A Bibliometric and Sociometric Study on Healthcare Systems Maturity Models (HSMM)

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Abstract. This research study identifies, using the Web of Science database, the most productive and cited journals, papers and authors in the field of Maturity Models (MM) applied to healthcare organizations, presenting the existent literature gaps. To do so bibliometrics, network analysis, and sociometrics were the tools of choice. The results present an exhibit with the most relevant papers found and revealed that 80% of the publications on MM are in the field of information systems and only 5% in the healthcare industry, concluding that there is a lack of MM that are able to fulfill the specificities of the healthcare organizations.

Keywords: Maturity Models · Healthcare · Process maturity level

1 Introduction

Maturity Models (MM) are based on organizational evolution and change predictable patterns, representing theories of how organizational capabilities evolve along an expected, intended or logical path [1]. An MM consists of sequencing maturity levels for a class of organizations or processes. It serves as a scale for evaluating the position and progress along the path to the desired maturity level [2]. [3] shows that MM present a comparison between an actual and a desired state of maturity and describe the required steps to reach that desired maturity level. A usual concern on the construction of MM applied to organizations is related to the suitable notion of maturity level; [3] proposes that maturity may have concepts focused on processes, object and products and people.

[4] poses that maturity Level refers to the effectiveness or capacity of any specific process. So, a maturity level is related to a level of organizational capacity gathered from the transformation and evolution of one or more processes' domains in an organization. Last decades' scenario shows more than one hundred MM created with focus on supporting TI management, as Analysis Capability Maturity Model (ACMM); Business Process Management Maturity Model

(BPMMM); Capability Maturity Model Integration (CMMI); Document Process Maturity Model (DPMM); E-Learning Maturity Model (eMM); IS/ICT Management Capability Maturity Framework (IC/ICT CMF) among others. By the way, [2] points out that limitations of the model building processes and methods have been described and that a gap exists respect to the documentation records of them. Research shows that, in the hospital context, a growing number of MM have been developed seeking improvement of the organizational processes [3]. However, [5] states that the existing BPMMM do not meet the specific needs of the healthcare industry.

[6] presents the design steps to a Business Intelligence (BI) MM development, on the specific domain of healthcare. They compare BI MM on multiple segments and conclude that the existent MM do not fulfill the healthcare area complexity, mainly on the external data integration and systems' interoperability. Although other segments had also presented needs of integrated data and external sources, in healthcare segment that requirement is a lot more complex, involving clinical data that should be integrated into the patient's health record, security issues on the information as well as interoperability and standardization of data meaning.

A recent study [3] presents the results of an MM five-year research study in the hospital environment. This research describes the project development and the challenges faced by the development team, since the design perspective through the implementation and assessment of the MM, presents the common barriers and restrictions to the implementation of MM in complex organizational environments, as are hospitals. A USA research study of 3,049 intensive care surgical general hospitals, affiliated to the American Hospital Association (AHA) [7] presented an electronic record system with 32 clinical functionalities considered as central to the hospital environment, targeting on assessing their implementation on the main clinical units of the researched hospitals. Results show that less than 2% of the hospitals have comprehensive electronic records, with an average of 10% having only basic systems and most with simple electronic records only.

[7] presents four essential functions that an electronic health record system must have. The research was carried in seven countries: USA, Canada, UK, Germany, Holland, Australia and New Zealand, and showed that, in the hospital context, the seven countries presented a rate of less than 10% of electronic records that contained the four essential functionalities.

Based on the organizational shortcomings presented in those research studies and in the healthcare area growing need to develop MM that permit to measure the maturity level of their processes, this paper aims — after identifying in the scientific literature related to MM applied to healthcare organizations the journals, papers and authors most relevant and those most cited by means of the use of bibliometrics and sociometry — to reveal the existent gap in the literature on the field and the need to fulfill it with adequate research.

2 Methodological Structure of the Research

According to [8], one can define bibliometrics as the study of the quantitative aspects of the production, propagation, and use of registered information in any

format. Bibliometrics develops patterns and a mathematical model to measure those processes, using the results to make forecasts and support decision making. Bibliometrics assumptions are based on statistical analysis to study the production characteristics and the use of catalog data or bibliographies of some knowledge area. [9] defines: Bibliometrics is the quantitative study of literature, as they are reflected in the bibliographies. Its task, immodestly enough, is to provide evolutionary models of science, technology, and funding.

