial design [11] that aims to overcome the existing difficulties before proceeding to the application in a university-industry R&D collaboration.

Table 1. The MPUIC method as a proposed improvement.

Program Phase & Weight	Performance Component & Weight [%]		Performance Indicator & Weight [%]
Program Preparation [25%]	Researchers' capability [15%]	1.	Average h-index of the academic researchers (excluding research assistants) [40%]
		2.	Percentage of researchers with past experience in university-industry R&D collaborations [30%]
		3.	Percentage of researchers involved that are not research assistants [30%]
	Researchers' motivation [15%]	4.	Percentage of researchers satisfied with the contribution of their participation in a collaboration with industry to the development of their academic careers [100%]
	Industry collaborators' capability [15%]	5.	Percentage of industry collaborators with a post-graduation or a higher education qualification [50%]
		6.	Percentage of industry collaborators with past experience in university-industry R&D collaborations [50%]
	Industry collaborators' motivation [15%]	7.	Percentage of industry collaborators satisfied with the contribution of their participation in a collaboration with university to the development of their professional careers [100%]
	Opportunities/challenges [20%]	8.	Number of project ideas to be studied [100%]
	Applied research [20%]	9.	Percentage of initial project ideas in which the detailing of objectives and potential solutions is jointly determined by university and industry members [100%]
*	Established governance [100%]	10.	Degree of establishment of a joint governance model [100%]
Program Benefits Delivery [50%]	Collaboration intensity [25%]	11.	Rate of Steering Committee meetings (performed/planned) [15%]
		12.	Rate of result-sharing events (performed/planned) [20%]
		13.	Rate of innovation meetings (performed/planned) [25%]
		14.	Rate of progress meetings (performed/planned) [20%]
		15.	Percentage of researchers and industry collaborators satisfied about each other's effective dedication to the collaboration [20%]
	Technology [15%]	16.	Rate of patent applications (submitted/planned) [100%]
	New knowledge [15%]	17.	Rate of publications (published/planned) [50%]
		18.	Percentage of joint publications [50%]
	Management and organizational quality [20%]	19.	Rate of deliverables executed on time [100%]
	Human capital [25%]	20.	Rate of recruitment of PhDs researchers from the program by the industry partner [25%]
		21.	Rate of recruitment of research assistants from the program by the industry partner [25%]
		22.	Variation in the percentage of collaborators with higher education qualifications [25%]
		23.	Number of master's degree dissertations and PhD theses obtained under the program context [25%]
Program Closure [15%]	Innovations [50%]	24.	Number of new products and product improvements developed [50%]
		25.	Number of new processes and process improvements developed [50%]
	Solutions concepts [35%]	26.	Number of new solutions concepts generated [50%]
		27.	Increase of technology readiness levels (TRL), in comparison to the beginning of the projects within the program [50%]
	New ideas [15%]	28.	Number of new project ideas generated from the program, which might result in a new R&D program [100%]
Post-Program [5%]	Technology achievement [30%]	29.	Rate of patents granted (granted/submitted) [100%]
	Sales growth [40%]	30.	Variation of annual sales volume (net all discounts and taxes), from the program closing year to the year of the measuring [100%]
	Partnership sustainability [30%]	31.	Investment value of new university-industry R&D projects/programs generated [100%]

*Program Initiation [5%]

In summary, the proposed improvement cover three sets of changes: 1) slight adjustments are made in the denomination of some performance indicators in order to facilitate their comprehension; changes in performance indicators, namely modifications in three of the performance indicators (4, 7, 15) and the removal of two from the original design of the method [11]; and the incorporation of criteria tables within the weighted scoring approach. These criteria tables allow to define the minimum and maximum margins of each score in all performance indicators and allow to measure them in a six-point scale (wherein 0 is not applicable, and “1” indicates “very low” and “5” indicates “very high”).

The MPUIC method adopted the weighted scoring approach, which is a simple, direct, and effective approach to combine data terms [29]. To do so, weighted scoring approaches require a well-defined number as an input to each criteria. However, often the criteria used in weighted scoring approaches to perform an evaluation are subjective and may not be well defined [30], hence the use of classifications such as “high”, “low” and so forth. These qualitative classifications frequently replace the well-defined numbers in the evaluation of features in a weighted scoring approach. These weighted scoring approaches are based on scoring models, which are often used in R&D project selection since they are consistent with other selection models [31] and have the already stated advantage of allowing the combination of both qualitative and quantitative factors [32].

