KEY PERFORMANCE INDICATORS AND DIMENSIONS FOR THE INNOVATION PROCESS

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ABSTRACT
Innovation helps promote significant social challenges and at the same time provides opportunities for established and newly emerging sectors and job creation. Clear evidence in the literature indicates that their competitive success is dependent upon an organization's management of the innovation process. However, to define suitable indicators to manage performance is a difficult task especially for small businesses and start-ups. Since performance frameworks and indicators are derived from favourable results to specifics types of organizations, are not suitable for small businesses as such practices are initially intended for large organizations. Drawing from literature, the measurement of the innovation process tends to be infrequently undertaken in an ad hoc fashion, unbalanced or under-specified frameworks. Therefore, this paper presents a comprehensive set of key performance indicators for the innovation process into a performance framework. This research followed a based on a three-step systematic literature review, followed by a systematization of the key performance indicators into dimensions for the innovation process. This approach is a well-established procedure to identify indicators within the new product development domain. As a result, nine dimensions for the performance framework were identified: innovation strategy; knowledge management; organization and culture; portfolio management; project management; technology management; team management; commercialization and innovation vanguard adoption referring to openness, sustainability and servitization orientation. Secondly, each dimension of the framework was populated with corresponding key performance indicators. A total of 146 key performance indicators were identified and systematized into a rapid assessment particularly fitted for small and midsized organizations and start-ups and an in-depth approach suitable for large organizations as well. This paper produces two important contributions. First, it takes the challenging step of incorporating broad and diverse studies into a single performance framework fulfilling a gap in the literature. Second, it provides a performance framework which provides a useful basis for managers in practice to select suitable indicators to monitor their innovation process, diagnose limitations and identify areas for improvement actions.

Keywords: Innovation process, performance measurement; key performance indicators.

INTRODUCTION

Innovation is crucial for productivity, competitiveness and economic growth. Innovation is essential to address significant social challenges and at the same time promotes opportunities for established and newly emerging sectors and job creation (EC, 2016). There is a clear association between investment in innovation, growth and job creation, since innovation accounted for 62% of economic growth in Europe between 1995 and 2007, according to the "Science, research and innovation performance of the EU" report (EC, 2016).

Innovation manifests its impact regarding products as the introduction of a good and services that are new or significantly improved with respect to its original characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user-friendliness or other functional characteristics (OECD, 2005). While the understanding of innovation activities and their economic impact has greatly increased in the last decades, it is still deficient (Adams, Bessant and Phelps, 2006; Crossan and Apaydin, 2010; Nilsson and Ritzén, 2014; Nicholas *et al.*, 2015). As the world economy evolves, so does the process of designing an innovative product (Crawford and Di Benedetto, 2011).

Managing innovation is essential for organisations to survive in a competitive and dynamic environment. Evidence shows that competitive success is dependent upon an organisation's management of the innovation process, a multifaceted number of events and activities occurring concurrently and in sequence at times. One significant challenge is to measure the complex processes that influence the organisation's innovation capability (Cordero, 1990; Cooper and Kleinschmidt, 1995; Adams, Bessant and Phelps, 2006; Zizlavsky, 2015).

For many organisations, managing the innovation process is a complex issue (Erkens *et al.*, 2014). It is also essential from the academic perspective (Adams, Bessant and Phelps, 2006; Zizlavsky, 2015). In this way, responding to the need of both practitioners and academics to understand the effectiveness of innovation actions, performance indicators are frequently proposed. The underlying reasoning supporting the use of performance indicators is to establish an objective and a tracking mechanism. The indicator will support managers to have enough information to make decisions and take actions to achieve the goals set concerning innovation (Cooper and Kleinschmidt, 1995; Chiesa, Coughlan and Voss, 1996; Crawford and Di Benedetto, 2011).

The approaches towards the use of indicators within the literature on the management of innovation are fragmented with most studies focusing on the innovation inputs and outputs, overlooking the processes in-between. With so many performance indicators presented in the literature, a problem appears to exist for people interested in using performance indicators to measure the innovation process in place. That is, even with so many indicators at hand, to define the dimensions that need to be measured and which ones are the "key" performance indicators (KPIs) to manage the innovation process is still challenging successfully (Acosta, Araújo and Trabassos, 2002; Adams, Bessant and Phelps, 2006; Berg *et al.*, 2008; Zizlavsky, 2015). In addition, these indicators were designed for large companies and can be especially difficult for small

companies and start-ups in implementing them, even if with an innovation process in place (Kleinknecht, 1987; McAdam, McConvery and Amstrong, 2004; Hudson Smith and Smith, 2007; Katila, Chen and Piezunka, 2012).

Within this context, the objective of this study is to identify dimensions and performance indicators for a framework to manage the innovation process, not only for large but also small-sized companies. Therefore, this paper presents a comprehensive set of dimensions and process-related performance indicator for managing the innovation process. The major challenge addressed in this research is related to the lack of systematized approaches that tackle the innovation management to support companies in the selection of key performance indicators.

It is worthwhile mentioning that this research is prescriptive in nature, since it is geared towards gathering relevant performance indicators and setting the theoretical foundation for building future practical applications. This paper is part of a greater research effort to develop a performance framework for companies monitor and manage the innovation process, diagnose limitations and prescribe appropriate actions. The specific application of the indicators in the practical context of the performance framework is not within the scope of this paper, and will be explored in future research.

