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Peculiarities of Evolution of Machine Technology and Its Industrialization in Italy during 19th Century

Yibing Fang[1], Marco Ceccarelli[2]

[1]Institute for the History of Natural Sciences, Chinese Academy of Sciences, Beijing, China
[2]LARM: Laboratory of Robotics and Mechatronics, University of Cassino and South Italy, Cassino, Italy
Email: yibing@ihns.ac.cn, ceccarelli@unicas.it

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Abstract

This paper deals with peculiarities of Italian Industrial Revolution on machinery by looking at aspects on enterprise developments and university frames. The outline showed a historical evolution that started in South Italy and after national reunification strong development was experienced mainly in North Italy with the still today character of few big enterprises and several small-medium companies. Examples are discussed with emblematic figures from University frames and cases of study on typical enterprises of the time. The Italian peculiarities are due both to political situations connected to Italy reunification and Italian attitudes to Science and Technology as combined with a strong individualism and creativity.

Keywords

History of Technology, Industrial Revolution, Italian Industrialization, History of Enterprises, History of Universities

1. Introduction

The evolution of Italian frames during the Industrial Revolution looks to be more complex than in other European countries not only for the heavy cultural backgrounds from the past but mainly for the intriguing situations due to the history of nation re-unification in those years and the influences of the other European nations from several perspectives. In addition, the variety of conditions made possible a variety of different evolutions both in term of geographical locations and in machine developments. Most of previous studies in the field of Italian history of 19th Century were focused mainly on political conditions and their influences in order to reconstruct a

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national plan of political, technological and social developments. Most of those studies on Industrial Revolution do not give particular attention to the fragmentation and slow evolution of Italian developments of Machine Technology and they just refer few cases with few details as for example in (Hartenberg & Denavit, 1956; Davis, 1979; Dimarogonas, 1993; Singer, 2012; Bautista et al., 2010; Capocaccia, 1977; Cafagna, 1972). Even in recent conference presentations, the Italian Industrial Revolution has not attracted strong interest but only limited focus as for example in the proceedings of the Italian Society of History of Engineering (see the last one in 2014 (D'Agostino, 2014) and in some case it is not even considered, as for example in (ASME, 1997) and HMM symposia (Ceccarelli Ed., 2000 and 2004; Yan & Ceccarelli, 2009; Koetsier & Ceccarelli, 2012).

Only recently, some scholars have been concentrated on the study of local evolutions even with interpretations of technological developments with engineering insights, like for example in (Curti & Grandi, 1998; Angotti et al., 2010; Cardone & Lamantia, 2006; Dameri, 2010; Della Pietra, 2010; Ceccarelli, 2014; Fang & Ceccarelli, 2013). Thus, there is still a fertile field of studies for understanding the technological developments in Italy in 19th century with differences in different parts of country as due to a past tradition and stimulating conditions because of the re-unification and emerging Industrial Revolution.

From the viewpoint of the technological history, the history of Machine technology in Italy in 19th century can be studied from two perspectives, namely looking at professional frames and industrial enterprises. Firstly, attention can be addressed to the evolution in the professional frames that regard the formation of a community on machine technology and engineering. This community was the responsible for the generation and the dissemination of technical knowledge that were the bases for the industrial developments. The second perspective can be focused on the industrial developments of machinery in Italy in 19th century, since during this period the technology capacity of machine production is evolved up to an industrial character that can give a picture of the early industrial revolution in Italy.

Those peculiarities are discussed in this paper through few emblematic examples that give a clear illustration of specific character of Italian Industrial Revolution.

As regarding with the professional frame, the three figures of Giuseppe Antonio Borgnis (1781-1863), Giuseppe Colombo (1836-1921), and Lorenzo Allievi (1856-1941) are presented with their different contributions in the different periods during the process of development of machine technology and engineering knowledge in Italy. The analysis of their activities and results can show the different conditions and situations within which the formation of the engineer community of Italian machine technology and its success have evolved in 19th century.