Weighted scoring approaches also integrate the possibility to customize the system through the specification of weights which act like coefficients [29] and can be changed in function of the specific context. This is important since it allows to reflect priorities [32]. If necessary, it is also possible to include or remove criteria, provided that all criteria are measurable on a scale, either a natural or artificial one, and a measurement unit is assigned to the criteria, such as a currency unit or percentage [31].Given its characteristics, the weighted scoring approach is underpinning the MPUIC method. This type of approach is employed not only through the use of various qualitative and quantitative performance indicators, but also through the attribution of coefficients. In the MPUIC method, these coefficients are denominated as weights and are represented by percentages. Through the attribution of these weights, the different impacts of all elements that constitute the method are considered in the overall performance of university-industry R&D collaborations and, consequently, are reflected in the final score reached through the application of the MPUIC method. The weights in Table 1 are the ones from the initial design [11], which result from the experience of the authors in university-industry R&D collaborations, slightly changed just to accommodate the removal of the two performance indicators.

5. MPUIC method application

The MPUIC method was applied within a strategic partnership between University of Minho and Bosch Car Multimedia (Portugal) in their R&D collaborative program, named IC-HMI. This application corresponds to the fourth activity of the DSRM (see Fig. 1) that implies a demonstration of the artifact as a solution to the initial problem that is the inexistence of a tool capable of measuring the performance of university-industry R&D collaborations. Since the IC-HMI program was in the Program Closure phase by the time of this application, not all results with respect to the performance indicators of this phase were yet available. Therefore, this application of the MPUIC method in the IC-HMI program only considers the first three phases of the method (and the corresponding performance indicators), namely: Program Preparation, Program Initiation, and Program Benefits Delivery. Therefore, the weights of the Program Closure phase (15%) and Post-Program phase (5%) are attributed to the Program Benefits Delivery phase that is applied with a weighted of 70%. All the remaining weights are the ones from the initial design [11], which result from the experience of the authors in university-industry R&D collaborations. Table 2 illustrates the measurement, at the date of the MPUIC method application, of the performance indicators constituting the phases of Program Preparation, Program Initiation, and Program Benefits Delivery.

Table 2. The MPUIC method's application.

Phase	Performance Indicator		Result	Score
Program Preparation phase (25%)	1.	Average h-index of the academic researchers (excluding research assistants)	139%	5 – Very high
	2.	Percentage of researchers with past experience in university-industry R&D collaborations	65.2%	4 – High
	3.	Percentage of researchers involved that are not research assistants	31.5%	4 – High
	4.	Percentage of researchers satisfied with the contribution of their participation in a collaboration with industry to the development of their academic careers	80.9%	5 – Very high
	5.	Percentage of industry collaborators with a post-graduation or a higher education qualification	60%	4 – High
	6.	Percentage of industry collaborators with past experience in university-industry R&D collaborations	86.2%	5 – Very high
	7.	Percentage of industry collaborators satisfied with the contribution of their participation in a collaboration with university to the development of their professional careers	78.5%	4 – High
	8.	Number of project ideas to be studied	41	5 – Very high
	9.	Percentage of initial project ideas in which the detailing of objectives and potential solutions is jointly determined by university and industry members	100%	5 – Very high
*	10.	Degree of establishment of a joint governance model	-	4 – High
Program Benefits Delivery phase (70%)	11.	Rate of Steering Committee meetings (performed/planned)	11/10 = 111.1%	5 – Very high
	12.	Rate of result-sharing events (performed/planned)	5/5 = 100%	5 – Very high
	13.	Rate of innovation meetings (performed/planned)	79/120 = 65.8%	4 – High
	14.	Rate of progress meetings (performed/planned)	445/720 = 61.8%	4 – High
	15.	Percentage of researchers and industry collaborators satisfied about each other's effective dedication to the collaboration	75.5%	4 – High
	16.	Rate of patent applications (submitted/planned)	23/22 = 104.6%	5 – Very high
	17.	Rate of publications (published/planned)	77/72 = 106.9%	5 – Very high
	18.	Percentage of joint publications	23/68 = 33.8%	5 – Very high
	19.	Rate of deliverables executed on time	226/307 = 73.6%	4 – High
	20.	Rate of recruitment of PhDs researchers from the program by the industry partner	3/13 = 23.1%	2 – Low
	21.	Rate of recruitment of research assistants from the program by the industry partner	45/134 = 33.6%	2 – Low
	22.	Variation in the percentage of collaborators with higher education qualifications	12.3 p.p.	5 – Very high
	23.	Number of master's degree dissertations and PhD theses obtained under the program context	54 dissertations and 6 theses	5 – Very high
			Overall score:	**4.4**

