

The relationship between Project Management and Industry 4.0: Bibliometric analysis of main research areas through Scopus

J. R. López-Robles ^{*af1}, J. R. Otegi-Olaso ^{af1}, M. J. Cobo ^{af2}, L. Bertolin-Furstenau ^{af3}, M. Kremer-Sott ^{af3}, L. D. López-Robles ^{af4}, N.K. Gamboa-Rosales ^{af5}
^{*} ricardolopezrobles@outlook.com

^{af1} University of the Basque Country, Alameda Urquijo s/n, 48013 Bilbao, Spain

^{af2} University of Cadiz, Av. de la Universidad 10, 11519, Cadiz, Spain

^{af3} University of Santa Cruz do Sul, Av. Independência 2293, Santa Cruz do Sul - RS, 96815-900, Brasil

^{af4} Tecnológico de Monterrey (Campus Zacatecas), Av. Pedro Coronel 16, Cañada de la Bufa, Guadalupe 98000, Zacatecas, México

^{af5} CONACYT- Autonomous University of Zacatecas, Jardín Juárez 147, Centro, Zacatecas 98000, Zacatecas, Mexico

Abstract:

Industry 4.0 has been adopted by the entire world as the fourth industrial revolution. It is also known as Advanced Manufacturing or Smart Manufacturing, and it is often used interchangeably with the notion of the digital transformation. The Industry 4.0 term is also multidimensional, and it refers to the current trends of automation, digitalization and data exchange in advanced technologies and manufacturing processes. In this respect, the project managers are seeking to understand technological changes and their impact on project management processes. With this in mind, the main objective of this contribution is to develop a bibliometric analysis to evaluate the performance and conceptual evolution of the authors and publications that are directly related to Industry 4.0 and Project Management.

Keywords: *Industry 4.0; Strategic Intelligence; Project Management; Bibliometric network analysis; Competitive Intelligence; Business Intelligence; SciMAT.*

1. Introduction

The Industry 4.0, or the fourth industrial revolution, is already evolving not only industrial production, but also the methods, techniques and tools that are related to any activity. This revolution is structured for multiple technologies and knowledge areas, among which are Automation and Control Systems, Computer Science, Engineering, Material Science, Mechanics, Robotics, Operations Research and Management Science, Telecommunications, Transportation, among others [1].

The term Industry 4.0 was presented in 2011 at the Hanover Fair as a strategy to improve and reach the technological level of European countries. Industry 4.0 has no generally agreed upon definition, but concepts frequently associated with it include the Digitalization, Automation, Machine Learning and Predictive Analytics, Additive Manufacturing, Integration of Data and Information, Remote Sensing, Disruptive Technologies, mainly [2-4]

With this in mind, it is interesting to analyze the relationship between Project Management and Industry 4.0 using advanced bibliometric methods. This analyze will help to understand the full impact of this revolution in the PM field [5, 6].

To do that, we target to quantify the main indicators related to bibliometric performance: published publications, received citations, most cited articles, most cited authors, data on geographic distribution

of publications, among others. Lastly, using a bibliometric analysis software based on a bibliometric network, we will review the connections. In this way, bibliometrics can be defined as a set of methods and tools for evaluating and analyzing academic publication and citation in order to explore its impact on a specific field and how it contributes to the progress of science in the main areas of research [7].

Furthermore, the role of the Project Management on the development of the Industry 4.0 is essential to its success, and vice versa. Taking into account that the Project Management evolves and is embedded in all work activities, it is necessary to engage in a serious analysis on main research themes within these fields and its evolution. Finally, PM is a suitable tool for achieving the objectives and challenges posed by the development of advanced and intelligent technologies [8].

2. Methodology and Dataset

Based on a prior review of the state of the art, we focused the analysis according to the terms related to Industry 4.0 (including Smart Manufacturing and Advanced Manufacturing concepts) and the Project Management as knowledge field. In addition to carry out the bibliometric performance and network visualization map analysis, the publications related to the Industry 4.0 and Project Management have been collected.

