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Evaluating Disruptive Innovation Project Management Capabilities

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Abstract: Firms must adapt to a business environment in constant flux. Economic and political factors and the constant interruption of new technologies force firms and organizations to change and to adapt, so that they are not left behind. Over recent years, the development of disruptive innovations has completely revolutionized past scenarios. These innovations break with what is already established and firms from various sectors face no choice other than to incorporate them into their project management portfolios, so as to ensure survival and business sustainability. Using MIVES methodology as its foundation, a business sustainability management model is presented in this paper for the management of disruptive innovation projects that a firm may wish to develop within a given sector. The management model is designed to facilitate disruptive innovation project management for firms within technological-industrial sectors, by assessing the sustainability of the project. The model is applied to two firms, one from the machine-tooling sector and another from the construction sector. Finally, a sensitivity analysis was performed, the results of which verified the validity and the stability of the proposed model.

Keywords: sustainability; project management; disruptive innovation; MIVES; AHP; DBM

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1. Introduction

We live in a business environment in continual flux seeking business productivity, performance and innovation, which entails both internal changes (adaptation and adoption of new technologies, changes of organizational business culture) and external changes (clients, the market, quality requirements . . .). Disruptive innovations are an important facet of these changes. In this rapidly changing and global environment there is a line of research in strategic management that has documented how challenging it is for established companies to adapt to technological disruptions initiated by new entrants [1].

A disruptive innovation is defined as the innovation of an existing technology that alters the characteristics of the products and services on the market, endowing them with greater value [1,2]. The term refers to a unique type of innovation that uses technologies under development to change current performance metrics and eventually, to displace established competitors [3]. Therefore, the "incumbents" can finally be interrupted by the "entrants" [4].

In this sense, we are at present living through a period in which disruptive innovations, such as cloud solutions, artificial intelligence (AI) and the internet of things (IoT) are emerging within all business sectors and displacing established technologies [5]. This change is to some extent due to the initiatives of many companies that try to stimulate innovation in their business projects. The promotion of innovative practices within these companies give them a competitive advantage over others where they are not promoted [6].

As project management develops both organizations and individuals taking charge of a project have to acquire a series of management skills and competencies so that their project can be quickly adapted to the changes that are afoot in an increasingly competitive business environment [7]. The management of business projects is now the main tool for the sustainable growth of organizations and the results of sustainable projects contribute significantly to long-term organizational growth [8].

In this sense, the capability to identify the disruptive potential of an innovation in its early stage could be a key factor in avoiding the possible failure of incumbents [9]. Nevertheless, frameworks and models for the ex-ante identification of disruptive innovations are still in short supply [10]. Rafii and Kampas [11] pointed in this direction, arguing that decision support tools are necessary when evaluating and characterizing emerging technologies. Such evaluation tools and models are very necessary when considering the current criticism of disruptive innovation theory, as it is based solely on a selective ex-post analysis, [9]. Along these lines and according to Si and Chen [12], research on the concept of disruptive innovation lacks effective, reliable and widely accepted scales or evaluation models. Although innovation theory is widely studied and debated today, its basic validity and universality have rarely been examined in the academic literature [12]. As research in this field gathers pace, some quantitative studies can in general be found, yet studies on disruptive innovation have mainly been limited to case analyses and qualitative studies. Furthermore, systematic quantitative research paradigms or frameworks have not yet been established. The development of scales, metrics and models for the evaluation and identification of disruptive innovations is therefore a promising line of research that is moving towards quantitative studies, improving theoretical predictability and its effectiveness [12].

In an attempt to shed light on this research gap, the principal objective of this paper is to present a disruptive innovation project management model that will quantify the capabilities of firms from technological-industrial areas to undertake and to manage a disruptive innovation project. In this way, the model can facilitate business decision-making when managing a disruptive innovation project within a given sector. It will be used to assess the project management capacity of the firm, paying attention to market conditions, and relevant external and internal factors, so as to evaluate the sustainability of a disruptive innovation project in each specific business context.

With this objective in mind, four phases will be described in this paper, which are depicted in Figure 1. The concept of disruptive innovation is presented to outline the first phase, together with the characteristics of these types of innovation. MIVES methodology that constitutes the second phase will then be presented, together with a mathematical method that generates the evaluation index. Having presented the theoretical framework, a sustainability management model will be proposed to assess the convenience of undertaking a disruptive innovation project. The application of the model to two firms–one from the machine tooling sector and the other from the construction sector–will constitute the third phase. In the fourth and final phase, a sensitivity analysis with varied weightings for each criterion and requirement will test the results of the model in terms of validity, stability and robustness.

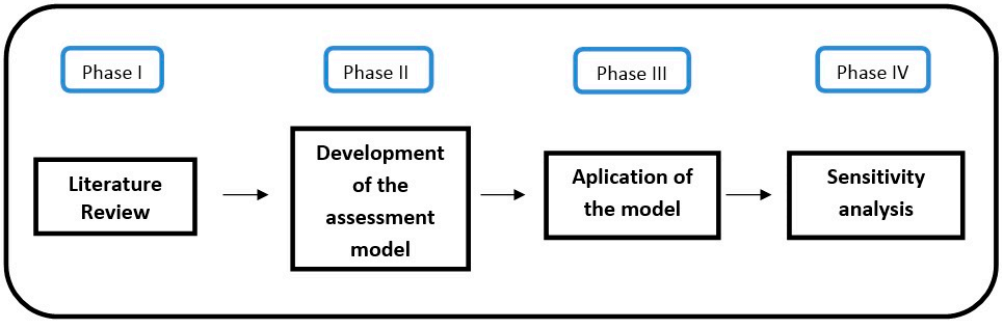

Figure 1. Investigative phases.

2. Phase 1: Literature Review

In this section, a review of the literature on the concepts of disruptive innovation and disruptive business models is carried out, analysing their characteristics and the indicators used to distinguish them.

A number of databases—Web of Science, ScienceDirect, Scopus, Google Scholar, JSTOR, IEEEXplore and SpringerLink—were searched using the following combination of keywords: "Disruptive innovation; Disruptive Business model; Disruptive & Machinery; Disruptive & Construction; Assessment; Additive Manufacturing; Digital twins; Blockchain Technology; Smart Buildings". A large number of the articles under analysis belonged to the machine-tooling sector, because it was there that the concept was first developed and where investment effort was greater. Even so, articles were also found on disruptive innovations within both the construction and the services sectors.

A large number of characteristics of disruptive innovations and disruptive business models emerged from the bibliographic search; we provide an overview of the elements assigned to both concepts in the literature in Table 1. Despite the variety of labels for these concepts, a more general description of each one may be deduced from this overview.

Table 1. Characteristics of Disruptive Innovations.

