

Industrial Engineering in Spain, the challenge of a new liberal profession in the Nineteenth Century¹

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Abstract

Industrial engineering was established in Spain in 1850. Despite the initial difficulties, the profession found its role in the process of the industrialization of Spain. The industrial engineers were the first free professionals in the world of engineering, given that there was not a State Corps linked to them. In this sense, there are some similarities between the Spanish industrial engineers and the French *Centraliens*. Moreover, the educational system developed in Spain in the nineteenth century gave little autonomy to the engineering schools, and this was a major difference from the French ones.

Keywords: Industrial engineering, Spain, nineteenth century, State Corps, engineering school autonomy, technical professions.

Engineering is a practical activity in relation to artefacts, communication, and processes. The profession has been linked to the design and construction of buildings, roads, bridges, and canals, but also to the design and construction of machines, and to the organization of the production.²

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Engineering became an organised profession inside the army. The most relevant case is the creation in 1676 of the French *Corps de Génie Militaire*, as the result of the intervention of Sébastien de Vauban (1633–1707), engineer-in-chief of the Army, who promoted engineering as a specialty. Scientific knowledge was considered the basis for engineering, for a military man.

During the eighteenth century, schools were created to provide engineers with a scientific education. The *École de Ponts et Chaussées* of Paris (1747) is considered the first of these institutions. It was organised to train the members of the *Corps de Ponts et Chaussées*, a State professional corps in charge of the design, construction and maintenance of the French network of communications.³ The close relationship between a school and a State professional Corps was central to the development of scientific engineering.

At the same time, practical engineers also felt the need for a scientific basis in their profession. They established, in 1771, the Society of Civil Engineers in Great Britain, which gives us an indication of the alternative way to renew the profession. The Society, as it did later as the Institution of Civil Engineers (1819), sought to stimulate discussion and mutual learning among its members, given that British universities were not particularly interested in engineering and technology.⁴ It seems that some students in Oxford and Cambridge obtained the professional title of engineer, despite the reluctance of the faculties of both universities. The result is that university-educated engineers played no relevant role in nineteenth-century Great Britain.⁵

In France and in other European countries, however, engineering became a State profession. At the height of the French Revolution, a centralized system was created with the

² There is a very extensive literature on the modern engineering. See, for example, as a recent overview, André Grelon, Irina Gouzévitch (2007) “Reflexión sobre el ingeniero europeo en el siglo XIX: retos, problemáticas e historiografías”. In: Manuel Silva Suárez (ed.) *Técnica e Ingeniería en España. IV. El Ochocientos. Pensamiento, profesiones y Sociedad* (Zaragoza: Real Academia de Ingeniería, Institución “Fernando el Católico”, Prensas Universitarias de Zaragoza, 2007), 269–321.

³ The main reference is: Antoine Picon, *L'Invention de l'ingénieur moderne: l'École des ponts et chaussées 1747–1851* (Paris: Presses de l'École nationale des ponts et chaussées, 1992).

⁴ Gordon W. Roderick, Michael D. Stephens, *Education and Industry in the Nineteenth Century* (London-New York: Longman, 1978). See also the comparative perspective in: Robert Fox; Anna Guagnini (eds.) *Education, Technology and Industrial Performance in Europe, 1850–1939* (Cambridge, Paris: Cambridge University Press, Éditions de la Maison des Sciences de l'Homme, 1993; Ana Cardoso Matos; Maria Paula Diogo; Irina Gouzevitch; André Grelon (eds.), *Jogos de identidade profissional/Les Enjeux Identitaires des Ingénieurs/The Quest for a Professional Identity. Os Engenheiros entre a Formação e a Acção/Entre la Formation et l'Action/Engineers Between Training and Action* (Lisboa: Colibri, 2009).

⁵ Robert A. Buchanan, *The Engineers: a history of the engineering profession in Britain 1750–1914* (London: Jessica Kingsley, 1989). For the context, see: Donald S. L. Cardwell, *The Organisation of Science in England* (London: W. Heinemann, 1957).

creation in 1794 of the *École polytechnique*.⁶ Given that the Revolution had suppressed all institutions of the Ancien Régime, the new school was meant to train State engineers. After a rigorous selection, made through an exam, students were taught in general scientific subjects and all that the basic education of an engineer required. After a two- or three-year course, they would further their education in an *École d'application* in order to specialize in *Ponts et Chaussées*, mines, etc. The *École polytechnique* and the engineering system soon acquired the greatest prestige, their graduates reaching a level equivalent to a university degree. It should be remembered that the French Revolution had also suppressed the universities. Napoléon established the *Université de France*, and all the *Facultés* in the French territory were included in this national entity. This meant that, despite the formal centralization, the provincial faculties had great autonomy.⁷ French provincial universities were re-established in the late nineteenth century.⁸

The result was that, in France, engineering schools were independent institutions, controlled directly by the government. Even the *École centrale des arts et manufactures*, a private engineering school created in 1829, maintained its independence when it became a State school, in 1859.⁹

From Mathematics to Engineering, the Army and the society in Spain

In Spain, scientific engineering arose first in the military milieu.¹⁰ At the end of the seventeenth century, some military engineers thought that a mathematical education was essential to the art of war. An Academy to teach mathematics to Spanish army officers was established in Brussels in 1675 under the initiative of Sebastián Fernández de Medrano (1646–1705).¹¹ The Corps of

⁶ There are many analyses of the *Polytechnique*. See, for example: Terry Shinn, *Savoir scientifique & pouvoir social. L'École Polytechnique, 1794–1914* (Paris: Presses de la Fondation Nationale des Sciences Politiques, 1980); Bruno Belhoste, Amy Dahan Dalmedico, Antoine Picon (dirs), *La formation polytechnicienne 1794–1994* (Paris: Dunod, 1994).