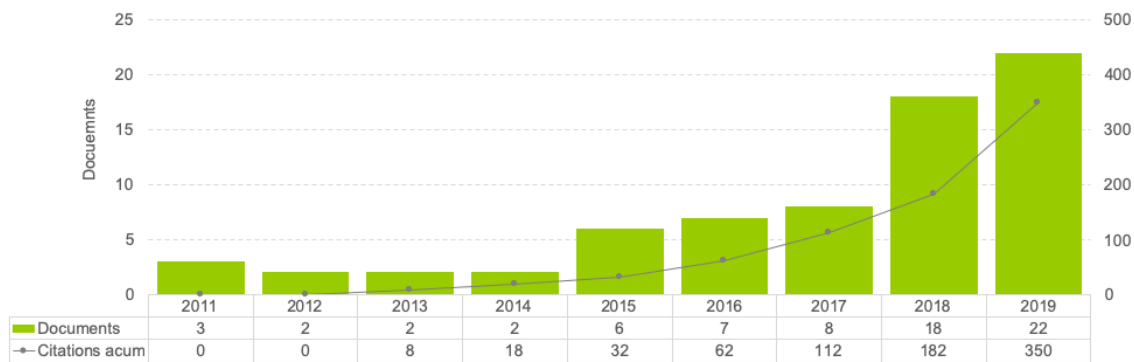


Figure 1. Distribution of Publications by year (2011-2019)

The raw data pertaining to Industry 4.0 and Project Management were retrieved from *Scopus* using the following advance query: *TITLE-ABS-KEY("Project Management") AND TITLE-ABS-KEY("Industry 4.0" OR "Smart Manufacturing" OR "Advanced Manufacturing") AND (LIMIT-TO(PUBYEAR, 2019) OR LIMIT-TO(PUBYEAR, 2018) OR LIMIT-TO(PUBYEAR, 2017) OR LIMIT-TO(PUBYEAR, 2016) OR LIMIT-TO(PUBYEAR, 2015) OR LIMIT-TO(PUBYEAR, 2014) OR LIMIT-TO(PUBYEAR, 2013) OR LIMIT-TO(PUBYEAR, 2012) OR LIMIT-TO(PUBYEAR, 2011))*.

In addition, the knowledge base was further refined and limited to Articles, Proceedings and Reviews published in English from 2011 to 2019 because the first publication related to Industry 4.0 concept was dated on 2011. This advance query retrieved a total of 70 publications. To accomplish this, we downloaded and reviewed all documents.

The bibliometric methodology used here classified the main Industry 4.0 research themes related to PM in four categories: (i) Motor themes, (ii) Highly developed and isolated themes, (iii) Emerging or declining themes and (iv) Basic and transversal themes. Moreover, the research themes within are represented as spheres, and its size is proportional to the number of publications associated with each research theme (see Figure 5) [9].

3. Performance Bibliometric Analysis of the Industry 4.0 in the Project Management field

To understand how the Industry 4.0 is moving in the Project Management field in terms of publication, citations and impact, we evaluated their performance through analysis of the following bibliometric indicators: most productive and cited authors, data on geographic distribution of publications, main sources and the most cited publications according to the h-index.

To do that, the bibliography performance analysis is structured in three sections. Firstly, evaluation of the publications and their citations with the aim of testing and evaluating scientific growth. Secondly, analysis of the authors performance, geographic distribution and most productive sources. Finally, thirdly, the most relevant publications according to the h-index.

3.1. Publication and Citations

The distribution of publications and citations related to Industry 4.0 and Project Management from 2011 to 2019 are shown in Figure 1.

Since the first publication related to Industry 4.0, the production was increasing every year. This evolution reveals the growing interest in the both areas and application and research of the Industry 4.0 technologies and the Project Management techniques, tools and methodologies.

As with the case of the publications, the citation distribution showed a positive developmental trend in the period 2011-2019. Based on the results of the advance query applied in the *Scopus*, the citation performance is summarized in the following indicators: Average citations per publication: 2,65, Sum of Times Cited (without self-citations): 186 (124) and 1.630 documents referenced.

