10° CONVEGNO DI
STORIA DELL'INGEGNERIA
6th international conference on history of engineering
13-14 June 2024

MARCELLO LANDO[1], MASSIMILIANO M. SCHIRALDI[2]
[1] Università degli Studi di Napoli "Federico II"
[2] Università degli Studi di Roma "Tor Vergata" schiraldi@uniroma2.it

HISTORICAL INDUSTRIAL ROOTS OF ENGINEERING AND MANAGEMENT:
FROM THE ORGANIZATION OF WORK IN THE FACTORY TO THE MANAGEMENT OF COMPLEX SYSTEMS

ABSTRACT
As early as after World War II, the increasing responsibilities gradually attributed to engineers in an industrial context - also behind the push coming from excellent examples found at large North American and European educational institutions - had made the need felt in Italy to integrate the traditional curriculum of industrial engineers with elements of Economics and Business Management. The activation of the University Degree in Engineering and Management, which took place in the last two decades of the last century at Italian universities, rewarded by the growing attention of companies in every sector and the preferential choice of young people, therefore stands to represent one of the most successful examples in the history of innovations introduced in university programs. It is not always recognized that, since the advent of the industrial era in the 19th century, the history of management has been written everywhere by excellent figures of industrial engineers. Yet, despite this historical connotation of the engineer working in business management, the not-everywhere-balanced evolution of academic institutions has sometimes come to produce an imbalance in the educational mix offered through the Engineering and Management program, giving an excessive relevance to disciplines in the area of economics and finance at the expense of other inescapable educational occurrences. In this regard, it should be noted that the very invasiveness of the verbal image of "industry" - which we find in expressions such as hospitality industry, agricultural industry, entertainment industry, healthcare industry, and others - makes a recognition, if anything, to the success of the typical engineering approach, pioneered in the manufacturing industry, when extended to the most varied fields of economic activity. This article aims to trace the historical "industrial" roots of the Engineering and Management programs, reaffirming the educational centrality of disciplines related to operations management, manufacturing technologies, and industrial automation, leading to the production of goods and services of primary interest to human society.

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FROM INDUSTRIAL TO MANAGEMENT ENGINEER

The figure of the industrial engineer has existed for much longer than when the first university degrees in industrial engineering were formalized and institutionalized. Too many times, the example of the Venice Arsenal has been cited, arguably the first example of shipbuilding run in an organized manner that anticipated many of the concepts of modern industrial engineering. But without wishing to go back to the 12th century and remaining focused on the modern era, we can say that the first milestone can be placed in 1886, when at the Annual Meeting of the ASME – the American Society of Mechanical Engineers, six years after its founding, already was questioned the training of the mechanical engineer, calling for the growth of the economic and managerial component in it. The idea that engineers must design and fabricate products at costs many consumers can afford was advocated. This idea gave birth to the subject of Management Engineering subsequently. On that occasion, the speeches of Henry Towne and Henry Metcalfe are of key importance. The former said: "*The monogram of our national initials, which is the symbol for our monetary unit, the dollar, is almost as frequently conjoined to the figures of an engineer's calculations as are the symbols indicating feet, minutes, pounds, or gallons. The final issue of his work, in probably a majority of cases, resolves itself into a question of dollars and cents, of relative or absolute values. This statement, while true in regard to the work of all engineers, applies particularly to that of the mechanical engineer, for the reason that his functions, more frequently than in the case of others, include the executive duties of organizing and superintending the operations of industrial establishments, and of directing the labor of the artisans whose organized efforts yield the fruition of his work.*" [1]. At the same time, the latter closed with "*efficiency being admitted, the excellence of an administration is universally measured by its cost.*"[2] Also attending that same ASME conference was Frederick Winslow Taylor - who would become its president in 1906 - speaking to confirm that he, too, was working on a publication idea that went in the same direction, and that came to fruition with his 1903 *Shop Management* [3] before even the more famous masterpiece *The principles of scientific management* of 1911[4].

