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The History of Organization Engineering in Spain
La historia de la Organización Industrial en España

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Abstract: Organization Engineering, more commonly referred to as Industrial Engineering in the English-speaking world, is a widespread discipline that covers fields from Economic Analysis to Production Management or Operational Research. Our objective with this paper is to describe the historical evolution of this discipline, starting from the strive of the Industrial Revolution for efficiently planning and managing the new production means. We discuss the main cornerstones in this evolution, starting with the works of F.W. Taylor, analyze the influence of World War II, which boosted the demand for increasingly complex models, algorithms and applications, and describe the current scenario for Organization Engineering and its main challenges for the future. The paper then turns to the Spanish context, where the academic development of the discipline is also analyzed, including mention of the different Engineering Schools where the corresponding fields were incorporated to their curriculum, and ending with the current scenario brought along at the European level by the Bologna agreement. The third and final part of the paper explores the relation between Organization Engineering and Business Organization in Spain. These two areas of knowledge, the first one related to engineering and industrial concepts while the second one is more focused on economics and usually based on Economics Faculties, are often perceived as identical due to their similarities, but we comment on their differences, which are also representative of the differences between Industrial Engineering and Economics, in terms of contents, methodologies and scope.

Resumen: La Ingeniería de Organización, comúnmente conocida como Industrial Engineering en el mundo anglosajón, constituye una disciplina ampliamente extendida que abarca campos que van desde el Análisis Económico hasta la Gestión de la Producción o los Métodos Cuantitativos. Nuestro objetivo con este trabajo es el de describir la evolución histórica de esta disciplina, empezando desde la necesidad de la Revolución Industrial de planificar y gestionar eficientemente los nuevos medios productivos. Así, describimos los principales hitos identificables en esta evolución, empezando con los trabajos de F.W. Taylor, analizamos la influencia de la Segunda Guerra Mundial, que disparó la demanda de modelos, algoritmos y aplicaciones cada vez más complejos, y comentamos el escenario actual de la Ingeniería de Organización y sus principales retos de cara al futuro. El artículo se centra a partir de ahí en el contexto español, para el que se analiza igualmente el desarrollo académico de la disciplina, incluyendo una mención a las diferentes Escuelas de Ingeniería que incorporaron las materias correspondientes a su plan de estudios, y finalizando con la situación actual generada a nivel europeo por el Tratado de Bolonia. La tercera y última parte del artículo explora la relación entre la Ingeniería de Organización y la Organización de Empresas en España. Estas dos áreas de conocimiento, la primera de ellas relacionada con conceptos industriales e ingenieriles mientras que la segunda está más orientada a la economía y se suele impartir en Facultades de Económicas, son con frecuencia percibidas como idénticas a causa de sus similitudes, pero nos centramos aquí en recalcar sus diferencias, en materia de contenidos, metodologías y ámbitos de actuación.

Keywords: Organization Engineering, Industrial Engineering, Historical Evolution, Academic Development.

1. Introduction

Drawing a map of Organization Engineering (Industrial Engineering in the Anglo-Saxon interpretation of the term) is not a simple task due to the variety of fields it contains, to the increasing complexity of the involved processes, both productive and organizational, and to the convenience of using Quantitative Management Methods based on Operational Research, defined in a broad sense. When this is also joined by the constant impact of technological progress on the design of organizations, it seems impossible, or at least a waste of time, to try and establish precise formulations and definitions about the matter at hand.

We have nevertheless tried to shed some light on the boundaries and different perspectives of Organization Engineering. In the following sections, we first examine the field, its origins and evolution. Focusing mainly on the Spanish scenario, we discuss the relationship between the Management area and the field of Organization Engineering. Finally, we identify the different areas of industrial application for the field's know-how techniques. We briefly describe the multiple application efforts of Organization Engineering, and how they

have evolved from the traditional limitation to the study and analysis of production systems.