On the other hand, sociometry is defined by [10, p. 564] as a broad sense term denoting a collection of retrieval and analysis of information about the choice, communication and interaction patterns of individuals in groups.

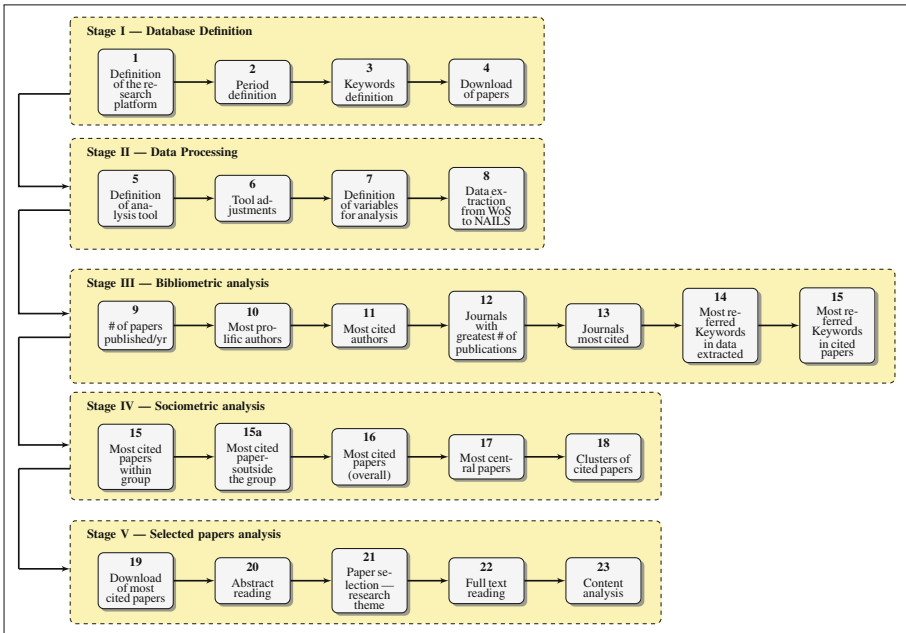Figure 1 presents the methodological structure of this research study.

Fig. 1. Methodological structure of the research

Stage I of the research defined the search platform, taking into account the academic prestige and the readiness to export summary data of the papers; after the definition and search of the keywords, the search time window was defined to the last 10 years, resulting in a small number of publications found. So the time window was removed and all publication were considered. Stage II defined the NAILS tool, which is a free software instrument capable of reading and processing summary data of the selected papers. Its use is fundamental due to the large amount of information retrieved. Stages III and IV developed the bibliometric and sociometric analysis identifying the publication volume,

most productive authors, most popular journals and most present keywords, as well as the most cited inside and outside the sample and the most central publications, and the clustering of cited publications inside the group. Finally, Stage V encompasses the most cited publications download, abstracts reading and selection of those directly related to the research theme. Those were fully read to develop their content analysis, which is condensed in an exhibit.
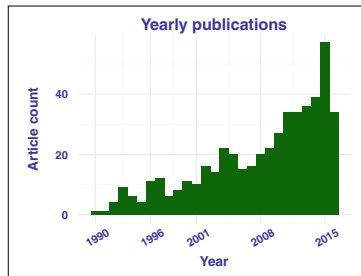
3   Development of the Research