The need to introduce economic training into the cultural baggage of the engineer was reiterated by engineers Emile Garke and John Manger Fells in their 1887 book *Factory Accounts - Their Principles and Practices* [5]. What emerged in the discussion concerning the engineer's training were considerations that emphasized the importance of ensuring preparedness in factory management. Thus, The emphasis was on management aspects and aspects related to the shop floor. Therein lies already, acknowledged in the literature, the first trigger for a reform of engineering education. As Monte Alan Calvert pointed out, "*by the 1880s, what one historian has called the 'shop culture' slowly began to give way to the 'school culture*"' [6]. As is often the case, these early signs of reform were strongly opposed by the

"old school" devotees, who saw the danger of losing more scientific knowledge in favor of learning more simple and practical elements, necessary to run the factory and not to design its components[7]. That danger, in fact, materialized, so much so that the stigma of Stephen Timoschenko at the University of Michigan was recorded in the annals when - as reported by Emmerson in 1973 - in 1922 he complained about the poor preparation of engineers in the theory of materials physics[8].

The first formal course in Industrial Engineering at a university can be said to be that of the University of Kansas in 1901, entitled *Factory Economics*[9], which was created with the goal of training professionals capable of managing manufacturing processes. It was followed by the Penn State College of Engineering in 1908 with the Industrial Engineering program founded by Hugo Diemer. Diemer coined the term "industrial engineering" in 1900 to describe the fusion of engineering and business disciplines and published in 1910 the book *Factory Organization and Administration*[10] , signing himself "professor of industrial engineering" and at that time already holding the position of head of the Department of Industrial Engineering in the same university. Diemer wrote: "*It is the business of the production engineer to know every single item that constitutes his finished product, and every step involved in the handling of every piece. He must know what is the most advantageous manufacturing quantity of every single item so as to secure uniformity of flow as well as economy of manufacture. He must know how long each step ought to take under the best attainable working conditions. He must be able to tell at any time the exact condition as regards quantity and state of finishedness of every part involved in his manufacturing process. The engineer must be able not only to design, but to execute. A draftsman may be able to design, but unless he is able to execute his designs to successful operation he cannot be classed as an engineer. The production engineer must be able to execute his work as he has planned it. This requires two qualifications in addition to technical engineering ability: He must know men, and he must have creative ability in applying good statistical, accounting, and "system" methods to any particular production work he may undertake.*"

To complete the overview of the emergence of degree programs in Industrial Engineering, it is worth mentioning in succession the Industrial Engineering Program launched in 1911 at Syracuse University "*As early as 1877 civil engineering courses were offered through the College of Liberal Arts. Electrical engineering followed in 1897, then mechanical engineering in 1900. In 1901 the university, thanks to the vision and financial support of noted industrialist Lyman Cornelius Smith, established a college dedicated exclusively to teaching various areas of applied science. Programs in industrial engineering (1911), chemistry (1914) and aeronautics (1927) were added in response to societal demand.[...] A master's program in engineering administration (engineering management) was established in 1957*" [11], as well as, three years later, in 1914, the Engineering Administration course at the Massachusetts Institute of Technology "*The Alfred P. Sloan School of Management began in 1914 as Course XV, Engineering Administration, at the Massachusetts Institute of Technology, within the Department of Economics and Statistics. The concept of providing business training in the academic environment was gaining popularity in the early 1910s and the idea of an engineering administration or a business engineering program at MIT was promoted by several faculty members including Professor Harold Pender of the Department of Electrical Engineering. Pender envisioned that the course would be taught in conjunction with engineering courses. In 1913 an ad hoc committee of the Alumni Council studied the*

matter and issued a report in favor of a program specially designed to train men to be competent managers of businesses that have much to do with engineering problems. In 1930 Course XV became an independent department and was named the Department of Business and Engineering Administration" [12].

In addition to initiatives in the United States, in Europe the forerunners were the Germans in 1927, launching the Industrial Engineering course at the Berlin - Charlottenburg University of Applied Sciences, initially called "Business and Technology." The Industrial engineering course was intended to create a bridge between an economic discipline and a technical specialization. This included designing and considering business objectives, given market needs and recording socio-cultural effects. "*Strategic interdepartmental problem solving is one of the core competencies of the industrial engineer, who is thus predestined for managerial positions.*"[13] It would then have taken more than 30 years to see the designation of M.S. Engineering Management emerge in 1959 at Drexel University - College of Engineering: "*The program was developed at the specific request of Delaware Valley industry, which found that many engineers lacked the management skills needed to advance to leadership positions*"[14] and in 1965 the University of Missouri-Rolla authorized the M.S. degree in Engineering Administration. In 1967, the world's first university department dedicated to the nascent field of Engineering Management was founded at that University[15].

