Trends and Proposals for European Industrial Engineering

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Abstract:
This article analyses the trends in scientific publications (Web of Science) in the field of industrial engineering (IE) from 1950 to the present. Specifically, it presents the evolution of the emergence of 'concepts' associated with IE for decades, their quantitative or qualitative nature and the prominence of the different world regions in their origin. The analysis reveals a decline in the capacity of the academe and the industry to propose new 'concepts' during the last 20 years, a considerable variation of the leading role of world regions in IE and significant changes in the preponderance of IE 'concepts' with a quantitative or qualitative character. To foster the capacity of the IE academe in contributing to European industrial development, the transformations that the industry will have to face during the next decades are proposed as areas of development of the research activity. Enhancing training and research on the consequences of digitisation on industrial management, enlarging the optimization scope from company to value chain and industrial ecosystems and prioritizing research aimed at developing new 'concepts', methodologies and tools are suggested as some of the future paths for IE.

Keywords: Industrial Engineering, Research, Trends, Value chain

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Introduction

Since the late 19th and early 20th centuries up to the present, with the contributions of F.W. Taylor (1911) on the scientific organisation of work, an area of research, knowledge and applications that straddle engineering and management without clear borders with other disciplines, has arisen. This area was termed industrial engineering (IE).

The evolution of industry, technologies and the needs of society (Hazarika et al., 2019) as well as the emergence of new production methods, techniques and philosophies have been transforming the role of IE in companies and the training and research carried out in universities. In turn, Universities have contributed to transforming the productive fabric of countries.

Despite the difficulties of 'acceptation' and the 'lack of recognition of the academic value' of the research carried out (Brustolin & Jonker, 2012), history tells us that

European Industrial Engineering has managed to grow into highly productive research teams and as a source of innovation.
Although the aforementioned difficulties generate nuances to the observation of issues addressed by the scientific production in IE, such observation allows us to reflect on the irruption of new 'concepts' in the academe and the industry. Moreover, the analysis of these 'concepts' helps us perceive some macro trends. In this article, these trends are presented and some possible development areas for IE are outlined.

Methodology

In this article, the term 'concepts' includes the frameworks, systems, models, maps, processes, procedures, techniques and tools associated with IE as defined by Shehabuddeen et al. (1999). To analyse the evolution of publications about the 'concepts', information was obtained through an exploration of the Web of Science database. The searching process in Web of Science was made in the fields Title, Abstract, Author's Keywords and KeyWords Plus®, which generates keywords from the citations of the article.

The 'concepts' considered in the research process are the following ones: AQL based on MIL-STD-105D, Methods-Time MTM, MRP, TOC, ISO 9.000 Series, TQM, Six sigma, Hoshin Kanri, Cell Layout planing (JIT), Kanban (JIT), Poka Yoke, 5S, SMED (JIT), TPM, Supplier Development, Kaizen teams, Lean Production, Logistics (OR, etc..), QFD, Digitization Industry 4.0, Management. model (EFQM,..), Quantitative Methods. (Simulation), Project Management (PERT, GANTT,), Seven Basic Quality Tools, Assembly Line Balancing, Queuing Theory, Skills Matrix, Computerized Maintenance Management Systems, Value Stream Mapping, Taguchi – Dis. of Experim., Innovation management, Ergonomics and Circular Economy.

For each of the 'concepts' considered, several aspect have been defined, including ding 1) the search terms; 2) the year of the first publication found; 3) the region of the world where the 'concept' first originated: and 4) the 'concept's fundamentally quantitative or qualitative nature. For 3), the 'concept' was classified as 'International' in case it was promoted by an international entity or emerged in a parallel way in different regions of the world. For 4), a 'concept' was considered quantitative if it aims at a precise calculation, is strongly based on numerical calculations or requires necessary computational assistance.
The process of defining search terms in English and some specific terms in Japanese was carried out through iterations in order to achieve a balance between finding the largest number of publications related to a 'concept' and, at the same time, avoiding the inclusion of publications related to other disciplines. Debugging of the terms was performed by reviewing the first 50 results of the searches obtained following roughly the first steps of the process proposed by Thomé et al. (2016) for a systematic literature review. Altogether, 73,729 publications were collected and classified.