3.2. Most Productive and Cited Authors, Geographic Distribution of Publications, Research Areas

It is also important to know which are the most productive and cited authors, along with the geographic distribution of publications and main sources. It complements the bibliometric performance analysis of the between Industry 4.0 and the Project Management field and allows for an evaluation of where developments have occurred within these fields. Consequently, the most productive and cited authors are shown in Figure 2 and Figure 3, respectively.

Authors	Publications (n=70, %)
Arashpour, M.	4 (5,71%)
Bai, Y.; Celebi, U. B.; de Lima, E. P.; Deschamps, F.; Hosseini, R.; Matt, D. T.; Turan, E.	2 (2,85%)
Rest of authors (n=151)	1 (1,42%)

Figure 2. Most productive authors (2011-2019)

Authors	Citations (n=186, %)
Seo, Y.; Jia, Q.	34 (18,27%)
Elragal, A.; Haddara, M.	23 (12,36%)
Rest of authors (n=190)	19 or less

Figure 3. Most cited authors (2011-2019)

It is important to mention that the most productive authors are not included in the list of most cited and vice versa. This reflects two scenarios, the first one is related to productivity and the second one to themes that are interesting for both thematic.

The most productive countries related to Industry 4.0 and PM field are shown in Figure 4.

Country/Region	Publications (n=70, %)
Germany	12 (17,14%)
Australia	7 (10,00%)
United States	6 (8,57%)
Spain	5 (7,14%)
United Kingdom	4 (5,71%)
Rest of countries/regions (n=32)	3 or less

Figure 4. Most productive countries and regions (2011-2019)

On the other hand, the sources with the largest number of documents published are *IOP Conference Series Materials Science and Engineering*, *Lecture Notes in Mechanical Engineering*, *Procedia Computer Science* and *ZWF Zeitschrift Fuer Wirtschaftlichen Fabrikbetrieb*. Finally, this supports the following research areas: Engineering, Computer Science, Business, Management and Accounting and Decision Science.

3.3. Most relevant publications according to h-index

Finally, the search query used in the database Scopus has an h-index of 7 [10]. Using as reference the h-index value, we could identify the following relevant publications to this research:

- (34 cites) Jia, Q., & Seo, Y. (2013). An improved particle swarm optimization for the resource-constrained project scheduling problem.
- (23 cites) Haddara, M., & Elragal, A. (2015). The Readiness of ERP Systems for the Factory of the Future.
- (19 cites) Arashpour, M., Bai, Y., Aranda-mena, G., Bab-Hadiashar, A., Hosseini, R., & Kalutara, P. (2017). Optimizing decisions in advanced manufacturing of prefabricated products: Theorizing supply chain configurations in off-site construction.
- (13 cites) Gentner, S. (2016). Industry 4.0: reality, future or just science fiction? How to convince today's management to invest in tomorrow's future! Successful strategies for industry 4.0 and manufacturing IT.
- (12 cites) Arashpour, M., Kamat, V., Bai, Y., Wakefield, R., & Abbasi, B. (2018). Optimization modeling of multi-skilled resources in prefabrication: Theorizing cost analysis of process integration in off-site construction.
- (11 cites) Chofreh, A. G., Goni, F. A., & Jofreh, M. G. (2011). Enterprise resource planning (ERP) implementation process: project management perspective.
- (11 cites) Whyte, J., & Levitt, R. (2011). Information management and the management of projects.

To effectively analyze, the next step is to determine the main themes for both knowledge areas using SciMAT, software tool for constructing and visualizing bibliometric networks.