Continuing the review of university launches of courses in Industrial Engineering or Management Engineering is relatively useful, as in the 1970s and 1980s these initiatives were rampant worldwide in response to the industrial growth needs of the period. In fact, as early as 1984, there were hundreds of universities in the world offering a B.S. or M.S. program with Management Engineering contents and with different titles: Engineering Management, Management Engineering, Engineering Administration, Industrial Management, Industrial Engineering, Systems Engineering with Engineering Management, Management of Technology, Engineering Executive, Engineering Operations, to name a few. Simultaneously, the course of study of Management Engineering was gradually enriched with increasingly "soft" elements in line with the transformation of the world economy: writes Chisholm, of the Department of Mechanical Engineering of the University of Salford, U.K., in 1989 "*Many engineers also are inclined to discount the importance of the human factor in improving industrial performance. Rather than crediting much of the Japanese success in world markets to their use of 'Kaizen'--people-based continuous improvement, which they may see as 'low tech." involving somewhat trivial, rather obvious concepts-- they favour an explanation based primarily on the successful application of advanced technology. Nevertheless. it is now difficult to deny that a major, if not crucial, component in achieving good overall company performance is the human factor. In the future, enterprises which may possess the embodiment of a wealth of the most advanced manufacturing technology, and yet which have failed to integrate it within a human-centered organization, are unlikely to survive in the market place. Researchers in manufacturing engineering, dedicated as they should be to the ultimate improvement in overall manufacturing performance, must therefore increasingly incorporate the human factor in their research planning and execution. The likely relevance of manufacturing research projects must be examined in the light of this new perspective of manufacturing as a whole. The marginality of some of them may then have to be recognized*"[16]. At that time, Kogaclu wrote: "*Universities are now offering formal educational programs designed for engineers*

and scientists moving into technical management positions while maintaining their background identity. These are rigorous programs blending mathematical approaches, behavioral considerations, organizational concepts and decision-making methodologies in a delicate balance. The strong demand for the Engineering Management programs is evident in the rapid growth pattern followed by these programs. This growth has been particularly visible since the mid-1970s, and shows no sign of a slow-down"[17]. With the benefit of hindsight, we can conclude today that this vision of balanced and harmonious growth of disciplines within the management engineer's education was quite optimistic, because it seems that this balance has not been maintained in all Management Engineering courses, in all countries.

THE ITALIAN CASE

It may be useful to recall the Italian experience: also in the wake of the experiment of the Center for Applied Engineering Economics Studies (CSEI) of the "Federico II" University of Naples[18], the Economic-Organizational curriculum of the M.S. in Engineering was launched in 1972 at the Arcacavata campus of the University of Calabria, for the purpose of "*combining specific managerial and - precisely - economic-organizational knowledge, with a broad engineering culture base*"[19]. It is now clear that, at the time, nothing new was invented then: as the academic studies of Industrial Engineering had historically developed under the impetus of the second industrial revolution and its effects on production processes and the organization of work in factories, the subsequent evolution of markets with the emergence of new processes and new products - in the second half of the last century, in the context of the third industrial revolution - gave impetus in Italy to the activation of diversified educational paths for the industrial engineer: this led to the degree courses in Aeronautical, Chemical, Electrical, Electronic, Mechanical Engineering, etc., with curricula appropriately differentiated with the educational needs identified for the different techno-mercial sectors. At that time, much greater specific weight was given to design-oriented disciplines rather than to others, aimed at training engineers destined to manage the primary factors of production (materials, machines, plants, utilities, human resources).

In a structurally "transforming" country such as Italy - whose economy is based by necessity on industrial manufacturing production - the realization of the pressing need for technicians capable of managing production processes with maximum efficiency, starting in the 1970s, both in the academic and in the competent political arenas, ignited the debate that over the next two decades would lead to the inevitable establishment of the degree course in Management Engineering. The Bachelor of Science in Management Engineering, far from aiming to train the engineer-economist, was institutionally conceived to train technicians prepared for the impact of that operational reality in which many other engineers had had to insert themselves, facing greater difficulties. By its unquestioned derivation from the pre-existing engineering courses with an industrial orientation, this new degree course should, in this sense, have seen an increase in the specific weight of the teaching disciplines addressed to the study of production technologies and processes, with a curriculum enriched by those fundamentals of economics and organization of the flows of material and immaterial resources to the presidium of which engineers are mostly called upon in companies, exactly as Kogaclu

wished.