Web of Science (WoS) was the platform used for this research study, and the NAILS tool [11] was adapted for producing the desired information. Data was collected during October of 2016. Targeting a general vision of the publications universe in the platform, the first search used only the term "Maturity Model", without any combination. The result set consisted of 491 papers that composed the corpus of analysis of the research; the term, in subsequent analysis, was compounded with other terms of interest, as represented in Table 1.
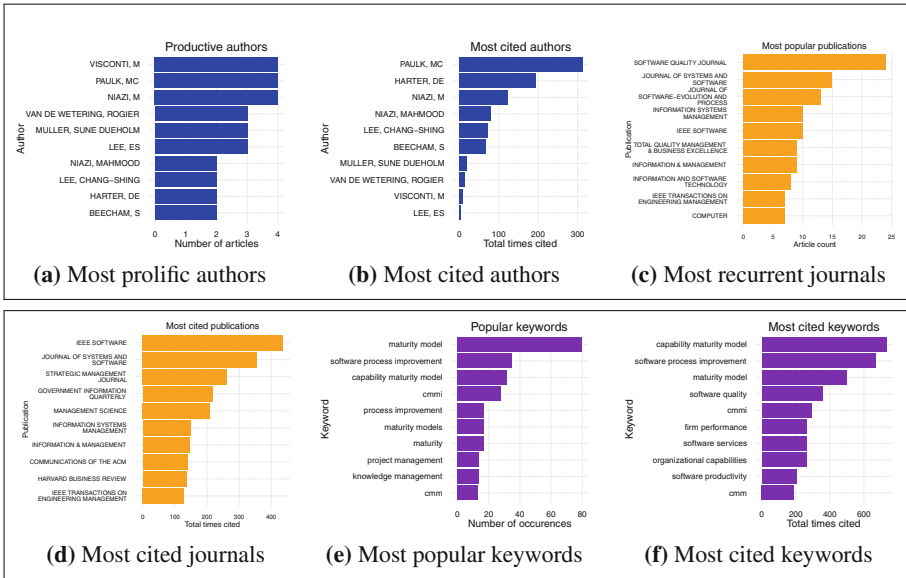
Table 1. Keyword selection

Terms	# of Papers found
"Maturity Model"	491
"Maturity Model" and "Health Care"	7
"Maturity Model" and "E-health"	0
"Maturity Model" and "Business Process Management"	6
"Maturity Model" and "Interoperability"	8
"Maturity Model" and "Information System"	32
"Maturity Model" and "Information Technology"	12

On the data collected in the previous step, the bibliometric analysis first phase (Fig. 2) presents the chronological evolution of the publication volume. There is a growth of the number of publications since 1990, with a strong inflection in 2008 and after, showing an acceleration of the rhythm of publication.

Fig. 2. Relative publication volume

(a) Most prolific authors   **(b)** Most cited authors   **(c)** Most recurrent journals

(d) Most cited journals   **(e)** Most popular keywords   **(f)** Most cited keywords

Fig. 3. Most prolific and most cited authors, publications and keywords

Figure 3 depicts the 2nd, 3rd and 4th phases of the research.

In the second phase, were identified the most productive and the most cited authors. The top producers are VISCONTI, M., PAULK, MC e NIAZI, M, with 4 works each. The third phase identifies the journals with the greatest publication indexes. The most popular inside the sample are SOFTWARE QUALITY JOURNAL, JOURNAL OF SYSTEMS AND SOFTWARE, and JOURNAL OF SOFTWARE — EVOLUTION AND PROCESS, and the most cited are IEEE SOFTWARE, JOURNAL OF SYSTEMS AND SOFTWARE e STRATEGIC MANAGEMENT JOURNAL. The fourth phase presents the most popular and the most cited keywords. Most popular among the producers (in the sample) are maturity model, software process improvement, and capability maturity model, and those most cited are capability maturity model, software process improvement, and maturity model.

Proceeding, a sociometric analysis was conducted, which presents the papers classified by their decreasing order of InDegree — i.e., the number of received citations, as shown in Table 2.

Network analysis is a sociometric technique largely used to understand the relations among individuals, institutions, works or objects of study of any nature. Using NAILS [11] it was possible to develop quantitative analysis by means of studying the relations among the selected papers, where are relational directions between the refer and the refereed. The result is a directed network, with a relation leaving the refer node and arriving the refereed node. One classical metric for the nodes of a network is the centrality degree, which can have multiple forms.

Table 2. Most cited papers

Article	InDegree	PageRank	External[a]
HUMPHREY W.S., 1989, Managing Software P	51	0.000216	1
PAULK M, 1993, V10, P18	41	0.000143	0
PAULK M.C., 1995, Capability Maturity	40	0.000156	1
HERBSLEB J, 1997, V40, P30	35	0.000107	0
HARTER D, 2000, V46, P451	25	0.000100	0
PAULK M., 1993, CMUSEI93TR24	22	0.000118	1

[a]External is: 0 = papers inside the original sample, 1 = papers outside the original sample.

For the citation network, the metric InDegree was used, which measures the number of paths that arrive in the node. So, in a citation network, the InDegree raises as the number of citations grows for a specific node, making it easy to determine the nucleus of most cited works and their connections. For the 491 papers downloaded from the WoS, were processed 16 variables (authors, addresses, ISSN/ISBN, ID PubMed, title, cited references, number of citations in WoS, number of access, source, type of document, keywords, source abbreviation, WoS categories, author identifiers, conference info and research areas). After processing, 11 duplicates were removed, retaining 480 records of papers, pointing to 14,790 unique citations.