As regarding with the industrial enterprises, the three examples on Pietrarsa Worksop, Ansaldo Company, and Riva Company give the possibility to discuss the peculiarities and differences in the industrialization both in terms of country distribution and company characters. The growth path of the Italian industrialization can be characterized by the three kinds engineering enterprises, namely the earliest factories in the south, the large-size engineering enterprises after the re-unification, and the small and middle size enterprises mainly in the north of the country. It is noted that the company growths are also stimulated and supported by the formation infrastructures and political conditions with every local opportunities. The industrial development of Italian machine technology can be considered as influenced by different political and social situations in different geographical areas. It is well known that north Italy, especially the triangle area among Milan, Genoa and Turin, gradually becomes the centre of industrialization in the Italian peninsula after the re-unification of Italy. However, limited attention is paid to the Kingdom of Two Sicilies in south Italy that started the process of the mechanical industrialization around 1840s just before the unification. Pietrarsa Workshop in Napoli, the first Italian locomotive producer which is developed directly by Ferdinando II, King of the Two Sicilies, can be considered the most important project during the earliest period of the mechanical industrialization. The Italy re-unification changed not only the political situations but also the conditions for the development of mechanical engineering industry. Most of the south machine companies declined slowly, while enterprises in the north grew up rapidly up to become famous engineering giants during the second half of 20th century thanks of the strategies for an economic nationalism supported by the government. The Ansaldo Company is an example of those big enterprises with governmental support. At the same time, a lot of small and middle size mechanical enterprises also emerged thanks to active entrepreneur behaviour in the north Italy

This paper is an attempt to clarify the differences and peculiarities of the evolution paths of Italian mechanical technology frames by looking at both professional and industrial perspectives through few emblematic examples. The characteristics of the historical development of mechanical technology are outlined from the early phase of

Italian industrialization up to the complex developments of the Italian successful machinery industry.

2. A Brief Note on General Conditions

The competitions among small states and kingdoms in Italy evolved from a stimulating environment of Renaissance to a complex puzzle at the end of 18th century, as imposed by influence of the powerful European nations. The political situation at the beginning of Industrial Revolution is summarized in the existence of different states as indicated in **Figure 1** as related to previous situations too.

Just after the Restoration subsequent to Napoleon's defeat, the Italian political situation was characterized by re-establishing the several kingdoms under the influence of different European countries. The change and state fragmentation is summarized in **Figure 1**. In **Figure 1(b)**), political situation is represented as referring to 1810 with a strong influence of France as from French Revolution all over the North and Center of Italy. In **Figure 1(c)**, the restored situation is illustrated as referring to 1840 with several kingdoms and North East Italy that soon was included in the Austrian-Hungarian Empire. But already at that time there were considerable hopes and actions for a reunification of Italy. This is to note that Italian society of that time, although fragmented in several

Figure 1. Italian states in: (a) 1796; (b) 1810; (c) 1840; (d) 1861; (e) 1870.

kingdoms, was very directed to the possibility of a unique Italian kingdom, that actually was achieved in the next two decades with several wars and large participation of the population, as shown in **Figure 1(d)** and **Figure 1(e)**. This is justified that in the next decades of 19-th century, because of efforts in this reunification, attention was difficult and even lost in circulation of works among those kingdoms.

The fragmentation of the territory produced also a fragmentation but a differentiation of conditions both for formation and evolution of technological frames. In general universities were organized differently not only in terms of curricula but even for professional perspectives. The emerging industrial environments were structured differently as referring not only to local markets and needs, but also as function of the possibilities that were supported by the influencing European leader nations.

After the reunification under the Italian Kingdom that was completed in 1871, national efforts were planned to achieve common formation frames producing professionals with skills useful in the whole nation territory and at the same time building a common industrial infrastructure that could generate a generally well distributed improvement in terms of growth of the economic, social conditions and technological capabilities. But the situations with their long-time backgrounds were so different in different areas of the country in general culture and technological activities that even today Italy suffers of non homogenous environments for technological developments. Most influent aspects can be considered the historical backgrounds both in terms of external influences and internal traditions as well as governmental strategic plans for development and formation after reunification. University frames were very active but with differentiation and limitation in vision and result circulation. Nevertheless considerable achievements were obtained even in engineering practice.

Just after the reunification there were governmental programs for a standardization of academic frames and consequent professional activities more than an extension of circulation of works. All this made even more problematic plans for international collaboration within academic frames.

Similarly, the absence of state barriers within the re-unified territory made available a national market for the emerging industrial environment with needs and conditions more challenging and promising for the industrial initiatives with special attention to Italian achievements.

3. The Italian Scientific Community on Machine Technology and Engineering

During the Industrial Revolution, the Italian community that was involved in developments of machine technology was characterized mostly by academic figures, who either centered their activity in University frames or used University backgrounds for their success as entrepreneurs or engineers.

In the following, we report three examples of those figures with significant personality in those past aspects characterizing the time evolution in Italian community, namely strong academic studies, influential transfer in professional and industrial frames, and successful participation in industrial developments.

