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A comprehensive performance measurement framework for business incubation centres: Empirical evidence in an Irish context

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Abstract

During the last 20 years, there has been an increased interest among academics and practitioners in the area of business incubation. However, limited attention has been devoted to developing a comprehensive framework that can measure business incubators' performances. Therefore, there is an urgent need for an appropriate, robust and useable performance framework. In this paper, we present a comprehensive framework using a weighted fuzzy inference system for business incubation centres' (BIC) performance measurement. The proposed approach utilises the input of a Delphi panel to identify criteria and subcriteria. Then a fuzzy analytic hierarchy process is used to weigh the criteria. Subsequently, a weighted fuzzy inference system is developed and applied to provide results based on the identified criteria and subcriteria. To show the proficiency and applicability of the proposed framework, a case study of Irish BICs is applied. The comprehensive performance measurement framework presented in this paper provides for accurate evaluation and monitoring across six criteria. The six criteria are facilities and infrastructure; clients; networking and marketing; products and services; finance; and human capital. The results show that although most of the BICs focus on facilities and infrastructure, there is a need to concentrate more on factors such as networking, marketing and finance. The detailed approach presented in this paper can be used by academics and practitioners who wish to apply fuzzy inference systems to performance measurement. In addition, the results from our pilot can be used by BIC managers and policymakers to improve performance.

KEYWORDS

business incubation, Delphi panel, fuzzy inference system, performance measurement

1 | INTRODUCTION

Despite a significant increase in interest among academics and policymakers, there is only a limited consensus on what business incubation is and which factors contribute to successful business incubation (Alaassar et al., 2021; Gozali et al., 2020; Liu, 2020; Sagath et al., 2019; Theodorakopoulos et al., 2014). The focus of much of the research on business incubation has been on understanding their social and fiscal contributions to various facets of government policy and vice versa (Ahmad, 2014). The proliferation of business incubators means that there is a need to develop a systematic approach to the measurement of their performance. However, business incubation centre (BIC) managers operating in isolation and reporting to an eclectic mix of agencies are unlikely to result in an appropriate level of performance measurement. Therefore, there is a need for a comprehensive performance framework for BICs. The comprehensive performance measurement framework presented in this paper can help BIC managers to identify their strengths and weaknesses and to develop evidence-based improvement plans. The broad range of criteria used to evaluate business incubation makes it difficult to benchmark the performance of individual BICs and also creates challenges when trying to undertake meaningful comparisons between BICs (Albort-Morant & Ribeiro-Soriano, 2016; Blanck et al., 2019; Hausberg & Korreck, 2020; Theodorakopoulos et al., 2014; Voisey et al., 2006).

The extant literature reflects a focus on facilities, services and activities (Bruneel et al., 2012; Ng et al., 2021; Pauwels et al., 2016; Stephens & Lyons, 2022; Torun et al., 2018; Wang et al., 2020). This focus is useful in terms of describing infrastructure but provides limited value in terms of comprehensive and rigorous performance measurement. The outcomes of business incubation are reported in many different formats and using a diverse range of measures. Several authors (Barbero et al., 2012; Kiran & Bose, 2020; Torun et al., 2018) proposed the use of a range of criteria/indicators, including the number of researchers, patents, revenue and copyrights to measure outcomes. Alternatively, authors including (Leendertse et al., 2021; Siegel et al., 2003) suggest the use of key indicators that focus on the survival rate of companies, job creation and research activity. Indeed, some studies use survival rate as a single key indicator (Blanck et al., 2019; Hillemane et al., 2019; Lai & Lin, 2015). Finally, a portion of the literature captures the activities that take place within a BIC to help profile the value-added of business incubation (Liu, 2020; Stephens & Onofrei, 2012; Torun et al., 2018). However, there is an absence of a comprehensive framework and approach for BICs performance measurement. Performance measurement has a significant role in organisational diagnosis and improvement purposes (Asiaei et al., 2022; Pinheiro et al., 2021). Several approaches have been proposed by different researchers (Govindan et al., 2021; Jasiulewicz-Kaczmarek et al., 2021; Peykani et al., 2021; Yu et al., 2021). Based on a review conducted by (Pourjavad & Mayorga, 2019), multi-criteria decision-making (MCDM), fuzzy MCDM (FMCDM) and data envelopment analysis are the most common techniques used for performance measurement. Table 1 shows some example of using these techniques with their application in performance measurement. Many researchers have tried to use MCDM techniques, such as analytic hierarchy process (AHP) (de Felice et al., 2015; Ikram et al., 2020; Yaghoobi & Haddadi, 2016), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Bai et al., 2014; Gök-Kısa et al., 2021),

TABLE 1 Some examples of the relevant techniques for performance measurement

Author	Technique	Application
de Felice et al. (2015)	AHP	Supplier performance measurement
Yaghoobi and Haddadi (2016)	AHP	Organisational performance measurement
Ikram et al. (2020)	AHP	Integrated management system
Bai et al. (2014)	TOPSIS	Economic performance evaluation
Gök-Kısa et al. (2021)	TOPSIS	Performance measurement of ports
Van Horenbeek and Pintelon (2014)	ANP	Maintenance performance measurement
Dahooie et al. (2021)	ANP	R&D organisation performance measurement
Ishizaka and Resce (2021)	PROMETHEE	School performance measurement
Kilic and Yalcin (2021)	DEMATEL	Municipality performance measurement
Digalwar et al. (2020)	ANP	Sustainable supply chain practice measurement
İç and Yurdakul (2020)	Fuzzy AHP-TOPSIS	Manufacturing firm performance measurement
Prabhu et al. (2020)	Fuzzy TOPSIS	Manufacturing firm performance measurement
Rouyendegh et al. (2020)	Fuzzy TOPSIS-DEA	Retail industry performance measurement
Pachar et al. (2021)	DEA	Sustainable performance measurement in retail chain
Yu et al. (2021)	DEA	Performance evaluation for high-tech companies
Azadnia et al. (2015)	FIS	Supplier performance measurement
Anjomshoae et al. (2021)	FIS	Performance measurement scheme in humanitarian relief operations

analytic network process (ANP) (Dahooie et al., 2021; Digalwar et al., 2020; Van Horenbeek & Pintelon, 2014), Preference Ranking Organisation Method for Enrichment Evaluations (PROMETHEE) (Ishizaka & Resce, 2021; Schwartz & Göthner, 2009) and Decision-Making Trial and Evaluation Laboratory (DEMATEL) (Kilic & Yalcin, 2021; Tseng et al., 2018) or a mixture of these techniques (Guru & Mahalik, 2019; Yurdakul* & Ic, 2005).

In performance measurement, there are several criteria; therefore, MCDM techniques are useful for measuring performance and/or ranking the alternatives. Typically, there are several tangible and intangible criteria used for performance measurement.

Some researchers have tried to incorporate fuzzy logic into the MCDM techniques to deal with this vagueness and uncertainty (Chen et al., 2018; İç & Yurdakul, 2020; Prabhu et al., 2020; Rouyendegh et al., 2020). However, most of the MCDM/FMCDM methods such as AHP, TOPSIS and PROMETHEE are ranking based. There need to be at least two or three alternatives available for these techniques to work. For example, TOPSIS is a distance-based approach, whereas AHP works based on pairwise comparisons (Adedeji et al., 2020; Bakır & Atalık, 2021). As a consequence, this means that if there is a situation in which a company wants to assess the performance of a unit, MCDM/FMCDM techniques are suitable, as the logic behind these techniques requires two or more alternatives/units. The same problem occurs with data envelope analysis (DEA). DEA is a non-parametric approach that can capture the relative performance of a series of decision-making units (DMUs), or alternatives, based on multiple inputs (Liu et al., 2019; Pachar et al., 2021; Yu et al., 2021). DEA works based on multiple units/alternatives and cannot give a performance index for a single unit without comparison with the other units. One technique that has been reported in the literature, with different applications, is FIS (Anjomshoae et al., 2021; Azadnia et al., 2015; Ghadimi et al., 2017; Sridharan, 2021). FIS can deal with both quantitative and qualitative data and also uncertainty and vagueness. FIS does not need several alternatives or units to work. FIS can provide a performance index for a single unit, because it provides a framework and calculator for measuring the performance of each unit. For these reasons, in this research, a FIS is developed and utilised to measure the performance of BICs.

There is a need for a comprehensive performance framework and model for BIC. To address this gap, this paper presents a comprehensive framework for measuring performance based on a five-step approach to data collection and design. We present the results from robust testing of the framework using an FIS. To measure the performance of a BIC, we use several tangible and intangible criteria and measures. Therefore, we collected a mix of objective and subjective data. Some of the data, especially those from expert opinions, have their uncertainty and vagueness (Haleem et al., 2021). In this research, the fuzzy logic theory is utilised to deal with this vagueness and uncertainty. The main contributions of the paper are as follows:

1. A comprehensive list of criteria and subcriteria for the performance measurement of a BIC are identified and validated.
2. A framework is proposed and validated that measures the performance of a BIC using an FIS.
3. A real case study of four Irish BICs is applied to show the proficiency and applicability of the proposed framework.