⁷ The premier Paris University, the Sorbonne, was a special case.

⁸ Christophe Charle, "Patterns". In: Walter Rüegg (ed.), *A History of the University in Europe*. Volume III. *Universities in the Nineteenth and Early Twentieth Centuries (1800–1945)* (Cambridge: Cambridge University Press, 2004), 33–79.

⁹ André Grelon (1996) "La naissance de l'enseignement supérieur industriel en France", *Quaderns d'Història de l'Enginyeria*, 1996, vol. 1: 53–81.

¹⁰ We give an overview of this subject in the introduction of our paper: M. Rosa Massa-Esteve; Antoni Roca-Rosell; Carles Puig-Pla (2011), "Mixed' Mathematics in engineering education in Spain: Pedro Luce's course at the Barcelona Royal Military Academy of Mathematics in the eighteenth century", *Engineering Studies*, December 2011, vol. 3, No. 3: 233–253.

¹¹ Juan Miguel Navarro-Loidi, *Las Ciencias matemáticas y las enseñanzas militares durante el reinado de Carlos II* (Madrid: Ministerio de Defensa, 2004).

Engineers of the Spanish Army was created in 1711, during the War of Spanish Succession (1700–1714), probably following the example of the French *Corps de Génie Militaire*.¹² The Chief-engineer was Jorge Próspero Verboom (1667–1744), disciple of Fernández de Medrano. At that time, the training of “scientific officers” (engineers and artillerymen) was not organised, given that the Brussels Academy was closed in 1705. Verboom proposed a plan to create academies of mathematics in the main Spanish cities. After the end of the war, the Crown finally ordered the establishment of an academy in Barcelona, where Verboom was living, given that he supervised the building of a new Citadel to control the city.¹³ The Academy was established in 1720, the first director being Mateo Calabro. It was proposed that army officers should learn mathematics in order to improve their capacity as military men and also to train those officers willing to join the Corps of Engineers (and also the Corps of Artillery). Thus, the Academy of Barcelona was not an academy of Corps.¹⁴ For the Military Engineers, an Academy was created in Alcalá de Henares, in 1803, following the closure of the Academy of Barcelona.

The Military Academy of Mathematics of Barcelona offered a mathematical education to several generations of army officers. Some of them became outstanding military engineers, designers of most of the public works in Spain and Latin America during the eighteenth century.¹⁵ In effect, the Corps of Military Engineers took charge of non-military works, such as the building of a new network of national roads.

The close relationship between the Barcelona Academy and the military engineers has created a conceptual confusion. The Academy was not a school of Corps like the French schools, perhaps because the link between a Corps and a school was established later on, in 1747, with the *École de Ponts et Chaussées*. The Academy of Barcelona was merely meant to teach mathematics to the military based on the conviction that mathematics was essential to war.

Given that the Military Academy of Barcelona was partially open to non-military people, its activity had a deep impact on the scientific and technical life of Barcelona in the eighteenth century. It was expected that four students would join the courses each year. This enrolment rate

¹² Horacio Capel; Joan Eugeni Sánchez; Omar Moncada, *De Palas a Minerva. La formación científica y la estructura institucional de los ingenieros militares en el siglo XVIII* (Barcelona: El Serbal/CSIC, 1988).

¹³ Massa-Esteve et al, “Mixed? Mathematics...”, p. 238–239.

¹⁴ Capel et al, *De Palas a Minerva*, p. 272–276.

¹⁵ Capel et al, *De Palas a Minerva*, especially the “Tercera Parte” (p. 255–345).

was probably felt as rather insignificant,¹⁶ and perhaps the creation of the Public Course on Mathematics (*Cátedra Pública de Matemáticas*), in 1756, represented the possibility to offer a mathematical education virtually to everybody, without restrictions. It is worth noting that admission to the Military Academy was reserved for the aristocracy and military families. The Public Course on Mathematics was promoted by Tomàs Cerdà (1715–1791), a Jesuit teacher in the College of Cordelles, a school attended by members of the aristocracy.¹⁷ As a “public” course, a building was erected in the rear of the existing College, in order to have a separate entrance. Cerdà prepared a complete course on mathematics, a few volumes from which were printed.¹⁸ The course included topics on mathematics in a broad sense, including optics, statics, fortification and architecture. There is some evidence that artisan-builders attended the Public Course.¹⁹ Following the expulsion of the Jesuits in 1767, the Course was moved to the Royal Academy of Sciences.²⁰ According to the criticism expressed in 1804 by Francesc Santponç (1756 –1821), a member of the Academy, the Mathematical Course had been restricted to pure mathematics, and he asked for the inclusion of mechanics. He eventually created a Course on Mechanics, in 1808, funded by the Board of Commerce (*Junta de Comercio*).²¹

The Spanish Crown had a real interest in promoting scientific and technical education. The Crown influenced various institutions or accepted proposals for the creation of this kind of

¹⁶ A conflict between Verboom and the director Calabro was centred in the fact that too many non-military (some of them non-aristocrats) were accepted at the Academy. Calabro finally left the Academy and Pedro Lucuce was the director from 1737 onwards. See: Capel et al, *De Palas a Minerva...*, p. 110–125. See also Ernest Lluch, *Las Españas vencidas del siglo XVIII: claroscuros de la Ilustración* (Barcelona: Crítica, 1999), p. 120–123. Calabro moved to Valencia with the idea of setting up a new Academy of Mathematics. He failed because there was a very active group of scientists who viewed the academy as an intromission to their projects. See Víctor Navarro Brotons, “Noticia acerca de Antonio de Bordázar y la fundación de una Academia Matemática en Valencia”, in *I Congreso de Historia del País Valenciano*, (Valencia: Universidad de Valencia, 1976), vol. III, p. 589–596.