In the following section, the research method employed in this research is presented. Next section describes the primary results obtained by the systematic literature review, followed by discussions and conclusions.

RESEARCH METHOD

The research method consisted of a three-step systematic literature review. This systematic review is a method used to map existing and preceding knowledge and proposals in a specific research domain. Besides the analysis of previous discovery, techniques, ideas and ways to explore topics, the systematic review also allows the evaluation of the relevance of information, its synthesis and summarization. The notion of systematic review has recently gained significance in the management literature to identify performance indicators for NPD, for instance: lean performance (Mascarenhas Hornos da Costa *et al.*, 2014); eco-design implementation (Rodrigues, Pigosso and McAloone, 2016), and environmental performance (Issa *et al.*, 2015). The research method followed the procedure proposed by (Brereton *et al.*, 2007) based on three main steps: 1) plan review; 2) conduct review and 3) document review (see Figure 1).

In the first step (plan review), a literature protocol was prepared based on the research question and definitions expressed through specific concepts and terms known as the search strings, inclusion criteria and tools and schedule. The second step (conduct review) refers to the literature search procedures, i.e., the search within the indexed electronic databases of primary studies, which were then properly assessed according to the inclusion criteria. As the studies had been selected, relevant data from the publications, notably the attributes of the KPIs, were recorded, analysed and classified and synthesized during the third step (document review).

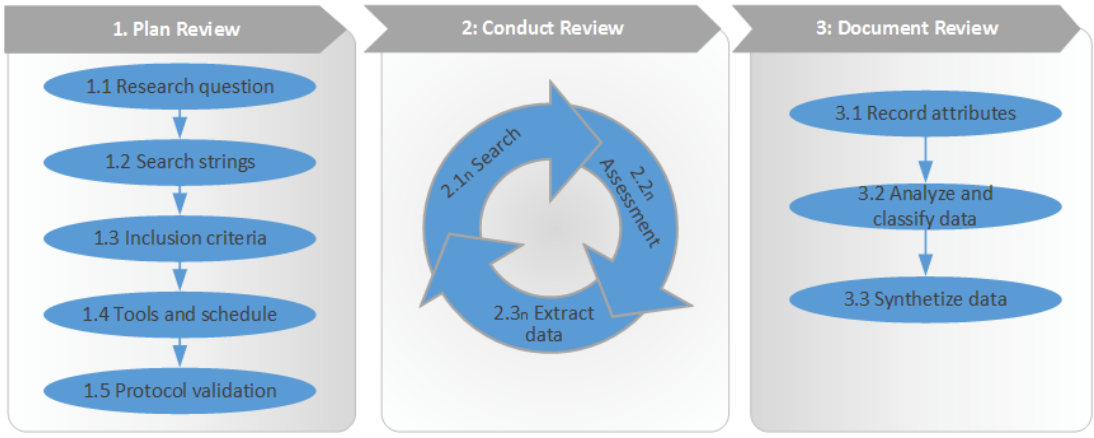

Figure 1. Research method with three steps.

The primary objective of the systematic literature review was to identify the available process-related KPIs for measuring the innovation process. Accordingly, the selected search keywords are related to KPIs and measurement and innovation process, and their synonyms. The terms indicator, measure, and metric are often used interchangeably (Mascarenhas Hornos da Costa *et al.*, 2014). Thus, in this paper, "key performance indicator" or "indicator" are the terms used its synonyms. To have a more comprehensive search, the keywords for indicators and innovation process were searched on the topic, which covers the paper's title, abstract, and keywords.

The process of creating the strings was iterative, in cycles of development, testing, and refinement. Each iteration involved the transcription of the keywords of the articles selected in the preliminary search and the selection of relevant terms for this research within these keywords. It also included the search for synonyms for relevant terms; the definition of the constraints, expressions that guarantee the right orientation of the searches; the preparation and test in the indexed electronic database, and finally the refinement of relevant terms and restrictions and string.

The final string was composed of the term "key performance indicator" and the synonyms: "indicator," "measure," "index," "indices," followed by broader terms as "performance measurement" and "performance evaluation." Additionally, the following synonyms of "innovation process" were selected: "innovation", "innovation management", "innovation planning", "innovation audit", "front end of innovation" or "innovation front end", "fuzzy front end", "research and development" associated with other terms "design process", "product design", "product development", "product service system development", and "product lifecycle management". Although these last associated terms are not usually linked with the innovation process, the creation of the string showed that they are crucial to providing a more comprehensive search. For instance, "product lifecycle management" can be defined as an integrated management approach of product-related information through the entire lifecycle and are highly associated to boosting innovation in manufacturing companies (Sudarsan *et al.*, 2005).

In the second step, the search used the indexed electronic database ISI Web of Science (WoS), due to its availability of advanced web search mechanisms, high volume of indexed publications and proven relevance in this field of research

(Adriaanse and Rensleigh, 2013). The studies retrieved from literature should empirically demonstrate that the KPIs are significant for managing innovation in the design process. In this way, a more mature and sound database was required, one like the WoS. The searches included journals, peer-reviewed conference papers, and books to capture both mature and more recent research under development in distinct fields. Further, cross-referenced publications were analysed for a more comprehensive review. The research fields were limited to cover WoS categories of management, business, planning development, economics, engineering (all kinds), operations research, computer science, multidisciplinary sciences, and social sciences mathematical methods. Also, no restriction was made concerning the publication dates in the WoS database to gain broader results.