Limitations

The methodology used has some limitations for which corrective measures were taken. Firstly, for each of the 33 'concepts' analysed, the number of publications identified per year was obtained, from the year of first appearance to the present. Taking into account the possible bias derived from access to only some databases and the initial period of data availability for some of them, this article analysed the percentage weight of the different 'concepts' and not the absolute value number of publications in each year.

Secondly, depending on the scope, 'concepts' of a more global nature were included along with more specific ones. The grouping of search results for partial 'concepts' was considered to compensate for the grouped search for global 'concepts'.
Lastly, it is difficult to establish the precise boundary of disciplines associated with IE with respect to other disciplines. The fields identified by the American Institute of Industrial Engineers (IIE, 2006) to cover the scope of industrial engineers' focus areas were taken as a reference. These include project management, manufacturing, production and distribution, supply chain management, productivity, methods and process engineering, quality measurement and improvement, programme management, ergonomics / human factors, technology development and transfer, strategic planning, management of change and financial engineering. The identification of the concepts covering these fields was carried out in three iterations by a group of university professors of Industrial Engineering with more than 25 years of teaching and research experience in the field. Considering the fuzzy boundaries of EI, this research could be extended by including other participants in the identification of terms from industry, consultancy as well as other representatives of industrial engineering.

Results

Figure 1 below shows the evolution of the appearance of new 'concepts' from 1950 to the present. It shows a progressive increase in proposals between the 1950s and 1990s and, subsequently, a drastic reduction in such proposal capacity.

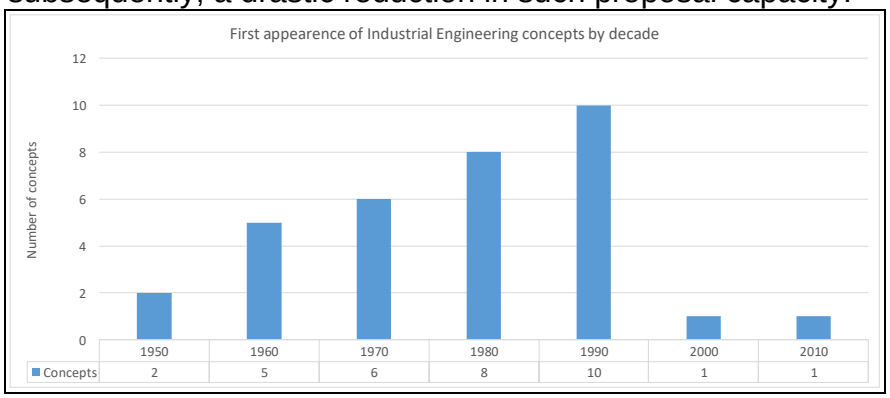

Fig. 1. First appearance of IE 'concepts' by decades.

A period of effervescence is also observed between 1980 and 1999, when the first publications related to 18 'concepts' appeared (54% of the total). During these years, aspects related to just-in-time, quality improvement tools from Japan (QFD, Poka Yoke, Taguchi, Kaizen, etc.), TPM, the quality management systems ISO 9000, Six Sigma, lean production and their associated techniques, including VSM, Theory of Constraints or more philosophical aspects such as the importance of respect and the participation of people in the competitiveness of companies (Kaizen, Hoshin Kanri, Skills matrix), emerged.

This period (1980–1999) represented a strong activity of incorporation into the IE profession of these 'concepts' through university training, continuous training and in research or consulting.

As shown in Figure 2, where the evolution of the percentage of publications by IE 'concepts' and by region of origin is represented, the increase in appearance of new 'concepts' coincides with a strong increase in the prominence of the manufacturing

model from Japan, represented in a paradigmatic way—though not unique—by the automotive company Toyota.

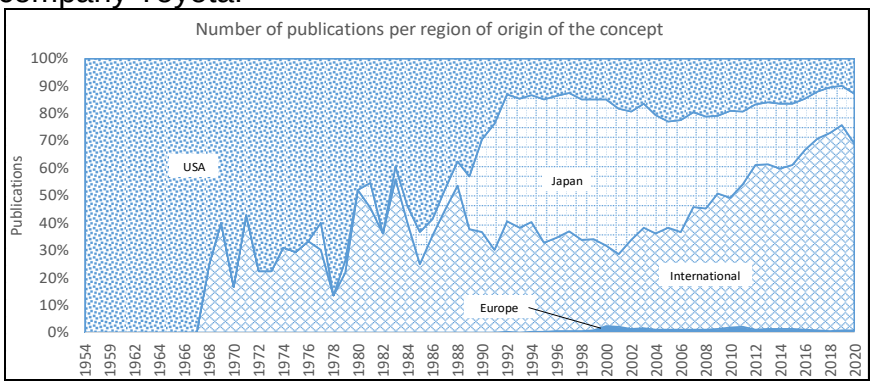

Fig. 2. Evolution of the percentage of publications by region of origin of the 'concept'.