Authors	Year	
[13]	2007	Different value propositions of other applications on the market that change the added value for customers, create new markets or customer groups and construct a logic for new forms of earnings.
[14]	2005	Cheap, simple, initially lower performing and then fast improving. They are only useful in remote or emerging markets. Consumers first reject them.
[15]	2020	They disrupt established models or redefine the meaning of value creation and acquisition. They focus on developing a more concise technology that is not valued within the mainstream markets. They enter the mainstream market as the technology is gradually improved.
[9]	2019	They enable a new set of product features different from those associated with mainstream technologies and are initially inferior to the latter in certain attributes. Over time, the performance of disruptive technologies surpasses that of the dominant technologies and they eventually 'invade' the mainstream markets.
[16]	2019	They bring a very different value proposition to the market and deliver products and services of greater simplicity, convenience, affordability and lower costs.
[1]	2000	Key feature: they lock customers in a new way; they do not follow the traditional trajectory of improving the performance valued by mainstream consumers; they improve performance along parameters different from the traditional ones.
[17]	2020	They start out in low-profit margin businesses or low-end markets. Over time, their performance continues to improve to a level that satisfies the mainstream clientele. They provide an appropriate innovation approach for SMEs through new market discovery and facilitate a "covert" attack on the incumbents.
[18]	2006	Their attributes are not valued among mainstream consumers because of their weaker performance; they provide a new value proposition to attract new customer segments and customers more sensitive to price; they sell at lower prices; they penetrate from a niche market into the mainstream market.
[10]	2009	Their performance is worse that the established attributes, they are cheaper, simpler, more comfortable or more reliable, they address current non-consumers, they are based on standard components, their business model is significantly different, their value network has a low overlap.
[19]	2015	They usually begin within small companies with low profit margins and little or no concern with existing organizational structures. Disruptive innovations are those that bring or emphasize unexploited attributes of products and services already offered on the market, unlike traditional forms.
[20]	2013	They provide better service than incumbent technologies and they change the way in which those technologies are used.
[21]	2013	They possess better value within one dimension (or more) that are orthogonal to those of existing products and, hence, are desired by some niche customers. Disruptive innovations are typically cheaper, simpler, smaller and, frequently, more convenient to use.

Table 1. *Cont.*

Authors	Year	
[22]	2016	Their performance is usually below that of mainstream products but lower price or unique features compensate it. They can provide significant competitive advantage to firms. Advantages may stem from being a quick mover or a quick follower.
[23]	2016	They use low-cost technology while ensuring high technical quality, key features and facilitate high service quality. They are easy to use.
[24]	2016	An innovation with "good enough" functionality that has a low cost. An innovation that changes the performance metrics, or consumer expectations, of a market by providing radically new functionality, discontinuous technical standards, and new forms of ownership.
Reference	**Year**	**Characteristics of Disruptive Business Models**
[15]	2020	They focus on building a new activity system in which new partners and activities are configured in an unprecedented way compared to existing business models.
[16]	2019	They arise to replace existing business models, redefining an existing product or service and how it is delivered to customers, through new technologies and innovation processes. They bring radical change to the market, disrupting leading and stabilized companies, making their existing business models obsolete.
[19]	2015	Characterizing elements of Disruptive Business Models: the search to reach a new business segment and new target audience; the proposition of benefits, convenience and low-value to customers; the inherent risk of changes and the need for the maintenance of organizational intellectual assets.
[25]	2015	They are conceptualised as a new-to-the-firm change in at least one out of three business model dimensions: (a) a firm's value offering, (b) a firm's value creation architecture, and (c) a firm's revenue model logic.
[26]	2018	They are created when the exploration of emerging technologies is not adequately leveraged in today's models, requiring new forms of business organization. Characteristics: differentiated value to consumers, competitive advantage, the opening of new markets and the obsolescence of existing business models.
[27]	2017	Designed, novel, non-trivial changes to the key elements of a firm's business model and/or the architecture linking these elements.
[28]	2012	They are customer centric. They involve constant market experimentation and learning. They are path dependent.
[29]	2004	They are business model replacements that provide product or service offerings to customers and end users that were not previously available.
[30]	2009	They are based on a reconfiguration of activities in the existing business models of a firm that is new to the product/service market in which the firm competes.
[31]	2020	They redefine value creation and value capture of an industry, threaten the competitive positions of incumbent firms, and even disrupt them.
[32]	2006	They concern the discovery of a fundamentally different business model in an existing business.
[33]	2016	They imply Risk-taking *behavior*, *proactive behavior,* innovative behavior, and the extent of autonomy
[34]	2010	They require entrepreneurs and managers to (1) understand the "deep truth" about the fundamental needs of customers and how competitors are or are not satisfying those needs; (2) understand all technical and organizational possibilities for improvements; (3) make many informed guesses about the future behavior of customers and competitors as well as about costs; and, (4) make requisite adjustments to the existing business model only after considerable trial and error learning.
[35]	2010	They are initiatives to create novel value by challenging existing industry-specific business models, roles and relations in certain geographical market areas.
[36]	2010	They are about generating new sources of profit by finding novel value proposition/value constellation combinations.
[37]	2011	They signal a change beyond current practice in one or more elements of a retailing business model (i.e., retailing format, activities, and governance) and their interdependencies, thereby modifying the retailer's organizing logic for value creation and appropriation.
[38]	2001	They innovate business models by redefining content (adding new activities), structure (linking activities differently), and governance (changing parties).
[39]	2012	They are defined as a process that deliberately changes the core elements of a firm and its business logic.

Table 1. *Cont.*

Reference	Year	Characteristics of Disruptive Business Models
[40]	2014	They can range from incremental changes within individual components of business models, to the extension of the existing business model, the introduction of parallel business models, right through to the disruption of the business model, which may entail replacing the existing model with a fundamentally different one.
[41]	2013	They refer to the search for new logics of the firm and new ways to create and to capture value for stakeholders; they focus primarily on finding new ways to generate revenues and to define value propositions for customers, suppliers, and partners.
[12]	2020	They build a new activity system in which new partners and activities are configured in an unprecedented way compared to existing business models, and they disrupt established models or redefine the meaning of value creation and acquisition.
[42]	2020	They create value by making changes to an organization's value propositions and to its underlying operating model. They require no new technologies or brand-new markets, yet they can be disruptive enough to change the game in an industry, due to their unique value propositions and operating models.