2. Origins and Evolution of Industrial Organization

The concept of Organization Engineering is strongly linked to Industrial Organization, and this is even more so as we go back into its origins. In the early years of Industrial Organization, the concept seems easier to delimit, given that the focus is exclusively in streamlining production processes. It is not until the late twentieth century when a broader perspective makes Organization Engineering embrace the rationalization processes that man faces in relation to the design, operation and management of organizations.

From the beginning, the basic questions of what, how, where and how much to produce have always been related to any organized productive activity of man. However, it was as a result of the Industrial Revolution when such decisions began to increase both in terms of complexity and of their impact on overall results. They thus started requiring specific techniques and methods for study. In the hundred years covering from the late eighteenth to the late nineteenth century, early thinkers like Adam Smith (1723-1790) or Charles Babbage (1792-1871) began formulating those techniques and methods, which initially consisted basically of theoretical analyses of the Industrial Organization and, in particular, of the benefits of the division and specialization of labor and use of tools and instruments.

However, it is not until the last years of the nineteenth century when the scientific method based on observation, measurement and systematic experimentation to confirm or rule out hypotheses about the characteristics of processes is fully established (Nelson, 1995). At first these activities were carried out by mechanical engineers and were aimed at improving the production system. Among the first known case studies, we may highlight those of Matt Boulton (1711-1780) and James Watt Jr. (1736-1819), son of the inventor of the steam engine, who conducted research on new forms of organization in their Soho foundry.

By that time, the Frenchman Maurice Leblanc (1857-1923) on one hand, and the American Eli Whitney (1765-1825) on the other, put into practice the idea of developing manufacturing machinery which, despite requiring a significant investment, allowed to produce large series with much lower costs per unit, and thus allowed to amortize that investment cost in a relatively short time. The mass production of complex products that were first manufactured as individual parts and then assembled brought along the development of standardization. To this respect, Henry Ford (1863-1947) completely turned the assembly activity inside out with his introduction of the concept of assembly line or chain, where specialized workers were fixed and the product moved from one to the next more or less continuously using a the appropriate handling systems.

However, the most significant milestone in the birth of Industrial Organization had occurred in 1903, with the publication by Frederick W. Taylor (1856-1915) of his article entitled *Shop Management.* Despite many criticisms, and taking into account the time when it was written, the attempt to establish and defend a scientific approach to the problem of production management must be acknowledged. One could even argue that the most important contribution of Taylor was simply to point out that any productive organization might benefit from devoting some of its members not to perform operations directly, but to study the most appropriate ways for others to do it. The problems addressed by Taylor were very diverse, including the study of time and motions, the standardization of tools, task planning, the use of cards to provide instructions to operators, the systematic classification of parts and products, the routing system, the cost estimation procedure, the selection of staff in accordance with the workplace, the introduction of incentives, or the measurement of productivity.

The «Taylorist» approach, which was analytical, reductionist and mechanistic, was continued in subsequent studies, among which were the ones carried out by the Gilbreths (Frank B. 1868-1924, and his wife Lillian M. 1878 - 1972). They proposed the subdivision of each task into individual elements, which should then be analyzed independently and in conjunction, seeking to eliminate those that were unnecessary or wasteful. Thus, the synthesis of the remaining elements would result in generate the new procedure. Another significant contribution was made about the same time by Charles Bedaux (1887-1943) who normalized the measurement of time using standard minutes, which also took into account the corresponding resting breaks. Also important were the works of Henry L. Gantt (1861-1919), who is responsible for the development of the bar charts that

are still in use today in production scheduling, sequencing and project management tasks.

The first professional practice-oriented association related to Industrial Organization was created in 1915 (year of Taylor's death) by the name of *Taylor Society.* By the end of the second decade of this century, the ideas of Taylor and his followers, known by the generic name of *Scientific Management,* were widely known and discussed throughout the industrial world. The post-Taylor development evolved into two different lines of progress. On one hand, it tried to develop methods for the study of complex processes using a systematic arrangement of the elements of the problem, resulting in analysis procedures aimed at an approximate evaluation of the consequences of each alternative. On the other hand, mathematical models were introduced for the treatment of certain problems which may be formulated in these terms.

