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Analysis of quantitative empirical papers on diffusion and adoption of methods, techniques and tools for innovation

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Abstract

Effective use of methods, techniques and tools for innovation (MTT-I) has been considered an important factor for successful innovation management. However, studies related to the topic are still scarce, especially those using the quantitative empirical approach for research. Thereby, with the analysis of quantitative empirical papers related to diffusion and adoption of methods, techniques and tools for innovation, we intend to present a portrait of the empirical research on the topic. The analyzed papers were obtained through a systematic survey on two databases: Scopus and Web of Science. It resulted on a corpus of 18 publications, from which main papers, authors, countries and journals that most published about the theme and the most common keywords were identified. Later, the analysis of papers generated an overview of quantitative empirical research related to the topic and indicated areas for further study, contributing to the development of the subject. The study identified the scarcity of research related to the theme of diffusion and adoption of MTT-I and the concentration of quantitative empirical researches in product development, rather than in other results of innovation, such as services and processes. Methodological variations between studies were also identified, making it impossible to compare different contexts. This paper concludes displaying important points for further development of the field.

Keywords: Innovation; Methods; Tools and techniques for innovation; MTT-I; Systematic survey; Quantitative methods

Introduction

The study of innovation gained notoriety as from the 80s, since organizations realized that their ability to innovate strongly affects the future of the business. There are various points of view and concepts regarding innovation (Crossan & Apaydin, 2010). Baregheh, Rowley, and Sambrook (2009) argue that innovation is the multi-step process through which organizations transform ideas into products, services, or new/improved processes, in order to successfully progress, compete and differentiate themselves in the market.

Given its importance for organizations, several studies have focused on the innovation process, particularly looking at ways to improve it as a whole. These studies began with an increased focus on product development area (focusing on physical goods) and, over time, efforts have been transferred to the area of innovation, in order to cover other results of the process, such as new and/or improved services and processes. In general and simplified terms, the process of innovation consists of three parts – front end of innovation, development and implementation. The first part, the front end of innovation, corresponds to all activities performed until the decision making about an innovative concept and the beginning of its development, including for example the identification of opportunities and the generation of ideas; the second part, the development, corresponds to activities performed in order to specify and detail the concept as to make implementation possible, including for example prototyping, testing and project detailing; and finally the last part, the implementation, represents activities that "bring the concept to life", including production and market introduction, if applicable, since not every innovation is commercialized (Herstatt, Stockstrom, Verworn,

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& Nagahira, 2006; Koen et al., 2001; Smith & Reinertsen, 1991).

The dimension covering important decisions to be taken in relation to the innovation process in general refers to which approaches (methods, techniques or tools) should be used in the process. These approaches support the understanding, analysis, decision and action throughout the innovation process (Phaal, Kerr, Oughton, & Probert, 2012). Among these approaches, here called methods, techniques and tools for innovation (MTT-I), are included brainstorming, morphological analysis, focus groups, concept testing, scenarios, return on investment (D'Alvano & Hidalgo, 2012; Nijssen & Lieshout, 1995). Other terms are used to refer to the MTT – tools (Coulon, Ernst, Lichtenthaler, & Vollmoeller, 2009; Hidalgo & Albors, 2008; Nijssen & Frambach, 2000); tools and techniques (Fleisher, 2006; Igartua, Garrigós, & Hervas-Oliver, 2010); methods (Lichtenthaler, 2005); models and methods (Nijssen & Lieshout, 1995). Analysis of the work related to the subject shows a confusion in the terminology (Phaal et al., 2012), since authors do not seek to explain the conceptual and operational differences, even when using two terms to name the approaches. Furthermore, few studies address the issue of terminology (e.g. Shehabuddeen, Probert, Phaal, & Platts, 1999). Here the terms methods, techniques and tools will be initially used without distinction between them, considering that they can be a document, framework, procedure, system or method that enables the organization to achieve or clarify a goal (Brady et al., 1997).

Effective use of MTT-I has been an important element in the management of the innovation process (Thia et al., 2005), since they facilitate the ability of an organization to appropriately introduce new technologies in products, processes and the necessary changes to the organization itself (Hidalgo & Albors, 2008). MTT-I can help them manage innovation, adapt to new circumstances and face the market challenges in a systematic way (Igartua et al., 2010). Chiesa and Masella (1996) stated in their audit model of the technological innovation process that the effective use of appropriate MTT-I is one of the three most important facilitators of the innovation process, together with the development of human and physical resources, leadership and support from top management. While they cannot guarantee success, the use of MTT-I may identify problems systematically, complementing the organization's efforts (Cooper & Kleinschmidt, 1986).

