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# TeknoRoadmap, an approach for depicting emerging technologies

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ABSTRACT

One of the biggest challenges for current enterprises is the adoption of emerging technologies as soon as these provide competitive improvements. In this sense, several types of technology forecasting and surveillance activities are present in their daily activity. From the academic point of view, technology forecasting activities involve the combination of methods of a diverse nature, with which the technology is depicted and its potential future paths are discussed. Within this conceptual framework, the present work aims at describing a novel approach, known as TeknoRoadmap, which combines bibliometrics and technology forecasting methods to depict emerging technologies. Thus, this contribution aims to widen the scope compared to those provided by previous works within the field, and to that end, the depiction of emerging technologies is provided based on two main elements, namely: the profile of the research activity; and a complete technology roadmap. The approach combines consolidated methods such as text mining and roadmapping, and novel ones such as web content mining, with special attention given to forecasting activities. The work provides a detailed description of the steps on which the approach is structured, as well as the results of one specific application to a cutting edge emerging technology: cloud computing.



## 1. Introduction

The contribution of the present work falls within the framework of two different research fields: *technology forecasting* and *bibliometrics*. Nowadays, the importance of technology forecasting activities is given by the fact that they are present in many forms of the current society. For example, big companies require it in several crucial aspects, such as prioritizing research and development paths, planning new products developments and taking strategic decisions such as technology license agreements (Firat et al., 2008). In the case of small and medium enterprises (SMEs), these kinds of initiatives are less common and usually need someone to help them initiate the change and adoption of new technologies (Major and Cordey-Hayes, 2000). Together with this, governments use technology forecasting for making choices between competing alternatives in science and technology, and for linking science and technology more closely to the nation's economic and social needs (Martin and Johnston, 1999). Forecasting initiatives have relied heavily and are still mainly based on qualitative methods. These kinds of methods present several shortcomings and a strong tendency towards the use of quantitative methods is establishing itself. In fact, many authors suggest the use of multiple methods to compensate in any one approach (Salerno et al., 2008). In regards to quantitative methods included in forecasting exercises, researchers have long realized that technology monitoring and forecasting aims can be served by bibliometric analyses. Thus, bibliometrics provide a powerful source of information on emerging technologies and their potential (Porter and Detampel, 1995).

Based on the above, the present work aims combining both fields based on a novel approach, known as *TeknoRoadmap* (*TKRM*), with which a complete depiction of emerging technologies can be obtained. This approach contains methods of a quantitative and qualitative nature. Quantitative methods are represented by *bibliometrics*, which more than a method, can be regarded as a research field; *data mining*, in terms of *text mining* and *web content mining*; as well as *trend analysis*. Semi-quantitative methods are represented by *technology roadmapping* (*TRM*). Finally, qualitative methods are integrated by means of *expert assessment*, which introduces a counterpoint to the quantitative methods. The approach is based on eight steps which are divided in two phases and the specific objectives can be summarized as follows:

- Collect and organize scientific and non-scientific information related to an emerging technology.

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- Describe the research activity profile of the technology. Specifically, the *literature profile and research community profile*; and *the state of the research and its evolution*.
- Depict the prior evolution of the technology and forecast potential paths of the short and medium-term future, identifying the necessary elements for this purpose: sub-technologies, technology applications, and links among both.
- Integrate all the information of the evolution of technology in a TRM.

The embryonic idea of the present approach was presented in Bildosola et al. (2015), where the combination and naming of the steps on which the approach is structured was motivated. In addition to this, further description of the first part of the approach (first three steps), and partial results from their application were provided in Bildosola et al. (2017). In that work, the selected technology to be depicted was cloud computing (CC), a cutting edge emerging technology with huge impact in the current enterprise. Following the logical path, the present work relies on the mentioned works and aims to delve deeper into the second part of the approach, detailing the steps that constitute it and the results of their application to CC technology, as well as presenting the complete approach as a whole. The structure of this paper includes the following parts: in "Research objective" a brief summary of the specific goals of the approach are provided. The "Background" section analyses the research fields which constitute the framework for the approach. The "Research approach: TeknoRoadmap (TKRM)" section provides a comprehensive explanation of the approach, with special attention to its second part. In this sense, each step is described thoroughly in terms of input information, output outcome and methods and tools used. In "Approach result: depicting cloud computing", the depiction of the CC technology is provided. Finally, the "Conclusions and future work" section is dedicated to the interpretation of the obtained results, as well as to describing the limitations and future lines of study that may result from this work.