The approach to performance measurement presented in this paper will contribute to the improved design of business incubation. The rest of the paper is organised as follows. Section 2 provides a literature review followed by Section 3 that presents methodology and implementations. Section 4 presents our discussions. Finally, conclusions are provided in Section 5.

2 | LITERATURE REVIEW

2.1 | Business incubation research

The provision of business incubation comprises physical infrastructure and services, including a variety of office spaces, R&D facilities and small-scale manufacturing suites. Business incubation also includes services like flexible lease terms, access to technology, financing and technical assistance and access to experts in a range of areas including marketing, legal issues, finance, human resources and online platforms. The literature (Alaassar et al., 2021; Hausberg & Korreck, 2020; Mrkajic, 2017; Pauwels et al., 2016; Sagath et al., 2019; You et al., 2020) indicates that there are three types of incubation process:

1. An incubation process that involves the diagnosis and treatment of business problems.
2. An incubation process that creates new businesses through the development of new entrepreneurs.
3. An incubation process that creates spin-offs and spin-outs.

BICs contribute to the knowledge economy, increase human capital levels and create employment (Fernández Fernández et al., 2015). Although these three contributions are at a national level, a key goal of a BIC will be to foster the growth of new businesses within its entrepreneurial ecosystem. There is substantial academic literature that discusses key aspects of incubation: its definition, components, inputs and outcomes (Adlešič & Slavec, 2012; Ahmad, 2014; Amezcua, 2010; Baraldi & Havenvid, 2016; Bruneel et al., 2012; Lukeš et al., 2019; Nair & Blomquist, 2021; Surana et al., 2020; Torun et al., 2018). In addition, numerous conceptual frameworks relating to the design and operation of BICs appear in the literature (Mrkajic, 2017; Sagath et al., 2019; Stephens & Lyons, 2022; Stephens & Onofrei, 2012; Theodorakopoulos et al., 2014; Voisey et al., 2006). However, differences in objectives, structures and practices remain (Albort-Morant & Ribeiro-Soriano, 2016). Indeed, Pergelova and Angulo-Ruiz (2014) explain that public investment in entrepreneurship policies includes trade-offs across alternative growth incentives including public support for business incubation.

Therefore, the principles for the evaluation of business incubation must be sophisticated, robust and up to date to ensure incubation meets the needs and expectations of clients and creates a meaningful connection with academia and the entrepreneurial ecosystem. The study of outcomes in business incubation has frequently focused on tangible outcomes like growth, financial support, turnover and profitability (Albort-Morant & Ribeiro-Soriano, 2016; Messeghem et al., 2018; Stephens & Onofrei, 2012).

2.2 | Performance measurement and business incubation

(Franco-Santos et al., 2007) reported that researchers in a range of areas, including strategy management, operations management, human resource management, organisational behaviour, information systems and management accounting, are contributing to the field of performance measurement. Smith and Bititci (2017) explain that the foundations of performance measurement are taken from organisational and management control theories. They propose that 'a performance measure is a metric can be used to quantify the efficiency and/or effectiveness of an action or activity'. There is no standard methodology for measuring the performance of a BIC. This makes comparisons between studies challenging (Phan et al., 2005). However, Messeghem et al. (2017) explain that policymakers, BIC managers and key stakeholders would benefit from reliable tools to monitor the performance of business incubation. Any approach to performance measurement will involve multiple stakeholders with different expectations and needs. Different countries set different missions, goals and objectives for business incubation. In addition, there be a mix of public and private funding and provision. Some BICs operate as for-profit enterprises, while other BICs are not-for-profit. These issues have significant implications for the approach to evaluation, specifically the use of financial indicators.

Ayatse et al. (2017) proposes that BICs are a cost-effective instrument for entrepreneurial promotion, which can impact positively on firm survival, turnover, employment and job creation. However, when trying to measure client performance, significant challenges emerge. Firstly, start-ups based in publicly funded BICs are often not required to report their performance. Access to relevant data is difficult, if not impossible. Furthermore, the development process and growth trajectory of both the BIC and its clients are likely to be inconsistent and erratic and have no meaningful pattern.

2.3 | Business incubation in Ireland

In Ireland, the development of indigenous businesses is led by Enterprise Ireland (EI). The mission of EI is to inspire and support entrepreneurs to develop a business. A key focus in recent years has been on export-orientated business models. EI (2021) outlines a diverse range of interrelated strategic priorities, including:

1. Maximizing company survival, efficiency and productivity through targeted financial and advisory measures.
2. Sustaining existing export sales and accelerating the diversification of exports.
3. Increasing digital adoption and transformation.
4. Increasing client awareness and capability in research and innovation.
5. Maximizing the number of new start-ups from diverse entrepreneurs in all regions.

A significant element of the work of EI is the sponsorship and the development of BICs on the campus of a higher education institution (HEI). In delivering business development initiatives, the BICs support skill development; low-cost resourcing; knowledge and technology transfer; the commercialisation of research; and access to markets. Publicly sponsored incubation programmes, venture capitalists and private finance companies support the operation of the BICs. In total, there are 31 BICs. All the BICs are supported (to some extent) by EI and are designed, structured and managed similarly. The BICs are classified in four groups: university incubation centres ($n = 8$); technological university incubation centres ($n = 7$); institute of technology incubation centres ($n = 9$); and university bio incubation facilities ($n = 6$).

2.4 | Performance measurement criteria and subcriteria

We undertook a detailed review of articles related to business incubation published in international scientific journals between 2000 and 2020 inclusive. Our search was conducted using Google Scholar. This search and analysis provided insights into the nature and trends of research on business incubation. Our initial search focused on a broad range of terms, which are used to describe business incubation-related facilities and processes. Initially, we searched for 'incubation', but this generated over 2000 articles, many of which had a health and/or veterinary science focus. Next, we searched for 'business incubation' generating 502 journal articles. This list was supplemented by additional searches for science technology park (48), business accelerators (79), innovation parks (25) and start-up ecosystem (75). Allowing for duplication of articles, we identified a list of 729 articles. We then created a library of the 729 articles and conducted a search using a series of keywords relating to performance. The 12 search terms were as follows: performance; assessment; outcomes; KPIs; measurement; success; value; best practice; impact; effective; benefits; and growth. This generated a set of 105 articles. A desk-based review of the articles facilitated a further reduction in the size of our library. A final set of 46 articles was identified. These 46 articles deal with the performance measurement of business incubation. We then conducted a review of the 46 articles to identify the criteria and subcriteria that can be used to describe the activities and outcomes associated with business incubation. The results are presented in Table 2. Although

TABLE 2 Performance criteria extracted from the literature

Criteria	Factors	References
Facilities and infrastructure (FI)	• Space (m2) • Occupancy • Desk/office space • RD&I facilities • Manufacturing	Abduh et al. (2007); Ayatse et al. (2017); Binsawad et al. (2019); Eveleens et al. (2017); Games et al. (2020); Kiran and Bose (2020); Theodorakopoulos et al. (2014); Torun et al. (2018)
Clients (CL)	• Recruitment • Graduation • Survival • Jobs per client • Diversification	Abduh et al. (2007); Amezcua (2010); Ayatse et al. (2017); Barbero et al. (2012); Canovas-Saiz et al. (2021); Eveleens et al. (2017); Hackett and Dilts (2004); Hausberg and Korreck (2018); Iyortsuun (2017); Kiran and Bose (2020); Theodorakopoulos et al. (2014); Torun et al. (2018)
Networks and marketing (NM)	• Number of events • Marketing budget • Reputation of BIC in the community	Abduh et al. (2007); Adlešič and Slavec (2012); Ayatse et al. (2017); Eveleens et al. (2017); Games et al. (2020); Iyortsuun (2017); Kiran and Bose (2020); Torun et al. (2018)
Product and service (PS)	• Number of products • Innovative products • Number of patents • Spin-offs/spin-outs	Ayatse et al. (2017); Eveleens et al. (2017); Hackett and Dilts (2004); Hausberg and Korreck (2018); Theodorakopoulos et al. (2014); Torun et al. (2018)
Finance (FI)	• Grant income • Venture capital funds • Sales growth • Profitability • Cost per job • Cap invest	Abduh et al. (2007); Ayatse et al. (2017); Barbero et al. (2012); Eveleens et al. (2017); Hillemane and Iyortsuun (2017); Leendertse et al. (2021); Torun et al. (2018)
Human capital (HC)	• Clients/staff with higher education or equivalent qualifications • Number of postgraduates • Training hours • Campus graduates • Female/male	Ayatse et al. (2017); Barbero et al. (2012); Eveleens et al. (2017); Hausberg and Korreck (2018); Teruel-Sánchez et al. (2021); Torun et al. (2018)

using these articles was helpful for identifying the relevant criteria and subcriteria for BIC performance measurement, a very limited number of them tried to develop a framework for the measurement purposes.

