



PERFORMANCE MEASUREMENT SYSTEMS: A BIBLIOMETRIC ANALYSIS

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Abstract: Performance measurement systems (PMS) may present different levels of evolution in different organizations. The model that represents the different levels of evolution of a certain research topic is known as a maturity model. The maturity models for PMS can help managers in the area, who can identify what level a certain organization is at, as well as what is needed for it to evolve the level of maturity in an efficient, effective, and sustainable way, achieving strategic goals. Due to the importance of the subject, this article presents an overview of the existing theory about the maturity models of performance measurement systems. To achieve this goal, a bibliometric analysis was developed in the Web of Science (WOS) database, to investigate the main publications, journals, research terms, and authors. The references with the greatest impact on the subject are Sivaraman and Trivedi (2013), Becker, Knackstedt, and Pöppelbuss (2009), Palmarini et al. (2018), Aghaeepour et al. (2013), and Akyuz and Erkan (2010). The most cited references are Bititci et al. (2015), and McCormack, Ladeira, and Oliveira (2008). The most used search terms are performance measurement and performance maturity. The results found show that the publications on the subject are growing and the result of the most used keywords showed that academics interesting in search maturity PMS evolution associated with “industry 4.0”, “SMEs”, “sustainability”, and “management”.

Keywords: PMS, Maturity Model, performance measurement.

1. Introduction

Organizations and management models update over time in response to challenges in the environment such as market conditions, technological, economic, and social changes, and competition through innovation. According to [1], the notions of evolution and progress over time are evident in several academic publications that define the term “maturity model”.

A maturity model represents a matrix and defines practices at the level of formality, sophistication, and rootedness for each model level [2]. It is growing and gaining more notoriety, as it establishes maturity levels based on the different companies’ characteristics with different levels of learning and practice. Thus, through this type of model, it is possible, by capturing good practices at each intermediate or transitional stage of evolution, to understand the specific characteristics of a management model [3].

A Performance Measurement System (PMS) is a set of performance measures used to quantify the efficiency and effectiveness of actions. Effectiveness can be understood as the measures related to customer requirements, while efficiency refers to the measures related to how economically the company's resources are utilized in providing a level of customer satisfaction [4]. A PMS is a central element in providing adequate information to managers and decision-makers to support their decision-making process. Therefore, to achieve these objectives, a PMS must be dynamic and evolve to meet the

organization's internal and external changes [5].

PMS maturity evolution can be summarized as follows: measurement systems based on purely financial indicators, non-financial performance indicators, key indicators, Balanced Scorecard (BSC), Business Intelligence knowledge support, and, finally, the system sustainability performance measurement, such as the sustainable BSC [6]. Zainurin et al. (2021) added that in the Fourth Industrial Revolution (Industry 4.0), a PMS is usually found using numerous technologies in companies of different sizes and various sectors, such as automobile, education, retail banking, and so on.

PMS plays an important role in helping organizations to accomplish their competitive strategy. For this purpose, the organization's measurement systems must be aligned with its internal and external capabilities to effectively support the company's strategic goals [8]. However, according to Couturier & Sklavounos (2019), despite the growing interest in PMS in recent years, many companies fail to correctly use performance metrics.

Therefore, as changes in the competitive environment, whether technological or strategic, the PMS must adapt to meet organizational needs effectively and efficiently. In this aspect, it is possible to develop maturity models on the PMS topic, presenting the characteristics of each stage of the evolution of the measurement systems.

In this context, the objective of this article is to present an overview of the existing theory on maturity models of performance measurement systems. To achieve this objective, a bibliometric analysis was developed in the Web of Science (WoS) database, to investigate the main publications, authors, and clusters on the topic, which will be presented in the next sections.

2. Research method

The research method used is bibliometric analysis whose objective is to identify the historical and current scenario of a given research topic. According to Ellegaard & Wallin (2015), bibliometric analyses are firmly established as scientific specialties and are an integral part of the research evaluation method, especially in the scientific and applied fields. The methods are increasingly used in the study of various aspects of science and in the way institutions and universities are classified around the world.

A bibliometric analysis goes beyond a simple online search to find a list of articles on a given topic, something that anyone could easily achieve. Often, the importance of a scientific publication is measured by the number of times it has been cited by other authors. Thus, the most cited articles can be used as a potential reading list, while also showing the most interesting key themes in each field of research [11].