*Program Initiation phase

6. MPUIC method evaluation

An evaluation of the MPUIC method implementation was conducted. This evaluation corresponds to the fifth activity of the DSRM (see Fig. 1) and has the objective of observing and measuring how well the MPUIC method constitutes a viable solution to measure the performance of university-industry R&D collaborations. The evaluation was performed through the conduction of a questionnaire to thirteen university members acquainted with the context of the university-industry R&D collaboration case study.

Firstly, it was asked to the respondents to indicate, in a 5-point Likert scale, where "5" indicates "very high" and "1" indicates "very low", the level of relevance of each performance indicator constituting the MPUIC method to the performance measurement of university-industry R&D collaborations.

The answers to the questionnaire showed that all performance indicators of the MPUIC method, except the performance indicators 3 and 8 (see Table 1), have, in average, a level of relevance above 3, considering the values of the mean, median, and mode. Moreover, all the performance indicators of the Program Closure and Post-Program phases have, in average, a high level of relevance, since they all display values above 4 in their mean, median, and mode.

Given that the weights used in the MPUIC method application at the IC-HMI program were the ones indicated in the initial design of the method [11], the questionnaire also aimed to identify a new proposal for the weights of importance of each program phase, each process component, and each performance indicator. Therefore, secondly, it was asked to the respondents to attribute a weight to all these elements. As a result, a new proposal for the weights used in the weighted scoring approach underpinning the MPUIC method was achieved, corresponding to the mean of the weights attributed by the thirteen questionnaire respondents.

Lastly, it was asked to the respondents to indicate the level of simplicity (i.e. interpretation) and ease of use of each criteria table constituting the MPUIC method, also in a five-point Likert scale, where “5” indicates “very high” and “1” indicates “very low”. According to the answers, several criteria tables are still considered, in average, complex to use with a mean below 3. A set of relevant suggestions were made by the respondents in order to improve these criteria tables; most of them were incorporated in the final version of the MPUIC method.

7. Conclusions

The research reported in this paper has both practical and theoretical contributions. The main practical contribution is the demonstration of the use of the MPUIC method in a collaborative university-industry R&D program. Moreover, an important theoretical contribution is the validation of the MPUIC method itself, capable of measuring the performance of university-industry R&D collaborations, for which there is limited understanding in the existent literature [7].

The initial design of the MPUIC method was provided by a previous research in which the authors of this paper were involved [11]. However, the identified difficulties in applying this initial design had to be addressed before proceeding to its application in a university-industry R&D collaboration. These difficulties were considered throughout the development of the MPUIC method as a proposed improvement (see Table 1) and, afterwards, an application of the MPUIC method in the IC-HMI program led to an overall score of 4.4 in a scale from 1 to 5 (where “1” indicates very low and “5” indicates “very high”), regarding the performance of this university-industry R&D collaboration by the time of the application (see Table 2).

An evaluation of the MPUIC method was performed through a questionnaire administered to university members involved in university-industry R&D collaboration case study. It was concluded that, from the 31 performance indicators constituting the MPUIC method, 29 of them have, in average, a level of relevance above 3 and 19 of these have, in average, a level of relevance equal or above 4 (high level of relevance of the performance indicators). Also, a new proposal for the weights used in the weighted scoring approach underpinning the MPUIC method was achieved. However, several of the criteria tables incorporated in the MPUIC method are considered to have, in average, a lower level of simplicity and ease of use. This is an issue that should be addressed in future research, with the objective of turning the level of simplicity (i.e., interpretation) and ease of use simpler to members experienced in university-industry R&D collaborations.

We acknowledge the drawbacks of the research, which mainly result from the limited iteration of the activities established and the limited cycles performed, specifically cycles that would continue with the design and development, the demonstration and the evaluation of the MPUIC method. The sample of respondents of the evaluation questionnaire is small and it does not have representatives from the industry side. In order to better evaluate the MPUIC method, a larger sample formed by members from both university and industry sides should be used in further research. Additionally, exploring more collaborative university–industry R&D cases would result in expanding the outcome of this research by providing more suggestions for the improvement of the MPUIC method.

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