¹⁷ The Cordelles College was a private school for the aristocracy, with little interest in scientific education. On its origins, see: Reis Fontanals, *La Fundació canònica i imperial del Col·legi de Cordelles* (Barcelona: Biblioteca de Catalunya, 1994).

¹⁸ See Santiago Garma Pons, “La enseñanza de las matemáticas”, In J. L. Peset (ed.) *Historia de la ciencia y de la técnica en la corona de Castilla* (Salamanca: Junta de Castilla y León, 2002), vol. 4: 311–346.

¹⁹ Massa-Esteve et al, “Mixed? Mathematics...”, p. 247–248; Jaume Rosell Colomina, *La construcció en l'arquitectura de Barcelona a final del segle XVIII* (doctoral dissertation, 1996) (<http://tdx.cesca.cat/handle/10803/6101>).

²⁰ Francesc X. Barca Salom (1993), “La Càtedra de Matemàtiques de la Reial Acadèmia de Ciències i Arts de Barcelona (1766–1870). Més de cent anys de docència de les matemàtiques”, in Víctor Navarro et al. (coords.), *II Trobades d'Història de la Ciència i de la Tècnica* (Barcelona: Societat Catalana d'Història de la Ciència i de la Tècnica, 1993), 91–105.

²¹ Carles Puig Pla (1996), “L'establiment dels cursos de mecànica a l'Escola industrial de Barcelona (1851–1852). Precedents, professors i alumnes inicials”, *Quaderns d'Història de l'Enginyeria*, 1996, vol. I: 127–196; Antoni Roca Rosell (2005), “Tècnica, ciencia e indústria en tiempo de revoluciones. La química y la mecánica en Barcelona en el cambio del siglo XVIII al XIX”, In M. Silva Suárez (ed.), *Tècnica e ingeniería en España, III, El siglo de las luces. De la industria al ámbito forestal* (Zaragoza, Real Academia de Ingeniería, Institución Fernando el Católico, Prensas Universitarias de Zaragoza, 2005), 183–235.

instruction in Spain. It is worth mentioning the case of the *Sociedad Vascongada de Amigos del País* (Basque Society of Friends of the Country) (1765) that established, in 1769, a college (*Seminario*) in Bergara, Basque Country, for the education of young aristocrats. A chemical laboratory was also created, in 1778, designed and directed for two years by the French chemist Joseph Louis Proust (1754–1826).²² Proust was working for the Spanish Crown in the subsequent years in Segovia and Madrid, returning to France in 1808. The Bergara laboratory was funded by the Spanish Navy, which was interested in improving the making of cannons.²³ Courses or schools for the teaching of subject matters such as navigation, chemistry, or experimental physics were created in various cities, including Madrid.²⁴ These institutions were closed in the subsequent decade for diverse reasons, mainly lack of students and funds. In Barcelona, there was another process under the initiative of the Board of Commerce, established in 1758. This was a board composed of merchants, industrialists, and agriculture promoters, which was funded by a tax, the “derecho de perage,” on the goods arriving into the port of Barcelona. The Board was dependent of the *Junta General de Comercio*, then equivalent to the Ministry of Economy, but it had a certain degree of autonomy to manage the funds that were collected – considerable amounts for that period. One of the main initiatives of the *Junta* was the establishment of courses and schools. The first was the School of Navigation (1770), followed by the School of Drawing (1775), which was soon named Fine Arts (*Nobles Artes*), to include painting, sculpture, and even architecture. Later on, in 1805, the Course on Chemistry Applied to the Arts was created. Other courses or schools were devoted to mechanics (1808), physics (1814), agriculture (1814), and mathematics (1819). Some of these courses were also funded by the *Junta General de Comercio*. An actual system of technical and artistic education was developed, under the supervision of the *Junta*, always very active as an industrialist centre of promotion.²⁵

²² Ramon Gago (1988), “The New Chemistry in Spain”, *Osiris*, 2nd series, 4:169–192; Leandro Silvan, *Los Estudios científicos en Vergara a fines del siglo XVIII ; El químico Luis José Proust: 1754–1826* (Donostia : Banco Guipuzcoano : Real Sociedad Bascongada de los Amigos del País, 1992); Inés Pellón, Ramón Gago, *Historia de las cátedras de química y mineralogía de Bergara a finales del siglo XVIII : incluyendo un informe inédito de Fausto de Elhuyar sobre las minas de Aralar* (Bergara: Ayuntamiento de Bergara, 1994).

²³ Ramon Gago (1978), “Bicentenario de la fundación de la Cátedra del Química de Vergara: el proceso de constitución”, *Llull*, 1978, 2:5–18.

²⁴ Agustín Escolano Benito, *Educación y economía en la España ilustrada* (Madrid: Ministerio de Educación y Ciencia, 1988).