To identify patterns in each sample of documents in a database or scientific indexer, bibliometric analysis uses statistical software. Therefore, to develop this article, the R-Bibliometrix package was used in the Biblioshiny interface, running the R language in open source in RStudio® [12], [13]. Biblioshiny is an application that provides a web interface for R-Bibliometrix, which supports scholars in easily using the package's main features [12].

A search was made in the Web of Science (WOS) database, in July 2023, using the following search string: "maturity" AND ("performance measure*" OR "performance indicato*" OR "performance metric*" OR KPI*). The result found 466 references, which were imported in BibTeX format for analysis in statistical and bibliometric software. The results and discussion of the bibliometric analysis will be presented in the next section.

3. Bibliometric analysis

Figure 1 shows the scientific production on the topic during the 1993-2023 period. The annual scientific production has been growing since the period was defined, however, there was a drop in the number of publications in 2016 and again a significant growth from 2017 onwards.

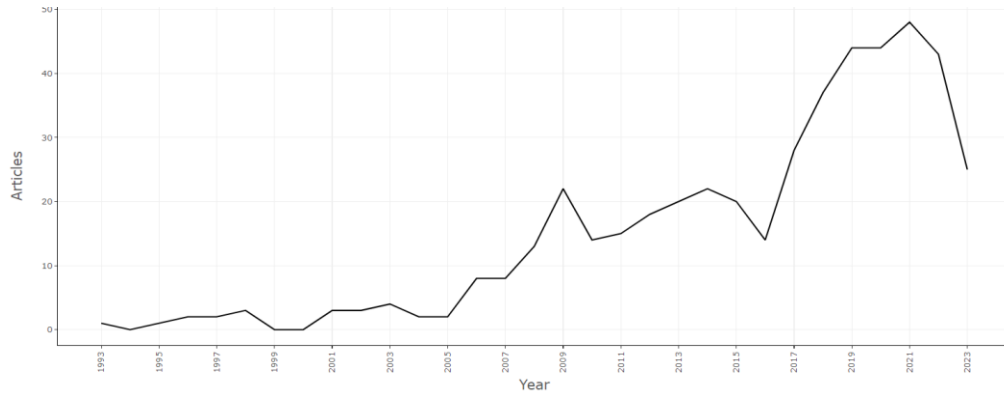


Figure 1: Annual scientific production

Figure 2 shows the sources with the highest number of publications. The five sources with the highest publication numbers are the Journal of Cleaner Production, International Journal of Operations and Production Management, International Journal of Production and Economics, International Journal of Production Research, and Harvard Business Review. All these sources are high impact journals in the Operations Management field.

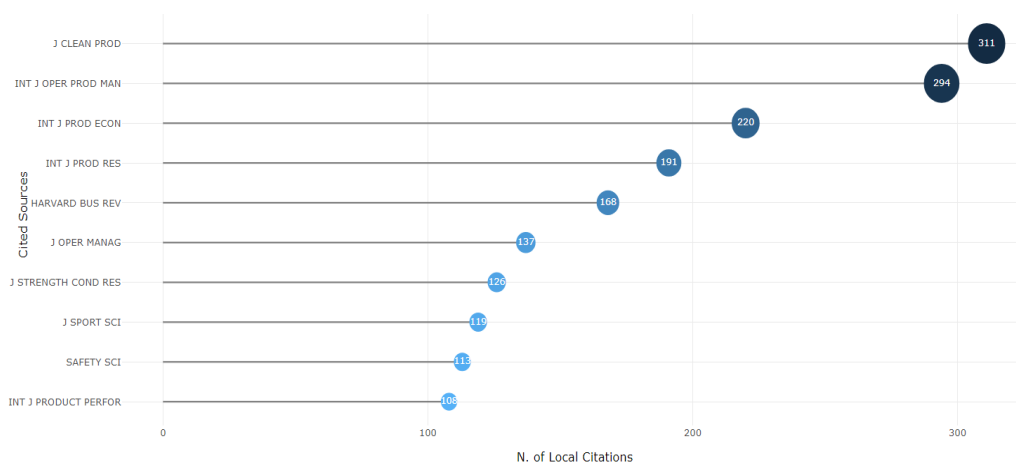


Figure 2: Most cited sources

Table 1 presents the most global cited documents, with total citations and total citations by year. Sivaraman & Trivedi (2013) present the highest cited document with a total of 607 citations and 55.18 citations per year. Furthermore, other most cited documents are Becker et al. (2009); Palmarini et al. (2018); Aghaepour et al. (2013); and Akyuz & Erkan (2010). Regarding the number of citations per year, the most cited articles per year are the same, but Guelpa & Verda (2019) also can be added.