With respect to the first approach, the decade of the thirties brought along a new interest in time and motion studies, which may be explained by several reasons. First, the critical situation of the global, and particularly the American, economy, which raised the interest in any method devised for cost reduction. Moreover, the increasing awareness of workers about the economic issues affecting the industry and their role in contributing to solve them. Finally, a certain view of time and motion studies as opposed to each other disappeared, and they started to be contemplated as a joint field.

Within this joint consideration of the different aspects affecting productivity related to the study of time and motion, the design of the plant layout was also incorporated. The link between these techniques was formulated using the analog representations of the routing diagram. Another step forward was incorporated with the introduction by Tippett in England in the mid-thirties of the sampling techniques for the study of activity and rest periods without the need to use direct timing.

Up until then, most management studies were designed to correct the existing inefficiencies. In order to develop new methods applicable to non-existing processes without any specific data available, new systems based on standardized basic time elements were required. These basic time elements would then be combined to obtain normal durations of full tasks. Along this line, at the request of Westinghouse Electric Co., a lengthy investigation began in 1940 directed by Harold B. Maynard and also conducted by G.J. Stegemerten and J.L. Schwab, which in 1948 eventually led to the publication of the *Methods Time Measurement System* (MTM), which was immediately a great success.

With respect to the second approach, focused on the use of mathematical models, the first highlight corresponds to the economic lot formula or Wilson formula, obtained by F.W. Harris in 1915 as the analytical solution to the lot sizing problem considering setup and maintenance costs. The simplicity and elegance of this formula stimulated the mathematical treatment of other production management problems. Another field that had an early mathematical development was the use of statistical methods for quality control of manufactured products. In 1912 Thortorn C. Fry published *Probability and its Engineering Uses* and later, in 1931, W. Shewart (1891-1967) published his book *Economic Control of Quality of Manufactured Products,* which included the first descriptions of statistical quality control graphs.

However, it was the war effort of World War II what produced the big push in the use of mathematical models to solve complex logistical and strategic issues. Indeed, war times systematically have represented a stimulus to develop new technologies and improve existing methods. Thus, research groups appeared and were operational on both sides focused on solving many new problems using classical techniques and developing new mathematical methods of modeling, systems analysis, simulation, etc. When, after the war, these scientists and engineers joined civilian life not only brought with them these new techniques and tools but something that ultimately proved even more decisive: a renewed willingness to solve problems via analysis, data collection, model and optimization. Thus were born linear programming, game theory, cybernetics, information theory, dynamic programming, etc. The quantitative effect of these techniques on the organization of production was immediate and still exists today. The planning and control of production, physical distribution, supply management, etc., were boosted in an unprecedented way. By then, Organization Engineering was already fully established as a discipline, completely independent of Mechanical Engineering. American universities incorporated a specific degree under the name of *Industrial Engineering.*

From there on, the birth of the computer and the progressive increase in computing power boosted the extensive and intensive use of mathematical models, able to solve both large-scale strategic problems and real time decision problems. The discipline entered a positive feedback loop in which data availability allowed practitioners to develop more sophisticated models, which in turn demanded more and more information and better quality data. Customers grew sophisticated and thought not only of cost but also of quality and variety. The response times to problems became shorter as a result of the shortening of product life cycles. Competition intensified, accelerated, and at the same time spread globally. The management of production operations was integrated with procurement and distribution resulting in the concept of supply chain, which linked the company's various facilities with suppliers and customers. The same decisions about what, how, where, when and how much to produce still required answers, but the difference was that the increasing scale and complexity of production systems no longer tolerated mistakes or tardiness. This new scenario led to the modern world.

This demanding, chaotic and uncertain context constitutes the environment where Organization Engineering activities take place nowadays, when the very survival of businesses is at stake. Only those companies using resources (human, financial and technological) in a more effective and efficient way, only those who are more agile in terms of exploiting the scarce business opportunities that may arise, only those which play their cards better from a strategic point of view will be able to survive and grow. The rest will be absorbed or disappear.