2.1. Results of the Literature Review

2.1.1. The Concept of Disruptive Innovation

The concept of disruptive innovation arose from the need to define the innovations that with little or no prior warning are appearing on the market, modifying products and services and creating new business models [43]. As Rasool et al. [3] affirmed, unlike sustained innovations, which are based on existing products and services for existing clients, disruptive innovations target new clients and offer different characteristics and values when compared with the latter. This type of innovation leads to the appearance of new products and services that lead to a rupture with established market norms, seeking progressive market consolidation [2,4]. They are classified as low performance and are based on new market technologies, in other words, they are introduced into markets where the clients are starting to acquire a product or a service that they have not used beforehand [44]. According to Petzold et al. [45], a disruptive innovation introduces an offer that is generally cheaper, easier to use and more convenient in comparison with offers from the principal market and its performance is weaker than the attributes evaluated by the main clients. Therefore, at first, disruptive technologies that are introduced into a market are targeted at less demanding clients and with lower purchasing power [2,9], unlike the established technologies, because the latter are dedicated to the development and improvement of their product or service and, in consequence, increase their value and price [46]. Firms from the principal markets tend initially to ignore disruptive innovations, considering them of low quality and unrelated to their industry [3]. As the disruptive technology increases, it starts to occupy niche markets that the established technologies abandon and it manages to increase its market share, "invading" the principal markets when doing so [9].

In general, there are two different types of disruptive innovation [9]: (a) new market innovations that create new demand for novel technologies and related products, and (b) low-range innovations that provide technologies with similar characteristics to existing technologies, but at a lower cost.

Over recent years, significant attention has been given to the concept of disruptive innovation within the scientific community and detailed analyses of the characteristics of this type of innovation have been carried out [4,9,10,16,47] and of the sectors that this sort of innovation affects [2,48]. According to some studies, the characteristics of disruptive innovations are as follows:

- They have characteristics that are undesirable among other segments of users;
- Their technologies are unsuitable for use in mainstream applications;
- They are technologies that make the appearance of new markets possible;
- At first sight they appear cheaper and simpler than the mainstream applications;

- They anticipate future client needs, permitting a group of consumers to access a product or service to which they earlier had no access.

In summary, these technologies will initially prioritize simplicity, commodity, the possibility of personalization and price, rather than results and high performance.

2.1.2. Evaluation of the Disruptiveness of an Innovation

Determining whether an innovation (product or service) is disruptive or not is critical, because this type of innovation has the capacity to disrupt the market status quo in a radical way, toppling incumbents. Knowing the disruptiveness of an innovation can prevent the possible failure of these traditional incumbents [9]. These adverse outcomes include reduced market share, decreased status, and even bankruptcy or the demise of an organization [24]. If managers could identify disruptive innovations before these technologies have affected markets, managers could take actions to turn a potential marketplace disruption into a new opportunity—or at the very least, prevent the failure of their organization. Because the ability to predict disruptive innovations can have far-reaching effects, researchers have sought to predict the disruptions caused by new innovations [24].

Assessing the potential disruptiveness of innovations is therefore an important yet challenging task for incumbents [9]. Compared with the volume of academic papers that address ex-post case analysis [10,21], research on measuring the disruptive potential of emerging innovations is limited. In this sense, the absence of quantitative models for evaluating the disruptive potential of innovations is a persistent problem [9]. This subsection describes some studies that have addressed the subject of the evaluation of the potential disruptiveness of innovations.

Guo et al. [9] developed a disruptive innovations quantitative evaluation model taking into account three dimensions: technological characteristics, market dynamics and external environment.

Hüsig et al. [14] presented a model for evaluating technologies from an ex-ante perspective and taking into account their disruptive characteristics. The model was based on the fundamentals of the concept of disruptive technology and analyzed the disruption of W-LAN technology.

Sainio and Puumalainen [13] analyzed the way in which companies measure the disruptive potential of a new technology and relate its effects to company operations. In their study, they created a conceptual framework that enables a company to evaluate ex-ante the disruptive potential of a new technology.

Keller and Hüsig [10] developed a model that allows the ex-ante identification of disruptive innovations in the software industry. Their model was based on a checklist related to a disruptive innovation.

Hardman et al. [20] identified three fundamental characteristics that characterize disruptive technologies (disruption for market leaders, disruption for end users, and disruption of existing infrastructure). These characteristics can be used when identifying a potentially disruptive technology. The authors concluded that a technology must share at least two of those three characteristics for it to be labelled as disruptive.

Klenner et al. [21] designed a disruptive susceptibility assessment model, aimed at analyzing markets with respect to their potential preparation to receive or host disruptive innovation. This model can be useful as a forecasting and evaluation tool for incumbents.

Anthony et al. [49] developed a tool called Disrupt-O-Meter. This tool is based on nine criteria and its objective is to evaluate the degree of disruption of the offers made by the company to specific customer segments, comparing them with existing solutions on the market.

Dijk et al. [22] studied the extent to which electric propulsion is disrupting the automotive industry market. The authors proposed six hypotheses that analyze whether a market disruption will be successful or not; three hypotheses were related to the key innovation framework and another three to the key drivers of innovation dynamics.

Roy [50] explored the role of leading users in the face of disruptive change. The authors concluded that the relevant lead user paves the way for a potentially disruptive technology to become a definitely disruptive one. The study also showed characteristics that can be significant in identifying relevant lead users.

2.1.3. The Concept of Disruptive Business Model

The concept of a disruptive business model has also attracted the attention of the scientific community and therefore has many definitions, as can be seen in the summary of the literature review that has been presented in Table 1.

Schiavi et al. [16] stated that Disruptive Business Models arise to replace existing business models, redefining what an existing product or service is and how it is delivered to customers, through new technologies and innovation processes. According to Si et al. [12], Disruptive Business Model innovation focuses on building a new activity system in which new partners and activities are configured in an unprecedented way compared to existing business models. Foss and Saebi [27] defined it as follows: designed, novel, nontrivial changes to the key elements of a firm's business model and/or the architecture linking these elements. According to de Almeida Pereira et al. [19], two strategies can be adopted to convert ideas into plans for new Disruptive Business Models: the creation of a new market as a basis for rupture and the rupture of the predominant business model of lower product value.

In this sense, disruptive technologies and disruptive business models create different types of markets, propose radically different challenges for established firms and they also have radically different implications for managers [32].

According to Paniagua [51], disruptive innovation business models are at present divided into 4 groups:

- Corporative digitalization: a business model in which the firms must rise to the challenge of a change in strategy, move their resources to digital initiatives, redesign their organization and transform their organizational culture [52,53].
- Economy of platforms: business models based on platforms and applications that operate under low demand and that digitalize what was done before in an analogical way [54,55].
- Decentralized model: model of person-to-person interaction where consumers no longer need an intermediary body that centralizes the provision of goods and services, but do so directly between each other through digital platforms [56].
- The pop-up economy and superfluous markets: models that open up new markets and that transform our understanding of firms and markets, facilitating decision-making, automation, robotization and new manufacturing modalities [57].