In the course of the second step, three inclusion criteria were applied for the assessment and selection of the publications. First, the publication must contain quantifiable factor(s) specified in terms of the necessary organizational capabilities to manage the innovation process. Second, the publications must present, at least, one KPI for the innovation process. Third, the KPI must focus on the process rather than on the product itself, meaning that the indicators should be aligned with following stages of the innovation process: innovation front end, technology development process, development/design and product accompanying and retirement. Therefore, indicators dealing directly and exclusively with technicalities of the product, such as physical characteristics, materials, were not considered. By using these inclusion criteria, the review intended to cover the publications with proposals of new KPIs as well as those publications presenting, reviewing, reporting, analysing KPIs from literature. The procedure for the inclusion assessment was applying the filters followed by the application of the three inclusion criteria: 1) read the publication's title; 2) read the abstract and keywords; 3) read the introduction and conclusion, and 4) read the full paper. Additionally, this assessment, which is the same procedure from (Mascarenhas Hornos da Costa *et al.*, 2014; Issa *et al.*, 2015; Rodrigues, Pigosso and McAloone, 2016), can also lead to the identification of other articles employing the cross-referencing.

In the third step, the selected studies were analysed with the purpose of identifying the dimensions empirically revealed to be significant in the innovation process. Meaning that the quantifiable factor(s) must have been specified in measurement, determined by empirical methodology (either based on case research presenting the samples with small, medium and large enterprises (SML) companies or survey/expert assessment). Moreover, the study must have presented clear linkage between with the innovation process outcomes (based on success rates in sales/profit, on-time and schedule performance or market objectives). Dimensions were defined as a categorisation of innovation measurement areas covering a broad spectrum of the in-between processes, in which the KPIs were grouped (Adams, Bessant and Phelps, 2006; Crossan and Apaydin, 2010). The concept of theoretical saturation was adopted to categorize the innovation dimensions, based on previous well-established SLR research (Glaser and Strauss, 1967; Adams, Bessant and Phelps, 2006). Meaning that a

dimension was considered fully explored when no additional data were being found, and the researcher was empirically confident that the category of the dimension in question was saturated. Subsequently, the KPIs were identified and documented in an electronic spreadsheet to function as a database. Capturing the following attributes: title; purpose; formula; scales proposed (if applicable); relate to (other indicators associated); comments, and bibliometric information (authors and year of publication) (Neely, Gregory and Platts, 1995).

Furthermore, the retrieved indicators were further systematized to offer a way to measure performance by adding two differentiations also to support overlooked small organizations. The rapid assessment is also mean for the small companies to provide a way to measure performance dimensions (Czuchry and Yasin, 2001). Rapid assessment indicators are the ones used to stimulate a quick-win situation for the companies, as a first "health check-up" to diagnose the current situation. Meanwhile, an in-depth approach indicator should be used in a later stage analysis, such as used in (Chiesa, Coughlan and Voss, 1996). To classify into these two differentiations, the procedure carried out for the indicator's assignment was based on the searches for specific keywords in the performance indicators database. These keywords were pulled out from the dimensions' definitions and inserted into the search field of the electronic spreadsheet. They can be further classified in either leading indicators (trends) or lagging indicators (outputs) (Kaplan and Norton, 1992). Finally, note that the indicators within the scope of this research are all potential KPIs, once a company selects them according to their strategy and drivers, since they are identified as crucial to the success of the innovation process. That is why performance indicators and KPIs are being used interchangeably during the length of this paper.

RESULTS

The dataset presented in this paper was constructed using the Web of Science database. Every available publication containing the combination of indicator and innovation process in its title, keywords or abstract was identified and downloaded. This search identified 251 papers, refined by the field areas mentioned in the research method. 240 publications (96% of total) presented the main text in either English or Spanish/ Portuguese. By applying the inclusion criteria and following the procedure for selection, 186 documents (74% of total) had their abstract and keywords analysed. From this sample, 150 publications (60% of total) were available for download. Further, introduction and conclusion were examined in 69 (27% of total), and 21 papers (8% of total) were thoroughly read, and finally selected. Figure 2 illustrates a summary of the results from papers' analysis and selection.

It is important to highlight that by analysing the selected papers, with their citations being cross-checked to ensure that any other publications were also captured. 60 publications were elected during this cross-reference analysis. This magnitude is understandable since a further study of the gathered KPIs showed that the majority of the selected documents (86%) presented its focus on reporting, analysing, re-defining the literature rather than originally proposing new KPIs.

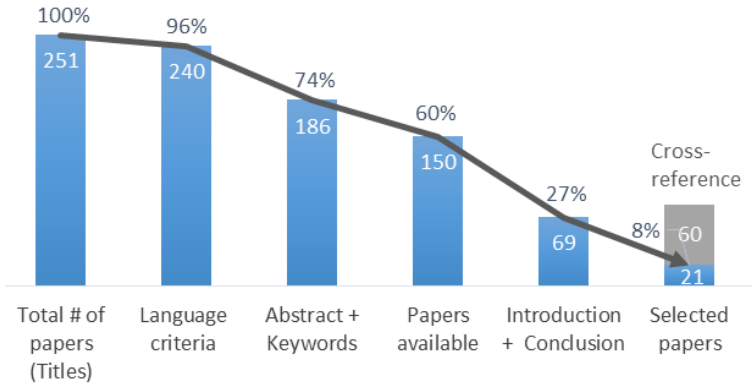

Figure 2. Graph of the utilization of the SLR extraction from Web of Science.