3 | METHODOLOGY AND IMPLEMENTATION

The objective of this research is to develop a performance measurement framework for BICs. In this section, a detailed explanation of the proposed research methodology and implementation is provided. We began with a systematic approach to reviewing the literature, the outcome of which is presented in Table 2. Next, we recruited 10 experts in business incubation from our existing networks. The experts included, managers, public agency representatives, academics and consultants. A Delphi panel is a group of experts meeting to reach a consensus through a series of discussions and votes. Delphi methodologies have a good track record in conducting research (Czinkota & Ronkainen, 2005; Rowe & Wright, 1999; Sánchez-Villar & Bigné, 2020). The Delphi panel performed two key tasks. First, they supported the creation of an agreed list of criteria and subcriteria. The second task involved the assignment of weightings to each criterion. The use of a Delphi panel allowed the criteria to be constructed, not based on a singular view or based on the limits of a literature review, but by a collection of expert inputs. Figure 1 illustrates the systematic five-step process. A comprehensive explanation of the steps is presented below.

3.1 | Step 1: Identifying BIC performance measurement criteria and subcriteria

This step is about identifying BIC performance measurement criteria and subcriteria. To find the criteria and subcriteria, the related literature is reviewed and the criteria and subcriteria are extracted (as described in Section 2.4 and Table 2). Then, an adjustment mechanism using the Delphi technique is performed to select the most

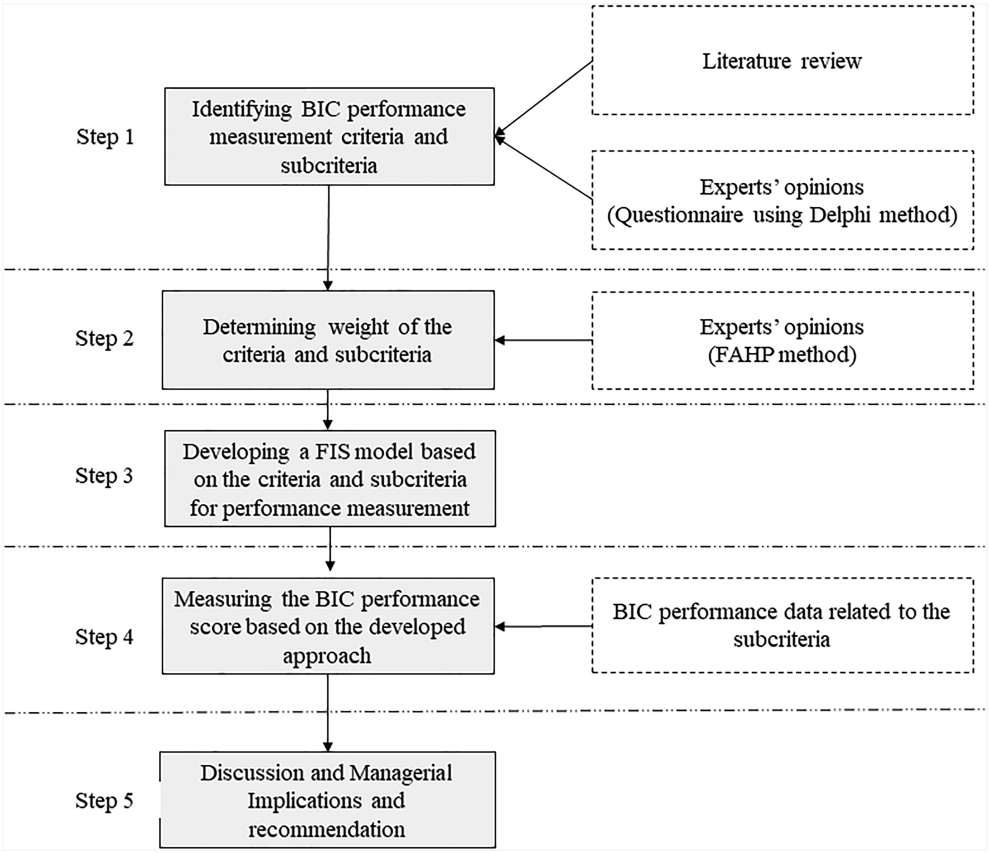

FIGURE 1 Five-step approach

TABLE 3 Experts' profile

P	Role	Experience	Education	Subject
1	Academic	25	PhD	Management
2	Public agency	15	MA	Law
3	Academic	25	MBS	Economics
4	Public agency	5	MBA	Management
5	Prog man	20	MSc	Marketing
6	Prog man	20	MBA	HR
7	BIC graduate	20	BSc	ICT
8	BIC graduate	20	BEng	Construction
9	Consultant	15	MBS	HR
10	Consultant	15	BBS	Marketing

appropriate and relevant criteria and subcriteria. To do this, a questionnaire was distributed to the experts. In this study, a purposive sampling method has been used to select the experts. Hence, the experts were selected based on their expertise in the field of business incubation. It is worth mentioning that to have precise and reliable data from the experts, a meeting with each expert is organised to explain the content of the questionnaire and discuss any possible questions or comments he/she might raise while completing the questionnaire. A profile of the experts is presented in Table 3.

To select the most relevant subcriteria, a yes/no-based list of extracted subcriteria is provided in the questionnaire. If 50% or more of the experts said yes, then the subcriteria were selected. In addition, we asked the experts to add any subcriteria that they believe to be relevant but which were not on the list. The data from the first round of the adjustment mechanism were gathered and analysed. After the first round, some words were modified, and some subcriteria added/removed based on the experts' opinion. Then, a second survey was conducted to select the most relevant criteria and subcriteria. The finalised list of criteria and subcriteria is presented in Figure 2. A brief description of each of the six criteria is then provided.

3.1.1 | Clients

Clients include all the current clients of the BIC and clients from the previous 5 years. This criterion includes four subcriteria which are described as follows:

1. **Recruitment:** The number of new clients recruited annually, measured as a percentage of total clients.
2. **Graduation:** The number of clients who exit the BIC annually, who continue in business, measured as a percentage of total clients.
3. **Jobs per client:** The number of new jobs created in an annual basis, per client.
4. **Survival rate:** A combination of the annual retention of existing clients and the survival of graduates (up to 5 years after they leave the BIC).

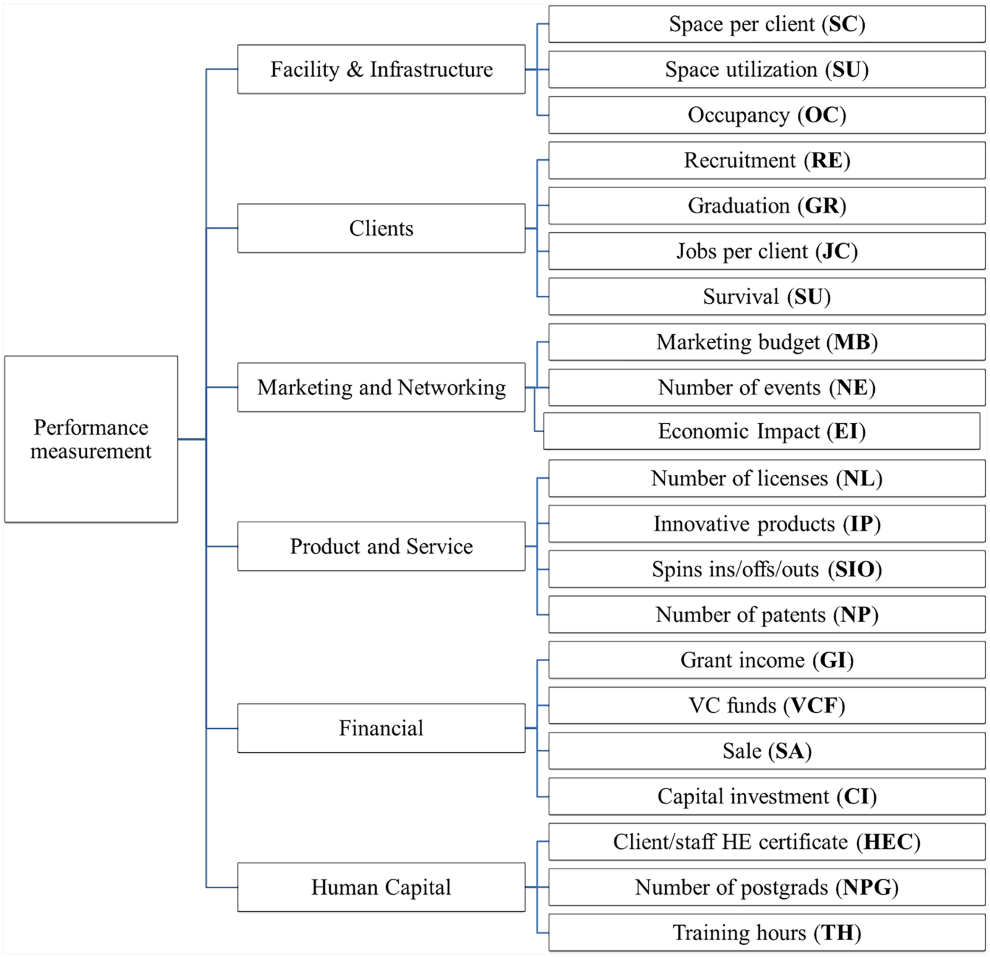

FIGURE 2 Performance measurement criteria and subcriteria

3.1.2 | Facility and infrastructure

Facilities and infrastructure refers to the physical space (campus) and equipment of the BIC. The subcriteria capture the efficiency of usage. This criterion includes three subcriteria which are described as follows:

1. **Space per client:** The average space allocated to each client, measure in square meters.
2. **Space utilisation:** The space per client as a percentage of the total area of the BIC.
3. **Occupancy:** Occupied offices/desks as a percentage of the total number of offices/desks.

3.1.3 | Networks and marketing

A BIC will have a budget to support initiatives that promote both the activities of the BIC and its clients. This criterion includes three subcriteria which are described as follows:

1. **Marketing budget:** Refers to the funding made available by the BIC to promote and publicise the services and activities of both the BIC and its clients, measured in euro per client.
2. **Number of events:** Refers to any organised gathering (which can be virtual) which brings the clients together and/or with invited external stakeholder.
3. **Economic impact:** The number of jobs created in the local ecosystem which can be connected to a client of the BIC, measured per client.

3.1.4 | Product and service

The activities of a BIC need to be understood in terms of types of products and services which are provided by its clients. A key element in assessing this portfolio is the level of innovation. This criterion includes four subcriteria which are described as follows:

1. **Number of licenses**: Developed on an annual basis, measured per client.
2. **Innovative products:** Developed on an annual basis, measured per client.
3. **Spin-ins/spin-offs/spin-outs:** The number of new businesses which are created that have a formal link to a client of the BIC, measured per client.
4. **Number of patents:** Developed on an annual basis, measured per client.

3.1.5 | Finance

A substantial element of the performance measurement of any publically funded organisation relates to finance. This criterion includes four subcriteria which are described as follows:

1. **Grant income:** Received on an annual basis, measured per client.
2. **Venture capital: Secured** on an annual basis, measured per client.
3. **Sales volume:** Measured as the average sales per client.
4. **Capital investment**: Measured in euro per year, per client.

3.1.6 | Human capital

The final criterion proposed in this study refers to the level of human capital within the BIC. This criterion includes three subcriteria which are described as follows:

1. **Higher education** is the number of clients/staff who hold a qualification from a HEI, measured as a percentage of the total number of clients/staff.
2. **Training hours** is the total number of training hours completed by clients in an annual basis, measure per client.
3. **Postgraduates** is the total number of postgraduate students working as researchers or on placement within the BIC, measured per client.

The developed framework for performance measurement includes the six criteria described above. It is important to note that there are other additional elements to the activities of BICs which are not included. Specifically, there are two criteria that we considered including. The review of the literature highlighted the possibility of developing criteria relating to social capital and to regional impact. Authors including (Abduh et al., 2007; Adlešič & Slavec, 2012; Breivik-Meyer et al., 2020) highlighted the role of BICs in facilitating social capital development. The challenge from a performance measurement perspective is capturing this in a useable data format. The Delphi panel concluded that BICs would not be able to collect or be able to access suitable data. The regional impact of BICs is referenced in the literature (Fernández Fernández et al., 2015; Lamine, 2017). However, the BICs do not have the capacity to do complex analysis of their impact across a region or ecosystem. Data that would help measure this criterion might include networking and job creation, both of which we included in other criteria. Finally, there are two additional challenges which characterise attempts at performance measurement for BICs. First, access to client data is limited despite the fact that financial reporting of labour and turnover information would enhance the sophistication of our approach to measurement. Second, of the limited data that are collected, most are in the form of quantitative reporting, with limited insights collected qualitatively.

3.2 | Step 2: Weighting the criteria using the fuzzy analytic hierarchy process

This step involves weighting the performance measurement criteria and subcriteria. We used Chang's (1996) fuzzy analytical hierarchy process (FAHP). To weigh the performance measurement criteria using FAHP, the experts were asked to make the pairwise comparison between criteria using the fuzzy scale shown in Table 4.

A nominal group technique was utilised to implement this step. To do this, an online meeting was conducted to gather the experts' opinions. At the meeting, the experts were equipped with an explanation to show them how to do the pairwise comparisons process. During the meeting, the experts discussed with each other to achieve a consensus for the pairwise comparison matrix. Using this approach, all the experts could share their thoughts and concerns regarding the pairwise comparison matrix that could facilitate the process of having a decision. Afterwards, a final pairwise comparison matrix t was conducted based on the experts' opinions. Subsequently, the linguistic variables were replaced by their relevant fuzzy numbers.

After changing the linguistic variables to fuzzy numbers, Chang's FAHP is used to analyse the data and find the final weight of each of the criteria (Chang, 1996). The steps of Chang's FAHP are provided below: As proposed by Chang (1996), the extent analysis method, used as the most common method in the solution of FAHP applications, the fuzzy number is utilised to measure the 'extent'. To conduct the extent analysis of each object, a fuzzy synthetic degree value is estimated according to the fuzzy values. Elements of the alternatives, $X = x_1, x_2, \ldots, x_n$, are represented as an object set, and the elements of the criteria are represented by $U = u_1, u_2, \ldots, u_m$ as a goal set. In his method, each object is taken, and extent analysis for each goal, g_i, is conducted correspondingly. Finally, extent analysis values for each object is calculated as follows:

TABLE 4 Fuzzy numbers and linguistic variables

Fuzzy numbers	Linguistic variable	Abbreviation	Reciprocal numbers
(1,1,1)	Just equal	E	(1,1,1)
(2/3,1,3/2)	Equally important	EI	(2/3,1,3/2)
(1,3/2,2)	More important	M	(1/2, 2/3, 1)
(3/2,2,5/2)	Strongly more important	S	(2/5,1/2,2/3)
(2,5/2,3)	Very strongly more important	VS	(1/3,2/5,1/2)
(5/2,3,7/2)	Absolutely more important	AM	(2/7,1/3,2/5)

$$M_{g1}^{1}.M_{g2}^{2}.....M_{gi}^{m}.... \quad i = 1.2.3.....n$$

where M_{gi}^{j} is a triangular fuzzy number that can be represented by a tuple such as (a,b,c), where all the $M_{gi}^{j}, j = 1,2,3,...,m$ are triangular fuzzy numbers. Now, the steps of Chang's extent analysis are described as follows:

1. The value of the fuzzy synthetic extent is defined as

$$s_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$$

If $M_{gi}^{j} = (a_{ij}.b_{ij}.c_{ij})\ then \sum_{j=1}^{m} M_{gi}^{j}$ with the fuzzy addition operation of m extent analysis values for a particular matrix is defined as

$$\sum_{j=1}^{m} M_{gi}^{j} = (a_{i1}.b_{i1}.c_{i1}) \otimes (a_{i2}.b_{i2}.c_{i2}) \otimes ... \otimes (a_{im}.b_{im}.c_{im}) = \left(\sum_{j=1}^{m} a_{ij}.\sum_{j=1}^{m} b_{ij}.\sum_{j=1}^{m} c_{ij}\right) = \left(\acute{a}_i.\acute{b}_i.\acute{c}_i\right)$$

Also, for calculating $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$, fuzzy addition operation is to be performed:

$$\sum\sum M_{gi}^{j} = \sum_{i=1}^{n}\left(\sum_{j=1}^{m} a_{ij}.\sum_{j=1}^{m} b_{ij}.\sum_{j=1}^{m} c_{ij}\right) = \left(\sum_{j=1}^{n} \acute{a}_i.\sum_{j=1}^{n} \acute{b}_i.\sum_{j=1}^{n} \acute{c}_i\right)\left(\sum_{j=1}^{n} a_{ij}.\sum_{j=1}^{m} M_{gi}^{j}\right)1 = \left(\frac{1}{\sum_{i=1}^{n} \acute{c}_i}.\frac{1}{\sum_{i=1}^{n} \acute{b}_i}.\frac{1}{\sum_{i=1}^{n} \acute{a}_i}\right)$$