It should now be noted that, since the second half of the last century, with a view to a pressing "lean thinking", many non-core-business activities, which large manufacturing industry has gradually chosen to outsource, have migrated to specialized areas of the tertiary sector (conventional or advanced as the case may be) while retaining the original managerial imprinting about the specific production processes and the resources correspondingly used. At the same time, especially with the advent of the digital age, the logistics-management model of industrial processes has been able to be taken as a reference for various other sectors of economic activities, up to the point where expressions such as credit industry, entertainment industry, hotel industry, hospital industry, agricultural industry, etc., have been used everywhere. And such expressions, which might appear to be "journalistic oxymorons", instead do definitive justice to the successful contamination contracted by so many areas of economic activity - including those concerning the production of entirely intangible services - that have been able to avail themselves of management techniques successfully tested in the manufacturing enterprise. Indeed, looking at the employment outlets of the modern management engineer in Italy, it is clear that placement in the so-called "factory" is still now increasingly on the decline (Fig. 1).

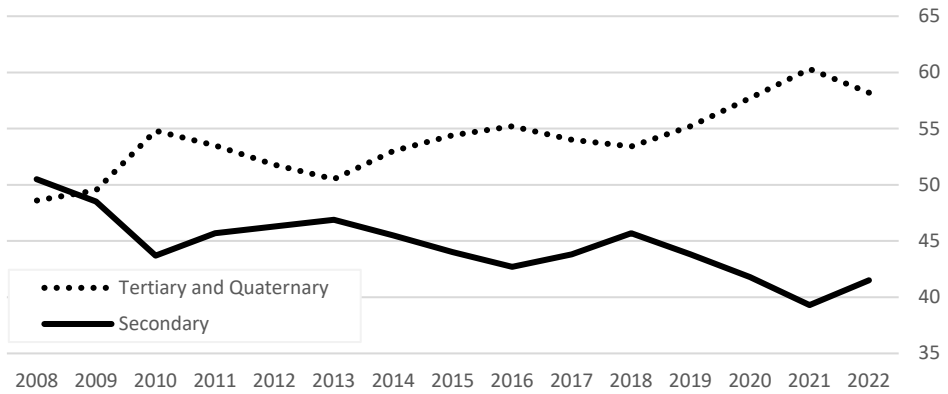

Figure 1: Changes in the employment sectors of M.S. engineering management graduates in Italy (%)
Source: Almalaurea, 2023

Ultimately, it appears, therefore, that the transversality of Management Engineering, and by the same token, the often heterogeneous employment opportunities of a management engineer, reside at the bottom in the traceability to the industrial production model of the processes developed in the most varied sectors of economic activities, in which - as in the best examples of modern "industrial" enterprise - the term "operation", which in the last century identified the active phase of a process (physical, chemical, biological, etc.) in which a well-defined transformation takes place in the manufacturing cycle of a product - now takes on the much broader meaning of "increase in value" achieved at that stage by the product/service in progress.

Unfortunately, however, almost about thirty years after the awarding of the first degree in

Management Engineering at an Italian university, it somewhere still happens that this course of study is attributed a content and value that at least does not correspond to the inspiring principles that at the time led to its very institution. In fact, it is not uncommon for the attribute "management" to be considered in some way pertaining to studies and disciplines with a "business" orientation, and for a management engineering graduate to be considered, therefore, as a sort of a mule, a hybrid between a technician and an economist with what may follow in terms of *deminutio* for each of the two qualifications affixed to the same person. Contributing to this image, moreover, has been the often over-emphasis that for certain disciplines - at the time new, compared to the centuries-old tradition of study paths in engineering - has been adopted at some universities in presenting the degree course in Management Engineering; what has given rise to the assumption that the introduction of such disciplines has had the sense of procuring a revolutionary change in engineering studies themselves, such as to give rise to a figure of an engineer entirely new to the labour market.