These disruptive business models permit the exploitation of infra-utilized resources, place new products and services on the market, facilitate the best trade-off between offer and demand, accelerate innovation, stimulate demand and dynamize the market, in addition to promoting self-organization [51].

3. Phase II: Methodology

The objective of this work is to present a business sustainability management model to assess the implementation of a proposed disruptive innovation project. The multi-criteria MIVES model methodology was used for the development of the evaluation model, for which purpose a decision tree was designed. MIVES [58] is a multi-criteria decision-making model that is used to evaluate each alternative that can resolve a defined generic problem, through an index value of between 0 and 1. A weighted sum of the valuations of the different criteria under consideration yields the value index of each alternative. Each alternative was defined by dividing their characteristics into: requirements (grouping of criteria); criteria (specific concepts that are contained in the indicators); and indicators (tangible characteristic that may be qualified). Having defined all the alternatives, the tree was completed and the model was generated.

The methodology was developed in 2009, focusing on the civil construction sector, but its field of application has over recent years been growing considerably and it has been applied for the evaluation of various situations. These MIVES-based models are described in the scientific literature [58–64]) and are based on AHP (Analytic Hierarchy Process) methodology [63,64].

The selection of MIVES methodology is based on certain favourable and differentiating particularities: the integration of fully recognized methods such as AHP and the customizable value functions tuned to the essence of the variables that constitute the last level of the decision tree. With this aim, the research was structured into three phases:

- Definition of the evaluation tree, by means of a semi-systematic literature review.
- Quantification of the evaluation tree, calculating the weights by means of AHP pairwise comparison and characterization of the indicators by the design of the value functions or value tables.
- Application of the model to two case studies

3.1. Definition of the Evaluation Tree

This research, taking into account the results of the literature review, is based on the premise that the characteristics that define disruptive innovations are multidimensional, so the evaluation process must also be based on multidimensional measures. Guo et al. [9] suggested that most of the current evaluation models mainly focus on technological aspects, with some that also include the market aspect [21,22], stating that the external environment receives even less attention. The external environment, such as the macroeconomic situation or the industrial policies promoted by governments, plays a very important role in the process of creating disruptive innovations, and should therefore be included in the evaluation tree [52,65].

Initially, the literature review was intended to define an indicator valuation method, something that was achieved, although not in all cases, because some of the indicators or characteristics proposed in other investigations were of a subjective nature or were difficult to measure as indicators or whose evaluation required great complexity, due to difficulties over gathering the necessary information.

The next step was to study the relations between the indicators, so as to group them into clusters. In this process, indicators from different investigations that presented similar characteristics were grouped into clusters to assemble a reduced group of evaluation indicators. For example, the indicator of organizational ambidexterity encompasses: high organizational management groups, firm leadership, departmentalization of the firm; in other words, indicators that were at the start considered to be independent from each other.

Figure 2 shows the evaluation tree, with 3 criteria and 13 indicators, specifically designed to evaluate business sustainability when undertaking a disruptive innovation project. In addition to the indicators of that tree, a series of weights and their degrees of importance were defined. Those weights were obtained from the literature review, taking into account the importance that different authors have attached to the set of selected indicators.

In the tree, as proposed above, three groups of indicators or criteria are shown. The first is related with the market, in which the projects of the firm are developed, the second with the internal factors that the firm presents, in order to undertake its business projects, and the third compiles a series of factors that are related with the socio-economic environment around the firm and its projects.

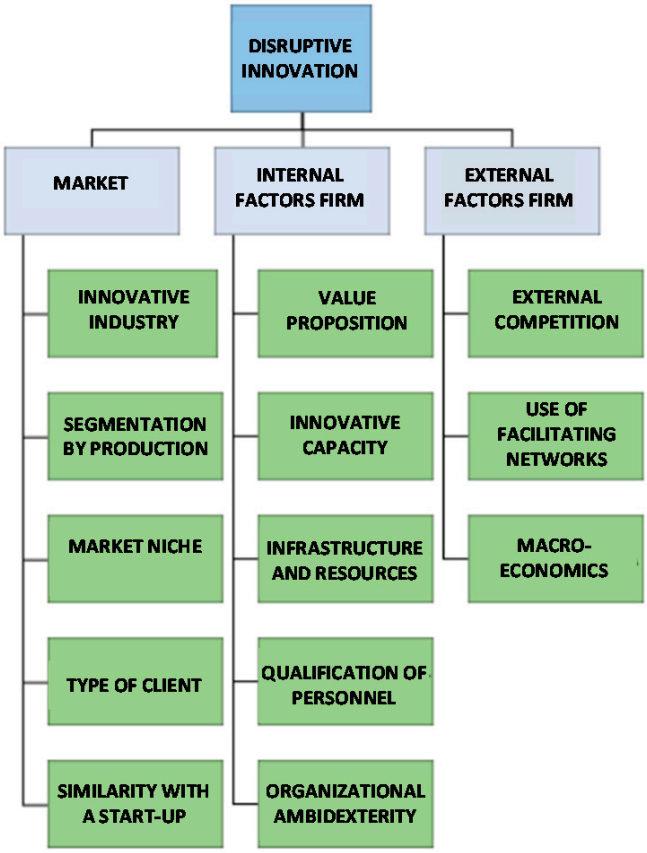

Figure 2. Decision Tree for Disruptive Innovation.

3.2. Description of the Criteria and Indicators

3.2.1. Market

A necessary aspect so that technologies are adapted through business projects consists of finding a market, which guarantees their sustainability over time. These technological markets are defined as markets for authorized and licensed intellectual property and their closest substitutes, in other words, the technologies or products that are close enough substitutions to compete in a significative way against the market power of licensed intellectual property [66].

It is important to define the market as a factor for the adaptation of firms to disruptive innovations, because it serves as a setting for possible behavioral scenarios among different firms.

Innovative Industry Indicator

It is important to know the industrial sectors where a disruptive innovation can find a home, which is usually related to those sectors where more is invested in innovation. In this sense, the firms that invest more in innovation will better adapt their projects to react to the emergence of some disruptive innovation.

Segmentation by Production Indicator

Technological markets will prosper when productive markets are fragmented and the firms have a capacity to produce general technologies [67]. This segmentation, based on looking for clients whose needs are not covered, is habitually divided into two groups:

(1) Market-directed innovation: entrepreneurial projects directed at designing products that respond to market gaps.

(2) Innovation directed by the technology or by the product: the entrepreneurial project offers a new technology or product that the business is trying to place on the market or to pioneer its entry into the market.

In any case, the business project has to show dynamism, for segmentation to incentivize and, in a constant and periodic manner, these segments must adapt themselves to market novelties.