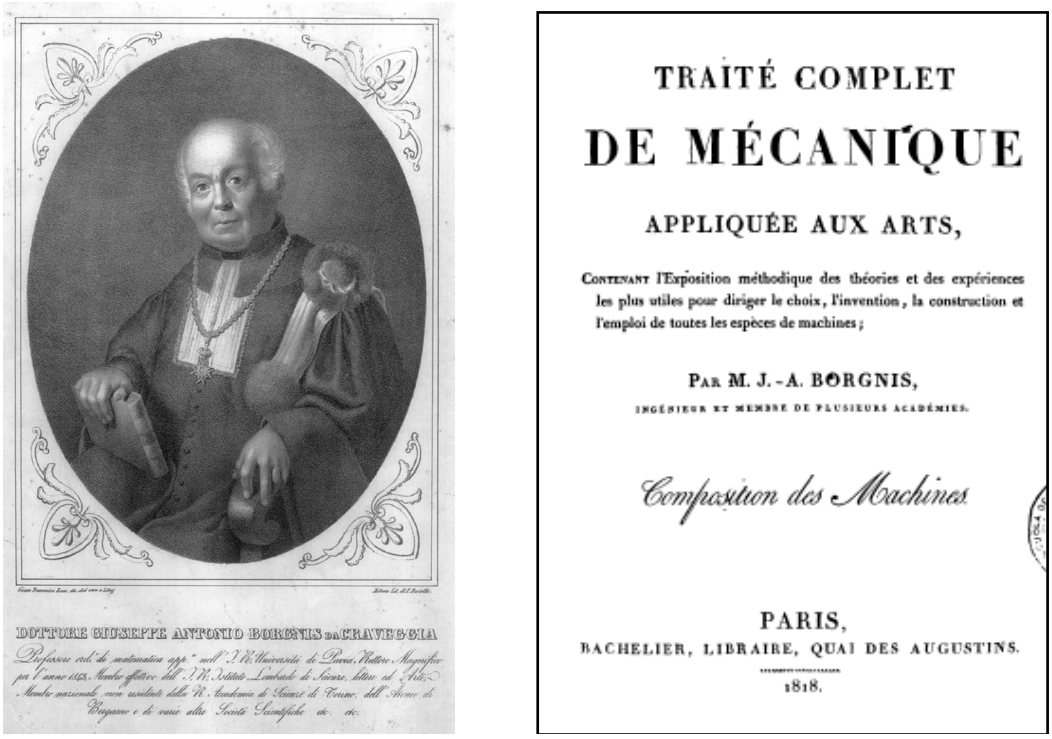
3.1. Giuseppe Antonio Borgnis

Giuseppe Antonio Borgnis, **Figure 2(a)**), was born on April 15, 1877 in Craveggia in Piemonte (northwest Italy) from a well established family since the father Giovanni was banker in Paris. He was well educated with special interest on mathematical disciplines and although the revolution time affected the family he was able to graduate as engineer. He got a position as naval engineer in Venice and because of gained expertise he wrote his first book on machines on 1809. This gave him a good reputation and got the possibility to attend the Ecole Polytechnique in Paris. During this period he deepened his expertise on machine design both on theoretical studies and practical applications, even evolving views from the Monge's approach. He published ten books from 1818 up to 1823 (Borgnis, 1818-23), as a handbook on machine designs and applications, with a new classification for an overall view, **Figure 2(b)**), (Ceccarelli, 2004). Once returned in Italy he got the position of professor at the University of Pavia where he became also rector in 1848.

He was well reputed professor of applied mathematics and civil transportation architecture with activity combining his interests and applications in machine designs that were influent during the first period of industrial revolution all around Italy, although he was in the north east state within in the Austrian-Hungarian Empire.

In particular, the content of the ten volumes of the handbook can be summarized as in the following:

1—"De la composition des machines" (450 pages, published in 1818), **Figure 2**, which contains classification and description of mechanical devices in agreement with the approach proposed by Gaspard Monge. The treatise is completed with drawing of 1200 mechanical devices, which are also compared in term of figure and operation



(a) (b)

Figure 2. Giuseppe Antonio Borgnis (1781-1863): (a) Portrait; (b) a Title page. (Massimo Borgnis is thankfully acknowledged for the portrait and additional biographical notes).

characteristics. The classification is summarized in Tables, which give a synopsis of available mechanisms at that time.