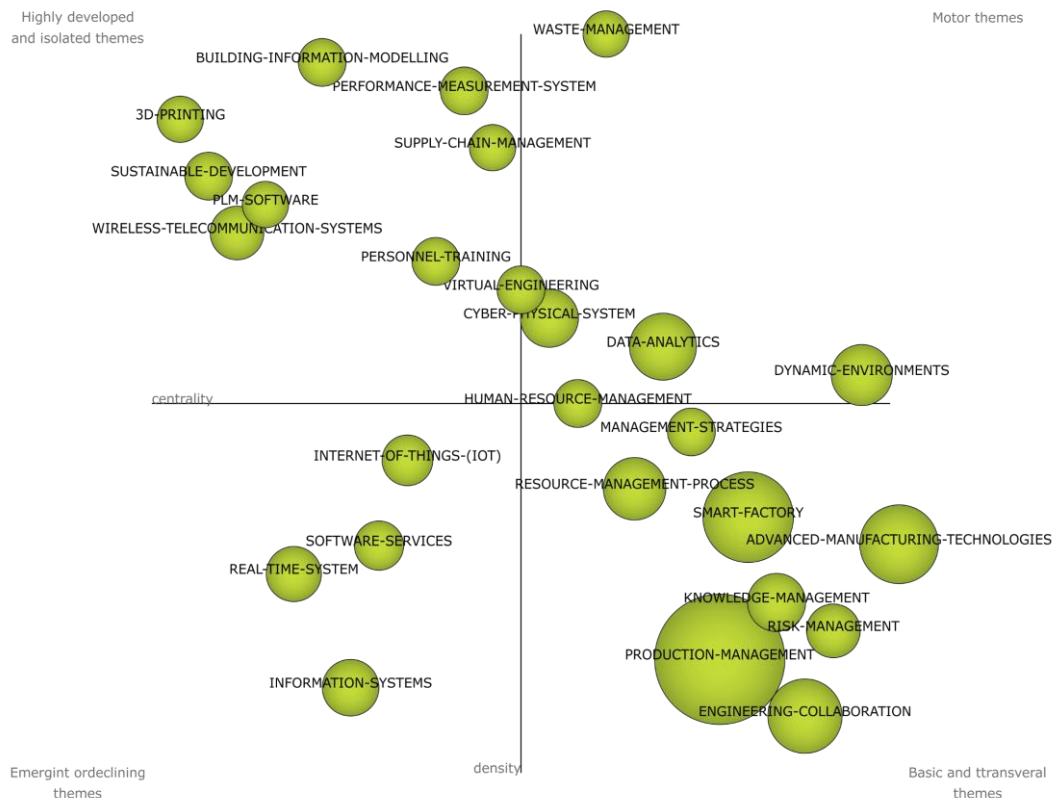


Figure 5. Main themes related to Industry 4.0 and Project Management

4. Network visualization map of Industry 4.0 in Project Management field

The main themes related to Industry 4.0 and Project Management from 2011 to 2019 are presented in the Figure 5. In this way, the most relevant and productive themes are: PRODUCTION-MANAGEMENT (59 publications), SMART-FACTORY (32 publications), ADVANCED-MANUFACTURING-TECHNOLOGIES (24 publications), ENGINEERING-COLLABORATION (21 publications) and DATA-ANALYTICS (16 publications).

The research themes are distributed in all four quadrants. With this in mind, the most relevant themes related to Industry 4.0 and Project Management are the themes included in the quadrant (i) and (iv). In this way, these themes are:

- Motor themes: DYNAMIC-ENVIRONMENTS, HUMAN-RESOURCE-MANAGEMENT, DATA-ANALYTICS, CYBER-PHYSICAL-SYSTEM, VIRTUAL-ENGINEERING and WASTE-MANAGEMENT.
- Basic and transversal themes: PRODUCTION-MANAGEMENT, SMART-FACTORY, RISK-MANAGEMENT, ENGINEERING-COLLABORATION, RESOURCE-MANAGEMENT-PROCESS, MANAGEMENT-STRATEGIES and ADVANCED-MANUFACTURING-TECHNOLOGIES.

5. Conclusions

The size of literature related to Industry 4.0 in the Project Management field showed a noticeable increase in the last years. Given the large volume of citations received in this field, it is expected that the penetration of the Industry 4.0 and themes related to it in the Project Management field will continue.