If initially the role of the United States in IE through its military and automobile industry was unquestionable (methods and times, balancing of assembly lines, statistical process control, project management, MRP, etc.) between 1950 and 1980, from the 1980s onwards, this leadership has declined in favour of Japan and the subsequent 'concepts' generated more internationally.

Figure 2 illustrates that the globalisation of industrial activity has brought with it an almost simultaneous appearance of new 'concepts' throughout the world. An example of this worth mentioning is the appearance in Europe of the Industry 4.0 'concept', with a translation having various nuances in the United States under the name of Advanced Manufacturing or in Japan as Connected Industries. This trend will certainly remain in the following decades.

As it appears in Figure 3, the general appearance of techniques from Japan increased the importance of more qualitative or even philosophical 'concepts'. Western companies needed time to understand and absorb these techniques very much related to Japanese culture. For this, certain terminological, philosophical and cultural adaptations were necessary.

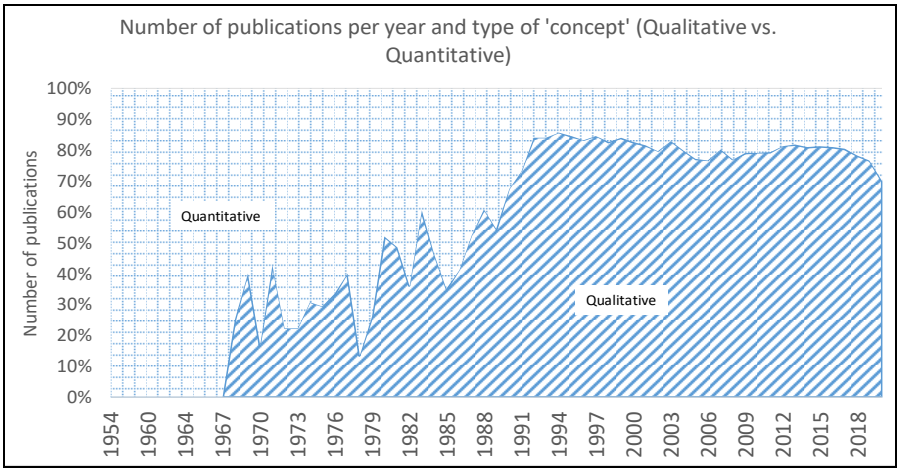

Fig. 3. Evolution of the percentage of publications by type of 'concept' (Qualitative vs. Quantitative).

On the other hand, the difficulties of homologation of research in IE with respect to the rest of the disciplines are known (Brustolin, 2012), especially in the qualitative aspects. Thus, the weight of qualitative 'concepts' by measuring publications in high-level journals is probably underestimated.
As can be seen in the figure, there has been a slight recovery in recent years in the research carried out on quantitative aspects, probably driven by the generalised automation and digitisation of the industry.

Conclusion

An analysis of the results reveals that, mainly, the 'concepts' associated with IE have come from the industry (military and automotive) and have subsequently been conceptualised and researched by the academe. During the last 20 years, there has been a decline in new proposals by the industry or the academe, and yet the industry is facing great transformations that will undoubtedly require techniques or methodologies for their optimisation. Among the major new trends that are expected to influence European industry in the coming years or decades, massive digitisation, energy transition, circular economy, climate neutrality or a strengthening of strategic value chains (European Commission, 2019; European Commission, 2020a) will certainly be addressed.

Digitisation of the industry, enhanced data analytics and artificial intelligence open a new field of action for the optimisation of business operations. These opportunities will make it possible to promote the appearance of quantitative tools to improve company performance (Moynihan, 2020). Industrial engineers are very well positioned to be the protagonists of these opportunities. For this, enhancing their training and related research in numerical tools (simulation, artificial intelligence, enhanced data analytics, etc.) associated with digitisation will be necessary.