2—"Du mouvement des fardeaux" (334 pages, published in 1818), which contains a description of mechanical design and operation characteristics of the machines that can be used for transportation and lifting all kind of weights.

3—"Des machines employées dans les constructions diverses" (336 pages, published in 1818), which describes the design and operation of machines that are used for construction in the field of civil engineering, hydraulic engineering, naval engineering and military applications.

4—"Des machines hydrauliques" (295 pages, published in 1819), which contains an overview of machines that can be used in hydraulic systems. An in-depth study is reported for machines applied in agriculture and mining.

5–"Des machines d'agriculture" (295 pages, published in 1819), which contains description of equipment and machines used in agriculture. Detailed studies are reported on mechanisms that are used for harvesting machines, winding and drilling machines, and devices for production of oil and wine.

6—"Des machines employèes dans diverses fabrications" (285 pages, published in 1819), which contains the description of machines used in industrial plants for production of metal components, paper products, textile manufactures, and tannery products.

7—"Des machines qui servent à confectioner les ètoffes" (335 pages, published in 1820), which contains description of procedures for spinning of vegetal or animal material, comparative analyses of mechanical means for industrial spinning and equipment of different kind of machines for different kind of products in textile manufacturing.

8—"Des machines imitatives et des Machines théatrales" (285 pages, published in 1820), which contains a description of mechanical device that are used for any kind of transportation and movement, including devices mimicking animal motions. The text includes an Appendix with interesting description of old machines for theatres and how to adapt their use to current needs and other aims.

9—"Thèorie de la Mecanique usuelle" (published in 1821), which contains an introduction to the mechanics

applied to practical industrial applications and refers to principles of Statics, Dynamics, and Hydraulics. Detailed descriptions and formulation are presented on main mechanical transmissions.

10—"Dictionnaire de Mecanique appliquèe aux arts" (published in 1823), which is a brilliant synthetic dictionary with technical terminology for Mechanical Science, with a vision anticipating the modern time.

The encyclopedic work by Borgnis on mechanisms and machines in 9 volumes was used as reference handbook by practicing engineers along the whole XIX century, as a first modern technical handbook, in Italy and in whole Europe. It was also considered as reference for further studies on classification and evolution of mechanical engineering handbooks.

The encyclopaedic handbook was organized by Borgnis from a classification overview up to specific studies of category of machines by discussing design and operation characteristics of each machine. The last book is on terminology with synthesis of concepts and understanding of terms that are related to design, operation, and manufacturing of machines. Borgnis worked out his encyclopaedic work of machine handbook as an evolution of both the tradition of Theatrum Machinarum and new analytical analysis of mechanisms. Thus, the handbook shows a considerable descriptive approach that is justified and indeed motivated by the fact that there was not yet a consolidated community of industrial engineers. Indeed the handbook can be also understood as a stimulus for an establishment of such a community. In this respect emblematic is the volume for the dictionary of technology as a need of standardization, probably also due to the fragmentation that he continuously experienced even from the Italy fragmentation.

3.2. Giuseppe Colombo

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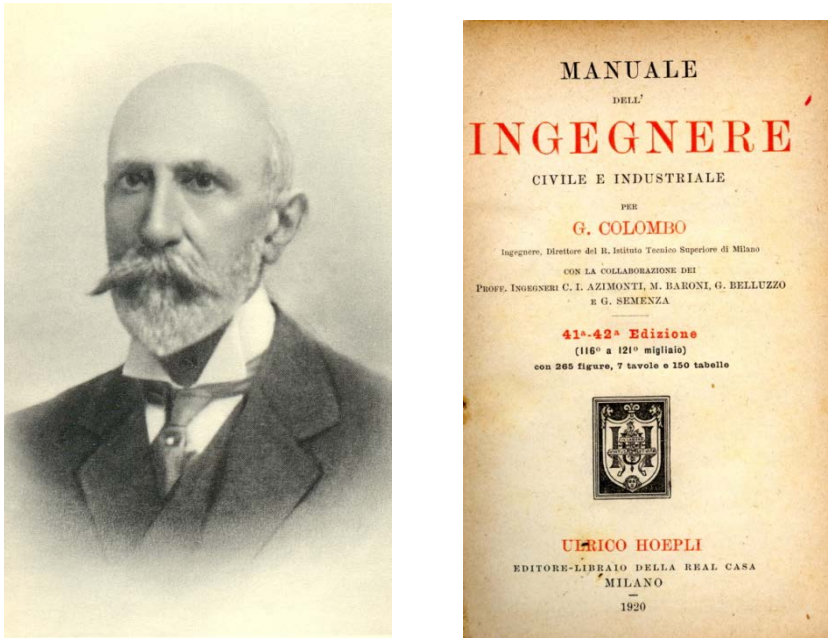
Giuseppe Colombo, **Figure 3(a)**), was born on December 3, 1836 in Milan from a middle-class family that permitted him to graduate in mathematics at the University of Pavia in March 1857.