²⁵ Francesc X. Barca-Salom; Pasqual Bernat; Maria Pont i Estradera; Carles Puig-Pla (coord.), *Fàbrica, taller, laboratori. La Junta de Comerç de Barcelona: Ciència i tècnica per a la indústria i el comerç (1769–1851)* (Barcelona: Cambra de Comerç, 2009).

The education provided in these courses and schools under the aegis of the *Junta* or of the “economic societies” (*sociedades económicas*) was not integrated in any university and, therefore, they did not provide a formal degree. Until the end of the eighteenth century, only the members of the Military Corps had the equivalent of a university degree. In 1777, the establishment of an Academy of Mines and Underground Geography in Almadén (in the province of Ciudad Real, in the south-centre of Spain) opened the way to civil (as opposed to military) degrees in engineering. This academy had been promoted by Enrique Cristóbal Storr, an engineer of German origin. Initially, it was located in the mining complex of Almadén. After several attempts, in 1835 the Academy moved to Madrid and was rechristened Higher School of Mining Engineering.²⁶

In 1799, the General Inspection of Roads (*Inspección General de Caminos*) was founded as a result of the influence of Agustín de Betancourt (1758–1824), who was soon Inspector General. This General Inspection became in the 1830s, the Corps of Roads (*Cuerpo de Caminos*), which was in charge of all public works. During the eighteenth century, these were under the responsibility of military engineers, but in 1802, the School for Roads and Canals (*Escuela de Caminos y Canales*) was established in Madrid in order to train engineers for the General Inspection of Roads. Despite the fact that the *Escuela de Caminos* was discontinued soon after,²⁷ it represents the beginning of civil (non-military) higher education in engineering in Spain.²⁸

²⁶ Luis Mansilla Plaza; Rafael Sumozas García-Pardo (2007), “La ingeniería de mines: de Almadén a Madrid”, in Manuel Silva Suárez (ed.), *Técnica e Ingeniería en España. Tomo V. El Ochocientos. Profesiones e instituciones Cíviles* (Zaragoza: Real Academia de Ingeniería/Institución “Fernando El Católico”/Prensas Universitarias de Zaragoza, 2007), 81–125.

²⁷ The School opened from 1802 to 1803; from 1820 to 1823; and reopened in 1834.

²⁸ On Betancourt, see the special issue of *Quaderns*, Konstantinos Chatzis, Dmitri Gouzévitch, Irina Gouzévitch (coord.), Agustín de Betancourt y Molina (1758–1824). Un Ingénieur Européen – An European Engineer – Un Enginyer Europeu, *Quaderns d’Història de l’Enginyeria*, vol X: 2009. Also: Alekséi Bogoliúbov, *Un héroe español del progreso: Agustín de Betancourt* (Madrid: Seminarios y Ediciones S.A., 1973); Antonio Rumeu de Armas, *Ciencia y Tecnología en la España Ilustrada. La Escuela de Caminos y Canales* (Madrid: Colegio de Ingenieros de Caminos, Canales y Puertos–Ediciones Turner, 1980); Centro de Estudios Históricos de Obras Públicas y Urbanismo, *Betancourt : los inicios de la ingeniería moderna en Europa* (Madrid: Ministerio de Obras Públicas, Transporte y Medio Ambiente, 1996).

Industrial engineering, new free profession (1850)

During the first half of the nineteenth century, some other engineering specialties were organized, such as Forests (1846).²⁹ In all cases, the structure was similar: a State Corps with a School as a means to access the Corps.

Following the death of the king Fernando VII, in 1833, the bourgeois political forces managed to take over the government and the process to establish a “liberal” regime began.³⁰ In the field of education various important educational reforms were launched. In 1845, a system of national, centralized universities was established, despite the fact that higher technical education remained excluded from it. Moreover, a central school for preparing the civil and mining engineers and the architects was set up in 1848, as a Spanish version of the French *École Polytechnique*. Nevertheless, the new unifying centre was rejected by all the corporate professions and was closed down in 1855.³¹

Industrial education was not included in the 1845 reform. Finally, a Royal Decree of 1850 organized this type of education.³² According to Gil de Zárate (1793–1861) in his recollections,³³ Joaquín Alfonso y Martí (1805–1867?) was given the task of preparing the system of industrial education but his proposal was too ambitious and difficult to apply. Gil de Zárate prepared a plan combining the proposal of Alfonso with his own ideas. Joaquín Alfonso, then

²⁹ In the case of Forest engineering, a State department was established some years before the creation of the higher school. See: Ignacio García Pereda; Inés González Doncel; Luis Gil Sánchez (2012), “La primera Dirección General de Montes (1833–1842)”, *Quaderns d’història de l’enginyeria*, 2012, vol. XIII: 209–253.

³⁰ It is worth noting that Fernando VII reigned after the War of Independence (1808–1814) against the Napoleonic invasion. In 1812, the first Constitution of Spain was approved in Parliament (*Cortes*), in Cádiz. Fernando VII rejected the Constitution and established an authoritarian government, in the Ancien Régime style. See, for example, one of the many editions of Raymond Carr, *Spain, 1808–1939* (Oxford: Clarendon Press, 1966).