Niche Market Indicator

The niche market is a small market opening that is hardly or not-at-all frequented by a set of consumers, which is presented as a hidden opportunity within a line of broader and more competitive businesses. Business projects must focus on a specific niche market, as it offers them the possibility of specializing in resolving a specific problem, something that is simpler than seeking to enter into other different sectors. Disruptive innovation seeks a market that is not unattended and offers sophisticated solutions at accessible cost. The niche markets suitable for disruptive technologies are usually low-range markets providing to undemanding clients.

Type of Client Indicator

A client is the recipient of a good, a service, a product or an idea. Clients in one segment are willing to try new things, to introduce innovations within their firms. Called "innovative clients", they are usually a small group, and experts affirm that 17 out of every 100 clients consider themselves innovative [68]. Once these innovative clients have introduced the products or services into their daily routine, then the products are converted into common-use products among market consumers. At the point when product sales are increasing and their price is falling a larger number of clients dare to acquire this new innovation.

Similarity to a Startup Indicator

A startup is defined as a newly-launched firm that commercializes products and/or services through the intensive use of information and communications technology (ICT), with a scalable business model that permits rapid and sustained growth over time. This advanced technological component allows them to be able to scale up a business in an agile and rapid manner and with lower capital requirements than traditional firms.

3.2.2. Internal Factors of the Firm

The internal factors of the firm are related with its physical, financial and intangible resource structure [69]. The internal factors of a firm are a key factor, because they are used to evaluate how suitable a firm might be for an innovation or a market or a disruptive technology.

Value Proposition Indicator

Value proposition is a fundamental element of the business model. It is the offer transmitted to clients that is designed to win them over. It is an aspect in which the firm invests a constant maintenance effort and improvement, in which the price, the novelty, quality, design, and customization all have an influence.

Innovation Capacity Indicator

Innovation capacity is measured through the innovative competency of a firm, defined as the optimization of results through the detection of problems and their description and resolution. Innovation has been turned into one of the key competences for firms to respond within the changing business environment that surrounds them, for which reason, the firms themselves are increasingly choosing to integrate innovative competency throughout the whole organization, so that it is not only present in the innovation department.

Infrastructure and Resources Indicator

Infrastructure and resources of the firm are the installations, structures and basic services upon which the construction of its business project is based. It includes fixed assets, such as the building, the machinery, and the necessary tools. And the resources include assets that are not considered fixed, also taking into account financial and technological resources.

Qualification of Personnel Indicator

Professional qualification is a long-term investment. Having a well-prepared team of employees is a guarantee that the firm may override any obstacle. Improvements in attitude, knowledge, skills and conduct of the personnel of the firm must be sought through continuous training. New knowledge and techniques mean that employees have greater confidence in themselves and increase their personal satisfaction.

Organizational Ambidexterity Indicator

Ambidextrous organizations are those that have the capability to balance the exploitation of the present-day business and the exploration of new fields of action, in other words, to explore new businesses, so as to maintain themselves in the present and at the same time ensure their future prospects.

3.2.3. External Factors to the Firm

Internal factors are necessary, but are not sufficient to determine the capacity of an entrepreneurial project to adapt to a disruptive innovation. To do so, it is necessary to define and to study the external factors, associated with continuous interaction with the environment. The main problem that they present is that the firm has no control over them and they may therefore represent as much an opportunity as a threat.

External Competitiveness Indicator

The analysis of competitiveness sheds light on the capacities, resources, strategies, competitive advantages and weaknesses of a firm, so as to take decisions and to formulate strategies that incite positive competitiveness.

Use of Facilitating Networks Indicator

The facilitating networks are a system of relations and/or contracts that link up firms between each other and stimulate the exchange of material goods, information, and technology. In this mechanism, each party maintains its legal independence and managerial autonomy, although the parties agree to cooperate, the use of these networks today is essential for transmitting information, generating confidence and strengthening exchanges.

Macroeconomic Indicator

Macroeconomics is the study of the economy of a zone, country or group of countries, considered as a whole and employing collective or global magnitudes for their assessment. Technological development is improved through economic growth, therefore the more the economy grows, the easier it will be to create new technologies and, in consequence, to find disruptive innovations.

3.3. Description and Valuation of the Set of Indicators

In this section, the methodology for the evaluation of one of the indicators "Qualification of personnel" under the criterion "Internal factors" will be described as an example, due to the greater weight attached to this criterion and limitations on the extension of this study.

Professional qualification is a long-term investment with the final objective of having a team of well-prepared employees in all aspects to face up to any obstacle. It is an activity that seeks to improve attitudes, knowledge, skills and the conduct of firm personnel, which

must be continuously maintained in the firm, without ever overlooking it. Obtaining new knowledge and techniques means that the people have greater confidence in themselves and increase their personal satisfaction. In addition, obtaining a better endowed workforce is synonymous with a more flexible team and, in consequence, with a greater capability to face up to critical situations.

The idea behind this indicator is that the firm will seek personnel that are as highly qualified as possible, because it will bring with it a greater capability to adapt to a disruptive innovation.

The analysis to determine the qualification of the personnel will be carried out by studying the proportion of higher education qualifications (PhD, Masters, Bachelor's degrees), vocational technical qualifications (higher level and medium level vocational training), and unqualified personnel available within the firm. Each type of qualification has a score and it is the firm that has to introduce the percentage of its staff within each group in the table of the tool under the heading "Data entry". The result of the indicator is calculated by multiplying the percentage of each qualification by its score and calculating the average (Table 2).

Table 2. Assessment of the indicator "Qualification of personnel".

Qualification	Assessed Weight
Higher Education qualifications (PhD, Master's Degrees)	40%
(Bachelor Degrees/Diplomas)	35%
Vocational courses High-level technicians	20%
Low-level technicians	5%
Unqualified	0%

As a function of the (quantitative, qualitative...) nature of the indicator, there is a different way of implementing the evaluation, through value tables or value functions. This evaluation methodology of the indicators, based on MIVES, has been described in various academic works [70–73].

4. Phase III: Application of the Model to Various Firms

In this section, the model is applied to two real firms, active in two different sectors: the machine tooling sector and the construction sector. The objective is to see with some clarity the results of the evaluation and their variations with some clarity.

4.1. Firm 1: Machine-Tooling Sector

The application of the model in the machine-tooling sector was thanks to the information facilitated by a firm (Firm 1), specializing in different manufacturing technologies such as grinding, milling and saws, it offers turn-key solutions for such sectors as railways, automotive components, aeronautics, petrol and gas and for the manufacture of structural pieces with composite materials. It is a large firm both in numbers of employees and business turnover. In addition, it holds demonstratable knowledge of project management and has a team of professionals that studies client needs and requirements, designs customized solutions, and assumes responsibility for the installation and start-up of the project. It is also worth highlighting that the firm has developed a digital approach over recent years, advancing towards the creation of intelligent factories where all the equipment is interconnected and can operate in an autonomous manner, offering valuable product ranges and internally developed solutions. Finally, the firm has participated in numerous national and European R&D projects, in order to muster the innovation that is needed to become a highly competitive firm. A questionnaire was shared with Firm 1 with the relevant questions in order to obtain the indicator values.