The selected publications, in addition to the cross-referenced ones, were published in a total of 39 distinct journals with the majority of 13 papers published and in the Journal of Product Innovation Management (JPIM). The earliest article included in the dataset was published in 1982 and the most recent 2016. Figure 3 presents the distribution of the selected paper and the cross-references regarding publication years. It is worth to mention that the reasonable increased from the references of the sample, five, were published within one especial issue addressing the Best Practices in New Product Development published in the JPIM. Out of 81 publication sources, 76 of them were retrieved from academic journals, two conference papers, and three books. This distribution reflects the maturity of the database Web of Science needed for this research.

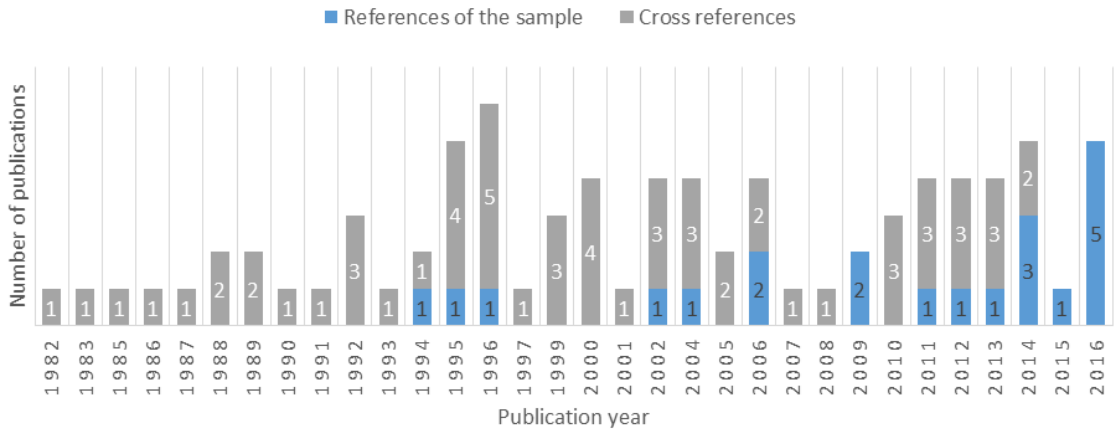

Figure 3. Distribution of selected publication by year.

As this research has the focus of gathering available KPIs from multiple sources in the literature, it should be highlighted that the distribution among different publication sources is essential, especially when it comes to the innovation process which is a multidisciplinary concept. This is a proxy for the leading research fields which are contributing to the proposal of the categorisation of the dimensions, which is relevant for future studies that will build on top of systematized KPIs. Figure 4 shows the distribution of papers by journals with at least two publications. JPIM is a well-

established journal of innovation management related issues from the operation management (OM) field. R&D and Research-Technology management represent the literature about innovation from a techno-centric focus within the 90's and early 2000. Engineering sources such as IEEE and the Journal of Engineering and Technology also presented a techno-centric approach towards innovation and more recently a process approach. Economics journal also present innovation-related publications, primarily related to the value creation chain in product development. The remaining journals are within the scope of management science as expected within the OM and Operations Research (OR).

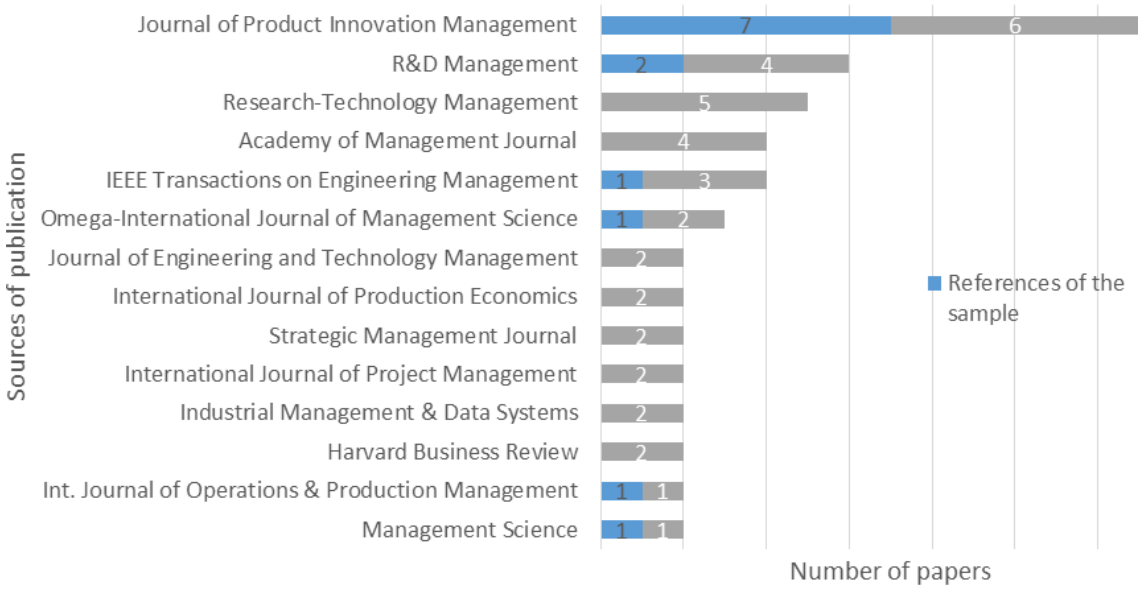

Figure 4. Distribution of selected papers by journal.