In some cases, there has been no lack of an unbalanced dosage among economic-organizational disciplines and those that are inalienably basic for the engineer, betraying in this the original mandate that, in conceiving the training in management engineering, envisaged a package of supportive rather than substitute knowledge. And, concerning the often confused image of the management engineering graduate - at least in Italy - it should be noted how recurrent is the case of young people who, close to exiting high school, are uncertain in their choice between a degree in Business Management or Management Engineering, as if, after all, these are two study paths that are substantially similar in terms of difficulty, albeit different in terms of prospects in the labor market. To the above, it should be added that teaching disciplines and diplomas (undergraduate and postgraduate) identified in combination with the universal Anglism "management" in Italy saw the light for the first time at academic venues institutionally addressed to the Economic Sciences, thus giving diffusion to the idea that Management, in all its articulations, is a subject of primary, if not exclusive, competence of economists. Differently, the doctrine of Management, from the beginning of the last century to the present day, has been predominantly taught all over the world by just such distinguished industrial engineers, among whom stand out figures everywhere cited as Henry Fayol (1841-1925), Frederick W. Taylor (1856-1915), Alfred P. Sloan (1875-1966), William E. Deming (1900-1993), Joseph M. Juran (1904-2008), Taiichi Ohno (1912-1990), Richard J. Schonberger (1937-), Henry Mintzberg (1939-), Kenichi Ohmae (1943-), Michal E. Porter (1947-).

If, therefore, the culture of Management should be credited with the doctrinal and applicative foundations that have sprung from the area of Industrial Engineering, with a wide-angle lens, it may also be possible to note how much the economic sciences, in their broadest sense, have been able to avail themselves of great contributions provided by historical Engineers, starting with Vilfredo Pareto (1848-1923) up to Vernon Smith (1927-), Nobel Prize in Economics in 2002. The only apparent singularity of the successful forays of engineers into the area of business sciences draws its explanation from the great analogical heritage that, about the latter, is constituted by some fundamental laws of

physics and chemistry; not to mention the applicative potential of the mathematical tools and statistical-probabilistic methods that constallate the studies path of engineers. It is not surprising, therefore, the lack of similar award-winning encroachment by economists into scientific and technological spheres traditionally intended for engineers.

CONCLUSIONS

The relative and steady growth of the Service Sector economy relative to manufacturing over the years creates a need for human resources with both technical and managerial training, and the management engineer is an excellent candidate. This has meant that, in the evolution of the management engineer's education, technical subjects – typical of industrial and manufacturing engineering – have gradually shrunk to make room for subjects of more general application. On the other hand, the dissemination of the success factors of the notorious Toyota case in the 1980s dragged the spread, in engineering culture, of concepts such as Total Quality Management, Lean Production, Six Sigma, Problem Solving, etc. While originating within the manufacturing factory par excellence – the automotive industry – these concepts have quickly transcended that contest to gain prominence in the management of service enterprises as well.

And so it is that the figure of the management engineering graduate, originally created to fill a specific market need, has changed over time – and with it, the related university degree structures – in line with the evolution of the market: while in the early part of the last century the market need was for professionals who could manage and administer the shop floor of the manufacturing industries, in the 1980s companies began to demand skills in quality and waste reduction methods, just as around the turn of the new millennium the focus shifted to logistics and supply chain management skills. All these skills gradually required by companies have been diligently incorporated by universities within the structure of engineering management courses, precisely to align education with the needs of society. Clearly, this has entailed a necessary "lightening" (i.e., elimination) of the skills of the harder sciences, from mechanic design to theory of structures, structural engineering, to applied physics, exactly in line with the trend that Timoshenko highlighted in 1922.

Today, companies are turning to universities to demand training for management engineers in the skills of the newly emerging fields of computer science and microelectronics, in support of the alleged latest industrial revolution, Industry 4.0. It is reasonable to imagine, then, that just as skills in the hard sciences have been progressively pushed aside over a hundred years, the management engineers of the future may also have to "lighten" on manufacturing systems engineering. University curricula have a ceiling of lecture hours (which, moreover, varies considerably from country to country) and even in countries like Italy where classroom training is still preeminent (in Italian universities, a B.S. plus M.S. curriculum in Management Engineering sums up to over 2,500 classroom hours, as an average), it is not possible to always incorporate new content while keeping pre-existing content unchanged. But since the manufacturing sector – and in general, the secondary sector – is still the backbone of the world economy, a reflection on the

evolution of teaching in Engineering in general, and in Management Engineering in particular, is called for. Already mentioned analyses such as Emmerson's 1973 and Kocaoglu's 1984 lead to important reflections, and it is hoped that Engineering Education researchers may want to update them.

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