Recently, organizational tasks have exceeded the production aspects of the business, and even the company itself. The context of logistics understood in a broad sense, of telecommunications, management of information, of energy resources, of natural resources, preservation of the environment and the specific characteristics of public administration systems, are analyzed and discussed from the perspective of Organization Engineering. In fact, the role of the Organization engineer in linking together the industrial and technological revolutions is accurately covered in Du Preez and Pintelon (1997). We are convinced that this field and the professionals who are active in it, whether as engineers or holding other degrees, are called to play a key role in the effective and efficient management of the operations taking place in companies, which is generally acknowledged as critical in the 21st century world.

3. Academic development of Organization Engineering within the Spanish context

Very little has been written about the birth of Organization Engineering in Spain. The first contributions to the issue were presented at the annual Conference of Organization Engineering held in Seville in 2001, corresponding to the papers by professors Companys (2001), Boronat (2001) and Zubillaga (2001). Organization Engineering came to life in Spain closely linked to the evolution of Industrial Engineering (again, a specifically Spanish term which does not correspond to the anglo-saxon Industrial Engineering, but to a broader discipline closer to Mechanical Engineering). During the first years, a series of Organization-related courses were taught within the Industrial Engineering syllabus, then it became an individual specialty of the Industrial Engineering degree, later a stand-alone second-cycle University degree, until currently becoming a full Engineering degree on its own.

The starting point may be located circa 1774, when the Basque Society of Friends of the Country founded the Vergara Patriotic Seminar. This event could well be, in the light of the guidelines provided for subsequent teaching contents and programs, the origin of the Industrial Engineer degree in Spain. As a novelty, the Seminar combined the possibility to study Physics, Chemistry and Metallurgy.

However, the first references to Industrial Engineering at the institutional level correspond to the Royal Industrial Institute, which was founded in 1850 as an extension of the Royal Conservatory of Arts, and that would serve as a transition between the origins of Civil Engineering, the Enlightenment, and the Industrial Engineering degree itself. Before that, several parallel processes had already contributed to spreading around the need to incorporate Industrial Engineering studies to technical schools. Such is the example of the School of Practical and Mechanical Equipment in 1808, which was promoted by the Board of Trade in Barcelona and that lasted for about 40 years. Likewise, in 1827, the Economic Society in Valencia established a new center similar to the Conservatory of Arts, which was followed by the creation of similar institutions in Oviedo, Sevilla, Zaragoza, Cadiz, Murcia, Badajoz and Burgos.

All these initiatives contributed to the state of affairs that in 1850 resulted in the issuing of the first Organic Plan for Industrial Education, containing the first conceptualization of the Industrial Engineering degree as such. The degree was organized in three levels: elementary, taught in first-class institutes; extension, which could be obtained in the Industrial Schools of Barcelona, Sevilla and Vergara; and superior, which could only be awarded by the Royal Industrial Institute in Madrid. Following the Public Instruction Act passed on 10th September 1857 by Minister Moyano, this superior degree was also incorporated to the schools of Barcelona, Sevilla, Valencia, Gijón and Vergara.

Then, the lack of industrial momentum in nineteenth-century Spain led to the closure of all those centers, except for Barcelona. Only the School of Bilbao, heir to Vergara, was reopened in 1899, followed shortly by Madrid in 1901, in Madrid. They remained, for more than half a century, the only three technical schools teaching Industrial Engineering in Spain.

In fact, the schools of Seville and Valencia did not reopen until the sixties. The Engineering School of Seville was put back in place in December 1963, by Decree 3608/63, with the support of the Organization for Economic Cooperation and Development (OECD). In July 1965 experts from that organization visited Seville to discuss the new contents to be taught in the school. The so-called OECD syllabus was passed in July 1967. The construction of the building began in August 1965, and the teaching activities started in Hall L-1 a year later, in September 1966. The school was officially opened in April 1967, with Mr. José Mª de Amores Jiménez as its first Dean.

With respect to the syllabus itself, it is worth noting that in those early years of the 19th century the degree was limited only to the mechanical and chemical specialties, until the electrical specialty was born years later in 1907. And finally, in 1964, the Industrial Organization specialty was created, directly linked to the scope of Organization Engineering.