Sivaraman & Trivedi (2013) and Akyuz & Erkan (2010) are from the field of transport and supply chain management. Becker et al. (2009) and Aghaepour et al. (2013) investigated technology information and industrial automation. Finally, Guelpa & Verda (2019) focuses on analyzing the maturity and performance of existing technologies regarding thermal energy in urban heating and cooling systems.

Table 1: Most global cited documents

| Paper | Total Citations | TC per Year | Normalized TC |
|---|-----------------|-------------|---------------|
| SIVARAMAN S, 2013, IEEE TRANS INTELL TRANSP SYST | 607 | 55.18 | 8.36 |
| BECKER J, 2009, BUS INF SYST ENG | 445 | 29.67 | 14.01 |
| AGHAEIPOUR N, 2013, NAT METHODS | 390 | 35.45 | 5.37 |
| PALMARINI R, 2018, ROBOT COMPUT-INTEGR MANUF | 325 | 54.17 | 21.67 |
| AKYUZ GA, 2010, INT J PROD RES | 207 | 14.79 | 7.14 |
| MORAN AL, 2001, ECOLOGY | 181 | 7.87 | 2.98 |
| GUELPA E, 2019, APPL ENERGY | 157 | 31.40 | 6.85 |
| ESTAMPE D, 2013, INT J PROD ECON | 153 | 13.91 | 2.11 |
| PODGORSKI D, 2015, SAF SCI | 145 | 16.11 | 6.95 |
| TORTORELLA GL, 2019, INT J OPER PROD MANAGE | 141 | 28.20 | 6.15 |
| JIANG JJ, 2004, INF MANAGE | 137 | 6.85 | 2.00 |
| LAUGIER P, 2008, IEEE TRANS ULTRASON FERROELECTR FREQ CONTROL | 135 | 8.44 | 3.92 |
| BITITCI US, 2006, INT J OPER PROD MANAGE | 131 | 7.28 | 5.73 |
| MICKLER C, 2008, PSYCHOL AGING | 105 | 6.56 | 3.05 |
| PILES M, 2016, REMOTE SENS ENVIRON | 91 | 11.38 | 4.49 |
| HANG L, 2019, SENSORS | 88 | 17.60 | 3.84 |
| MCCORMACK K, 2008, SUPPLY CHAIN MANAG | 83 | 5.19 | 2.41 |

Table 2 complements the information in the previous table by presenting local citations, that is, the citations resulting from the study sample. In Table 2 it is possible to find the calculation of normalized local and global citations. The analysis can be performed on three different units: documents, authors or sources and the coupling strength can be measured using the classical approach (coupled by references) or a novel approach based on unit contents (keywords or terms from titles and abstracts). The x-axis measures the cluster centrality (by Callon's Centrality index) while the y-axis measures the cluster impact by Mean Normalized Local Citation Score (MNLCS). The Normalized Local Citation Score (NLCS) of a document is calculated by dividing the actual count of local citing items by the expected citation rate for documents with the same year of publication [12].

Bititci et al. (2015) and McCormack, Ladeira, and Oliveira (2008) are most cited about the sample, that is, they caused the greatest impact on the documents in the sample. Both documents investigated performance measurement systems' maturity models. Bititci et al. (2015) provided a generic treatment, while McCormack, Ladeira, and Oliveira (2008) considered, specifically, the performance measurement maturity model for supply chain management.

Garengo, Nudurupati, and Bititci (2007), Boney, Comer, and Kelly (2009), Estampe et al. 2013), Finnerty et al. (2017), Popesko (2018), and Sardi et al. (2021) have two local citations. Garengo, Nudurupati, and Bititci (2007) published about performance measurement in small and medium-sized companies, Boney, Comer, and Kelly (2009) researched investments, Estampe et al. 2013) investigated the evolution of supply chain management, Finnerty et al. (2017) investigated about maturity models in energy management, Popesko (2018) researched about financial performance, and Sardi et al. (2021) about human resources management in the innovation of performance measurement systems.