³¹ Lusa discusses the project of 1845 as an antecedent to the second general school. Guillermo Lusa Monforte (1999), “¡Todos a Madrid! La Escuela General Preparatoria de Ingenieros y Arquitectos (1886–1892)”, *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, 1999, núm. 9: 3–34, (http://upcommons.upc.edu/revistes/bitstream/2099/936/1/todos_madrid.pdf, accessed August 2013). See also Manuel Silva Suárez (2007), “Presentación. Sobre la institucionalización profesional y académica de las carreras técnicas Civiles”, in Manuel Silva Suárez (ed.), *Técnica e Ingeniería en España. Tomo V. El Ochocientos. Profesiones e instituciones Civiles* (Zaragoza: Real Academia de Ingeniería /Institución “Fernando El Católico”/Prensas Universitarias de Zaragoza, 2007), 7–78.

³² There is an edition of the decrees of 1850 (and 1855) in: *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, 1993, núm. 3 (<http://upcommons.upc.edu/revistes/bitstream/2099/832/1/numero%205.pdf>).

³³ Antonio Gil de Zárate, *De la Instrucción en España* (Madrid: Imprenta del Colegio de Sordomudos, 1855), vol. 3, p. 314–338.

director of the *Conservatorio de Artes of Madrid*, completed a degree in engineering, in 1837, from the *École centrale des arts et manufactures* of Paris.³⁴

Finally, in September 1850, a Royal Decree organised industrial education in Spain. The objective was to regulate all levels of technical education, from apprenticeship to higher engineering. Following the organization of technical education in Berlin, the Spanish government created three levels of education: primary, *ampliación* (extension), and higher. The *institutos* (state secondary schools, equivalent to the French lycées, created in 1845) were in charge of primary technical education. Four centres were authorized for the *ampliación* level: Seville, Barcelona, Bergara, and Madrid.³⁵ The higher level was reserved for a new institution in Madrid, the Royal Industrial Institute (*Real Instituto Industrial*).³⁶ All these institutions pre-existed in some form, and they had been providing some kind of technical education in the previous decades.³⁷ The novelty was the creation of a new degree in engineering, that in industrial engineering. In the following years new schools were created: Valencia, and Gijón, both in 1855. In addition, the schools claimed to have the right to include higher engineering. This was recognised by the Law of Public Instruction of 1857, known as Moyano's Law, after the name of Claudio Moyano (1809–1890), the minister who managed to approve it in Parliament. In subsequent years, all schools were turned into engineering schools for higher education (Barcelona in 1860).³⁸

Industrial engineering was not linked to a State professional corps. The government declared that the direction of the workshops or factories could not be restricted to a title or

³⁴ Pío Javier Ramón Teijelo (2002–2003), "Aproximación al Real Conservatorio de Artes (1824–1850): precedente institucional de la ingeniería industrial moderna", *Quaderns d'Història de l'Enginyeria*, vol. V, 2002–2003: 45–65; Pío Javier Ramón Teijelo (2007), "Alfonso y Martí, Joaquín (Valencia, 1807–post. 1867)", in Manuel Silva Suárez (ed.), *Técnica e Ingeniería en España. Tomo V. El Ochocientos. Profesiones e instituciones Civiles* (Zaragoza: Real Academia de Ingeniería /Institución "Fernando El Católico"/Prensas Universitarias de Zaragoza, 2007), 618; Ana Cardoso de Matos; Antoni Roca-Rosell, "L'Ecole centrale, les centraliens et la péninsule ibérique: des intérêts réciproques", in press.

³⁵ José M. Alonso Viguera, *La ingeniería industrial española en el siglo XIX* (Madrid: Imp. Hauser y Menet, 1944. New Edition: Madrid : Asociación de Ingenieros Industriales de Andalucía, 1993).

³⁶ Jose Manuel Cano Pavón, "The Royal Industrial Institute of Madrid (1850–1867). A Historical Overview", *Quaderns d'Història de l'Enginyeria*, vol. V, 2002–2003: 66–73; idem (2007), "El Real Instituto Industrial de Madrid y las escuelas periféricas", in Manuel Silva Suárez (ed.), *Técnica e Ingeniería en España. Tomo V. El Ochocientos. Profesiones e instituciones Civiles* (Zaragoza: Real Academia de Ingeniería /Institución "Fernando El Católico"/Prensas Universitarias de Zaragoza, 2007), 295–350.

³⁷ Nevertheless, Gil de Zárate, *De Instrucción Pública*, vol. 3, p. 335, thought that the system of courses and schools of Barcelona was the most consolidated.

³⁸ An overview of the history of the Barcelona school: Guillermo Lusa Monforte; Antoni Roca Rosell (2005), "Historia de la ingeniería industrial. La Escuela de Barcelona 1851–2001", *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, vol. 15, 2005: 13–95 (http://upcommons.upc.edu/revistes/bitstream/2099/1013/1/historia_ingeneria.pdf).

graduation, it should be free. Nevertheless, several ministers promised some sort of special protection for the new industrial engineers, such as the supervision of State companies or industrial services. In effect, some industrial engineers were appointed to such positions, but there was no employment exclusive for industrial engineers.

In 1862, the Central Association of Industrial Engineers was founded to claim for these exclusivities. In a declaration, they required the government to protect the profession.³⁹ A similar association was created in Barcelona, in 1863. These attempts at lobbying on behalf of industrial engineers failed partly because the Spanish government did not recognise exclusive “competences” for them. In fact, the first laws giving this kind of privileges to industrial engineers date from 1932.⁴⁰

Spanish industrial engineers had a similar professional situation to the French *Centraliens*. Graduates from the *École centrale des arts et manufactures* did not constitute a State Corps. They were in the industrial job market, beginning in France and expanding their action to the world.⁴¹ In addition, the Spanish industrial engineers joined the project of “engineering science” promoted by the *École Centrale*.