Taking into account the main research lines of Project Management and the areas of action covered by the fourth industrial revolution, we have identified as potential common themes in the short term the following: PERFORMANCE-MEASUREMENT-SYSTEM, SUSTAINABLE-DEVELOPMENT, PERSONNEL-TRAINING, DATA-ANALYTICS, DYNAMIC-ENVIRONMENTS, HUMAN-RESOURCE-MANAGEMENT, RISK-MANAGEMENT, MANAGEMENT-STRATEGIES, KNOWLEDGE-MANAGEMENT, INFORMATION-SYSTEMS and ENGINEERING-COLLABORATION.

Finally, some future work is necessary to provide a more in-depth examination of the use of Project Management in the fourth industrial revolution.

Acknowledgment

The authors thank to the Consejo Nacional de Ciencia y Tecnología (CONACYT) and Dirección General de Relaciones Exteriores (DGRI) for the support provided to carry out this study. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brazil (CAPES) - Finance Code 001.

References

- [1] L. M. Kipper, L. B. Furstenau, D. Hoppe, R. Frozza, and S. Ilespen, "Scopus scientific mapping production in industry 4.0 (2011–2018): a bibliometric analysis," *International Journal of Production Research*, 2019.
- [2] S. E. Lemões Iepsen, L. B. Furstenau, and L. M. Kipper, "Relações entre educação em engenharia e o desenvolvimento de habilidades para a indústria 4.0," presented at the II Simpósio de Engenharia, Gestão e Inovação, Brazil, 2018.
- [3] L. B. Furstenau and L. M. Kipper, "Produção enxuta e indústria 4.0 com foco na demanda do cliente: desafios e oportunidades para o desenvolvimento de pesquisas aplicadas.," presented at the XXXVIII Encontro nacional de engenharia de produção, Brazil, 2018.
- [4] J. R. López-Robles, M. Rodríguez-Salvador, N. K. Gamboa-Rosales, S. Ramirez-Rosales, and M. J. Cobo, "The last five years of Big Data Research in Economics, Econometrics and Finance: Identification and conceptual analysis," *Procedia Computer Science*, vol. 162, pp. 729-736, 2019.
- [5] J. R. López-Robles, J. R. Otegi-Olaso, H. Robles-Berumen, H. Gamboa-Rosales, A. Gamboa-Rosales, and N. K. Gamboa-Rosales, "Visualizing and mapping the project management research areas within the International Journal of Project Management: A bibliometric analysis from 1983 to 2018," presented at the Research and Education in Project Management - REPM 2019, Bilbao (Spain), 2019.
- [6] J. R. López-Robles, "La integración de los enfoques de Inteligencia para la promoción del desarrollo de ventajas competitivas científicas, tecnológicas e innovadoras en el Sector Vasco de Automoción," Tesis doctoral, Departamento de Expresión Gráfica y Proyectos de Ingeniería, Universidad del País Vasco/Euskal Herriko Unibertsitatea, Bilbao, Spain, 2019.
- [7] Y. R. Wang, Q. J. Wang, X. Z. Wei, J. Shao, J. Zhao, Z. C. Zhang, *et al.*, "Global scientific trends on exosome research during 2007-2016: a bibliometric analysis," *Oncotarget*, vol. 8, pp. 48460-48470, Jul 2017.
- [8] J. R. López-Robles, J. R. Otegi-Olaso, I. Porto-Gómez, and M. J. Cobo, "30 years of intelligence models in management and business: A bibliometric review," *International Journal of Information Management*, vol. 48, pp. 22-38, 2019.
- [9] M. J. Cobo, A. G. López-Herrera, E. Herrera-Viedma, and F. Herrera, "SciMAT: A new science mapping analysis software tool," *Journal of the American Society for Information Science and Technology*, vol. 63, pp. 1609-1630, 2012.
- [10] M. A. Martínez, M. Herrera, J. López-Gijón, and E. Herrera-Viedma, "H-Classics: Characterizing the concept of citation classics through H-index," *Scientometrics*, vol. 98, pp. 1971-1983, 2014.