Furthermore, in this context, in addition to seeking the optimisation of operations within the company, the industrial engineer will have to do so with a systemic vision of the value chain and industrial ecosystems (European Commission, 2020b). This perspective is especially true for addressing the challenges of energy transition, circular economy or backshoring. In this sense, being able to identify the opportunities derived from industrial cooperation alliances with other companies or organisations will be a key competence. For example, supplier development programmes, strengthening the local value chain or collaborative innovation can be areas for future development.

Complementary to improving existing techniques already applied, the future of the IE discipline will depend largely on the ability of the academe to conceptualise and propose new methodologies, 'concepts' and tools to the industry that will allow them to adapt efficiently to the new reality that awaits them. Research oriented to generating new approaches should be prioritised. Action research could be an appropriate methodology to promote addressing the operational realities experienced by practicing managers while simultaneously contributing to knowledge (Coughlan & Coghlan, 2002; Cauchick, 2010).
Butuner (2015) proposes that the most significant development in IE in the next 50 years will be systematic planning as a means to teach people how to arrive at decisions better. The new 'concept' proposals from IE should contribute to that purpose.
These approaches could make it possible to reactivate the lagging proposal capacity and contribute to an enrichment of training, research and transfer activities. Considering the limitations of this research, a deeper analysis from other perspectives

of the trends and the future role of IE academe to contribute to European transformation processes is necessary. This article is just a partial contribution to this important discussion.

Reference list

Brustolin, F., Jonker, G.H. (2012) Research in Industrial Engineering and Management: An Explorative Survey among Seven European IEM Departments. International Journal of Industrial Engineering and Management (IJIEM), Vol.3 No 2, Month 2012, pp. 105-111. ISSN 2217-2661

Butuner, H. (2015) The Next 50 Years of Industrial Management and Engineering. Proceedings of the 2015 International Conference on Industrial Engineering and Operations Management. Dubai. United Arab Emirates (UAE), March 3-5.

Cauchick, P.A. (2010) Qualitative Research in Industrial Engineering – an Assessment of a Research Project and a Sample of Dissertations. XVI International Conference on Industrial Engineering and Operations Management. Challenges and Maturity of Production Engineering: competitiveness of enterprises, working conditions, environment. São Carlos, SP, Brazil, 12 to 15 October – 2010.

Coughlan, P., Coghlan, D. (2002) Action Research for Operation Management. International Journal of Operations & Production Management, Vol. 22, No. 2, pp. 220-240.

European Commission (2019) Communication from the Commission to the European Parliament, The European Council, The Council, The European Economic and Social Committee and the Committee of the Regions. The European Green Deal. Brussels, 11.12.2019. COM(2019) 640 final

European Commission (2020a) Communication from the Commission to the European Parliament, The European Council, The Council, The European Economic and Social Committee and the Committee of the Regions. Europe's moment: Repair and Prepare for the Next Generation. Brussels, 27.5.2020. COM(2020) 456 final

European Commission (2020b) Communication from the Commission to the European Parliament, the European Council, The European Economic and Social Committee of the Regions. A New Industrial Strategy for Europe. Brussels, 10.3.2020. COM(2020) 102 final

Hazarika, M., Dixit, U.S., Davim, J.P. (2019) History of Production and Industrial Engineering Through Contributions of Stalwarts. Manufacturing Engineering Education. https://doi.org/10.1016/B978-0-08-101247-5.00001-0

IIE Institute of Industrial Engineers (2006) Industrial Engineering Roles. Downloaded the 2021/02/20 from https://www.iise.org/uploadedFiles/IIE/About_IIE/What IEs Do IIE-IAB v2.pdf

Moynihan, G.P. (2020) Background and Current Trends in Industrial Engineering. Concepts, Applications and Emerging Opportunities in Industrial Engineering. DOI: http://dx.doi.org/10.5772/intechopen.94606.

Shehabuddeen, N., Probert, D., Phaal, R., Platts, K. (1999) Representing and approaching complex management issues: Part 1 – Role and definition. University of Cambridge Institute for Manufacturing. ISBN 1-902546-21-0.

Taylor, F.W. (1911) The principles of Scientific Management. New York: Harper and Brothers Publishing.

Thomé, A.M.T., Scavarda L.F., Scavarda A.J. (2016) Conducting systematic literature review in operations management, Prod. Plan. Control 27 (5) 408–420.