So,

$$s_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left(\sum_{j=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right) - 1 = \left(\acute{a}_i.\acute{b}_i.\acute{c}_i\right) \otimes \left(\frac{1}{\sum_{i=1}^{n} \acute{c}_i}.\frac{1}{\sum_{i=1}^{n} \acute{b}_i}.\frac{1}{\sum_{i=1}^{n} \acute{a}_i}\right) = \left(\frac{\acute{a}_i}{\sum_{i=1}^{n} c_i}.\frac{\acute{b}_i}{\sum_{i=1}^{n} b_i}.\frac{\acute{c}_i}{\sum_{i=1}^{n} a_i}\right) = (a_i.b_i.c_i)$$

2. Possibility degree calculation: If $S_i = (a_i.b_i.c_i)$, $S_k = (a_k.b_k.c_k)$, then possibility degree of $S_i \geq S_K$ that indicated by $V(S_i \geq S_K)$ is defined as:

$$V(S_i \geq S_K) = SUP_{y \geq x}(\min\{\mu_{si}(x).\mu_{sk}(y)\})$$

And can be equivalently expressed as follows:

$$V(S_i \geq S_K) = hgt(S_i \cap S_K) = \mu_{si}(d)$$

$$V(S_i \geq S_K) = \mu_{sk}(d) \begin{cases} 1 = \text{if}(a_i \geq a_K) \\ 0 = \text{if}(a_k \geq c_i) \\ \dfrac{a_k - c_i}{(b_i - c_i) - (b_k - a_k)} = \text{otherwise} \end{cases}$$

where d is the ordinate of the highest intersection point between μ_{si}, μ_{sk}.

3. The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $S_i; I = 1,2,...,k$ can be defined by

$$V(S \geq S_1.S_2.....S_k) = V((S \geq S_1).(S \geq S_2)....(S \geq S_k)) = \min(V(S \geq S_1).V(S \geq S_2).....V(S \geq S_k)) = \min(V(S \geq S_i)i = 1.2.....k$$

If it is assumed that for $(k = 1.2.....n\, k \neq i).\acute{d}(A) = \min(V(S_i \geq S_k))$, then weight vector is given by

$$\acute{w} = \left(\acute{d}(A).\acute{d}(A_2)\right).....\acute{d}(A_n)T$$

4. Via normalisation, the normalised weight vectors are defined as

$$w = (d(A).d(A_2)).....d(A_n)T$$

where w is a non-fuzzy number. This gives the priority weights of one alternative over another.

To implement the FAHP steps, Microsoft Excel software was utilised. The finalised results of pairwise comparison for the criteria are tabulated in Table 5.

3.3 | Step 3: Developing a FIS model based on the criteria and subcriteria for performance measurement

In this step, an FIS model is designed to measure the Irish BIC performances. It is worth mentioning that MATLAB software was used to implement FIS model. This model can address the inherent vagueness

TABLE 5 Final weight of the criteria

Criteria	Final weight
Facilities	0.16910
Clients	0.24181
Networks and marketing	0.14128
Product and service	0.20054
Finance	0.13248
Human capital	0.11479

of expert judgements in the assessment. Figure 3 shows a schematic view of the FIS model.

The steps of constructing the FIS model are provided as follows:

Fuzzification: In this step, triangular membership functions (MFs) are designed for the input variable (subcriteria) under each criterion. For each subcriteria, initially, a target range that shows a minimum and maximum value of that subcriterion is defined. To find the proper target ranges for the input variables, several meetings were conducted with the experts. In addition, policy documents and reports from the Irish government and EI were reviewed to help identify appropriate ranges for the target ranges. Then, based on the target range, for each subcriterion, low (L), medium (M) and high (H) are defined as the three MFs. The constructed MFs are presented in Table 6. In addition, an output target range from 0 to 1 is defined, and five output MFs are defined within the target range as very low, low, low to medium, medium to high, high and very high. MATLAB software was used to

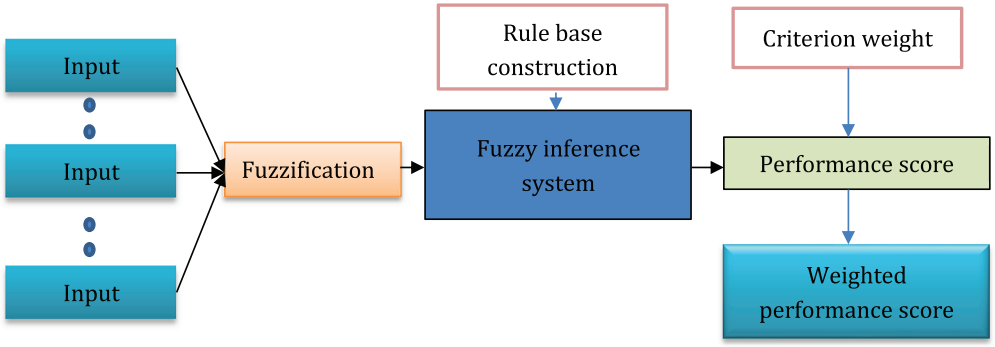

FIGURE 3 Fuzzy inference system model

TABLE 6 Fuzzified input variables

Linguistic	Fuzzy number	Linguistic	Fuzzy number	Linguistic	Fuzzy number	Linguistic	Fuzzy number
Input: SPC		**Input: RE**		**Input: NOE**		**Input: NOP**	
Low	[3 6 9]	Low	[0 0 0.125]	Low	[5 15 25]	Low	[0 0 5]
Medium	[6 9 12]	Medium	[0 0.125 0.25]	Medium	[15 25 35]	Medium	[0 5 10]
High	[9 12 15]	High	[0.125 0.25 0.25]	High	[25 35 45]	High	[5 10 10]
Input: OC		**Input: Gr**		**Input: MB**		**Input: SIO**	
Low	[20 20 60]	Low	[0 0 0.125]	Low	[0 0 20000]	Low	[0 0 5]
Medium	[20 60 100]	Medium	[0 0.125 0.25]	Medium	[0 20000 400000]	Medium	[0 5 10]
High	[60 100 100]	High	[0.125 0.25 0.25]	High	[20000 40000 40000]	High	[5 10 10]
SU		**Input: SU**		**Input: EI**		**Input: NOL**	
Low	[20 40 60]	Low	[0 0 50]	Low	[0 0 25]	Low	[0 0 5]
Medium	[40 60 80]	Medium	[0 50 100]	Medium	[0 25 50]	Medium	[0 5 10]
High	[60 80 100]	High	[50 100 100]	High	[50 100 100]	High	[5 10 15]
Input: VCF		**Input: JPC**		**Input: IP**		**Input: GI**	
Low	[0 0 50000]	Low	[0 0 5]	Low	[0 0 5]	Low	[0 0 25000]
Medium	[0 50000 100000]	Medium	[0 5 10]	Medium	[0 5 10]	Medium	[0 25000 50000]
High	[0 100000 100000]	High	[5 10 10]	High	[5 10 15]	High	[2500050000 50000]
Input: CI		**Input: S**		**Input: TH**		**Input: NP**	
Low	[0 2500 5000]	Low	[0 0 20000]	Low	[0 20 40]	Low	[0 0 5]
Medium	[2500 5000 7500]	Medium	[0 20000 40000]	Medium	[20 40 60]	Medium	[0 5 10]
High	[5000 7500 10000]	High	[20000 40000 40000]	High	[40 60 80]	High	[5 10 10]
Input: HEQ		**Input: NPG**					
Low	[0.4 0.4 0.7]	Low	[0 2.5 5]				
Medium	[0.4 0.7 1]	Medium	[2.5 5 7.5]				
High	[0.7 1 1]	High	[5 7.5 10]				

define the MFs for inputs and outputs. Figure 4 presents a sample of constructed inputs and output for finance criterion in MATLAB.

To link the input variables to the output variable, the rule base is constructed as the engine of the FIS model. This engine encompasses many IF_THEN fuzzy rules. The number of fuzzy rules can be calculated by Equation 1) (Ghadimi et al., 2017).

$$R = n^{v} \quad (1)$$

where

R = number of potential rules for each main criterion

n = number of MF types for each subcriteria

v = number of subcriteria (input variables) related to each main criterion.

For example, we have three subcriteria under facility and infrastructure criterion. We have three MFs for evaluation of the factors. Hence, based on the Equation 1, we have 27 rules. The number of possible rules for each criterion were calculated and shown in Table 7.

As shown in Tables 7, 324 rules should be constructed for developing the FIS system that measures the performance of the BICs. Some of the constructed rules are presented in Table 8. These rules were defined and implemented in MATLAB software.