When applying the model to Firm 1, an evaluation index of 0.78 over 1 was obtained. Table 3 represents the values obtained by the firm for each indicator.

Table 3. Evaluation results of Firm 1.

Weight Requirements	Criteria	Weights Criteria	Indicators	Weight Indicators	Indicator Values Machine-Tooling
0.24	MARKET FACTORS	1	Innovative industry	0.15	0.78
			Segmentation by production producción	0.10	0.27
			Niche market	0.27	0.8
			Client type	0.24	0.67
			Similarity to a Startup	0.24	0.6
0.67	INTERNAL FACTORS	1	Value proposition	0.2	0.95
			Innovative capacity	0.24	1
			Infrastructure and resources	0.12	0.97
			Qualification of personnel	0.12	0.75
			Organizational ambidexterity organizacional	0.32	0.67
0.09	EXTERNAL FACTORS	1	External competitiveness	0.64	0.5
			Use of facilitating networks redes facilitadoras	0.28	0.65
			Macroeconomy	0.11	0.97

4.2. Firm 2: Construction Sector

It was also chosen to apply the model to the construction sector, in order to analyze a real case from another sector. To do so, a construction sector firm (Firm 2) was contacted and asked to supply the necessary data for the computation of the model.

This firm is one of the reference manufacturers of precast concrete for civil works, drainage, urbanizations and building in the north of the Iberian Peninsula. It has a wide portfolio of solutions and innovative programs and technological developments, through its participation in R&D projects, principally of an autonomous nature, although it has also on occasions participated in national and European projects. The firm has a wide range of traditional low-price products, but it also manufactures special products of higher added value, for which there is hardly any competition within the region.

Its products of higher economic value have been implemented through collaborative agreements with other firms (exploitation of external patents). A large part of its workforce in its manufacturing processes is non-specialized, and the firm has shown interest from the environmental point of view, despite having no accreditations, boosting the recycling of materials and participation in R&D projects for the reuse of industrial residues from other firms which have been implemented in its productive process.

It is in expansion at present, with two commercial delegations in France and Holland that are commercializing its products of higher added value.

When applying the model to Firm 2, an evaluation index of 0.41 over 1 was obtained. Table 4 represents the value obtained by the firm for each indicator.

Table 4. Evaluation results of Firm 2.

Weight Requirements	Criteria	Weight Criteria	Indicators	Weight Indicators	Value Indicators Construction
0.24	MARKET FACTORS	1	Innovative industry	0.15	0.88
			Segmentation by production	0.10	0.204
			Niche market	0.27	0.434
			Client type	0.24	0.33
			Similarity to a Startup	0.24	0.27
0.67	INTERNAL FACTORS	1	Value proposition	0.2	0.78
			Innovative capacity	0.24	0.5
			Infrastructure and resources	0.12	0.79
			Qualification of personnel	0.12	0.26
			Organizational ambidexterity	0.32	0
0.09	EXTERNAL FACTORS	1	External competitiveness	0.64	0.67
			Use of facilitating networks	0.28	0.13
			Macroeconomy	0.11	0.14

5. Results and Discussion

It may be mentioned that the results from the two practical cases were in accordance with expectations; a business sustainability index to face a disruptive innovation project in the machine-tooling sector (0.78) as against the construction sector (0.41). The machine-tooling sector has progressed a lot over recent years since the fourth industrial revolution. In this sense, its industrialization and manufacturing processes have undergone changes, following the implementation of digitalization, while the construction sector is not at the same level of development and innovation.

In what follows, the evaluation results are described, analyzing the result of each indicator in both firms.

5.1. Innovative Industry

Investments in innovation within each sector over recent years were analyzed to obtain the indicator value. In this case, Firm 2, belonging to the construction sector, obtained a value of 0.88, higher than the value for Firm 1, which was 0.78. This result is reasonable because the construction sector has been aware of the needs to innovate and has made constant efforts to invest over recent years, much more so than the machine-tooling sector.

5.2. Segmentation by Production

The production levels of both sectors were studied to analyze market segmentation. In this sense, the more that is produced, the stronger the sector and the easier innovation will be within that sector. In this case, Firm 1 obtained a value of 0.27 as opposed to 0.204 for Firm 2 in the construction sector. This result for machine-tooling is explained by its higher unit production levels in comparison with the construction sector, which result in higher overall levels of production, in order to satisfy market demand.

5.3. Niche Market

The specific characteristics of the disruptive innovation niche market were analyzed. Firm 1 was centered on compliance with all aspects that the niche market requires, save the price, because this sector manufactures specialized products in which it is difficult to offer an easily affordable price. On the contrary, Firm 2 had low levels for all aspects, except for

price. Thus, a large difference was observed when the machine-tooling firm obtained a value of 0.8 and the construction firm 0.434.

5.4. Client Type

In this case, the machine-tooling sector complied with eight of the characteristics of the innovative client, while the construction sector complied with only three. Therefore, Firm 1 obtained a value 0.8, higher than the value of 0.434 for Firm 2 (construction).

5.5. Similarity to a Startup

The specific characteristics of a startup were analyzed for this indicator. Accordingly, Firm 1 obtained a value of 0.8, because it rated all the characteristics between a high level and a medium-high level. On the contrary, Firm 2 obtained a value of 0.4 due to it having rated its characteristics between low and medium-low, except for financing needs that required less in the machine-tooling sector, but much more in the construction sector.

5.6. Value Proposition

Among the internal factors of the firm, the value proposition was analyzed: Firm 1 obtained an indicator value of 0.95, because its projects are centered on differentiation from its competitors and providing flexibility to its clients. The value for Firm 2 of 0.78 was lower than for Firm 1, because Firm 2 is centered more on making efforts to guarantee that its products are functionally better than those of its competitors.

5.7. Innovation Capacity

The innovation capacity that each firm presented was also analyzed as an internal value of the firm. To do so, the percentage turnover of innovative projects, services and products of the firm was studied, as well as its investment in innovation. Firm 1 had a value closer to 7% for the two percentages, so it obtained an indicator with a value of 1, while Firm 2 had in both cases lower percentages and therefore obtained half the highest value of the indicator or 0.5.

5.8. Infrastructure and Resources

The principal characteristics of the innovative firms were studied to obtain this indicator: their infrastructure and resources are very advanced and their innovation adoption capacity is therefore greater. Firm 1 complied with 10 of the benchmarks proposed in the investigation, obtaining an indicator value of 0.97, while Firm 2 complied with only 6 benchmarks and obtained an indicator value of less than 0.79.