Based on the selected studies, mostly from OM and OR, evidence shows that there is diverse literature and as a result, it is hard to operationalize innovation measurement (Adams, Bessant and Phelps, 2006). Nevertheless, there are areas of commonality across the literature, and nine dimensions of the innovation process were identified. The dimensions presented here were empirically demonstrated in the selected studies to be significant for the management of the innovation in the product development process. Within these studies, the most relevant ones for identifying the dimensions of the innovation process are presented in Table 1. These studies were retrieved from the systematic literature and highlighted here for their importance within the field based on citation analysis for older studies (at least ten citations) and significance and scope of the journal for more recent studies (from 2012 onwards).

This sample of studies shows a range of publication years from 1995 to 2016. To extract dimensions of the innovation process, the concept of theoretical saturation was adopted to categorize the innovation dimensions, as mentioned in the research method, based on previous well-established research using SLR (Glaser and Strauss, 1967; Adams, Bessant and Phelps, 2006). Meaning that an innovation dimension was considered fully explored when no additional data were being found, and the researcher

was empirically confident that the category of the dimension in question was saturated. In this way, nine dimensions were identified.

In the first column of Table 1, the dimensions of the innovation process derived from this synthesis are presented: innovation strategy; knowledge management; organisation and culture; portfolio management; project management; technology management; team management; commercialization and innovation vanguard adoption referring to an orientation towards more openness, sustainability, and servitization.

Table 1. Identified dimensions of the innovation process.

References / **Dimensions**		**(Cooper and Kleinschmidt, 1995)**	**(Chiesa, Coughlan and Voss, 1996)**	**(Verhaeghe and Kfir, 2002)**	**(Adams, Bessant and Phelps, 2006)**	**(Barczak and Kahn, 2012)**	**(Nicholas *et al.*, 2015)**	**(Lee and Markham, 2016)**
Innovation strategy		✓	✓	✓	✓	✓		✓
Knowledge management			✓	✓	✓		✓	✓
Organisation and culture		✓	✓	✓	✓	✓	✓	
Portfolio management			✓	✓	✓	✓		✓
Project management			✓	✓	✓			✓
Technology management			✓	✓				
Team management		✓	✓	✓	✓	✓	✓	
Commercialisation		✓			✓	✓	✓	
Innovation vanguard adoption	Openness			✓			✓	✓
	Sustainability							✓
	Servitization							✓

One of the most influential studies in new product development measurement (Cooper and Kleinschmidt, 1995) empirically demonstrated five main constructs for new product performance across 135 firms: NPD process, NPD strategy, project management, culture (climate and development team) and management commitment. Although this framework many contributions' to the advance of literature, it presents a bias prevalent in innovation and NPD studies, which is the techno-centric focus. This narrower focus hinders the incorporating of innovation in non-technical contexts and, as (Adams, Bessant and Phelps, 2006) states it overlooks other vital factors such as the role of knowledge.

Another study that influenced many others and also presents the techno-centric focus is the technical innovation audit (Chiesa, Coughlan and Voss, 1996) tested in eight SML firms. It describes a framework with two dimensions: inputs with three enabling processes: human resources, financial resources, adding the new dimensions

use of systems and tools and management leadership and four core processes: concept generation, product development, process innovation and technology acquisition, already presented in (Cooper and Kleinschmidt, 1995).

Verhaeghe and Kfir, (2002) extended technical innovation audit (Chiesa, Coughlan and Voss, 1996) to comprehend not only "hard" and technical based products also more "soft" innovation, either research or consultancy project. It was applied to the service context resulting in the following main dimensions: leadership, resourcing innovation, systems and tools, technology transfer and acquisition, market focus, innovation performance, networking.

Further research based on a synthesis of the previously mentioned studies, Adams et al., (2006) produced a theoretical proposal that reflects factors apparently significant to the innovation process. It consists of seven dimensions: inputs, strategy, organization and culture, portfolio management, project management, and introducing, explicitly, knowledge management and commercialization. Moreover, although other studies, such as (Crossan and Apaydin, 2010), have recognized the importance of this study, these dimensions still need to be applied in real cases.

Barczak and Kahn, (2012) developed a best practice benchmarking framework for the NPD, using the findings of a survey conducted by the Product Development Management Association (PDMA) in 2004. This framework includes: strategy, portfolio management, process, market research, project climate (including project team), and metrics and performance evaluation. This proposal is particularly interesting because it comprehends the notion of a progression path, which an organization evolves thru distinct levels of sophistication. Additionally, the authors introduced the dimension of market research.

Nicholas et al., (2015), on the other hand, developed their framework with dimensions identified within the literature related to the development of radical innovation in products. Afterward, these dimensions were validated in a sample of 87 organisations. The resulting dimensions validated were: market awareness, idea management, customer involvement, open environment and internal networking. Furthermore, these authors introduced the factor of open environment, adding the concept of open innovation into the dimensions of the innovation process.

Finally, based on another survey by PDMA in 2011, (Lee and Markham, 2016) identified factors revealed to be significant within in the 87 companies. In addition to the well-established dimensions from the literature (strategy, portfolio management, fuzzy front end management, project management, organization and culture and customer focus), the research added new ones: sustainability orientation on new products, open innovation, and servitization. Especial attention must be given to these new ones since evidence of their importance have been emerging from diverse fields of literature (Baines and W. Lightfoot, 2013; Calik and Bardudeen, 2016; Shaner, Beeler and Noble, 2016).