Therefore, two concepts are important in the study of MTT-I: diffusion and adoption. Adoption refers to the company's decision to use an MTT-I in their innovation process or reject its use, and diffusion refers to the cumulative number of companies that have adopted a particular MTT-I over time (Chai & Xin, 2006).

Exploratory surveys in the literature conducted by the authors of this study showed a predominance of works focusing on proposing and/or studying a MTT-I rather than studies focusing on the diffusion and adoption of MTT-I by organizations, which would focus on an amount of MTT-I. Thus, given the importance of methods, techniques and tools for the innovation process and the need of understanding how the empirical research have been approaching the diffusion and adoption of MTT-I, we established the following research question: how diffusion and adoption of methods, techniques and tools for innovation (MTT-I) have been empirically studied?

To answer the research question, a systematic survey was performed in two scientific databases, followed by categorization of collected works and analysis of those whose empirical studies have focused on the diffusion and adoption of MTT-I. This paper discusses the results of the analysis of quantitative empirical papers, considering that, by representing larger samples and often testing hypotheses, quantitative papers bring stronger conclusions to the field and are more appropriate to answer the research question. However, qualitative papers collected in this research were used additively, in order to substantiate the analysis here exposed.

In second section, this paper presents the methodological procedures to the study; in third section, the results of the analysis of quantitative empirical papers; in fourth section, the final considerations and proposals for future research; and finally the literature references.

Methodological procedures

Results were obtained from two distinct phases: (a) survey of papers related to MTT-I; (b) analysis of quantitative empirical papers related to MTT-I. In the first phase, in addition to the survey of papers, we made a bibliometric overview of research in this area as well as the identification of quantitative empirical papers central to this study. This phase was performed through the steps proposed by Botelho, Cunha, and Macedo (2011). The authors divide the process of an integrative review in six steps:

Step 1. **Identification of theme and selection of the research question**: From the aim of the research and the proposed research question, it is necessary to define the keywords that will be used in the search. Accordingly, the search was conducted in January 2014 in Scopus and Web of Science databases to the following terms combined with the term *innovation*: *method*; *technique*; *tool*. The search observed titles, abstracts and keywords. Tens of thousands of papers were found, which could make the analysis impracticable. Also, we found out that in some cases, MTT-I are discussed in such fields as development of new products and technological intelligence, and these terms are mentioned in the papers' titles without the term "innovation". Thus, in order to facilitate the analysis we decided to conduct the search only in the titles of papers. So that relevant papers were not lost, it was decided to expand the keywords search. Thereby, the terms *front end*; *innovation*; *product development*; *technology development*; *technology intelligence*; *technology management* were selected to search in the databases, individually combined with the terms method, technique and tool.

Step 2. **Establishment of inclusion and exclusion criteria**: Through an in-depth analysis, the papers were classified

according to four criteria: (a) the amount of MTT-I (one; more than one); (b) the predominant source of data (empirical; theoretical); (c) the predominant search approach (qualitative; quantitative); (d) the subject (diffusion and adoption of MTT-I; others). The classification regarding the amount of MTT-I specifically is justified since the analysis of the papers showed that those discussing more than two MTT-I had a predominantly generic approach to the MTT-I study, mainly focusing on diffusion and/or adoption of these, differently from those of the second group whose focus was mainly the proposal and/or application of a specific MTT-I. From the result of this analysis, two sets of empirical papers on diffusion and adoption of MTT-I were obtained: Group A, with 10 qualitative empirical papers and Group B, with 14 quantitative empirical papers.

Step 3. **Identification of pre-selected and selected studies**: Titles, keywords and abstracts from pre-selected studies were read in order to verify if they would contribute to the purpose of this research. When it was not possible to extract the necessary information to these criteria, the papers were read in full. At the end, a summary table of selected studies was created for this review. As to the selected works, an analysis of their references was also made to check for other published related work in journals that were not available in the databases. At the end of this analysis, four quantitative papers were found and added to the analysis portfolio (Group B). No other relevant qualitative papers were found.

Step 4. **Categorization of selected studies**: Searches were carried out differently according to the available parameter in each database, but with the help of the software EndNote® – to which the references were imported – the results were filtered to obtain the same criteria for the four bases. With selected papers, information such as number of citations, context in which they were developed, methodological approach, purposes, and others were verified as needed in order to have an overview on the topic.

