The research evolution of the "Platform" concept: a bibliometric study

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Abstract
The objective of this research is to carry out an analysis of the evolution of scientific research on the concept of "platform". The study employed a bibliometric method for the quantitative analysis, followed by a qualitative analysis of the contents of selected articles and books identified of greater relevance.

Keywords: Platforms, Innovation, Development of New Products

Introduction

The role of product and service platforms within companies and in mediating the activities of business conglomerates or ecosystems has been widely recognized as being of great importance to manage processes of new businesses, in the development of new products, and in innovation (Meyer and Lehnerd 1997; Baldwin and Woodard 2008). According to Baldwin and Woodard (2008), the concept "platform" has been explored in research on product development, technological strategy and industrial economics.

Taking these considerations into account, the objective of this work is to carry out an analysis of the evolution of scientific research on the concept of "platform" and its consequences, considering the works of a number of researchers, and using bibliometric techniques.

The bibliometric analysis was used to try to ensure that different theories were tested extensively and represented satisfactorily the universe of knowledge on the subject. In addition, it is understood that this process should be sufficient for the construction of history and description of different theories on the concept "platform".

This paper aims to obtain an overview of research on the concept of "platform" and its evolution over time. It aims to improve understanding of this concept, to use it in future field

research related to this topic, such as the study of the role of "platforms" of products and services in the chain or ecosystem of software production of Brazilian companies.

Next, the research methodology is presented describing the first stage of the bibliometric analysis and the second stage of content analysis of the main references highlighted in the first stage. Also it will be presented the criteria for obtaining the sample of articles that will be analyzed.

Then search results will be discussed, and finally, will be presented the conclusions of this study.

Methodology

To achieve the objective of this study, the research was conducted in two stages:

- Bibliometric study for identification and selection of the main theoretical references about the concept "platform" through quantitative analysis of a sample of publications and citations;
- Content analysis of the main bibliographic references, selected from the first stage.

The reason for choosing the method is the increase of relevance of bibliometric studies, considering the growing number of scientific publications, and the ability to use techniques that can quantify the process of written communication (Ikpaahindi 1985), and also capacity of the citation analysis to identify important scientific works as well as their interrelationships (Chai and Xiao 2012; Chen 2006).

Sample

The database for bibliometric study was extracted from the database *ISI Web of Science* from *Thomson Reuters*, chosen for providing one feature that allows extracting a set of metadata, such as abstracts, authors, institutions, number of citations, references cited and the journal impact factor, among others, which are essential for carrying out a bibliometric analysis.

To select the database for the research, the search criteria were considered for the following topics: "*Product Platforms*" or "*Product Platform*" or "*Technological Platforms*" or "*Technological Platform*" or "*Industrial Platforms*" or "*Industrial Platform*" or "*Technology Platforms*" or "*Technology Platform*". This search resulted in 2227 studies, categorized by Web of Science in diverse research areas. From this initial sample, some filters were used to refine the results, as described below.

For the "Document Type" was considered the "Article" filter, since this type of document passes through peer review and has the most complete set of metadata on the ISI Web of Science database. After this refinement the sample was at 1088 articles.

Among the first 100 "categories of the Web of Science", we decided to use "*Management*", "*Engineering Manufacturing*", "*Operations Research Management Science*", "*Engineering Industrial*", "*Engineering Multidisciplinary*", "*Business*", "*Computer Science Software Engineering*" and "*Computer Science Interdisciplinary Applications*", which are categories regarding the focus of interest of this study. With this refinement, the sample resulted in 288 articles.

All 288 abstracts were then read. Some articles were excluded after this analysis. As a criterion for exclusion, we considered the fact that certain articles, despite containing the topics used in the search, do not address the concept of "platform" as its central theme or as part of its

theoretical contribution. After reading the abstracts, 72 articles were excluded, leaving a final sample of 216 articles published in 77 journals, between the years 1993 and 2013.