After that, as already mentioned in the research method section, the performance indicators were identified, compiled and systematized. To that end, the KPIs were collected into a database with an electronic spreadsheet format documenting title;

purpose; formula; and scales used (if applicable), relate to (other KPIs associated with this particular indicator); innovation process alignment (innovation front end, technology development process, development/design and product accompanying and retirement); comments and bibliometric information (author and year of publication). Subsequently, they were also assigned to dimensions of the innovation process, using specific keywords extracted from the dimensions' terms and inserting them into the search field of the electronic spreadsheet, the database of performance indicators.

As an example to illustrate the performance indicator assignment, consider the dimension "innovation strategy." This dimension deals with planning a synchronized focus for the new product related processes efforts. Therefore, to assign performance indicators for this dimension, the studies that were focused on strategy orientation and leadership (Cooper and Kleinschmidt, 1995, 2007; Tipping, Zeffren and Fusfeld, 1995; Chiesa, Coughlan and Voss, 1996) were given priority and firstly inspected. Later on, all other indicators retrieved from the literature were then assessed for alignment with the dimensions. One of the assigned KPIs was "goals for NPD/innovation effort clear to everyone involved" for example.

146 unique key performance indicator that met the inclusion criteria were identified and catalogued. Then, the indicators were consolidated in a single standard database, representing an average of 1.8 unique KPIs per publication. Almost 90% of the database were classified as leading indicators rather than lagging as expected, since they are dealing with the innovation process improvement. Due to its considerable size, Table 2 presents one example of KPI for each dimension identified, showing: title; identification number (ID); corresponding dimension; references; and number of KPIs for the rapid assessment, the in-depth approach, and total. As mentioned previously, the reason to differentiate is that the need to stimulate a quick-win situation for the companies, resulting in 34 KPIs for rapid assessment more suitable for small companies and 112 KPIs more for in-depth analysis. For the previous illustrative case of the innovation strategy dimension, a total of 13 indicators were identified, being four of them used for a rapid assessment and the remaining ones used for the in-depth approach.

The results of the distributions of the indicators through dimensions of the innovation process is also presented in Table 2. The most considerable number of indicators (15%) addresses the project management and also the technology management dimension. Second is the indicators regarding knowledge management (14%), followed by organisation and culture (12%), then by team management (11%), innovation vanguard adoption (10%), innovation strategy (9%), commercialization (8%), and portfolio management (5%). The widely recognized idea that project management excellence promotes the delivery of innovation in product, system, and service excellence (Barczak and Kahn, 2012) appears to have impacted the proposition and dissemination of indicators for the innovation process, since, as mentioned, 33% of the indicators relate to project management. Furthermore, the technology management dimension presented 15% of total KPIs identified, and as the previous dimension, technology management indicators are widely spread across the R&D research literature since the 90s.

Table 2. Examples of KPIs for each dimension

Title	ID	Dimension	Reference	Rapid assessment	In-depth approach
Goals for NPD/ innovation effort clear to everyone involved	IS1	Innovation strategy (IS)	(Cooper and Kleinschmidt, 1995, 2007; Tipping, Zeffren and Fusfeld, 1995)	4	9
				Total: 13 KPIs (9%)	
Percentage of ideas generated according to formal and informal activities	KM1	Knowledge management (KM)	(Eling, Griffin and Langerak, 2016; Gurtner and Reinhardt, 2016; Lee and Markham, 2016)	3	18
				Total: 21 KPIs (14%)	
Team Climate Inventory	OC1	Organisation and culture (OC)	(Anderson and West, 1996)	2	16
				Total: 18 KPIs (12%)	
Existence of a formal portfolio management process	PFM1	Portfolio management (PFM)	(Chiesa, Coughlan and Voss, 1996; Archer and Ghasemzadeh, 1999; Beringer, Jonas and Kock, 2013; Markham and Lee, 2013)	3	5
				Total: 8 KPIs (5%)	
Commitment of resources for innovation/ new products projects	PM1	Project management (PM)	(Cooper and Kleinschmidt, 1995, 2007; Adams, Bessant and Phelps, 2006)	6	16
				Total: 22 KPIs (15%)	
Continuously thinking of next-generation technology	TM1	Technology management (TM)	(Prajogo and Sohal, 2006)	4	18
				Total: 22KPIs (15%)	
Cross-functional team	TEAM1	Team management (TEAM)	(Prajogo and Sohal, 2006; Markham and Lee, 2013)	5	11
				Total: 16 KPIs (11%)	
Use of market research tools	CO1	Commercialisation (CO)	(Adams, Bessant and Phelps, 2006; Markham and Lee, 2013)	3	9
				Total: 12 KPIs (8%)	
Recognition of key problems that must be solved with skills that reside outside the organisation	IVA1	Innovation vanguard adoption (IVA)	(Markham and Lee, 2013; Dubiel, Durmusoglu and Gloeckner, 2016; Gurtner and Reinhardt, 2016)	4	10
				Total: 14 (10%)	
					Total: 146 (100%)

It is noteworthy that these indicators are not meant to be an end result concerning achieving superior performance in the innovation process, but rather a means to manage it. Proposing to apply these indicators alone, without customization and using in their raw data formats, would not be sufficient when seeking for improved performance. The application of these indicators works as a roadmap for companies to develop their competences further, in terms of applying new innovation practices within the cycles of improvements.