Table 2 – Most local cited documents

| Document | Year | Local Citations | Global Citations |
|---|------|-----------------|------------------|
| BITITCI US, 2015, INT J PROD RES | 2015 | 9 | 73 |
| MCCORMACK K, 2008, SUPPLY CHAIN MANAG | 2008 | 8 | 83 |
| GARENGO P, 2007, COMPUT IND | 2007 | 2 | 30 |
| BONEY V, 2009, J EMPIR FINANC | 2009 | 2 | 20 |
| ESTAMPE D, 2013, INT J PROD ECON | 2013 | 2 | 153 |
| POPEŠKO B, 2017, ACTA POLYTECH HUNG | 2017 | 2 | 3 |
| FINNERTY N, 2017, J CLEAN PROD | 2017 | 2 | 22 |
| SARDI A, 2021, EMPL RELAT | 2021 | 2 | 27 |
| AKYUZ GA, 2010, INT J PROD RES | 2010 | 1 | 207 |
| MAGNAYE R, 2014, INT J PROJ MANAG | 2014 | 1 | 16 |
| BIDAURRAZAGA-LETONA I, 2015, INT J SPORTS MED | 2015 | 1 | 11 |
| UNGER CJ, 2015, RESOUR POLICY | 2015 | 1 | 29 |
| FINNERTY N, 2017, ENERGY | 2017 | 1 | 17 |
| MAMADE A, 2017, URBAN WATER J | 2017 | 1 | 30 |
| DE CAMARGO TF, 2018, ENVIRON DEV SUSTAIN | 2018 | 1 | 4 |
| ZHAN Z, 2019, S AFR J IND ENG | 2019 | 1 | 4 |
| LAWRENCE A, 2019, J CLEAN PROD | 2019 | 1 | 31 |
| COLLI M, 2019, ANNU REV CONTROL | 2019 | 1 | 60 |
| AMINI M, 2019, IND ENG MANAG SYST | 2019 | 1 | 2 |
| FAISAL M, 2020, IEEE ACCESS-a | 2020 | 1 | 15 |
| ZANON LG, 2021, PROD PLAN CONTROL | 2021 | 1 | 10 |

Figure 3 illustrates a Sankey diagram to identify the areas associated with the most cited references, authors, and authors' keywords, respectively. Seven main areas identified by acronyms in Figure 3 are associated with the search terms and authors in the same figure.

The first column contains the ten main documents on the topic. The authors associated with these documents are C. Felden, T. Pidun, and A. Zanin, who are from the information systems and Capability Maturity Models (CMM) areas, are identified in Figure 4. The authors P. Garengo, A. Sardi, and V. P. Afonso have published in partnership, and they developed research about performance measurement in Small and Medium-sized Enterprises (SMEs), human resources management, and innovation. In addition, author P. Garengo also researched about maturity models of SMEs. Furthermore, authors J. Pirhonen, A. Jaaskelanein, and S. Tappura also have a partnership and they published about maturity models on performance measurement. These last authors cited the references in the first column of Figure 3 in their research, which are also the most cited references presented in Tables 1 and 2.

The Sankey diagram seeks to present complex relationships through its networks. The relationships presented are classic references, presented in the first column, central themes associated with the PMS maturity model, presented in the third column, and authors, which are presented in the second column. The third column presents potential clusters of themes associated with PMS maturity models and their flow of relationship between authors and references. In addition to the topics directly linked to the topic, which are performance measurement and maturity model, possible trends in topics such as Industry 4.0 and Sustainability can be analyzed. The authors' keyword Industry 4.0 was used by the authors Garengo, Pirhonen, Sardi, Toneli, Jaaskelein, and Tapura. The authors' keyword sustainability was used by authors Afonso and Rodrigues. Furthermore, the mentioned authors used the references mentioned in the first column as a source of references, creating a flow of relationships between recently used words, authors, and more classic references on the topic. Thus, when observing the terms Industry 4.0, and Sustainability as also more frequent, it is possible to infer that there is a growing interest of the academic community in investigating the evolution of the PMS in comparison with new technologies and structure of Industry 4.0, as well as improving stakeholder requirements for Sustainability.

Figure 4 shows the 30 keywords most used by authors. The four most used terms are directly linked to the research topic, which are "performance measurement", "performance", "maturity" and "maturity model". The terms "industry 4.0", "measurement", "SMEs", "sustainability", "management", "indicators" and "performance indicators" are the next most mentioned terms. It can be observed that these terms give an idea of the specific research topics within the subject of PMS maturity models and corroborate the results observed in Figure 3. Furthermore, it is observed that they can be treated in a general way or associated with a management model (for example, supply chain management or the management of some object (for