Back to the 1860s, the economic crisis—some scholars claim that it was the first *capitalist* crisis in the country—had serious consequences upon the system of industrial engineering education. The lack of students and the little integration in local economic activities caused the closure of the schools of industrial engineering created from 1850. In 1860, the schools in Bergara and Gijón were closed; in 1865, Valencia; in 1866, Seville. Finally, in 1867, the Royal Industrial Institute in Madrid was also closed so that the only surviving school was in Barcelona.

Given the paucity of economic resources, the government had told the schools to look for funds from local institutions so that they could cover two-thirds of the budget. In 1866, the School of Barcelona managed to establish an agreement involving the Municipality of Barcelona,

³⁹ The document, “Exposición dirigida al Ministro de Fomento” (11/04/1862) is reproduced in *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, vol. 7, 1997 (<http://upcommons.upc.edu/revistes/handle/2099/903>).

⁴⁰ The competences were consolidated during the Franco regime, in the context of the creation of professional “Colegios” that restricted the activities. These “Colegios” have recently lost their exclusivities in the context of the European Union regulations. Only a few professions, such as the physicians and pharmacists, maintain the exclusivity.

⁴¹ See, for example, Jean-Louis Bordes; Annie Champion; Pascal Desabres (dir.), *L'ingénieur entrepreneur. Les Centraliens et l'industrie* (Paris: PUPS, 2011).

the provincial *Diputación* of Barcelona,⁴² and the State.⁴³ This agreement ensured the continuity of the Barcelona School, which remained the only school of industrial engineering in Spain until 1899, when a new school opened in Bilbao.⁴⁴ For all these reasons, industrial engineering became a “Catalan” speciality for more than 30 years (from 1867 to 1899), the schools of the other specialities being located in Madrid or near the capital city.

The schools of higher engineering were not integrated in the universities. Despite the process of unification of universities promoted by the Spanish government from 1845, higher engineering was linked directly with the ministry associated with the same kind of engineering. University rectors were responsible for the academic diplomas. It is worth noting that for several decades only industrial engineers trained as free professionals needed a diploma to demonstrate their education in the market.

Industrial education at elementary and secondary levels

One of the consequences of the crisis in the system established in 1850 was the practical disappearance of elementary and secondary industrial education. The *Institutos* were not prepared for elementary education, and they offered a limited number of specialities. The provincial schools, claiming for the higher engineering, abandoned the “*ampliación*” level. Consequently, *formal* secondary industrial education, that was included in the 1850 decrees, disappeared.

To compensate this situation, some initiatives were launched. Ramon de Manjarrés, an industrial engineer from the early promotions, created evening courses for workers in Seville. When the Industrial School of Seville closed down in 1866, Manjarrés was appointed to a chair in Barcelona and, in 1868, he promoted there similar courses.⁴⁵ These courses offered complementary education for workers in subjects such as drawing, arithmetic, geometry, physics,

⁴² In 1833, the Spanish State was divided into provinces, which the government denominated *Diputación*. A *Diputación* was in charge of collecting State taxes, managing the network of secondary roads, and social welfare, etc.

⁴³ The agreement appeared in a Royal Order of 16–08–1866. This order is reproduced in *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, vol. 7, 1997 (<http://upcommons.upc.edu/revistes/handle/2099/903>).

⁴⁴ In 1901, the school of Madrid reopened. In the twentieth century, Barcelona, Bilbao, and Madrid were the three centres of industrial engineering for several decades.

⁴⁵ Francesc Barca Salom; Guillermo Lusa Monforte (1995), "Ramon de Manjarrés i de Bofarull. La química agrícola i la professionalització dels enginyers industrials", in Josep M. Camarasa, Antoni Roca Rosell (dir.), *Ciència i tècnica als Països Catalans. Una aproximació biogràfica* (Barcelona: Fundació Catalana per a la Recerca, 1995), pp. 381–423.

chemistry, mechanics, or modern languages. The courses were delivered by the teachers of the Barcelona School of Industrial Engineering, and managed to be supported by the *Diputació* of Barcelona. In 1874, the courses were recognised as the School of Arts and Crafts (*Escuela de Artes y Oficios*). At the time, similar courses were also offered in some other cities. In Madrid, the former *Conservatorio de Artes* resumed.

The Barcelona School of Arts and Crafts was able to offer some professional titles, such as Foreman and Head of the Workshop (*Capataz* and *Jefe de Taller*). The reference was the *Conservatoire national des arts et metiers* at Paris, which produced many textbooks and experience. The State regulated the School of Arts and Crafts in a Decree of 1886, which opened the possibility of creating new schools such as the schools of Terrassa and Vilanova i la Geltrú, in Catalonia. In the rest of Spain, schools were established in Alcoi, Almería, Béjar, Gijón, Logroño, and Santiago de Compostela, cities in which industry was already developed.⁴⁶ Technical education was also promoted by some municipalities and also by religious orders.⁴⁷ In 1901, a new reform established graduations in secondary technical education.⁴⁸

A liberal or free profession

Spanish industrial engineers thought that their profession would be similar to other careers in engineering, that is a profession linked to the State administration. In a first phase—from 1851 to the early 1880s—industrial engineers claimed to have exclusive “competences”. Associations were created to promote the recognition of the profession with State protection.⁴⁹ It is worth noting that, for example, all public works in Spain should be controlled by the Civil Engineering Corps (*Cuerpo de Caminos*) by a decree of 1834. Some exceptions were introduced following protests

⁴⁶ Guillermo Lusa Monforte, "El final de la soledad de la Escuela de Barcelona (1892–1899)", *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, 10, 2000: 3–28 (http://upcommons.upc.edu/revistes/bitstream/2099/948/1/final_soledad.pdf).