DISCUSSION

It is important to highlight that all of these dimensions should not be seen as linear and sequential to the process, but they flow across the many cycles of the product development process and consequently being more or less present in distinct stages of the development.

In contrast to the indicators distribution, the most recurrent dimension identified across the studies was, in fact, organisation and culture (see Table 1). Since (Pugh *et al.*, 1969), the structure and culture of an organisation are strongly related to the context of the new product development functions. Further, it has been widely established that the work environment (organisation structure and culture) makes a difference in the level of innovation in organisations (Adams, Bessant and Phelps, 2006). The organisation and culture dimension refers to the organisational culture within which they work, meaning the perceived work environment, in which innovation can be encouraged or hampered, and the way staff are organised (Cooper and Kleinschmidt, 1995; Chiesa, Coughlan and Voss, 1996; Verhaeghe and Kfir, 2002; Adams, Bessant and Phelps, 2006; Barczak and Kahn, 2012; Nicholas *et al.*, 2015; Lee and Markham, 2016). The corresponding example in Table 2, indicator OC1, refers to the culture based on the concepts of teams perception concerning a shared vision; support for innovation; participative safety, and task orientation (Anderson and West, 1996). This indicator from the rapid assessment approach can and should be used by small manufacturing enterprises, as it was also validated in small teams perception (Mathisen *et al.*, 2004).

The second most cited dimension was innovation strategy. Scholars have extensively demonstrated that activities must be consistent with an overarching organisational strategy, implying that management must take conscious decisions regarding innovation goals. The innovation strategy dimension represents defining and planning a coordinated focus for the new product related processes efforts of business units, division, product line, or an individual project. Organisations that possess strategic leadership to enable a clear vision and to prospect future market opportunities are considered more refined in terms of identifying a clear, new product strategy orientation (Cooper and Kleinschmidt, 1995; Chiesa, Coughlan and Voss, 1996; Verhaeghe and Kfir, 2002; Adams, Bessant and Phelps, 2006; Barczak and Kahn, 2012; Markham and Lee, 2013). The indicator IS1, presented as an example in Table 2, refers to the strategic orientation and dissemination goals for the innovation effort (e.g., percentage of sales, profit or growth over the next X years) (Cooper and Kleinschmidt, 1995, 2007; Tipping, Zeffren and Fusfeld, 1995). This indicator for the rapid

assessment presents a 5-pointed Likert scale to be compiled to be used of distinct company sizes (Cooper and Kleinschmidt, 1995).

The third most cited dimension was team management. Team factors have been argued as inputs for the innovation management in the new product development process largely in literature, not only on OM research but also in the literature on creativity. Leading organisations rely significantly on cross-functional teams throughout the NPD process and are likely to have a individuals with potential skills to work full time on such activities (Cooper and Kleinschmidt, 1995; Chiesa, Coughlan and Voss, 1996; Verhaeghe and Kfir, 2002; Adams, Bessant and Phelps, 2006; Kahn *et al.*, 2012). Table 2 exemplified the indicator TEAM1 for the rapid assessment, which refers to cross-functional teams (Damanpour, 1991; Prajogo and Sohal, 2006; Markham and Lee, 2013). This indicator was also applied in small companies, especially in Asia (Markham and Lee, 2013).

Furthermore, the knowledge management dimension is concerned with obtaining and communicating ideas and information that underlie innovation competencies. It includes idea generation, knowledge repository and information flows of the new product development (Cooper and Kleinschmidt, 1995; Chiesa, Coughlan and Voss, 1996; Verhaeghe and Kfir, 2002; Adams, Bessant and Phelps, 2006; Nicholas *et al.*, 2015; Lee and Markham, 2016). The indicator KM1 showed in Table 2 relates to idea generation (Eling, Griffin and Langerak, 2016; Gurtner and Reinhardt, 2016; Lee and Markham, 2016). This indicator for the rapid assessment was also used in small and medium companies. It is important to highlight that there is a tendency for small companies to present less formalized idea generation process. However, if these companies present an innovation process in place, using formal idea generation both for radical and incremental new product ideas leads to highest firm's ideas success rates (Eling, Griffin and Langerak, 2016).

The portfolio management dimension refers to the on-going review and screening of new projects ideas, using evaluation tools, and identifying preferable product concepts with which to proceed existing products to ensure alignment with strategy and resource availability (Chiesa, Coughlan and Voss, 1996; Verhaeghe and Kfir, 2002; Adams, Bessant and Phelps, 2006; Lee and Markham, 2016). The example in Table 2, the indicator PFM1 for the rapid assessment, refers the existence of a formal portfolio management process. This indicator was applied in small companies, and as the previous which presents a tendency for small companies to perform a less formalized idea generation process, it is essential to new product development (Lee and Markham, 2016).

The technology management dimension concerns the anticipation of the potential of new technologies, implementing long-term programs for developing technological competences (potential), technology orientation and R&D effectiveness when applicable (Chiesa, Coughlan and Voss, 1996; Verhaeghe and Kfir, 2002). The illustrated example in Table 2, the indicator TM1, refers to technology potential analysis used in the in-depth approach, with the purpose of enabling organisations to assess in more detail their management of innovation, making possible to identify areas

within each where attention should be focussed. In this way, this indicator was tailored to be used in large companies (Verhaeghe and Kfir, 2002).