Step 5. **Analysis and interpretation of the results**: As mentioned earlier, this paper presents the results of the analysis of quantitative empirical studies related to diffusion and adoption of MTT-I. Thereby, the 18 papers of Group B were analyzed. We tried to generally identify – besides purposes and results of the studies – how the quantitative approach was used. Then, hypotheses, constructs and variables of the studies were analyzed and the results are presented in the next section.

Step 6. **Presentation of the review/synthesis of knowledge**: In this step – described in the next chapter of this work – the main results of the research are presented, summarizing the studied papers and explaining possible relationships between them. In addition, gaps of research were identified as well as proposals for future work (see for example Graner & Mißler-Behr, 2012), aiming to meet the goal set for this research.

Results

With respect to the total of papers collected, there was a predominance of research related to a single MTT-I, whether related to the study of an existing MTT-I or to the proposal of a new one. Papers dealing with a single MTT-I were disregarded from the analysis of this study. From qualitative and quantitative papers surveyed, there was a predominance of those using the quantitative approach (see graph in Fig. 1), which are the focus of this work, since they provide a more comprehensive view of the diffusion and adoption of MTT-I.

Although the selection of papers has focused on those whose object is the adoption and diffusion of MTT-I – and this is quite explicit in quantitative papers–, in qualitative papers the subject is in some cases incorporated by other aspects of the studies, such as benefits from the adoption, for example. Exceptions are Thia et al. (2005) and Lichtenthaler (2005) which deal explicitly with the adoption, and Libutti (2000) who focuses on MTT-I diffusion. Thus, between the two approaches, there is a greater importance of quantitative studies rather than qualitative. This difference may reflect the research method used because some of the quantitative studies used hypothesis testing, which facilitates the generalization of results for different contexts. The qualitative studies have limitations regarding internal and external validation of data.

Consequently, as mentioned, this paper focuses on the results arising from the analysis of empirical papers that have adopted the quantitative research approach (Group B), which are a total of 18 papers. The 18 selected papers involved 35 authors (including co-authors), were published in 14 different journals and used 55 different keywords. However, qualitative papers collected in this survey were used in addition, in order to substantiate the analysis here exposed.

The author who has published more quantitative empirical studies on MTT-I published three papers (E.J. Nijssen). Following, are those who have published two papers (R.T. Frambach, F.J.M. González, A. Hidalgo, T.M.B. Palacios). Other authors published only one paper related to the topic. It was also observed that some of these authors have publications in common: E.J. Nijssen and R.T. Frambach (Nijssen & Frambach,

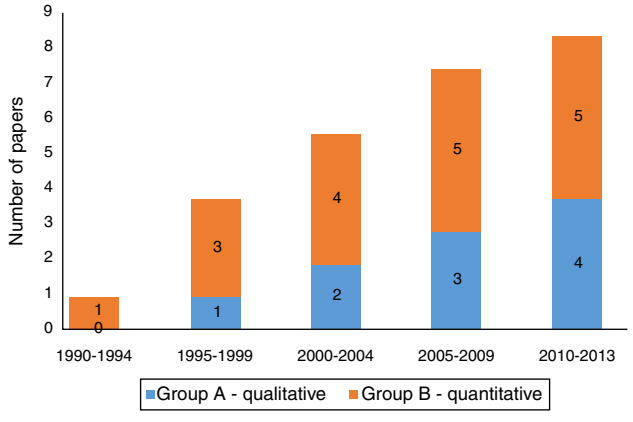

Fig. 1. Number of papers over the years.
Source: Authors (2014).

1998, 2000); F.J.M. González and T.M.B. Palacios (González & Palacios, 2002; Palacios & González, 2002).

Among the journals that most published papers from quantitative empirical research on diffusion and/or adoption of MTT-I, are the *Industrial Marketing Management* (2 papers), the *European Journal of Innovation Management* (2), the *Journal of Engineering Design* (2) and *R&D Management* (2). Other journals published only one paper.

Concerning keywords used to describe papers, it was observed that the majority of those most frequently cited keywords are related to product development, meaning physical goods. The most used terms were: *new product development* (3 cases); *knowledge management tool* (2); *product innovation* (2); *tools and techniques* (2). Analysis of keywords showed that most studies focus on the context of product development, specifically goods. Few of these works address the topic of services, and when it is addressed it only appears as one of the research contexts (see Hidalgo & Albors, 2008; Mahajan & Wind, 1992). No papers were found addressing, even if secondarily, innovations in process, in marketing methods or in organizational methods.