Based on the definition of the sample, the generation of the export file with all metadata available in the database of the ISI *Web of Science* for the 216 articles was performed, to be imported and used in the CiteSpace software. Some of the results of the quantitative data analysis of this sample, shown below, were obtained with the assistance of bibliometric analysis tools available at the ISI Web of Science and the software CiteSpace for citation analysis and cluster analysis

Quantitative Data Analysis

With one of the bibliometric analysis results you can check the progress of research on the subject studied, considering the number of publications over the years (Figure 1). The graph shows an upward trend in the number of articles addressing "platform", until about 2009, when there was a peak in the number of publications, with 25 publications. Despite the sharp drop in the number of publications displayed in 2010, when 8 articles were published, it can be observed in 2011 and 2012 a resumption of the upward trend, with 16 and 18 articles published respectively, showing that this is still an issue that attracts the interest of researchers.

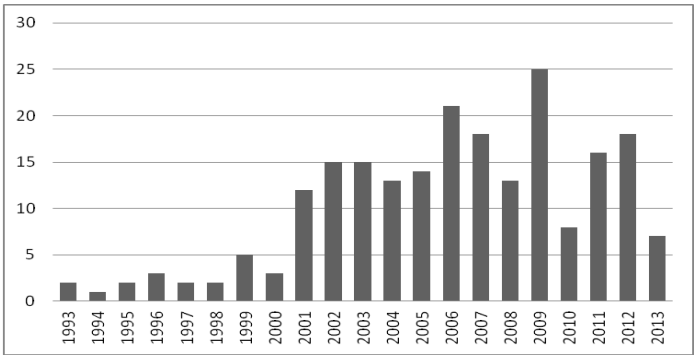

Figure 1 - Number of articles per year in the sample. Source: Elaborated by the authors.

The bibliometric analysis also allowed the identification of the authors that stood out among the publications involved in this study. Within the set of 424 authors of 216 articles selected, Table 1 lists some of the authors with highest number of publications in the sample.

Table 1 - List of 8 most cited authors of the articles in the sample. Source: Elaborated by the authors.

Autores	Qtd. Artigos
Simpson, TW	20
MEYER, MH	11
Chen, CH	7
Yan, W	7
Huang, GQ	6
Shooter, SB	6
Alizon, F	5
Siddique, Z	5

One of the premises of bibliometric analysis takes into account the number of times a given article is cited by other papers, to consider it more influential. That is, the most cited, the greater the influence of an article as concepts and methods driver in a given field of research.

Under this assumption and using the information on amount of quotes from an article by the other items that make up the database, you can draw up a list of the most relevant articles within the 216 selected articles. Table 2 lists some of the items with the highest number of citations and, therefore, those considered the five most influential in this sample.

Table 2 - List of 5 most cited scientific articles in the sample. Source: Elaborated by the authors.

Article	Author	Journal	Published	Times Cited
Planning for product platforms	Robertson, D.; Ulrich, K	Sloan Management Review	1998	293
Product platform design: method and application	Simpson, TW; Maier, JRA; Mistree, F	Research in Engineering Design	2001	215
The product family and the dynamics of core capability	Meyer, MH; Utterback, JM	Sloan Management Review	1993	146
Metrics for managing research and development in the context of the product family	Meyer, MH; Tertzakian, P; Utterback, JM	Management Science	1997	123
Product modularity: definitions and benefits	Gershenson,JK; Prasad, GJ; Zhang, Y	Journal of Engineering Design	2003	121

Analyzing the citations of the sample articles it can be highlighted the authors who were most cited (Table 3), on the references of the 216 articles of the sample.

It is observed a relationship with previous analyzes, where Simpson and Meyer authors once again lead the list of the most cited authors, considering the references of articles. In this list there are two other authors that are noteworthy for having articles published among the most cited in Tables 2 and 4, Karl T. Ulrich, professor of entrepreneurship and e-commerce at Wharton School of the University of Pennsylvania and Mark Martin, chief executive officer of the company Design4X and PhD in mechanical engineering from the University of Stanford.

Table 3 - List of the 12 most cited authors in the references of the articles in the sample. Source: Elaborated by the authors.