⁴⁷ Ramon Alberdi, *La formación profesional en Barcelona* (Barcelona: Ediciones Don Bosco, 1980).

⁴⁸ Antoni Roca-Rosell; Guillermo Lusa-Monforte; Francesc Barca-Salom; Carles Puig-Pla (2006), "Industrial Engineering in Spain in the First Half of the Twentieth Century: From Renewal to Crisis", *History of Technology*, vol. 27, 2006: 147–161; Antoni Roca Rosell (coord.), *L'Escola Industrial de Barcelona. Cent anys d'ensenyament tècnic i d'arquitectura* (Barcelona: Diputació de Barcelona, Ajuntament de Barcelona, Consorci de l'Escola Industrial de Barcelona, 2008).

⁴⁹ There is a coincidence in time with the creation of the *Amicale des Anciens Élèves de l'École Centrale*, founded in 1863. In France, the *Société des Ingénieurs Civils* was established in 1848 gathering non-State engineers. Thus, the *Centraliens* had renounced to a major role. The *Amicale* of 1863 attempted to recuperate the corporate efforts of the graduates of the *École Centrale* of Paris.

from architects, gathered initially at the San Fernando Royal Academy of Fine Arts (*Real Academia de Bellas Artes de San Fernando*).⁵⁰

Industrial engineers did not manage to obtain protection from the State and were forced to create a professional market for themselves. Ramon Garrabou studied the Catalan industrial engineers in the nineteenth century,⁵¹ and analysed the role played by industrial engineers in the development of industry in Catalonia and Spain. They managed to be contracted in textile and mechanics factories, and also played an important role in the railway companies established in the 1850s.⁵² They also had an important intervention in the modernization of agriculture, dealing with the production of natural (and, at the end of the century, artificial) dyes, the process of production of wine or the mechanization of work.

Until the 1880s, industrial engineers sought to strengthen the links to the State without important results. At the same time, industrial engineers began to play relevant roles in industry, in the modernisation of agriculture and of communications—mainly, railways—and they finally changed their discourse. The “true” engineers found their jobs in the market and “official” engineers were considered mere bureaucrats.⁵³ Garrabou signals that in the late nineteenth century more than 30% of the industrial engineers were free professionals. They have reached high positions in industry – some of the sons of the bourgeoisie gained the graduation to supervise their companies; other engineers were directors or members of staff, but one-third of the industrial engineers worked as technical consultants or agents of foreign manufacturers of machines or chemical products. In this sense, industrial engineers played an important role in technical journals, such as those delivering information on patents.⁵⁴

⁵⁰ See the analyses and the documents offered by Antonio Bonet Correa, Soledad Lorenzo Fornies, Fátima Miranda Regojo, *La Polémica ingenieros–arquitectos en España: siglo XIX* (Madrid: Colegio de Ingenieros de Caminos, Canales y Puertos, Turner, 1985).

⁵¹ Ramon Garrabou, *Enginyers industrials, modernització econòmica i burgesia a Catalunya* (Barcelona, L’Avenç, 1982).

⁵² The first line of railway constructed in peninsular Spain was the Barcelona-Mataró line, built by British engineers. Soon after, Spanish engineers took charge of the design, construction, and management of the new railways. See: Pere Pascual Domènech, *Los Caminos de la era industrial: la construcción y financiación de la Red Ferroviaria Catalana* (1843–1898) (Barcelona: Edicions Universitat de Barcelona, 1999).

⁵³ Guillermo Lusa (1994), "Contra los titanes de la rutina. La cuestión de la formación matemática de los Ingenieros Industriales (Barcelona 1851–1910)", in: S. Garma D. Flament; V. Navarro (eds), *Contra los titanes de la rutina. Encuentro de investigadores Hispano-franceses sobre la historia y la filosofía de la matemática* (Madrid: Comunidad de Madrid/CSIC, 1994), 335–365.

⁵⁴ Antoni Roca Rosell, “Industria e Invenciones” (online), *Almirall*. Portal del pensament i cultura del segle XIX <http://almirall.ateneubcn.org:9080/Almirall/obra:357>.

The relative success of industrial engineering in the 1880-decade can be shown in two episodes. First, the idea to move the School of Barcelona began to be expressed in Madrid and in Spanish political circles. One of the arguments was that such a speciality of engineering “could not” be taught far from the capital. The members of the School of Barcelona reacted against these rumours, and managed the Catalan members of the Spanish parliament to declare their opposition. Finally, the plans were abandoned, but another project of a Spanish “*Ecole Polytechnique*”, the General Propaedeutic School for Engineers and Architects (*Escuela General Preparatoria de Ingenieros y Arquitectos*) was established in 1886. This new school, located in Madrid, was the only one for the two first courses of all engineering degrees and architecture. The School of Barcelona opposed the plan, but it was not able to stop it. In addition, some teachers of Barcelona were transferred to the new school in Madrid.