The terms *methods*, *techniques* and *tools* also appear among the keywords, together with other terms or separately. *Method* appeared once, *technique* three times and *tool* seven times. Although the term *method* is used only once among the keywords, it is used in the title of six of the collected papers, indicating the recurrence of its use in literature (Araujo, Benedettoneto, Campello, Segre, & Wright, 1996; Creusen, Hultink, & Eling, 2013; Engelbrektsson & Soderman, 2004; Fujita & Matsuo, 2006; Graner & Mißler-Behr, 2013; Nijssen & Lieshout, 1995).

Table 1 introduces the purposes of research, types of innovation focused by studies and context of the studies. As already mentioned, most of the works focused on innovation in products, specifically goods. It should be noted in this regard the works of Mahajan and Wind (1992) and D'Alvano and Hidalgo (2012), which addressed the issue more broadly, also covering services.

Regarding purposes, the analysis showed that the first studies have focused on identifying which MTT-I are known and adopted in specific sectors of industry, and in some cases also identifying factors that determine their adoption (e.g. Chai & Xin, 2006; Graner & Mißler-Behr, 2013; Nijssen & Frambach, 2000), their deficiencies (e.g. Mahajan & Wind, 1992; Nijssen & Lieshout, 1995), level of satisfaction with them (e.g. Araujo et al., 1996) and which activities from the innovation process are used (e.g. D'Alvano & Hidalgo, 2012). It is important to note that the subjects' diffusion and adoption were not separated because studies, in general, deal with both issues. Some studies also discuss benefits of the MTT-I use, e.g. Yeh, Pai, and Yang (2010) who related the adoption of MTT-I to improving new product performance. Still, some studies have focused on a specific set of MTT-I, like those dedicated to the identification of consumers requirements (Creusen et al., 2013) and knowledge management (Vaccaro, Parente, & Veloso, 2010).

After Nijssen and Frambach (2000) we found studies which, through hypothesis testing, aim to identify the factors which determined the adoption of the MTT-I by organizations surveyed (see Table 2). Three works, besides Nijssen and Frambach (2000), fit this category (Chai & Xin, 2006; Graner & Mißler-Behr, 2013; Vaccaro et al., 2010). Table 2 presents the hypotheses tested in analyzed studies, as well as their results. In the Results column, the following nomenclature was used: S for "supported"; WS for "weakly supported"; PS for "partially supported"; R for "rejected".

Although there are a considerable number of quantitative studies related to the adoption of MTT-I, few of them actually tested hypotheses, even indirectly, on determinants of the adoption (Chai & Xin, 2006; Graner & Mißler-Behr, 2013; Nijssen & Frambach, 2000; Vaccaro et al., 2010).

Determinants related to the organization and to the development process, intrinsic to the MTT-I and related to their use were also studied. Regarding the organization, the influence of the support and involvement of top management (Chai & Xin, 2006; Graner & Mißler-Behr, 2013; Nijssen & Frambach, 2000), the size of the organization (Chai & Xin, 2006; Nijssen & Frambach, 2000), the sector of industry in which it operates (Chai & Xin, 2006), the innovation strategy (Chai & Xin, 2006; Nijssen & Frambach, 2000) and the culture of change (Vaccaro et al., 2010) were observed.

In relation to the development process, the influence of the number of process steps (Nijssen & Frambach, 2000), the number of departments involved in the process (Nijssen & Frambach, 2000), the communication and collaboration in the process (Nijssen & Frambach, 2000; Vaccaro et al., 2010) and the formalization of the process (Graner & Mißler-Behr, 2013) have been studied.

In relation to the intrinsic characteristics of MTT-I, the influence of the tangible benefits provided by MTT-I (Chai & Xin, 2006) and the usability level of MTT-I (Chai & Xin, 2006) were examined. Finally, regarding the use of the MTT-I, the influence of experience and ease in the use were studied (Nijssen & Frambach, 2000).

From the analysis of the quantitative works, it also stands out the recurrence of the study of the relationship of adopting MTT-I and benefits to the innovation process, with more emphasis on the study of the context of new products development. Some of the analyzed studies relate the MTT-I use with benefits such as product quality (Araujo et al., 1996), gross profit in relation to competitors (Nijssen & Lieshout, 1995), identification of consumer requirements (Creusen et al., 2013; Engelbrektsson & Soderman, 2004), reduction of development time (Llorente Galera, 2009; Vaccaro et al., 2010), reduction of development costs (Llorente Galera, 2009), and maturity of the innovation process (D'Alvano & Hidalgo, 2012). Others in turn related MTT-I use with the performance of the new product development process using criteria. It is important to notice that the sources of the presented criteria are distinct – considering criteria used by companies surveyed (Mahajan & Wind, 1992) or criteria developed from the literature (Palacios & González, 2002; Vaccaro et al., 2010; Yeh et al., 2010).