Calculation process: The calculation process of the proposed FIS is conducted using the following steps. This process includes the fuzzy conclusion for the rules using some operators such as AND, OR and NOT. Afterwards, an aggregation process is considered to aggregate the conclusions output. Finally, the output of the aggregation process is processed using the centre-of-gravity approach to finding the score of each alternative (Ghadimi et al., 2017). Again, MATLAB software was utilised for the implementation purpose.

TABLE 7 Number of rules for each criterion

Criteria	Number of rules
Facility and infrastructure	27
Client	81
Networks and marketing	27
Product and service	81
Finance	81
Human capital	27
	Total = 324

TABLE 8 Sample fuzzy rules

1	If (SC is low) and (SU is low) and (OC is low), then (FI is very low)
2	If (SC is high) and (SU is high) and (OC is high), then (FI is very high)
3	If (SC is high) and (SU is low) and (OC is medium), then (FI is medium)
4	If (MB is low) and (NE is low) and (EI is low), then (MN is very low)
5	If (MB is high) and (NE is high) and (EI is high), then (MN is very low)

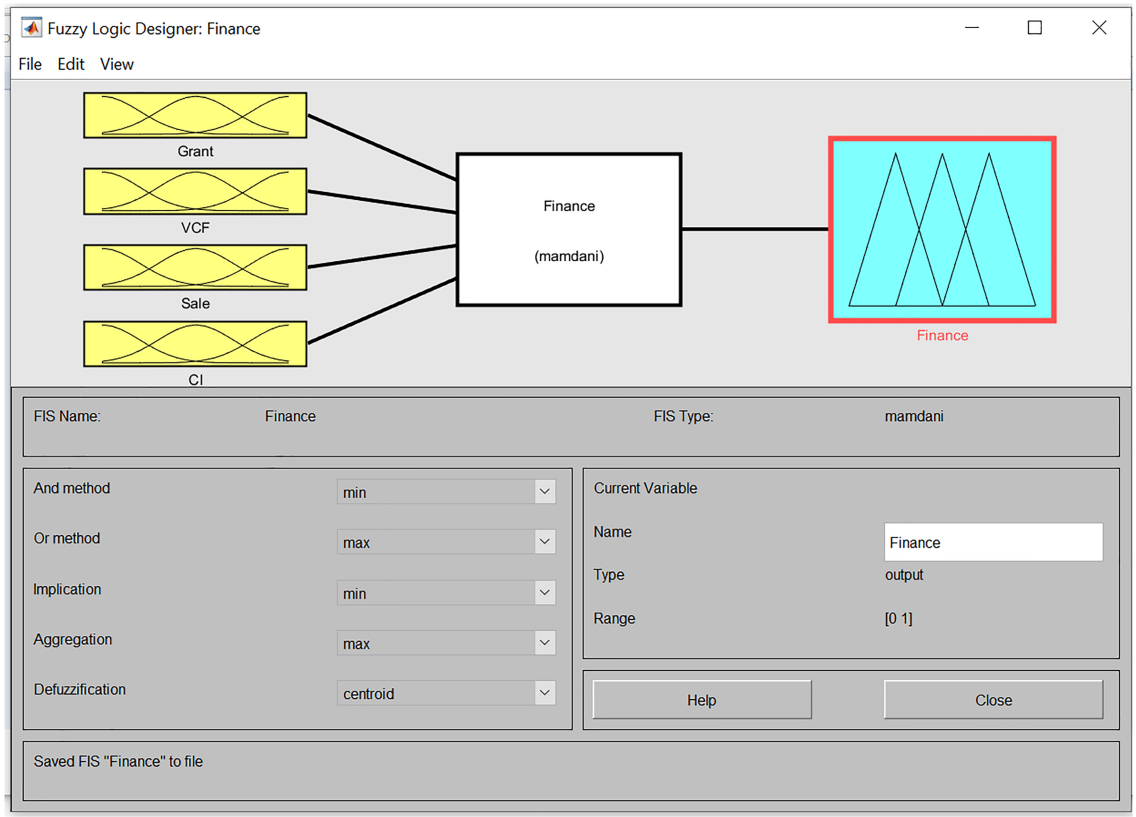

FIGURE 4 Sample of constructed inputs and output (finance criterion) in MATLAB

TABLE 9 Data for four BICs

	BIC1 Public	BIC2 Public	BIC3 Semi-private	BIC4 Semi-private
SC (square meter)	8	10	8	8
SU (per cent)	80	70	75	80
OC (per cent)	100%	90	85	80
RE (per cent)	10%	10%	25%	15%
GR (per cent)	5%	5%	20%	10%
JC	1	1	3	3
SU (per cent)	100	100	75	75
MB (euro)	1000	1000	12,000	20,000
NE	10	4	10	10
EI	25	20	40	35
NL	3	3	5	5
IP	5	5	5	5
SIO	1	1	2	5
NP	1	1	3	3
GI (euro)	10,000	25,000	25,000	30,000
VCF (euro)	2000	1500	10,000	25,000
SA (euro)	15,000	10,000	48,000	50,000
CI (euro)	4000	2500	5000	5000
HEC (per cent)	80%	80%	90%	90%
NPG	25	10	25	9
TH	24	40	45	50

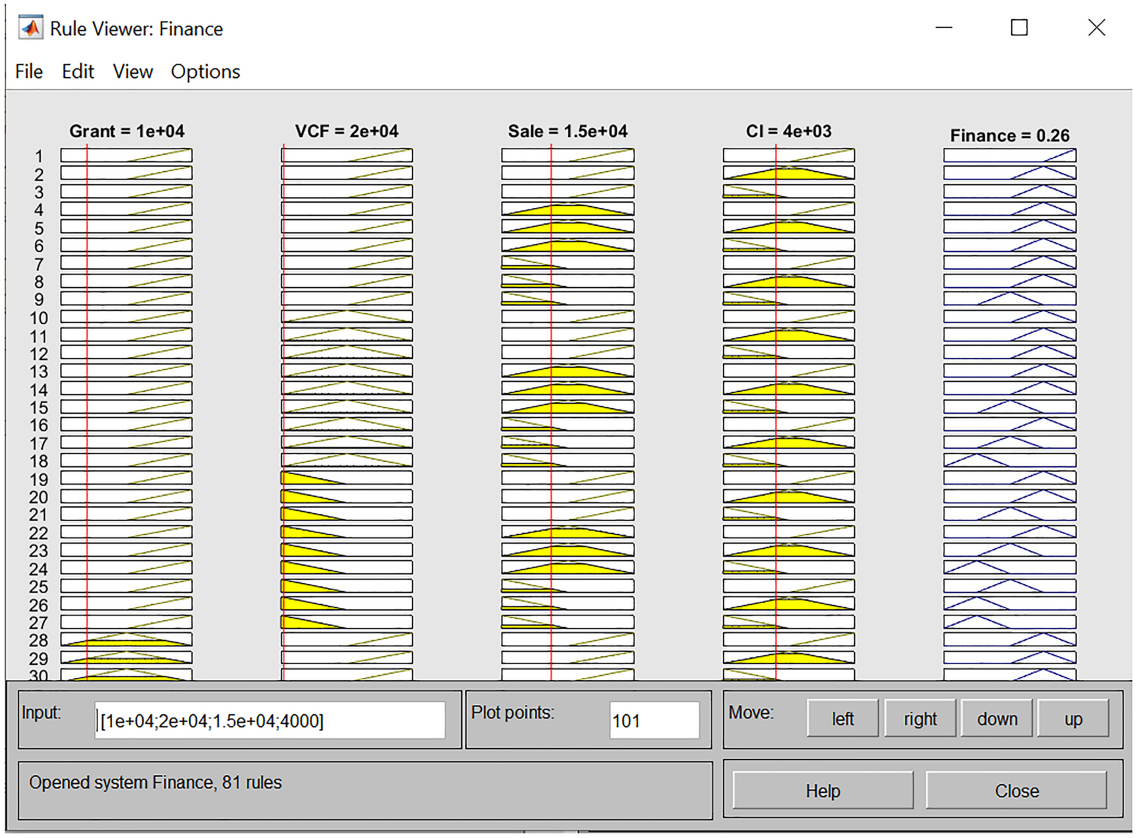

FIGURE 5 MATLAB output for BIC1 in finance criterion

3.4 | Step 4: Measuring the BIC performance using the developed FIS

In this step, BIC performances are measured using the proposed weighted FIS. The data for the BIC performance in each subcriterion are gathered. In this study, to show the applicability and proficiency of the proposed approach, we then recruited four BIC managers to facilitate the testing of our performance measurement framework. The four BICS are all based in Ireland. Two of the BICs are public and two are semi-public. The size of the four BICs in terms of facilities and the overall budget are similar. All four are located on the campus of an HEI. The BICs were asked to provide information for each of the defined subcriteria. The data are presented in Table 9. Due to privacy considerations, specific details about the name or location of the BICs are not provided. After gathering the relevant data, the developed FIS in MATLAB software was used to measure the performance of each BIC. Initially, the score of each BIC in each criterion was calculated. Figure 5 provides an example of the performance measurement for BIC1, in the financial criterion, generated by MATLAB. The same procedure was applied for each criterion. Table 10 shows the performance of the BICs in all six criteria.