The General Propaedeutic School for Engineers and Architects raised opposition not only from industrial engineering but also from the civil engineering and architecture. In 1890, thanks to the pressure, the School of Barcelona organized again the first courses and therefore attending the Madrid School became a mere option. In 1892, the General Propaedeutic School for Engineers and Architects was finally closed down and the new attempt to unify technical education failed again.⁵⁵

This experience has several interpretations: one is that industrial engineering began to be interesting for the powerful groups of Spain who realised that they had little control upon it if the School continued to be in Barcelona; another indication of the consolidation of industrial engineering could be found in the Barcelona International Exhibition of 1888. The Exhibition was directed by three high experts: the architect Elies de Rogent (1821–1897), was in charge of the construction of the buildings;⁵⁶ the industrial engineer, Lluís Rouvière (18?–1904) supervised the technical aspects of the exhibition (water, electric and gas supply, communication, etc.); finally, the Barcelona official Carles Pirozzini (1852–1938) was entrusted with the administrative and economic aspects.⁵⁷ Industrial engineers played a relevant role in the industry and energy

⁵⁵ Guillermo Lusa Monforte (1999), “¡Todos a Madrid! La Escuela General Preparatoria de Ingenieros y Arquitectos (1886–1892)”, *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, 1999, núm. 9: 3–34 (http://upcommons.upc.edu/revistes/bitstream/2099/936/1/todos_madrid.pdf).

⁵⁶ Pere Hereu Payet (ed.), *Arquitectura i ciutat a l'Exposició Universal de Barcelona 1888* (Barcelona: Universitat Politècnica de Catalunya, 1988).

⁵⁷ Maria Ojuel, *La Barcelona prodigiosa de Carles Pirozzini (1852–1938)* (Lleida: Pagès Editors; Barcelona: Ajuntament de Barcelona, 2012).

sections, and also in the Congress on Engineering.⁵⁸ The success of the Barcelona Exhibition as a great scientific fair⁵⁹ was also very much based on the intervention of professional groups like the industrial engineers.

As mentioned before, in France, the graduates from the *Ecole Centrale*, the *Centraliens*, constituted also a free profession. Given that Spanish industrial engineers wished to develop an “engineers’ science”, there was a certain equivalence between both professionals groups.

Conclusion

Industrial engineering was established in 1850 as a new speciality of engineering at the service of industry, communications and modern agriculture. The Spanish government planned to have a complete system of industrial education ranging from apprenticeship to higher engineering. The establishment of various industrial schools shows that there were not enough resources to maintain this system. State secondary schools were unable to consolidate an elementary education. The industrial schools all became schools of higher engineering but they were not able to attract students. Given the economic crisis, during the 1860s all schools closed down with the exception of that in Barcelona. During the nineteenth century, this School trained industrial engineering graduates in Spain.

Industrial engineering was the first engineering professional title in Spain that was not associated with a State Corps. Consequently, industrial engineers worked as free professionals. They finally managed to be recognised as higher engineers with a prestige similar to other higher engineering degrees.

Industrial engineers were not university graduates but they were recognised as university graduates similarly to France where engineers graduated from special schools equivalent to universities, but without any formal relationship with a university.

⁵⁸ Antoni Roca-Rosell; Guillermo Lusa Monforte; Jesús Sánchez Miñana (2010), “Scientists and Engineers at the Universal Exhibition of Barcelona (1888)”, in Ana Cardoso De Matos; Irina Gouzévitch; Marta C. Lourenço (dirs.), *Expositions universelles, musées techniques et Société industrielle / World Exhibitions, Technical Museums and Industrial Society* (Lisboa: Edições Colibri, CIDEHUS, Centre Maurice Halbwachs, CIUHCT, 2010), 125–140.

⁵⁹ Agustí Nieto-Galan (2012), “Scientific “marvels” in the public sphere: Barcelona and its 1888 International Exhibition”, *HoST*, Vol.6, Fall 2012. <http://johost.eu/>

Nevertheless, the schools of industrial engineering in Spain were not as autonomous as the French schools. Initially part of a system of technical education, they were always controlled by the State. The government defined the syllabus, and contracted the teachers. The School of Barcelona, however, because it was funded by the Municipality and the *Diputación* of Barcelona, reached a certain degree of autonomy in economic matters. This situation lasted until 1917, when the School of Barcelona “returned” to the exclusive dependence on the central State.⁶⁰

The crisis of the system of industrial education in the 1860s caused the disappearance of elementary and secondary levels. The reaction from society—with the support of industry—caused the reconstruction of this level of education in the *Escuelas de Artes y Oficios*. These schools saw themselves as modelled on the *Conservatoire d’Arts et Métiers* in Paris. The activity of the *Conservatoire*, by promoting the industrial sciences, was also closely followed by the higher industrial engineers whose direct model was the *École centrale des arts et manufactures*. Nevertheless, it should be taken into account the very different contexts. The Spanish industrial engineers consolidated a new liberal or free profession, paving the way to other kinds of engineers to act as free professionals.

⁶⁰ Lusa, Roca-Rosell (2005), “Historia de la Ingeniería industrial...”, p. 54–59. See also: Guillermo Lusa Monforte (2005), “El conflicto con la Diputación (1915). La plena incorporación de la Escuela al Estado (1917)”, *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, 2003, núm. 13: 3–48 (<http://upcommons.upc.edu/revistes/bitstream/2099/975/1/conflicto.pdf>).