Authors	Number of Citations
Meyer M. H.	228
Simpson TW	184
Ulrich K. T.	101
Martin M.V.	71
Sanderson S. W.	60
Gonzalez-Zugasti	54
Robertson D	53
Pine B. J.	46
Messac A	46
Sanchez R	46
Wheelwright S.C.	44
Baldwin CY	42

With assistance from the CiteSpace software (Chen 2006) it was performed a citation analysis (Figure 2) that supported the development of Table 4, with the list of the 18 most cited references on the sample articles of 216 articles. In this list there are, not only articles, but also books that are referenced in the sample articles, so in Table 4 are shown the names of the publishers who have published these books, as well as the names of the journals in the case of the most cited articles.

Table 4 - List of the 18 most cited references by the articles in the sample. Source: Elaborated by the authors.

References	Journal/Editor	Citations
Meyer and Lehnerd (1997)	The Free Press	104
Robertson and Ulrich (1998)	Sloan Management Review	54
Ulrich (1995)	Research Policy	43
Simpson, Maier and Mistree (2001)	Research in Engineering Design	42
Ulrich and Eppinger (2000)	McGraw-Hill	35
Meyer and Utterback (1993)	Sloan Management Review	33
Pine (1993)	Harvard Business School Press	33
Simpson (2004)	Ai Edam	32
Wheelwright and Clark (1992)	The Free Press	25
Simpson, Siddique and Jiao (2006)	Springer	23
Sanderson and Uzumeri (1995)	Research Policy	23
Baldwin and Clark (2000)	MIT Press	22
Nayak, Chen and Simpson (2002)	Engineering Optimization	21
Martin and Ishii (2002)	Research in Engineering Design	20
Meyer, Tertzakian and Utterback (1997)	Management Science	20
Henderson and Clark (1990)	Administrative Science Quarterly	19
Messac, Martinez and Simpson (2002)	Engineering Optimization	18
Baldwin and Clark (1997)	Harvard Business Review	18

To generate Figure 2, the tool was parameterized to consider the 30 most cited references in each interval of a year in the period from 1993 to 2013, which allowed us to consider practically all references of the 216 articles of the sample. But in this case, it is difficult to make any visual analysis, being necessary to work with the information that the tool provides, after the generation of the network.

With CiteSpace software is also possible to build "clusters" from a set of quotes, which are nothing more than groups of papers that address a subject under a particular point of view. The generation of these "clusters" is determined by groups of citation network and can receive a nomenclature from terms used in the title, keywords and references of articles of summary. In CiteSpace there are tools that allow the generation of these groups automatically. In Figure 3 it is shown the result in the generation of "clusters" considering only the 40 most cited references throughout the period 1993-2013.

The "clusters" automatically mapped in CiteSpace software, can demonstrate an interest of these authors on the concept "platform" from the point of view of product development, as can be seen by the generated clusters, references cover topics related to the projects of new products, the product lines and the design of the product platform.

When considering the 30 most cited references in each interval of one year, in the period from 1993 to 2013, other groups were generated, since more references began to be considered in the citation network, pointing to the emergence of other areas of interest. This can be seen in Figure 4.

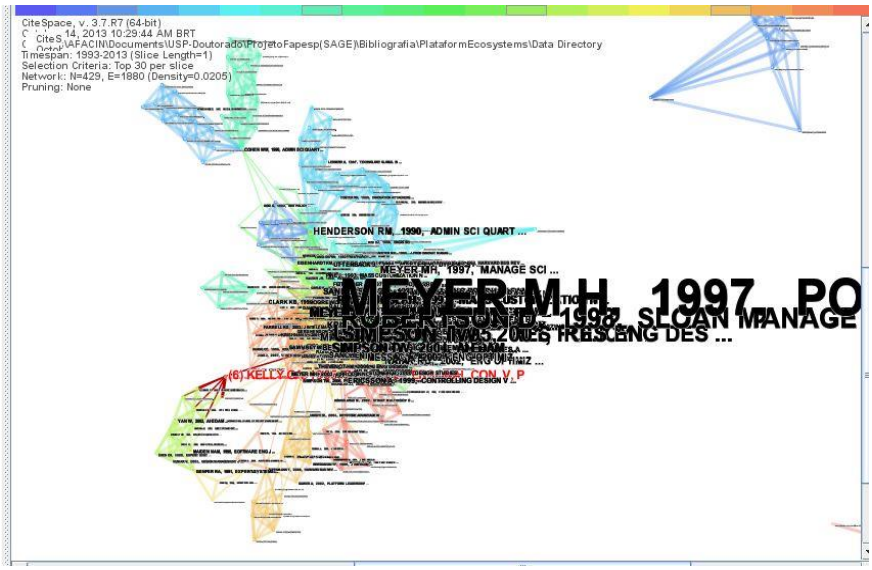

Figure 2 - Expanded network of citations generated in the software CiteSpace (Chen 2006)