Several studies were able to confirm the positive impact of MTT-I implementation during the development process of new products on making this new product successful in the market (González & Palacios, 2002; Graner & Mißler-Behr, 2013; Yeh et al., 2010). According to Nijssen and Lieshout (1995), the

Table 1
Context of research in surveyed papers.

Reference	Purposes	Type of innovation	Context
Mahajan and Wind (1992)	To determine the role of product development models in the support or improvement of NPD process	Development of new products (goods and services)	USA
Nijssen and Lieshout (1995)	To study diffusion, adoption and satisfaction of NPD methods and techniques	Development of new products (goods)	Netherlands
Araujo et al. (1996)	To determine the methods' level of utilization during the product development process and their contribution to the quality of the product	Development of new products (goods)	United Kingdom
Nijssen and Frambach (1998)	To study the adoption and use of NPD tools by companies offering market survey services	Development of new products (goods)	Netherlands and Belgium
Nijssen and Frambach (2000)	To study the determinants of adoption and diffusion of tools and techniques for the development of new products by industrial companies	Development of new products (goods)	Netherlands
González and Palacios (2002)	To examine the relationship between popular techniques of new product development and the success of the new product	Development of new products (goods)	Spain
Palacios and González (2002)	To identify the most useful techniques to accelerate the product development process	Development of new products (goods)	Spain
Engelbrektsson and Soderman (2004)	To investigate the use and perception of methods and product representations in Swedish companies and its possible impact on the problems associated with the late discovery of customer needs	Development of new products (goods)	Sweden
Chai and Xin (2006)	To investigate the adoption of NPD tools in Singapore, measured by the frequency and depth of the tools used and factors related to these tools that can affect the application	Development of new products (goods)	Singapore
Fujita and Matsuo (2006)	To investigate the awareness and use of tools and methods in Japanese companies	Development of new products (goods)	Japan
Hidalgo and Albors (2008)	To provide a comprehensive review of the scope, trends and major actors (companies, organizations, consultants, academia, etc.) in the development and use of methods to manage innovation in the knowledge-based economy	Innovation	Europe
Val Jauregui and Justel Lozano (2008)	To determine the level of use of different tools applicable to the FEI in Basque companies	Innovation (goods)	Spain
Llorente Galera (2009)	To check if direct suppliers to automakers located in Catalonia develop technological innovations, using certain systems and automation techniques to perform the design and/or development of their products, which enable to achieve product innovation with competitive cost, quality and time	Innovation (goods and processes)	Spain
Vaccaro et al. (2010)	To analyze the impact of knowledge management tools (KMTs) on the performance of business units involved in collaborative projects of inter-company innovation, and the role of critical organizational variables in the exploitation of these virtual technologies	Innovation (goods)	Brazil
Yeh et al. (2010)	To investigate the frequency of use and extent of implementation of tools and techniques at each stage of the NPD process and the effect of individual effectiveness of tools and techniques	Development of new products (goods)	Taiwan
D'Alvano and Hidalgo (2012)	To analyze the relationship between the use of innovation management tools (IMT) and the degree of development of an innovation process through the application of a five-stage model of innovation (TEMAGUIDE)	Innovation (services)	Venezuela
Creusen et al. (2013)	To investigate the choice of consumer survey methods in the fuzzy front end (FFE) of new product development (NPD)	Development of new products (goods)	Netherlands
Graner and Mißler-Behr (2013)	To analyze two key determinants for the successful use of methods for development of new products: top management support; formalization of the product development process	Development of new products (goods)	Germany, Austria and Switzerland

Source: Authors (2014).

Table 2
Hypotheses and test results.