The first phase of the sociometric analysis show the most cited works inside the sample: (1) Paper PAUL M, (1993) cited 41 times; (2) Paper HERBSLEB J, (1997) cited 35 times; (3) Paper HARTER D, (2000) cited 25 times. The second phase presents the most cited works outside the sample: (1) Paper HUMPHREY W.S., (1989) cited 51 times; (2) Paper PAULK M.C, (1995) cited 41 times; (3) Paper PAULK M., (1993) cited 35 times. The third phase presents the most cited works overall: (1) Paper HUMPHREY W.S., (1989) cited 51 times; (2) Paper PAULK M., (1993) cited 40 times; (3) Paper PAULK M.C., (1995) cited 22 times. Figure 4 shows the most central papers and their clustering. There are three distinguishable groups: (1) Group of papers HUMPHREY (1989), HERBSLEB (1997), HARTER (2000), DIAZ (1997) and NIASI (2005); (2) Paper PAULK (1993); (3) Paper PAULK (1995). After the bibliometric and sociometric analyses, all the cited papers were downloaded from the WoS. Used importance criteria were (1) the most cited papers by the papers in the sample and; (2) the most cited papers in WoS, among those forming the sample.

The search revealed 42 papers; although, in the first screening were removed from the sample those that not possessed the terms "Maturity Model" in their abstracts. The sample retained 11 papers, those being considered the most relevant for the present research study. Considering that the research theme is maturity models applied to healthcare, 8 other papers were added to the sample, due to belonging to the research theme and presenting as keywords "Maturity Model" and "Healthcare" or "Maturity Model" and "BPM", totaling 19 papers. The refinement process is shown in Fig. 5.
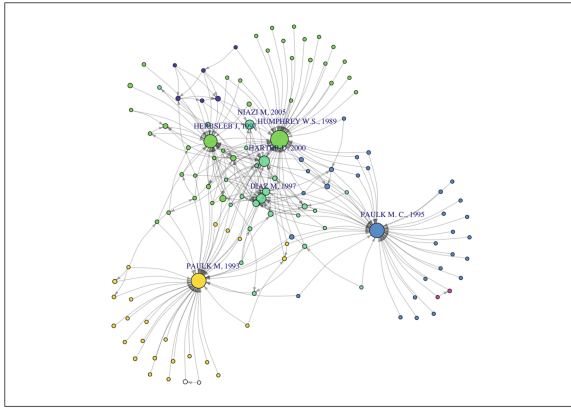
Fig. 4. Sociometric network of papers receiving more than 15 citations
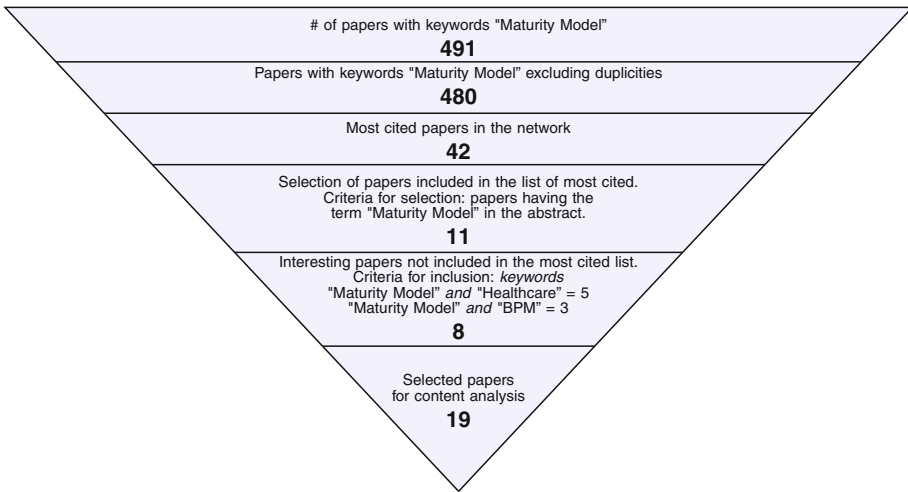
Fig. 5. Publication research refinement

4   Content Analysis

After minutely reading each one of the 19 papers forming the corpus of study, the primary approaches of each one were identified and put together in a synthesis (Table 3) depicting a general vision of their contents.