Figure 3 - "Clusters" generated for the 40 most cited references between 1993-2013 (using Software CiteSpace (Chen 2006))

These clusters also address aspects of modular architecture, product platform development, complementarity, product development management, product concept, etc. As expected, the most cited references have common interests on the same subject, as they present a large number of links between them. In Figure 4, as in Figure 2, it is also possible to verify that there are more references groups distant from network center, which can demonstrate the migration of the search for more specific areas of interest, thereby forming the other groups of researchers.

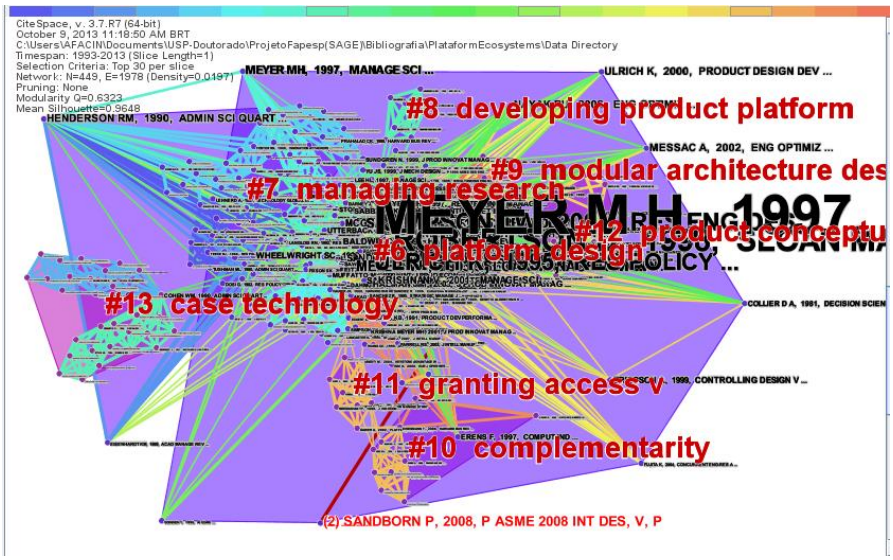

Figure 4 - Some "clusters" generated from the expanded network of citations (using Software CiteSpace (Chen 2006))

Content Analysis

In Meyer and Lehnerd (1997), a definition for the term "product platform" is presented as a set of subsystems and interfaces which form a common structure from which a number of derivative products can be developed and produced efficiently. This would be a central and common technological basis of a "product family". The "product family", in turn, is defined as a set of products that share this "product platform" and that meet a certain set of market applications.

Meyer and Utterback (1993) had already defined "product platform" as something that encompasses the design and components shared by a set of products, and emphasized that a robust platform is the heart of a family of successful products, and serves as a foundation for a series of closely related products. In his article, they state that to have the ability to build a family of products, rather than just single products, requires companies to manage their "core competencies", those discussed by Prahalad and Hamel (1990).

Before them, Wheelwright and Clark (1992), cited by Gawer (2009), had used the term "product platform" to describe new products that address the needs of a core group of consumers and should be designed to be easily transformed into derived products through addition, replacement, or removal of features.

Kim and Kogut (1996) introduced the concept of "technological platform". They discuss the fact that technological discoveries can branch out into new applications and new markets. In this context, the "technological trajectory" would be the evolution and branching of technologies to be derived from the new discoveries.

A "platform" is defined by Robertson and Ulrich (1998) as a group of assets categorized as components, processes, knowledge, and people that are shared by a number of products.