## 2. Background

The main goal of the TKRM approach is to depict emerging technologies, with particular attention to its forecasting. Martino (1993) defined technology forecasting as a prediction of the future characteristics of useful machines, procedures, or techniques. From its origins, there have appeared many overlapping ways of forecasting technology developments and their subsequent impact, including technology intelligence, forecasting, roadmapping, assessment, and foresight (Firat et al., 2008). The existing diversity of methods belonging to forecasting activities has led to attempts to summarize and structure the field. In this sense, Popper (2008), created a Foresight Diamond which identifies 33 methods and distributes them within a diamond, based on seven attributes. It is analyzed from one side depending on whether the methods are based on evidence, expertise, interaction or creativity, and from the other side analyzing the nature of each methodology, their proximity given to be qualitative, semi-quantitative or quantitative. This schematization is a clear indicative of the diversity of methods involved in this field.

Focusing on research fields and methods included in the TKRM, bibliometrics is used for the structuring of information, which is the base for a consistent forecasting exercise. Bibliometric analysis is based on three basic principles (Kongthon, 2004): measurement of the activity by counting publications; measurement of the impact by the analysis of the citations; and measurement of the citations by the analysis of the co-citations and the use of keyword article by article. Currently, specific tools that are used in this field encompass authors, affiliations, conceptual maps, clusters and factor analysis, citation and co-citation analysis (Daim et al., 2006). For instance, bibliometrics can help researchers in mapping and profiling their entire research domain (Börner et al., 2003). Analyzing the connection between bibliometrics and technology forecasting, it should be highlighted that both fields have experienced an important expansion within the last years and this has resulted in the proliferation of numerous methods within them. In addition, it can be said that both fields have suffered an interlinking process, especially in terms of technology-foresight-approaches using bibliometrics-methods. As an indicator of the connection between the two fields the following graph (Fig. 1) shows the number of works, contained in SCOPUS and WoS databases, which contain at least the word *bibliometrics* or *scientometrics*, and the word *technology foresight* or *technology forecasting* within their title, abstract or keywords. Even though the search is not consistent enough to draw solid conclusions, the observed evolution allows the increase in the combination of both fields to be described.

With regard to the methods included in the TKRM, text mining is used to complete the bibliometrics analysis. Text mining can be defined as the process of obtaining information from text-based data. Moreover, whereas bibliometrics focuses on measurement of scientific activity to find patterns and trends, text mining goes beyond processing the content of publications (Kostoff and Geisler, 1999). The importance of text mining and its applicability is supported by the appearance and growth of dedicated software options (Mikut and Reischl, 2011). Text mining tools can be used to examine research trends and patterns in the fields of technology management, using software developed specifically for these types of knowledge mining applications (Porter et al., 2003). In this context, numerous papers can be found where text mining and bibliometrics analysis methods construct the basis for some kind of forecasting exercise (see for example: Daim et al., 2006; Bengisu and Nekhili, 2006; Kajikawa et al., 2008).

TKRM makes also use of a novel method within the data mining field: web content mining. Gök et al. (2015) presented a work which examined the practicalities and effectiveness of web content mining as a research method for innovation studies. The authors concluded that website data offers additional insights when compared with other traditional research methods. However, it is hard to find actual web content mining applications for technology forecasting, with few examples such as that presented by Thorleuchter and Van den Poel (2013). In any case, it is worth noting that this method has demonstrated its potential to provide useful forecasting information for topics such as the price of mobile phones selling online (Zhu et al., 2011). Therefore, it can be said that technology forecasting and web content mining promises to be a profitable combination, however, it is only starting to be approached.

The final outcome of the TKRM approach is a complete TRM, which is used to integrate all the information in a single visualization element. Generally speaking, TRMs have a very varied use in both scientific and professional fields. Bray and Garcia (1998) underscore the major uses and benefits derived from technology roadmapping, and within the framework of technology forecasting they highlight that roadmapping provides a mechanism to help experts forecast S&T developments within targeted areas. Regarding the use of TRMs and its combination with other methods, the usefulness of bibliometrics to support technology roadmapping was already stated by Kostoff et al. (2004), and this connection has since grown. Thus, several works which combine bibliometrics and TRMs have been carried out (see for example: Zhang et al., 2013; Yoon and Phaal, 2013; Huang et al., 2014), although not all of them perform technology forecasting.

All the results obtained by applying the approach are finally evaluated by experts. Expertise has been widely used when it comes to forecast the evolution of technologies. This is justified by several reasons: some of the key behavioral elements are included; the variety of inputs and thereby the quality of results will increase; it will lead to broader support for the results and it may contribute to the democratic character of the process (Porter et al., 2004). In fact, many of the works cited above make use of it somehow (Daim et al., 2006; Bengisu and Nekhili, 2006; Thorleuchter and Van den Poel, 2013; Zhang et al., 2013; Huang et al., 2014).