Mostly, the analyzed papers present aspects of IT, as of software development or IT management. Few of them care of a general approach to MM in the healthcare industry and all of these present the lack of MM specific to that industry.

Table 3. Papers' content analysis

Year	Author	Document title	Publication	Cited in WoS	Contents
1997	Diaz, M; Sligo, J	How software process improvement helped Motorola	IEEE Software	84	Offer metrics and data showing the results of CMM use in Motorola and presents the benefits
2005	Niazi, M; Wilson, D; Zowghi, D	A maturity model for the implementation of software process improvement: an empirical study	Journal of Systems and Software	79	Present a CMMI approach and develop an MM for SPI implementation
2004	Jiang, Jj; Klein, G; Hwang, Hg; Huang, J; Hung, Sy	An exploration of the relationship between software development process maturity and project performance	Information & Management	74	Presents an MM for software development (CMM) and analyzes 5 levels of maturity
2007	Hammer, Michael	The process audit	Harvard Business Review	60	MM - PEMM applicable in every industry and every process
2009	Becker, Joerg; Knackstedt, Ralf; Poeppelbuss, Jens	Developing Maturity Models for IT Management - A Procedure Model and its Application	Business & Information Systems Engineering	58	Proposal of requisites relative to development and modeling of a generic MM design procedure
2003	Luftman, J	Assessing IT business alignment	Information Systems Management	55	MM to assess the organization alignment, focused in a set of more strategic business practices
2007	Agrawal, Manish; Chari, Kaushal	Software effort, quality, and cycle time: A study of CMM level 5 projects	IEEE Transactions on Software Engineering	50	Analyzes CMM level 5 of various organizations to assess the impacts of heavily mature processes on the effort, quality and cycle time
2012	Wendler, Roy	The maturity of maturity model research: A systematic mapping study	Information and Software Technology	33	It does a systematic mapping study to identify the pioneering research on MM
2011	Valdes, Gonzalo; Solar, Mauricio; Astudillo, Hernan; Iribarren, Marcelo; Concha, Gaston; Visconti, Marcello	Conception, development, and implementation of an e-Government maturity model in public agencies	Government Information Quarterly	21	MM e–Government — describes how the model was conceived, designed, developed and tested
2009	Van De Wetering, Rogier; Batenburg, Ronald	A PACS maturity model: A systematic meta-analytic review on maturation and evolvability of PACS in the hospital enterprise	International Journal of Medical Informatics	12	Proposes an MM of PACS (PMM) in the hospital industry and describes the 5 levels of maturity of PACS
2016	De Boer, Jan C.; Adriani, Paul; Van Houwelingen, Jan Willem; Geerts, A	Game Maturity Model for Health Care	Games for Health Journal	1	Presents an MM of games for the healthcare sector and reports its use by two applied case studies

Table 3. *(Continued)*

Year	Author	Document title	Publication	Cited in WoS	Contents
2011	Rohloff, Michael	Advances in business process management implementation based on a maturity assessment and best practice exchange	Information Systems and E-Business Management	0	BPM — implementation of BPMMM in a big enterprise, basing the MM on 9 categories of BPM
2011	Van Looy, Amy; De Backer, Manu; Poels, Geert	Defining business process maturity. A journey towards excellence	Total Quality Management & Business Excellence	0	BPMM — studies three gaps related to BPMM, nomenclature, and design
2007	Scott, Judy E	Mobility, business process management, software sourcing, and maturity model trends: Propositions for the IS organization of the future	Information Systems Management	0	BPMM — MM of IS and the new capacities and abilities for the future IS organization
2015	André Blondiau; Tobias Mettler; Robert Winter	Designing and implementing maturity models in hospitals: Na experience report from 5 years of research	Health Informatics Journal	0	Presents the challenges on implementing three MM in distinct areas in hospitals
2015	Patti Brooks; Omar El-Gayar; Surendra Sarnikar	A framework for developing a domain specific business intelligence maturity model: Application to healthcare	International Journal of Information Management	0	Proposal of a structure for the development of an MM domain for BI specific to the healthcare area
2015	Jay Payette; Esther Anegbe; Erika Caceres; Steven Muegge	Secure by Design: Cybersecurity Extensions to Project Management Maturity Models for Critical Infrastructure Projects	Technology Innovation Management Review	0	Explore three MM for cybernetics and proposes one model for cybernetic security
2011	Zhilbert Tafa; Goran Rakocevic; Djordje Mihailovic; Veljko Milutinovic	Effects of Interdisciplinary Education on Technology-Driven Application Design	IEEE Transactions on Education	0	Depicts the structure of a CMMI of wireless sensor design (WSNs) for biomedical application
2000	Gillies A	Assessing and improving the quality of information for health evaluation and promotion	Methods Inf Med Journal	0	Presents an MM of General Practices Information (GPIMM) and reports a case study of implementation

5   Concluding Remarks

This bibliometric and sociometric research studied a field of science named "Maturity Models" (MM), that presented, in the last decade, a remarkable growth in the publication volume about development and application of MM in healthcare organizations.