The commercialization dimension includes the application of activities for understanding customers, competitors, and macro-environmental forces in the marketplace. Usually, more sophisticated organisations employ a variety of market research techniques so that the customer can be involved throughout the new product development process, testing and marketing and sales validation (Cooper and Kleinschmidt, 1995; Adams, Bessant and Phelps, 2006; Kahn *et al.*, 2012; Nicholas *et al.*, 2015). As the example in Table 2, the indicator CO1 refers to market research tools for both small, medium and large companies (Nicholas *et al.*, 2015) and should be used within the scope of the rapid assessment.

The innovation vanguard adoption dimension is concerned with the new trends in innovation and new product development practices: openness, meaning development regarding external and internal collaboration (Adams, Bessant and Phelps, 2006; Nicholas *et al.*, 2015; Lee and Markham, 2016); sustainability orientation referring to the incorporation of the triple bottom line into the new product development process (Verhaeghe and Kfir, 2002; Lee and Markham, 2016); and, servitization as an intentional and coordinated effort to incorporate Product Service Systems (PSS) (Lee and Markham, 2016). The indicator CO1 for the rapid assessment presented in Table 2 refers to openness as the recognition of key problems that must be solved with skills that reside outside the organisation. This indicator was used in companies with various sizes, predominantly small firms (Dubiel, Durmusoglu and Gloeckner, 2016).

It is important to highlight that the vast majority the use of KPIs, and consequently, performance measurement systems, were designed and tested in, and for, large companies (Hudson Smith and Smith, 2007). Literature has demonstrated that there can be considerable difficulties in implementing these indicators and systems effectively and that difficulties are particularly prevalent in smaller companies (McAdam, McConvery and Amstrong, 2004). The basis for the development of a performance measurement also focused on small and medium firms is grounded on an incremental approach (Hudson Smith and Smith, 2007). This progressive approach aims to design performance indicators one at a time, according to current strategic priorities and immediately cascade the measurements down to the operational level, to ensure implementation. In this way, the present dimensions aim to give a rapid assessment to provide a diagnostics and, in time, works as a checklist providing indicators which can be selected, defined and implemented, even one at a time, respecting the strategic priorities of the company.

Overall, although the literature present notable approaches regarding performance measurement and categorisation of dimension and a few KPIs to the innovation process, most approaches do not provide a comprehensive database of indicators where managers can select from. In this sense, the results of this research contribute to the enhancement of knowledge concerning: the systematic identification of existing KPIs; systematization of the KPIs into relevant classification to the innovation process; creation the database and their related indicator’s attributes.

CONCLUSION

This paper reported the definition and systematization of a set of KPIs for measuring the innovation process. The research method was designed on the grounds of a systematic literature review to cover performance measurement, accompanied by a systematization of the KPIs. The resulting 146 KPIs were catalogued and systematized in an electronic spreadsheet, being 34 for rapid assessment and suitable for small-sized companies and 112 for the in-depth approach. This database in the current form is not intended to offer specific support for selecting and defining the performance indicators without assuming contextualization (designing specifically to meet local needs of the company), avoiding "one size fits all" type of framework. It constitutes an additional resource advancing the knowledge for both academics and practitioners working with performance measurement in the innovation process.

The main findings of this paper are: i) the identification of nine dimensions: innovation strategy; knowledge management; organisation and culture; portfolio management; project management; technology management; team management; commercialization and innovation vanguard adoption referring to openness, sustainability and servitization orientation; ii) the identification of most cited dimensions: organisation and culture; innovation strategy and team management and iii) the identification of highest numbers of KPIs: project management and technology management, which are not correspondent to the most cited dimensions, probably due to the role played by of PMI and the evolvement of literature, respectively. Furthermore, from an applied perspective, the proposed study also enables a benchmarking of process-related KPIs based on the state of the art and in the content of the database.

A few limitations of this research can also be pointed out. First of all, the KPI database was systematized based on purely academic sources, journals without considering a potential systematic review of "state-of- the-practice" sources and databases. Secondly, the classification and systematization of the catalogued KPIs are subjected to the researchers' own judgements regarding the classification of two-level analysis. Thirdly, due to the abovementioned judgement analysis, their interpretation of the KPIs was sometimes solely based on their titles, and surrounding definitions and further assumptions were made in a subjectively.

These limitations can be addressed by the following: i) broadening the scope of the literature review to cover practitioner-oriented sources to include insights from practice, which could potentially lead to a higher number of KPIs systematized and ii) subject the KPIs systematization to a panel of experts in the fields of innovation management, product development and performance measurement.

To effectively capture and measure the performance of the innovation in the new product development process, more efforts should be put on developing a step-by-step procedure showing how to deploy and customize this KPIs to a practical application within an organisation. Hence, future research should overcome potential limitations of this research, in addition, to propose actions to be taken within the overall context of this paper. Next steps within the frame of this research include addressing

the limitations by extending the scope of the systematic literature and submitting the KPIs database systematisation to an expert panel.

Finally, as mentioned before, this paper is part of a more significant research to develop a performance measurement framework. The resulting measurement framework will not only contribute to fulfilling a gap in literature but also provide a useful basis for managers in practice to select KPIs to monitor their innovation processes, diagnose limitations and prescribe appropriate actions. In the future, this prescriptive support tool should be instantiated with empirical data by conducting an action research and geared towards laying out the fundamental rationale of how performance measurement framework can improve an organisation's innovation performance.

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