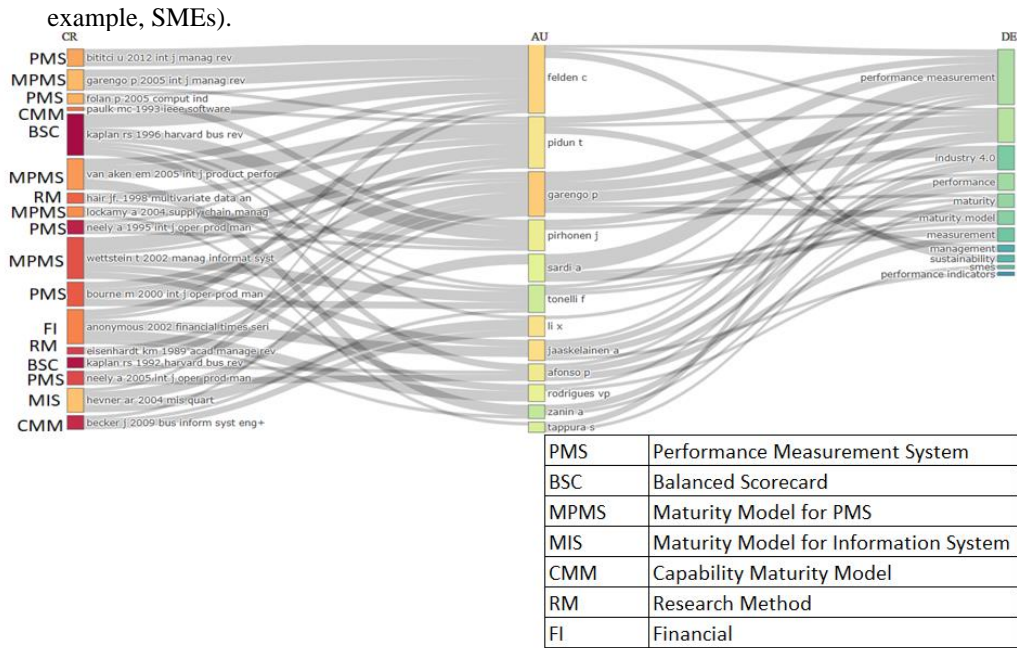


Figure 3: Sankey diagram



Figure 4: Most frequent keywords

Regarding authors in the field, Figure 5 presents the main authors in a timeline. The size of the bubbles represents the number of articles published in the year. The intensity of the color is proportional to the total number of citations per year. P. Garengo and X. Li are two authors who appear in the graph as constants over time. However, when analyzing the sample data from the bibliometric analysis, it was noticed that X. Li is a common name for different authors from different areas, which include health, ecology, and data mining. In this way, it can be understood that P. Garengo is the only frequent author over time. This author publishes about performance measurement topics, PMS maturity models, and performance measurement in small and medium-sized companies.

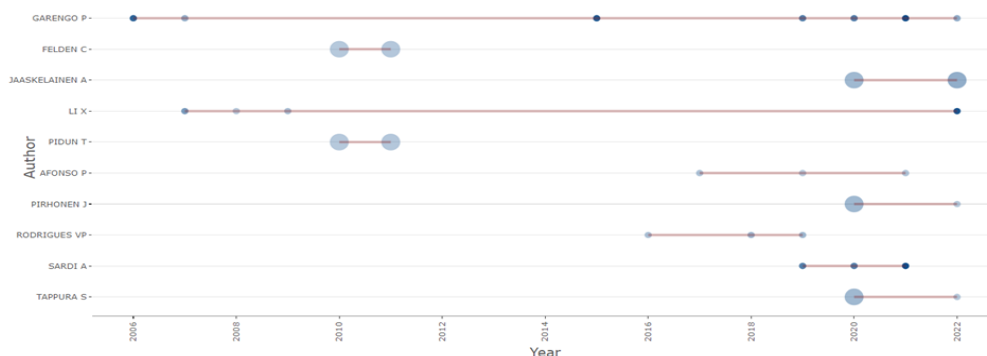


Figure 5: Most relevant authors

Figure 6 presents a graph developed by Lotka's Law. Lotka's law describes the frequency of publication by authors in any area of knowledge so that it is possible to identify whether there are frequent authors in each research topic [12]. Lotka's law states that the number of authors, y_x , each credited with x number of articles, is inversely proportional to x , which is the output of each author. The relationship is expressed: $x^n \times y_x = c$. Where y_x is the number of authors who made x contributions to the subject, and n and c are the two constants to be estimated for the specific set of data. This calculation shows the individual productivity of each author on a specific topic over time. Lotka's law includes all co-authors in a dataset of scientific publications, as it was often observed that joint contributions were credited only to the senior author [28].