After calculating the performance scores for the individual BICs for all the criteria, the criteria weights were then considered to calculate the final weighted score. To do this, for each BIC, a sum of the products of the BIC performance in each criterion and the criterion weight was calculated (see Table 11).

As shown in Table 10, the final weighted performance scores for BIC1, BIC2, BIC3 and BIC3 are 0.413, 0.408, 0.547 and 0.515, respectively. Therefore, BIC3 with the final weighted performance score of 0.547 was ranked as the best BIC, and BIC4, BIC1 and BIC2 were ranked second, third and fourth, respectively.

TABLE 10 BIC performance across the six criteria

Criteria	BIC1	BIC2	BIC3	BIC4
Facility and infrastructure	0.647	0.684	0.547	0.529
Clients	0.41	0.41	0.664	0.547
Marketing and networking	0.273	0.262	0.5	0.484
Product and service	0.317	0.317	0.355	0.395
Financial	0.26	0.264	0.56	0.625
Human capital	0.587	0.5	0.682	0.547

4 | FINDINGS AND DISCUSSIONS

In this study, we had two main objectives. The first one is to identify the most relevant criteria and subcriteria for BIC performance

TABLE 11 Final weighted performance score

Criteria's weights	Criteria	BIC1	BIC2	BIC3	BIC4
0.1691	Facility and infrastructure	0.647	0.684	0.547	0.529
0.24181	Clients	0.41	0.41	0.664	0.547
0.14128	Marketing and networking	0.273	0.262	0.5	0.484
0.20054	Product and service	0.317	0.317	0.355	0.395
0.13248	Financial	0.26	0.264	0.56	0.625
0.11479	Human capital	0.587	0.5	0.682	0.547
	Final weighted performance score	**0.413**	**0.408**	**0.547**	**0.515**

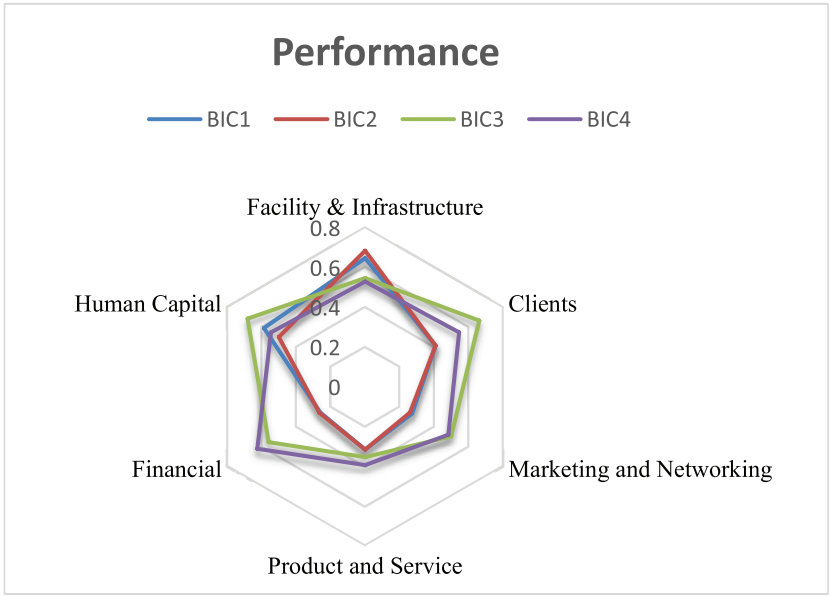

FIGURE 6 Radar diagram of BIC performance

measurement. In order to achieve this objective, a comprehensive review of the existing literature of BIC was performed, and the relevant criteria and subcriteria were extracted (Table 2). Then using a Delphi technique and experts' opinions, the most relevant criteria and subcriteria for BIC performance measurement were identified.

The second objective of this study is to develop a comprehensive approach for measuring the performance of the BICs based on the identified criteria. In order to achieve this objective, an integrated approach of FAHP and FIS was developed. Using the developed approach, the Irish BIC performances were measured.

To support our discussion of the findings, we present Figures 6 and 7. Figure 6 presents a schematic comparison between the performances of the four BICs. As shown in Figure 7, the BICs can be classified into four groups, very weak, weak, strong and very strong based on their performance scores.

The BICs with a performance score between 0 and 0.25, 0.25 and 0.5, 0.5 and 0.75 and 0.75 and 1 are classified into weak, slightly weak, slightly strong and strong categories, respectively. The overall performances of both BIC1 and BIC2 are categorised into the slightly week category, as they have a score of 0.413 and 0.408, respectively. BIC3 and BIC4 fall into the slightly strong category. A review of both Table 10 and Figure 6 helps us to identify that BIC2 has the best performance in the first criterion (facilities and infrastructure) followed by BIC1, BIC3 and BIC4. Although BIC1 and BIC2 have good performance in relation to facilities and infrastructure; and partially good performance in relation to human capital, they both perform weakly across the other four criteria. Both of the BICs are fully reliant on public funding. The publically funded BICs have large budgets. However, a significant proportion of their funding is directed to capital spending such as extensions, new equipment and upgrading (Harper-Anderson & Lewis, 2018; Sagath et al., 2019). This means that they can provide access to up-to-date resources in modern facilities. However, they have a limited ability to adjust current spending which can make them less responsive to the needs of their clients. It is also worth mentioning that during the interviews, the managers of the publicly funded BICs, mainly talked about the infrastructure and facilities that they had and its importance. But they spoke less about the other criteria, such as marketing and network and product and services. For the second criterion (clients), BIC3 achieved the highest performance score followed by BIC4 and BIC1/2. BIC3 and BIC4 perform better in relation to recruitment, graduation and jobs per client. This can partially be explained by their shorter incubation period (up to 24 months). But, predominately, it is driven by a desire to deliver a return on investment with a focus on two key deliverables: jobs and new enterprise creation (Bruneel et al., 2012; Hillemane et al., 2019).

The weak performance of the publicly funded BICs, in four of the criteria, can to some extent be explained by the lack of flexibility around budgets and current spending. Based on the data presented in Figure 6, BIC1 and BIC2 achieved very low performance scores in the third criterion, marketing and networking. This is because of a lack of spending on network and marketing activities which we propose is vital BIC. There is evidence that the performance of the public BICs can be improved by additional spending both networking and marketing activities. Indeed, Kiran and Bose (2020) argue that networking has a positive impact on BICs performance. In contrast, the semi-public BICs have a reduced budget for capital investment but have greater financial autonomy and the ability to fund services like marketing and networking events. That is why for the third criterion (marketing and networking), BIC3 achieved the highest performance score followed by BIC4, BIC2 and BIC1.

In relation to the fourth criterion (product and services), BIC3 achieved the highest performance score followed by BIC4, BIC1 and BIC2. During our meeting with the management of BIC4, they indicated that the number of new products and services is one of the significant factors they use to assess their performance. Table 8 provides evidence of this. Both BIC4 and BIC 3 have a higher number of innovative products, licenses, patents and spin-ins/spin-offs/spin-outs. For the fifth criterion (financial), BIC4 achieved the highest performance score followed by BIC3, BIC2 and BIC1. The performance of both BIC1 and BIC2 is extremely weak, with scores of 0.26 and 0.264, respectively. It is the criterion for which both of these BICs perform worst. This is despite their strong performance in relation the subcriterion, capital investment. However, these two publically funded BICs are not achieving an appropriate level of performance in terms of additional grant income and venture capital. There is significant scope for both BIC1 and BIC2 to improve their performance in this criterion (and overall). The BICs need to prioritise the attraction of additional funding, perhaps best achieved by appointing a funding officer. Their current inability to do this is also related to their poor performance in the third criterion (marketing and networking). In order to attract venture capital, their clients need support to promote themselves and their businesses. For the sixth, and final criterion (human capital), BIC3 achieved the highest performance score followed by BIC1, BIC4 and BIC2. All four of the BICs are based on campus at an HEI. Therefore, it is not surprising that they score above 0.5 for this criterion. However, there is significant scope for improvement. The HEI connected to the BIC will have multiple programmes to facilitate upskilling and reskilling as well as established pathways for continuous professional development (CPD). The BICs should work to develop and maintain an up-to-date skills audit. This will support them

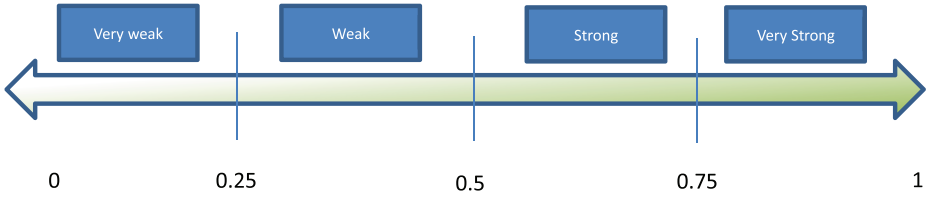

FIGURE 7 Performance scale (very weak to very strong)

to work with a dedicated liaison officer from the HEI so that they can achieve better performance in this criterion.