Reference	Hypotheses	Results
Nijssen and Frambach (2000)	H1: The level of involvement of top management with the NPD process has a positive effect on the level of adoption of NPD tools and techniques	WS
	H2a: The size of the company has a positive effect on the level of adoption of NPD tools and techniques	R
	H2b: The number of steps within the NPD process is positively related to the level of adoption of NPD tools and techniques	S
	H2c: The number of departments involved in the company's NPD has a positive effect on the level of adoption of NPD tools and techniques	FS
	H2d: The level of communication between departments has a positive effect on the level of adoption of NPD tools and techniques	S
	H3: An NPD strategy focused more on changing many products has a positive effect on the level of adoption of NPD tools and techniques	S
	H4: Former users of NPD tools and techniques are more likely to adopt new NPD tools and techniques	S
Chai and Xin (2006)	H1: NPD tools that bring high tangible benefits will have high-level application in the industry	WS
	H2: NPD tools with a high level of usability will have high-level application in the industry	R
	H3a: A company strategy with high orientation to innovation will lead to a high-level application of NPD tools in the industry	S
	H3b: This effect will be less significant in an industry with high level of R&D and innovation than in an industry with low level of R&D and innovation	S
	H4: A high level of management support will lead to high-level application of NPD tools in the industry	S
	H5a: The size of the company has a positive effect on the application of NPD tools in the industry	S
	H5b: This effect will be less significant in an industry with low level of R&D and innovation than in an industry with a high level of R&D and innovation	S
Vaccaro et al. (2010)	H1: The higher the level of culture of change, the higher the level of trust in KMTs	WS
	H2: The higher the level of ease in the use of tools replacing face-to-face contacts, the greater the trust level in KMTs	S
	H3: The higher the level of collaboration experience, the higher the level of trust in KMTs	S
	H4: The higher the level of mutual trust, the higher the level of trust in KMTs	WS
	H5: Higher levels of trust in KMTs will be positively associated with higher levels of financial performance of the business unit	S
	H6: Higher levels of trust in KMTs support higher levels of performance of the new product	S
	H7: Higher levels of trust in KMTs support faster speed to the market in the development of new products	S
	H8: Higher levels of performance of the new product will support higher levels of financial performance	S
	H9: Faster speed to the market will lead to higher levels of financial performance	R
Graner and Mißler-Behr (2013)	H1: Top management support has a positive impact on the application of methods in NPD	S
	H2: The existence of a formal and structured NPD process has a positive impact on the application of methods in NPD	S

Source: Authors (2014).

goal for using MTT-I is to avoid failure of the project, increasing their probability of success. Thereby, there is a positive relationship between the application of MTT-I and the performance of organizations (Chai & Xin, 2006; Nijssen & Frambach, 2000; Nijssen & Lieshout, 1995). Then, to encourage the successful use of these MTT-I in order to positively influence the development of new products and the performance of the organization, it is necessary to have a well-structured development process (Nijssen & Lieshout, 1995).

The use of MTT-I throughout the development process has several benefits, which were highlighted by several studies (González & Palacios, 2002; Mahajan & Wind, 1992; Nijssen & Frambach, 2000; Thia et al., 2005; Yeh et al., 2010). In this context, they can help organizations manage the complexity of innovation projects, adapt to changing circumstances, and systematically meet the challenges of the market (D'Alvano & Hidalgo, 2012; Igartua et al., 2010). In addition, they can be an effective way to generate new ideas and improve the innovation capacity of organizations (Fernandes et al., 2009; Graner & Mißler-Behr, 2013).

There are several reasons for using MTT-I. According to Nijssen and Lieshout (1995) identifying problems is the main motivation. Given that the MTT-I can help analyze problems more systematically, they can therefore help supporting the communication between the parties involved in the development process of new products and in decision-making processes (Nijssen & Frambach, 2000). Improving the success rate and supporting the sales force are also strong reasons for adopting MTT-I (Nijssen & Lieshout, 1995). Besides those already mentioned, other studies have also pointed to identifying problems and improving the success rates as the main reasons for the adoption of MTT-I by organizations (e.g. Chai & Xin, 2006; Mahajan & Wind, 1992).

According to D'Alvano and Hidalgo (2012), MTT-I can significantly increase the ability to solve problems and productivity, making possible the solution of types of problems that otherwise would be impossible to answer. It is noteworthy that although it is not a guarantee of success, the MTT-I use can help in identifying problems in a systematic way, complementing the organization's efforts (Cooper & Kleinschmidt, 1986; Nijssen

& Frambach, 2000) and reducing the inherent uncertainties to the development process of new products (Chai & Xin, 2006), to improve the overall success rate of new products (Mahajan & Wind, 1992; Nijssen & Frambach, 2000; Yeh et al., 2010).

Hidalgo and Albors (2008), through research developed mainly in small and medium-sized enterprises in Europe, found that the MTT-I can help promote competitive advantage, increasing flexibility and efficiency, helping managers to effectively manage knowledge, improving productivity and time to the market, improving relations with suppliers, gathering online marketing information, and facilitating teamwork. In addition, the integration of different sources of information about customers, cost reduction, assistance to IT-based solutions, and the elimination of redundant processes were also benefits cited in this research (Hidalgo & Albors, 2008).