5.9. Qualification of Personnel

In this case the difference in the indicator values of each firm were very notable. The firm within the machine-tooling sector obtained a value of 0.75, while the construction sector firm obtained a value of 0.26. This difference was due to the percentage of unqualified staff in Firm 2 that stood at 50%, while all the personnel in Firm 1 held some sort of qualification.

5.10. Organizational Ambidexterity

In this case, neither firm had the design of an ambidextrous organization, which is ideal when adopting a disruptive innovation. Firm 1 had a matrix organizational structure that is closest to an ambidextrous organizational design, hence its value of 0.67. In contrast, Firm 2 had a functional organizational design, furthest away from the ideal design, leaving it with a value of 0.

5.11. External Competitiveness

The indicator of external competitiveness was evaluated for the analysis of the external factors. It was studied in a different way, depending on whether the firm has more or

less than five competitors. In the case of Firm 1, there were between 11 and 20 strong competitors, so it therefore obtained an indicator value of 0.5. Firm 2 had only four notable competitors, so the size, the tendency and the intensity of each one was analyzed, obtaining a value of 0.67. It is logical that the indicator value of Firm 1 should be lower than that of Firm 2, as it has more competitors and, in consequence, higher external competitiveness.

5.12. Use of Facilitating Networks

The data from countries at a European level with which the firms were collaborating and the use of facilitating networks in collaboration with other organizations or firms were studied, in order to analyze this indicator. Firm 1 had a presence in a higher number of countries than Firm 2, so it therefore obtained an indicator value of 0.65 as opposed to 0.13 for the construction firm.

5.13. Macroeconomy

The last indicator that was evaluated was also an external indicator that valued the macroeconomy of each country at a European level, in relation to exports and imports of goods and services, the added value and the workforce productivity of each country. In the same way as with the earlier indicator, Firm 1 had a greater presence in European countries and it therefore obtained a value of 0.97 while Firm 2 had 0.14.

6. Phase IV: Sensitivity Analysis

The final value of the sustainability index of a firm undertaking a disruptive innovation project was directly related with the weights assigned to the requirements and to the indicators. Slight changes can therefore lead to high swings in the final value of the evaluation [74,75]. These weights are a consequence of the authors' own evaluation with a degree of subjectiveness, on the basis of the literature review on disruptive innovation, for which reason the validity, the stability and the solidity of the index results have to be tested through a sensitivity analysis [76]. In addition, it is a simple approach, that needs few computational resources and the results it yields are easy to interpret [77]. When the results of the evaluation are very similar even having made the changes, it may be concluded that the evaluation model is reliable.

Therefore, once the results of the evaluation had been obtained, a sensitivity analysis was completed, presenting different situations for change. In all, three changes were introduced in relation to the original proposal.

CASE 1: The results for Firm 1 were analyzed, assuming that it had a presence in 15 countries (Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Holland, Ireland, Italy, Poland, Portugal, Romania, Spain and Switzerland) whereas, in reality, it only had a presence in four of them (Denmark, Finland, Germany and Spain). This distribution implies a lower level of innovation for the firm, because the firm obtains less knowledge from others. In Figure 3, the difference is shown between the indicators of the real situation of the firm and the indicators obtained when case 1 is applied. As can be observed, all the indicators remained constant except for the Use of Facilitating Networks and Macroeconomy, which obtained lower values.

In Table 5, the indicator values are presented when case 1 is applied. Although the value of the indicators of Use of Facilitating Networks and Macroeconomy were notably reduced when the change was introduced, the value of the final index for Firm 1 was only reduced by 0.01. It may therefore be concluded that the evaluation model accurately reflected the change introduced in Case 1, because the change of the final index was almost insignificant.

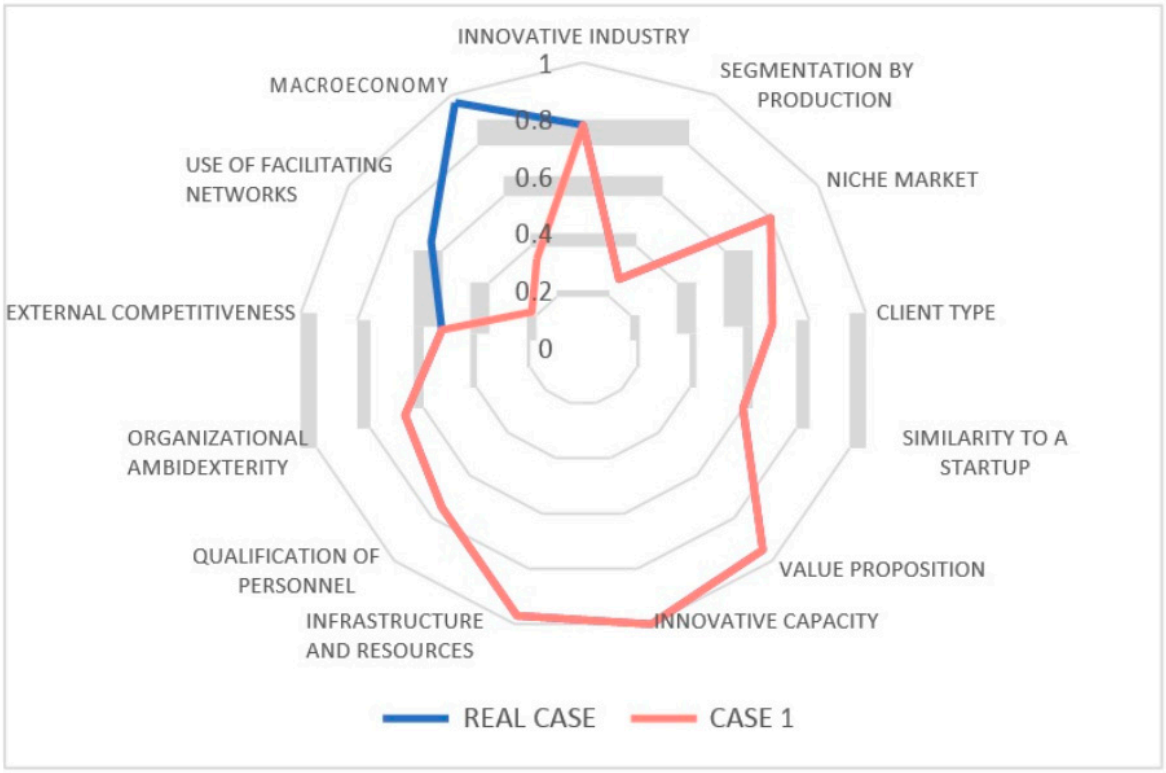

Figure 3. Case 1 sensitivity analysis.