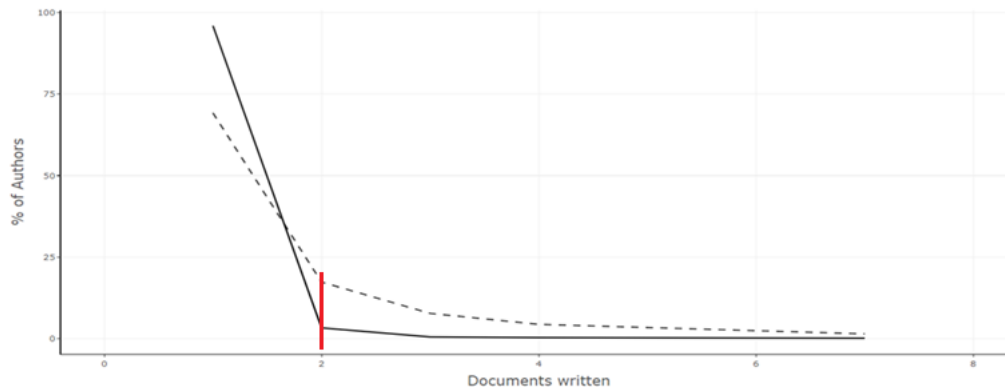


Figure 6: Lotka's Law

The red line in Figure 6 divides the point at which it is possible to identify several authors who publish more or less than two articles on the topic. Thus, Figure 6 indicates that there are many authors, just below 75, who wrote less than two articles on the topic. According to Lotka's law, these are the occasional authors. After the red line, it is possible to identify the number of main authors or core authors, which are the authors who publish many articles and more than two papers on the topic. When analyzing the data from the bibliometric software, it can be identified that there are around 1500 authors who wrote one or two documents on the topic, which confirms the result in Figure 5.

4. FINAL REMARKS

There are stages with different levels of evolution concerning PMS, which can be presented in matrices with different levels of maturity, i.e., PMS maturity models. Due to the importance of the topic, this article presented a bibliometric analysis of the maturity models of performance measurement systems. The bibliometric analysis presented an overview of the topic, with the identification of the most cited global and local documents, most published journals, keywords, and most cited authors.

The results presented an increasing publication on the topic in recent years. The references with the greatest impact are Sivaraman and Trivedi (2013), Becker, Knackstedt, and Pöppelbuss (2009), Palmarini et al. (2018), Aghaeepour et al. (2013) and Akyuz and Erkan (2010). The most cited references are Bititci et al. (2015) and McCormack, Ladeira, and Oliveira (2008). The most cited authors, P. Garengo and X. Li, are the only constant authors over time, but X. Li is the same name for different authors. Therefore, P. Garengo is the only constant author over time.

It was also possible to identify the relationship between the most cited references, authors, and keywords, using the Sankey diagram. The diagram reinforces the most cited references are the same references that are associated with the authors of the Sankey diagram. Furthermore, the terms associated with research are the same as those associated with authors and references, reinforcing the results of the bibliometric analysis.

The most cited keywords are “performance measurement”, “performance”, “maturity” and “maturity model”, followed by the terms “industry 4.0”, “measurement”, “SMEs”, “sustainability”, “management”, “indicators” and “performance indicators”. The result of the most used keywords showed the search terms themselves as more frequent, which was expected, however, it is possible to observe the most cited terms that are

different from the search term. The terms are “industry 4.0”, “SMEs”, “sustainability”, and “management”. This result shows that academics interested in investigating the evolution of PMS maturity concerning Industry 4.0 and Sustainability, which are themes that have changed in recent years. Industry 4.0 emerged in the mid-2010s and the use of Industry 4.0 technologies to mature performance measurement may be of interest to academics. Sustainability has been a topic of interest in organizations since the Brudtland report in 1987, and the need to improve the efficiency and effectiveness of the use of natural resources may require improvements in the maturity of the PMS. SMEs, which are characterized by being small and medium-sized companies, may present difficulties in investing in performance measurement, which demonstrates the interest of academics in analyzing the maturity evolution of this type of company.

The results presented the current academic context on the topic of maturity models of performance measurement systems. Thus, these results assist academics in developing research in this area. For future research, it is proposed to delve deeper into this topic, to find relationships between the themes, possible groupings, and trends about the research topic.

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