According to Chai and Xin (2006), an MTT-I will only be valuable when used in a position to provide tangible or intangible value to the user. Thereby, to the authors, the improvement of the project and the reduction of developing time are tangible benefits that can be observed in the short term (Chai & Xin, 2006). On the other hand, intangible benefits such as better understanding of consumer needs and the improvement of cross-functional communication between teams are more likely to be revealed in the long term (Chai & Xin, 2006). Empirical evidence suggests that most of the MTT-I users are satisfied with their performance (Mahajan & Wind, 1992; Nijssen & Frambach, 2000; Nijssen & Lieshout, 1995) and are more likely to experience other MTT-I (Nijssen & Frambach, 2000). However, some studies have shown that despite the benefits, there is an underutilization of MTT-I (Mahajan & Wind, 1992; Nijssen & Frambach, 2000; Nijssen & Lieshout, 1995; Yeh et al., 2010).

Nijssen and Lieshout (1995) identified in their research that few organizations abandoned previously used MTT-I. Thus, the low number of users who discontinued use of MTT-I and the high level of satisfaction reported in the studies show that MTT-I are really effective and can help improve the organization's performance (Nijssen & Frambach, 2000).

On the topic of shortcomings, Hidalgo and Albors (2008) state that the main difficulties in relation to the MTT-I seem to revolve around its introduction in an organization, since it means an extra effort that requires time, motivation and money (Hidalgo & Albors, 2008). In this context, some studies have raised the main shortcomings and difficulties for MTT-I. The main shortcomings of the MTT-I use are the time it takes to execute or implement (Mahajan & Wind, 1992; Nijssen & Lieshout, 1995), predictability of unforeseen problems (Chai & Xin, 2006; Mahajan & Wind, 1992; Nijssen & Frambach, 1998; Nijssen & Lieshout, 1995) and the possibility that the market is too complex to capture all the aspects of MTT-I (Mahajan & Wind, 1992; Nijssen & Lieshout, 1995). MTT-I are also mentioned for having a high cost of implementation (e.g. Mahajan & Wind, 1992 cite the home use test) and being of difficult implementation (e.g. Nijssen & Lieshout, 1995 cite the QFD). Moreover, the complexity of the MTT-I, the possible difficulty of learning how to use it and the lack of an easy-to-use software are deficiencies that negatively affect the application of MTT-I (Chai & Xin, 2006; Mahajan & Wind, 1992).

There are still MTT-I based on matrices that according to Phaal, Farrukh, and Probert (2006) have potential disadvantages. Thereby, authors state that many practical problems are difficult to be simplified in only two dimensions. Moreover, in practice these MTT-I may require some degree of customization or development, which can generate an extra effort of the organization. Also in relation to these types of MTT-I, Phaal et al. (2006) call attention to the relative simplicity of these approaches which, combined to the large availability number, can result in misuse since the theoretical foundations of the MTT-I may not be sufficiently clear or the knowledge and skills necessary for its use are not suitable.

With the difficulties involved in implementing and/or using an MTT-I, comes the challenge of motivating the management support, of thinking about the future and encouraging creativity, to install a culture of formulating an innovation strategy and for the implementation of the innovation process (Hidalgo & Albors, 2008).

Regarding context, it appears that most of the work is concentrated in Europe and the United States. It was found only one work dealing with the Brazilian context (Vaccaro et al., 2010). Although a significant part of the works seek to identify which MTT-I are used in every part of the product development process, or the innovation process (e.g. Mahajan & Wind, 1992; Nijssen & Lieshout, 1995; Yeh et al., 2010), few studies have focused specifically on the initial activities of the innovation process or the product development process, except for Creusen et al. (2013) and Val Jauregui and Justel Lozano (2008). However, both works deal with the product development context. Still on the topic of context, some researches make possible – due to being quite similar – the comparison of results between different contexts, as is the case Mahajan and Wind (1992) and Nijssen and Lieshout (1995).

Under the methodological point of view, the low response rate obtained by a relevant part of the studies stands out. The mean response rate was about 30%. However there are rates such as obtained by Chai and Xin (2006), of 4.7%, and as obtained by Hidalgo and Albors (2008), 10.65%. Few studies indicate the reasons for the low response rate. Chai and Xin (2006) for example attribute this problem to the difficulty of identifying companies involved in developing new products in the database of companies available for the study.

It was also verified, by the types of respondent companies, that most of the research has been developed in the context of goods rather than other types of innovation, such as services and processes. Many of the studies even use the term "new product development". This complicates the understanding of the role of MTT-I in the context of innovation, wider and more complex for dealing with other types of results that not only goods, for example, services and processes.