Table 5. Results of the sensitivity analysis for Case 1.

	Real Case	Case 1	Variation 1
Innovative Industry	0.78	0.78	0
Segmentation by Production	0.27	0.27	0
Market Niche	0.8	0.8	0
Client Type	0.67	0.67	0
Similarity to a Startup	0.6	0.6	0
Value Proposition	0.95	0.95	0
Innovative Capacity	0.01	0.01	0
Infrastructure and Resources	0.97	0.97	0
Qualification of Personnel	0.75	0.75	0
Organizational Ambidexterity	0.67	0.67	0
Exsternal Competition	0.5	0.5	0
Use of Facilitating Networks	0.65	0.22	−0.43
Macroeconomy	0.97	0.35	−0.62
Final Indicator	0.78	0.77	−0.01

CASE 2: In this case, it was proposed to change the weight of the requirements and observe the effects on the value of the final index for Firm 1. In other words, on the basis of AHP methodology, the requirements of Market, Internal Factors and External Factors will be revalued, adding greater weight to the Market requirement.

In Table 6, the final result of the index is presented after having introduced the change:

Table 6. Results of the sensitivity analysis for Case 2.

Weight Requirements	Criteria	Weight Criteria	Indicators	Weight Indicators	Indicators Firm 1
0.67	MARKET FACTORS	1	INNOVATIVE INDUSTRY	0.15	0.78
			SEGMENTATION BY PRODUCTION	0.10	0.27
			NICHE MARKET	0.27	0.8
			CLIENT TYPE	0.24	0.67
			SIMILARITY TO A STARTUP	0.24	0.6
0.24	INTERNAL FACTORS	1	VALUE PROPOSITION	0.2	0.95
			INNOVATIVE CAPACITY	0.24	1
			INFRASTRUCTURE AND RESOURCES	0.12	0.97
			QUALIFICATION OF PERSONNEL	0.12	0.75
			ORGANIZATIONAL AMBIDEXTERITY	0.32	0.67
0.09	EXTERNAL FACTORS	1	EXTERNAL COMPETITION	0.64	0.5
			USE OF FACILITATING NETWORKS	0.28	0.65
			MACROECONOMY	0.11	0.97

Having introduced these changes, the final index value for the firm was 0.7, or 0.08 points less than in the initial (real) case. It can be concluded that a change with such a small variation in the final index value confirmed that the evaluation model was balanced.

CASE 3: Finally, it is proposed to change the weight of the requirements, but this time giving the maximum value to External Factors and studying the final index value for Firm 2 from the construction sector.

The results following the change can be seen in Table 7:

Table 7. Results of the sensitivity analysis for Case 3.

Weight Requirements	Criteria	Weight Criteria	Indicators	Weight Indicators	Indicators Firm 1
0.09	MARKET FACTORS	1	INNOVATIVE INDUSTRY	0.15	0.88
			SEGMENTATION BY PRODUCTION	0.10	0.204
			NICHE MARKET	0.27	0.434
			CLIENT TYPE	0.24	0.33
			SIMILARITY TO A STARTUP	0.24	0.27
0.24	INTERNAL FACTORS	1	VALUE PROPOSITION	0.2	0.78
			INNOVATIVE CAPACITY	0.24	0.5
			INFRASTRUCTURE AND RESOURCES	0.12	0.79
			QUALIFICATION OF PERSONNEL	0.12	0.26
			ORGANIZATIONAL AMBIDEXTERITY	0.32	0
0.67	EXTERNAL FACTORS	1	EXTERNAL COMPETITION	0.64	0.67
			USE OF FACILITATING NETWORKS	0.28	0.13
			MACROECONOMY	0.11	0.14

After the change, the result of the final index was 0.46, while its former (real) value was 0.41. Therefore, the change implies an increase of 0.05 points that may be considered non-significant, so the tool may be said to be stable.

Concluding the sensitivity analysis, it may be highlighted that the tool is stable, because in no case has it implied a change in the value of the final sustainability index for each firm.

7. Conclusions

Today, we live in a society in constant flux and we are obliged to adapt ourselves so as not stay behind. In this sense, and over recent years, disruptive innovations have been developed that have revolutionized what was known before. These are innovations that break with what was already established in society and that, in addition, they have reached such undoubtable levels of success that firms from different sectors are obliged to introduce these changes into their day-to-day routines. The management of these innovations in entrepreneurial projects is no easy process, because it consists in managing something completely new that is unknown and the generates endless doubts.

Taking into account that research on the concept of disruptive innovation lacks effective, reliable and widely accepted scales or evaluation models, the aim of this study was to try to shed some light on this research gap, through the development of a sustainability management model that may quantify the capabilities of firms from technological-industrial areas to undertake and to manage a disruptive innovation project.

This evaluation model could help firms to reduce the uncertainty that surrounds the management of disruptive innovation projects in an easy and rapid way and without a high economic cost. The adoption of the right disruptive innovation project can generate many benefits, both for the firm and for its clients. To do so, the configuration of a series of indicators is of great interest that can serve as a reference for the selection of the most suitable disruptive innovation project in accordance with a series of data that is compiled, with the objective of optimizing the existing resources its implementation. This conclusion is graphically reflected in the decision tree that has been presented where three principal branches may be observed that correspond to the market and both the internal and the external factors of the firm.

Through the tool that has been proposed, a final index value is obtained between 0 and 1 that defines the capacity of a firm to manage a disruptive innovation project; the value of 1 referring to a high capacity and 0 to null capacity. The values obtained in the case study that has been proposed were very clear and were as expected: 0.78 in the case of business project in machine-tooling sector and 0.41 in the case of the construction firm. These results therefore imply that Firm 1, within the machine-tooling sector, is better prepared for adaptation, unlike Firm 2, from the construction sector, that still has to improve many aspects in order to gain sufficient capacity for adaptation.

8. Limitations and Future Lines of Work

It must be taken into consideration that only two isolated cases have been analyzed with a view to testing the functional results of the tool. A larger population of firms, both from the same sector and from different sectors, could be analyzed, in order to obtain more consistent results.

It is true that one of the principal objectives of this study has been to develop as objective a tool as possible to evaluate the adaptative capacity of a firm considering a disruptive innovation project, but those responsible will always have an element of subjectivity in their evaluations. In particular, the indicators that presented greater subjectivity were those in which the evaluation was in the hands of a manager where it had to be indicated whether the firm had a High, Medium-High, Medium-Low, or Low level for the indicator. This was the case of the indicators "Niche market" and "Startup". As a future line of investigation, the possibility is also proposed of investigating another form of measuring these indicators to do so in a more objective manner. Despite these drawbacks, the tool has another eleven indicators, in addition to the two mentioned above, which are valued in an objective way.

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