To show the impact of the criteria weights on the final scores of the BICs, the performance scores of the BICs with equal weights of the criteria were calculated. As shown in Table 12, the performance scores of the BICs are slightly changed when the equal weights are considered. For example, the BIC4 final performance score increased to 0.521. This can be justified by the fact that the weight of financial criteria increases from 0.13248 to 0.166667 where BIC4 has a strong performance (0.625). Also, the weight of product and service is decreased from 0.20054 to 0.166667 where BIC4 performance is weak (0.395). Therefore, the changes in weights impact the final score of the BICs.

5 | MANAGERIAL AND POLICY IMPLICATIONS

This paper presents a real-world application of the identification of the criteria and subcriteria for the measurement of the performance of BICs. Our measurement framework has implications for the design and delivery of business incubation initiative. The approach presented in this paper can be utilised as a road map for BIC managers to consistently evaluate the services and facilities that they provide to their clients. Specifically, the scoring system for each subcriterion can provide concrete measures for managers to identify which subcriterion is causing difficulty and needs to be amended and improved. Although internal operations may be managed by the often 'hands-on' 'firefighting' approach of a BIC manager, the need to secure a return on public investment and to contribute to the development of their entrepreneurial ecosystem requires a systematic approach to performance measurement. The framework we have developed provides a structure within which a BIC manger can conduct a rigorous annual review of their performance. The managers can identify which of the six criteria that they need to prioritise in order to improve the performance of their BIC. Then they can adjust their spending plans and activities to focus on these areas. Using this framework, it should be possible for a BIC manager to develop an appropriate set of action plans that over the medium term deliver an improvement in each subcriterion and overall performance.

Policymakers have very high expectations for how business incubators will affect local economic development, resulting in a focus on short-term performance goals (Messeghem et al., 2017). Considerable public funding has and is being direct towards business incubation initiatives and BICs. However, there needs to a (re-)evaluation of how this funding is distributed across the capital and current spending. Specifically, funding needs to be distributed across the six criteria we have identified. This is a complex challenge. There is a culture of focussing on capital spending. However, capital investment can only improve the performance of a BIC to a certain extent. To develop strong performance, there is a need to invest funding in a range of activities. This will allow the BIC to perform consistently in each of six areas measured by our criteria. The outcome of a more sophisticated funding allocation would be a measurable increase in overall performance with associated benefits for clients, sponsors, HEIs and the local ecosystem.

As a conclusion to our section on policy and managerial implications, we now provide proposals for how BICs can improve their performance by addressing issues related to each of the six criteria.

1. **Facility and infrastructure:** The BICs all scored above 0.5 for this criterion, and the four managers report that they have access to capital funding to provide necessary facilities. There is capacity for the BICs to increase their collaborative spaces and to develop sophisticated virtual spaces. Virtual facilities and cloud-based infrastructure offer a realistic route for the BICs to improve their score for this criterion.
2. **Clients:** There was some variation between the four BICs, but there was evidence of the ongoing recruitment, graduation and survival of clients. The BIC managers report a focus on recruitment. In order to improve their performance in relation to this criterion, the BICs need to develop a system of performance reviews (every 3 months) to help increase survival rates. In addition, there needs to be an emphasis on success post-incubation. This process is best managed by a dedicated external engagement officer who should maintain links with the graduates and support them to access the support and resources they need from the ecosystem.
3. **Networks and marketing:** There was a big difference between the two public BICs and the two semi-private BICs in the criterion. Additional funding will allow the public BICs to make this criterion a priority. For all the BICs, there is a need to integrate the BIC into the local ecosystem. This is a two-way process. Key stakeholders must be invited on campus, and clients must be supported to engage with key stakeholders. The promotion of the BIC and its

TABLE 12 BIC performance measurement comparison with different criteria weights

Criteria's weights	Criteria	BIC1	BIC2	BIC3	BIC4
0.166667	Facility & Infrastructure	0.647	0.684	0.547	0.529
0.166667	Clients	0.41	0.41	0.664	0.547
0.166667	Marketing and networking	0.273	0.262	0.5	0.484
0.166667	Product and service	0.317	0.317	0.355	0.395
0.166667	Financial	0.26	0.264	0.56	0.625
0.166667	Human capital	0.587	0.5	0.682	0.547
	Final performance score (equal weights)	**0.416**	**0.406**	**0.551**	**0.521**
	Final weighted performance score	**0.413**	**0.408**	**0.547**	**0.515**

services must be done in conjunction with the promotion of the products and services of its clients.

4. **Products and services:** All four BICs performed poorly in this criterion. There needs to be a reorientation towards higher value activities, similar to those that characterise science parks and technology incubators. To date, the focus in the BICs has been on new services, but this is changing, and the managers are now focusing on high potential/growth start-ups that can impact on entrepreneurial environment (Martínez-Fierro et al., 2020). It is this transition that will enable the BICs to improve their performance in this criterion.
5. **Finance:** This criterion captured a significant gap between the public and semi-public BICs. The key for improvement is the ability of the BICs to dedicate resources and a staff member to support their clients to make independent funding applications. In addition, there is a need to develop connections with venture capitalists and private funders. There is a need for a dedicated individual to oversee these activities. The individual needs to be integrated into the ecosystem so that they can leverage appropriate opportunities.
6. **Human capital:** Being located on the campus of an HEI, it is not surprising that all four of the BICs scored above 0.5. However, there is still significant scope for improvement. The development of a skills audit will support the identification of training and educational needs. It will also help to match postgraduate researchers with clients. In addition, it will help facilitate an approved approach to knowledge transfer. Knowledge transfer can be from clients to staff and/or students in the form of guest lecturers and co-supervision arrangements.

6 | CONCLUSION

Although many studies during the past 20 years have examined the topic of business incubation, none have focused on developing a comprehensive framework for measuring the performance of BICs. Indeed, there are very limited studies that applied a real-world case for BIC performance measurement. Authors including (Barbero et al., 2012; Hasani & O'Reilly, 2020; Torun et al., 2018) propose that although challenging, there is a significant need to assess performance in order to improve incubator policy. In order to fill the gap, in this research, a comprehensive framework for BIC performance measurement using FAHP and FIS was developed. Then a real case application of Irish BICs was applied to show the proficiency of the proposed framework. In this study, a comprehensive list of criteria and subcriteria related to BIC performance measurement was identified and validated using a Delphi method. Then, FAHP was used to find the relevant weight of the main criteria. Next, a rule-based FIS was developed and applied to measure performance at four BICs.

The current study contributes towards knowledge theoretically and practically. In terms of theoretical contribution, the current study contributes towards knowledge in the business incubation by providing a comprehensive list of the criteria and subcriteria (performance measure). We have identified a comprehensive set of criteria and subcriteria for BIC performance measurement by examining the literature and collecting expert opinions using a Delphi method. Furthermore, an explanation of each criterion and subcriteria for measuring the performance was provided to enhance the understanding of the relevant criteria and subcriteria. In addition, the structured approach using FAHP-FIS followed by an extensive analysis has been developed for BIC performance measurement that can deal with tangible and intangible performance measures and inherent vagueness associated with the judgement of experts. In terms of practical contribution, this study contributes to the theory and practice of BIC performance measurement by providing a real-world application in four BICs, with a particular focus on the Irish context. The results of the study provide a comprehensive insight to governments, policymakers and industry practitioners regarding the BIC performance. One of the main limitations of FIS methods is the number of rules exponentially will be increased if the number of the input variable is increased. For example, if we have five input variables and three membership functions, the number of the rule would be 243. Developing this number of rules is cumbersome. To solve this, some heuristic techniques can be applied. In addition, implementation of the Delphi technique is complicated and time consuming. In order to facilitate that we have done some interviews with the experts to facilitate the process. The implications for the design of business incubation are significant. However, the framework would benefit from additional testing, and further research should be undertaken with a greater number and diversity of BICs. There is an opportunity to use other fuzzy decision-making techniques such as fuzzy data envelopment analysis and fuzzy analytic network process to determine the final score of BICs. In addition, techniques including interpretive structural modelling can be applied to find the interrelations among the performance criteria and subcriteria.

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