Regarding the analysis unit, two of the works (Graner & Mißler-Behr, 2013; Vaccaro et al., 2010) deal with projects rather than companies. This strategy has two advantages that are worth mentioning. The first one concerns the fact of enabling a greater number of respondents, since in the same company two or more professionals can answer the questionnaire. This enables, for example, the evaluation of similarities and differences between

the responses of the same company, when related to general aspects of the organization. The second advantage is related to the fact that for different projects in the same company, some of the variables may also be different. For example, if a product is especially important for the company, it is likely to have a greater involvement and top management support (Graner & Mißler-Behr, 2013), variables associated with the adoption of MTT-I (Chai & Xin, 2006; Graner & Mißler-Behr, 2013; Nijssen & Frambach, 2000).

Final considerations

This study analyzed the quantitative empirical researches regarding the diffusion and adoption of methods, techniques and tools for innovation (MTT-I). The papers analyzed were obtained from a systematic survey in two databases: Scopus and Web of Science. After the elimination of repeated papers and those not relevant to the study, we reached a total of 14 papers, which were added to four other papers selected from the references of papers initially surveyed. Thus, the basis of analysis consisted of 18 quantitative empirical papers. The little attention given to the subject, despite the clear benefits in relation to the MTT-I use, indicates that this field is fertile for further research.

Terminology issues seem to be still unresolved in this field. It was found that although conceptually distinct, the terms diffusion and adoption are poorly differentiated in studies. Works mainly use the term adoption, and the issue of diffusion appears implicitly since the adoption of a particular MTT-I depends on its diffusion. The latter is often measured by knowledge of a particular MTT-I by the respondent company (e.g. Nijssen & Lieshout, 1995). Future research may address factors that influence the MTT-I after the example of those few works that explicitly discuss the factors related to adoption (e.g. Chai & Xin, 2006; Graner & Mißler-Behr, 2013; Nijssen & Frambach, 2000). Since the benefits of MTT-I use seem clear (González & Palacios, 2002; Graner & Mißler-Behr, 2013; Yeh et al., 2010), the identification of factors related to diffusion and adoption of MTT-I may help so that more organizations have access to them. This can also facilitate the construction of approaches to choose the most appropriate MTT-I to the organizational context, in step with the theory of contingencies.

The focus of most studies on products (goods) demonstrates the need of introducing more strongly the theme in the innovation field which, for contemplating other results like new/improved services and processes, becomes more complex regarding the development of goods. A future research could compare the MTT-I adoption and the characteristics of each type of result of the development process. Specifically, one can seek to identify factors related to adoption that are also related to the type of innovation developed.

The inclusion of the theme of innovation in the studies eventually leads to another important point, the degree of process structuring. While in the development of new products the design process appears to be related to a higher performance, there are still discussions regarding the structuring in the beginning of the innovation process, the front end of innovation (FEI). The activities that take place within the FEI are traditionally characterized by low levels of formalization and often remain interrelated, unstructured and uncertain (Khurana & Rosenthal, 1997). While in the development of new products the structuring is related to a greater use of MTT-I, this may not be true in FEI, or may even reduce its performance. One argument against the formality and structure of the FEI is that much time can be spent in preparation for evaluations (Aagaard & Gertsen, 2011; Cooper & Kleinschmidt, 1990). An even more problematic concern is that excessive formality can reduce creativity and flexibility to the FEI (Verganti, 1999). The low number of studies related to MTT-I adoption in FEI demonstrates the latent need for further understanding in this field.

Another point that deserves further development is related to shortage of works in different contexts. Like Nijssen and Lieshout (1995), who compare their results to those previously obtained by Mahajan and Wind (1992), few studies can suffer this kind of comparison given the methodological differences between them. Still on the methodological point of view, the samples used in the works are usually unrepresentative in number, often less than 100. This brings clear limitations to generalizing the results. It is also important to point out that the measures for adoption are usually dichotomous (yes and no). Few studies measure the intensity in which MTT-I are used, meaning the frequency of use as well as the depth, according to the specifications of use (see Graner & Mißler-Behr, 2013; Nijssen & Frambach, 2000). It is believed that these measures are also important to explain the adoption of MTT-I.

Finally, considering the presented context, different focus areas of the papers were identified (Knott, 2008): MTT-I diffusion (related to the number of organizations and potential users aware of specific MTT-I); MTT-I application (extending their use in the development process); factors that determine the adoption; application areas in the development process; obstacles to adoption (both internal and external to the organization); deficiencies of MTT-I; types of organizations adopting them; common characteristics of MTT-I users; and performance in the development process with application of MTT-I. Therefore, further research is expected to deepen the issue of diffusion and adoption of MTT-I, both theoretically and empirically.

Conflicts of interest

The authors declare no conflicts of interest.

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