Whereas Meyer and Utterback (1993), Meyer and Lehnerd (1997) and Meyer, Tertzakian and Utterback (1997) brought great visibility for the approach of developing product families based on platforms and mainly stressed the benefits of the platforms, the research conducted by Robertson and Ulrich (1998), by contrast, emphasized the potential loss of product differentiation that can occur with the use of platforms, without neglecting their beneficial effects on the efficiency of the product design.

Ways of measuring the performance of R&D in new product development have been proposed by Meyer, Tertzakian and Utterback (1997), in order to more clearly understand the dynamics of renewal of platforms and generations of derivative products, and the consequences of this dynamic in the success of the companies in the long term. In this sense, Meyer and Mugge (2001) reinforce the need for planning platforms that incorporate innovation as a way to drive business growth.

Krishnan and Gupta (2001) define platforms as being assets, which in turn are components and subsystems shared by a family of products. When companies make use of this sharing, their investments in design and new product development are mobilized more efficiently.

The fact that the design of a product family inherits all the challenges of a single product design, added to the complexity of coordinating the design of multiple products in an effort to maximize the sharing of components (commonality) within a set of products, without compromising the individual performance of each product, is covered by Nayak, Chen and Simpson (2002). To deal with these challenges, these researchers propose a method called VBPDM (Variation-Based Platform Design Method) to design a family of products that must satisfy a range of performance requirements using the least variation in designs of this family of products.

An approach that employs the "Physical Programming" method to enable product designers to formulate problems of continuous improvement of product families using terms and parameters with physical significance was proposed by Messac, Martinez and Simpson (2002). To prove its efficiency, this method was tested in the design of a family of ten universal electric motors.

Simpson, Maier and Mistree (2001) shows methods for designing a product platform, which is defined as a set of parameters, features and/or components that remain constant for each product within a product family.

Martin and Ishii (2002) deal with aspects of standardization and modularization in the development of the architecture of the product platforms, aimed at building robust architectures that bring competitive advantage by reducing project efforts and time to market for future product generations. According to Henderson and Clark (1990), the effect of product architecture innovation is a central issue of research on technological innovation.

Is worth mentioning that the use of the concept of modularization in new product development is shown in Baldwin and Clark (1997), as a way for companies to deal with the increasing technological complexity of their products. This growing complexity caused a migration of modularization of production processes for the design phase of products.

A review of the research activity, aimed at facilitating the design of product families and the product development based on platforms to meet mass customization, was performed by Simpson (2004). In his research, he identifies two basic approaches to design product family. The first is a proactive approach in which the company strategically manages and develops a family of products based on the product platforms and its derivatives. The second is the reactive approach in which the company redesigns or consolidates a distinct group of products to standardize components to improve economies of scale. These two approaches are also discussed by Simpson, Siddique and Jiao (2006), which mentions that the product platform can additionally promote learning about the products, which can reduce testing and certification procedures for complex products, such as aircrafts.

Fixson (2005) worked on the development of a model to evaluate product architecture. For this, he constructed a multidimensional theoretical framework based on product characteristics, such as sharing of components (commonality), product platforms and modularization of products. He proposes that the model be used focuses on the product architecture dimensions that are critical for a given operating strategy. In this way, he proposed to make it possible to know the advantages and limitations of operational strategies, along with certain product architectures.

Conclusions

The adoption of a systematic process of literature review has shown to be useful in the analysis of emerging concepts, making it possible to find certain patterns that characterize the studied field. In all analyzes, were observed the same group of highlighted authors. The results of this bibliometric study phase showed the influence of authors such as Meyer, Simpson, Ulrich and Martin. This is an important result of the research. Using the process of systematic literature review, a list of authors and publications were obtained as the most relevant in this field and therefore deserving a in depth study.

It is important to note as a limitation of this study the fact that it was only used one database, which does not cover all research work carried out on "platform" concept. It is evident the lack of works that reflect the use of this concept in the Brazilian scenario. The fact that the analysis involves only articles and references with the highest number of citations may also have compromised the assessment of research trends on "platform" concept.

A bibliometric study of this magnitude, involving so many quotes, depends on the quality of the information contained in the articles analyzed. Errors and lack of standardization, particularly in the register of references may compromise the results.

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