Nevertheless, the degree of Industrial Engineering had always featured contents that clearly fall nowadays within the boundaries of Organization Engineering, like courses on «Political Economy with Application to Industry» and «Industrial Law», already present in the official syllabus established by the Moyano Act. In fact, even though the 1947 syllabus did not contemplate the Industrial Organization specialty, it did result in the creation of the Economics, Organization and Law Chair, which was responsible for courses on «Theoretical and Applied Economic Policy», «Industrial Health and Hygiene and Labor Psicotechnics», «Economic Structure in Spain in Relation to the World», «Economy of Companies and Production», «Organization and Accounting in Industrial Companies», and «Industrial, Labor and Administrative Law», all of them in the 6th year.

Later, the 1957 syllabus divided the aforementioned chair into Management and Organization, on one side, and Economics on the other. Courses on «Economic Theory, Structures and Institutions» and «industrial Safety and Psicotechnics» were taught in the 4th year as core subjects. The 5th year included «Business Administration» and «Production Management», also included in all the specialties, and «Planning and Organization of Workshops» only for the specialty of Mechanics.

As mentioned above, the 1964 syllabus finally created the specialty of Industrial Organization, thus unfolding the Chair of Management and Organization into Business Administration on one hand and Production Organization on the other, while keeping the Chair of Economics. At that time, most of the teachers working in these chairs chose to adhere administratively to the area of Management, although in some cases they favored Statistics and Operations Research instead.

Throughout this time, all the issues associated with the Organization Engineering had been gradually gaining strength in society in general and within the industrial environment in particular, largely due to the increased competition and the need for new management approaches. Thus, both the specialty of Industrial Organization and the Organization courses taught in other specialties were reinforced. Although later the 1983 syllabus modified the names of several courses, in 1964 the Organization specialty included (among other Mechanical, Chemical and Electrical contents) the following courses over three years: «Economic Theory and Institutions», «Economic Theory of the Enterprise», «Production Management», «Operations Research I», «Psycho-sociology and Law», «Business Administration», «Information Integration», «Markets» and «Operations Research II».

From this moment on, the incorporation of Organization Engineering disciplines was a constant not only in all the different fields of Industrial Engineering, but also in every other superior engineering degree. This was the case, for example, in the Sevilla

school, to which the 157/1993 Act of 5th October 1993 allocated the Telecommunications degree besides the Industrial Engineering degree it was already providing. Organization contents were also incorporated in the same school to the subsequent degree in Chemical Engineering and to the second cycle degrees in Engineering in Automation and Industrial Electronics and Electronics Engineering. The degree of Industrial Organization Engineer was also taught in the same school, another second cycle degree which includes much of the wide range of contents nowadays identified by Organization Engineering. Finally, the Aeronautical Engineering degree was started in 2002/03.

However, and despite the fact that the new degrees had not yet reached their maturity stage, a new major reform was again introduced in the university education sector. The process began on May 25th, 1998, when the Education Ministers of France, Germany, Italy and the United Kingdom signed at the Sorbonne a statement urging the development of a «European Higher Education Area». Shortly after that came the most famous Bologna Declaration on June 19th, 1999, that brought together 29 European countries, including countries within the European Union and many Eastern and Central European countries. This Bologna Declaration set the stage for the development of the «European Higher Education Area», organized according to certain principles of quality, mobility, diversity and competitiveness, and oriented towards achieving two strategic objectives: increasing employment capabilities in the European Union and promoting the European System of Higher Education as a magnet for students, teachers and professionals from around the world.

Bologna incorporated drastic and important changes to the design of the Spanish university system. Not isolated from it, this brought along new challenges for the Organization Engineering discipline, in order to gain a decisive weight in the new syllabi of Industrial Engineering and the specific Organization Engineer degree. Focusing on the objectives of the Bologna Declaration, Organization Engineering, based on its important historical legacy and recast with the new information technologies, provides new perspectives and insights to the engineer of the future.