Bibliometric analysis has shown the journals, papers, authors and keywords most recurring in the scientific literature as well as their relational networks.

The research study shows that the most productive and most cited journals are in the area of Information Systems. Sociometric analysis reinforced this notion, revealing that, among 41 papers being cited inside the sample, 80% are related to information systems and only 5% are about the healthcare industry.

Following the content analysis, an exhibit with syntheses of 19 most relevant papers was built. This research study identified that MM developed for healthcare organizations are, in a general way, mostly concerned with specificities typical of complex organizations like hospitals. The existent literature shows that the healthcare industry is more concerned with implementation of MM than their development. There is a consensus that standard MM are not adequate for those organizations, recommending specific MM that fit well the needs of safety and assistance of the patients as well as the public policies.

The content analysis also shown a tendency of using the general purpose MM as a base to specific MM development, as for the healthcare industry, considering the domain specificities. Important gaps were found in the literature that indicate the path to new future investigations. Those gaps encompass (1) the lack of documentation about structural development of existing MM; (2) most of the literature presents the MM development in a purely empirical way; (3) misalignment among information systems MM with organizational processes; and (4) lack of MM that are specific to the healthcare industry and organizations.

In view of the research study limitation of using a single database, the Web of Science, it is suggested that future research watch at other databases, looking forward the knowledge of the state of the art on the theme.

References

1. Röglinger, M., Pöppelbuß, J., Becker, J.: Maturity models in business process management. Bus. Process Manag. J. **18**(2) (2012)
2. Becker, J., Knackstedt, R., Pöppelbuß, J.: Developing maturity models for IT management - a procedure model and its application. Bus. Inf. Syst. Eng. **1**, 213 (2009). doi:10.1007/S12599-009-0044-5
3. Blondiau, A., Mettler, T., Winter, R.: Designing and implementing maturity models in hospitals: an experience report from 5 years of research. Health Inf. J. **22**(3), 758–767 (2015). doi:10.1177/1460458215590249
4. Curtis, B., Hefley, W.E., Miller, S.A.: Overview of the people capability maturity. Software Engineering Institute, Pittsburgh - PA, Model CMU/SEI-95-MM-02, July 2001
5. Mens, J., Ravesteyn, P.: Using the Delphi method to identify hospital-specific business process management capabilities in The Netherlands. In: 29th Bled eConference Digital Economy, Bled, Slovenia (2016)
6. Brooks, P., El-Gayar, O., Sarnikar, S.: A framework for developing a domain specific business intelligence maturity model: application to healthcare. Int. J. Inf. Manag. **35**, 337–345 (2015)

7. Jha, A.K., DesRoches, C.M., Campbell, E.G., Donelan, K., Rao, S.R., Ferris, T.G., Shields, A., Rosenbaum, S., Blumenthal, D.: Use of electronic health records in U.S. hospitals. New Engl. J. Med. **360**(16), 1628–1638 (2009). doi:10.1056/NEJMsa0900592. ISSN:0028–4793
8. Tague-Sutcliffe, J.: An introduction to informetrics. Inf. Process. Manage. **28**, 1–3 (1992)
9. White, H.D., Mccain, K.W.: Bibliometrics, vol. 24, pp. 119–186. Elsevier Science Publishers BV for the American Society for Information Science, Amsterdam (1989)
10. Kerlinger, F.N.: Foundations of Behavioral Research. HRW international edition. Holt, Rinehart and Winston, New York (1986)
11. Knutas, A., Hajikhani, A., Salminen, J., Ikonen, J., Porras, J.: Cloud-based bibliometric analysis service for systematic mapping studies. CompSysTech (2015). http://www.codecamp.fi/lib/exe/fetch.php/wiki/nails-compsystech2015-preprint.pdf