4. Relation between Organization Engineering and Business Organization in Spain

Once more, it is necessary to stress the difference between the Spanish terms and those acknowledged by the anglo-saxon world, as shown in Table 1. This paper, as mentioned before, uses the translations of the Spanish terms for the different disciplines, instead of the English ones.

The historical record described throughout the previous sections establishes a first approximation to the relationship between Business Organization and Organization Engineering. This section further explores into the different changes and developments undergone by both over the last years.

The Annex to the Royal Act 1888/84 of 26th September (BOE 10/26/1984) established the joint incorporation to the Business Organization area of all the courses on Industrial Organization taught in technical schools and engineering schools, together with the courses on Business Economics and Economic Policy of Enterprises, taught at Economics and Business Faculties. In the spirit of this regulation was thus to turn Business Organization into a wider area, as well as making it the main reference framework for all the scholarly knowledge on all the subsystems that conform enterprises and their relations

Table 1
Correspondence between Spanish and English terms

English term	*Spanish term*	*English translation of the Spanish term*
Mechanical / Electrical / Chemical Engineering	Ingeniería Industrial	Industrial Engineering
Industrial Engineering	Ingeniería de Organización	Organization Engineering
Management	Administración de Empresas	Business Administration
	Organización de Empresas	Business Organization

to one another. Industrial Organization would thus fit as an integral feature of the area of Business Organization, following the classical tradition of labor management schools as described by Cuervo García (1989).

What is nevertheless clear, also according to the Act, is that the engineering bias of Industrial Organization had to confer the field a distinct identity within the scope of the Business Organization area, different from the purely Economics approach. This identity stems, on one hand, from the use of engineering methodologies, and also from its technological orientation, which separates it from other non-technical professional areas. Particularly in relation to this latter aspect, it is important to remember once again the long history of Industrial Organization. In fact, the specialty of Organization Engineering has been taught in technical schools since the implementation of the 1964 Plan, whereas Faculties of Business and Economics were not created in Spain until October 1971.

Furthermore, another element that characterizes and differentiates Organization Engineering within the area of Business Organization lies in the types of courses associated with that area at technical schools. For example, the specialties offered within Organization Engineering and Industrial Organization rely mostly on Departments of Industrial Organization located at engineering schools. These courses have titles like «Operations Research», «Production Management», «Information Systems», «Business Administration», «Marketing», «Human Resources», «Quality Management» or «Economy» among others. In Faculties of Business and Economics, many of these courses have been extracted from the Business Organization area in order to create new areas of knowledge that are specific for them.

Thus, Organization Engineering is a scholarly field whose boundaries are clearly defined:

- By its knowledge framework and its contents, which focus on the analysis of the organizational, economic and management aspects related to the design, implementation and operational and service systems, especially those where technology plays a key role.

- By its methodology, which, both in terms of research and of professional activity, is largely based on the building of descriptive, quantitative optimization models, and the interpretation of the behavior of these models in order to design or incorporate improvements to real systems, often favoring the use of information and communication technologies (ICTs). This usually implies the use of a wide range of Operations Research techniques, plus a series of more general purpose engineering tools (Statistics, Differential and Integral Calculus, Differential Equations, etc.), as well as other approaches derived from Organizational or Socio-Economic fields, Innovation and Technology Management, etc.

- By its scope, engineering-oriented, eminently pragmatic and focused on practical applications to design, implement and operate increasingly large and complex systems within productive or service industries. The objective is to extract the maximum benefit from the system given the set of technological, organizational, socio-economic and environmental constraints involved, and also to identify, within the current context of rapid innovation, potentially interesting opportunities for technological and organizational changes, and estimate and evaluate their advantages and disadvantages

This is why Engineering schools claim Organization Engineering as their own, given its inherent features, characteristics and objectives. All this breadth of knowledge must be taken into consideration by the Organization engineers in order to solve the wide variety of problems encountered in professional practice within any sector of society. They will be expected to possess theoretical and practical knowledge on all the decision areas and processes existing in companies, including their technological aspects.

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