He was attracted to engineering and he started to teach in Milan with a position of professor of Mechanics applied to Industry in 1864. Just after in 1865 he got position of full professor at just founded Politecnico di Milano. During his teaching, he was always interested to look at the developments coming from abroad also with the aim to stimulate similar experiences and new initiatives in the frames of the Milan society and its surroundings. He dedicated efforts in research whose results are reported in several publications, with several articles in the journal Politecnico and other Italian publication frames up to work the milestone hand book for engineers in 1877, **Figure 3(b)**). He was attracted also to implement expertise in industrial activities with foundation of



(a) (b)

Figure 3. Giuseppe Colombo (1836-1921): (a) portrait; (b) title page of his handbook.

companies by his former students and even with his personal participation, like for example in the case of Pirelli started in 1872. Emblematic is the initiative that he promoted and supported personally for the installation of first electricity network in Milan with construction and operation of the first European power plant in Santa Ragedonda in the center of Milan.

After those experiences he was involved in government activities from local frames up to national positions in the Italian Parliament with increasing influence mainly in aspects linked to technological developments. He reached also the role of minister and Head of the Parliament. While he ran an intense political activity mainly in the last decade of 19th century, he continued to teach and spend efforts for developing proper technical formation of engineers. After reducing the politics activity he came back with great attention to the academy and design of industrial machinery up to his death in Milan on 16 January 1921.

Colombo can be recognized as a modern engineer with activity for technological developments towards the society benefits up to be an influent actor of governmental politics. From technical viewpoints, historical significance of his personality can be summarized in having well defined a technical formation of industrial engineers with practical skills up to the publication of the milestone handbook of engineers and in having stimulated even with personal participation initiatives in industrial activities both in new emerging fields and in expanding local enterprises. Colombo worked out his engineering handbook as inspired by a similar work by Reuleaux in Germany with the aim of providing a means for facilitating the practice of engineering. The handbook was thought as a synthesis of practical information that can help practitioners (engineers or not) to get a first insight of a problem with its solution. It was accepted immediately with great success and several editions were published year after year up today.

3.3. Lorenzo Allievi

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Lorenzo Allievi, **Figure 4**, was born in Milan on 18 November 1856 and died in Rome on 30 October 1941.

He was son of Francesca Bonacina Spini and Antonio Allievi, who was Senator in the Italian Parliament in the recently established Italian Kingdom. Lorenzo started the school in Como but when the father was appointed Senator, in 1871 the family moved to Rome where he completed the college and got the Engineer degree on 24 October 1879. He received a grant as visiting scholar in Germany and successively he got a temporary position at the Royal School of Engineering in Rome where he worked out mainly studies on Mechanism Design. During this period he spent efforts also in other design problems, such as the Metro system in Rome and the railway line

(a) (b)

Figure 4. Lorenzo Allievi (1856-1941) (a) Portrait; (b) Title page of his treatise.

to Castelgandolfo. On 31 August 1885 Lorenzo Allievi married Anna Brenna, who later gave him three children: Francesca, Raimondo, and Antonio.

In 1893, he left Rome since he got the position of Director of the industrial enterprise "Risanamento di Napoli" in Naples where he promoted industrial developments until 1901 when he came back to Rome. There, he worked in many industrial enterprises (Carburo Calcio, Risanamento della Romana Gas, Anglo-Romana, Terni, Romana Elettricità, Banca Commer-ciale, Meridionale di Elettricità, Elettrochimica, Saline Eritreee) and because of this activity he even became President of the Association of User Electrical Companies. This successful activity brought him to the position of President of the Industrial Union of Region Lazio and later he became vice-President of the Italian Industrial Union.

Particularly interesting is his activity in the company Elettrochimica for which he designed plant enlargements in Popoli but mainly he studied problems in the plant at Papigno in Terni where in 1902 a hydraulic pipe exploded with great damages for the structures. Since then Lorenzo Allievi continuously addressed attention to the study on perturbed motion of water in pipelines by working mainly during the night after day-work duties for industrial companies.

The study of Hydraulics always attracted his attention, even after he solved the problems in Papigno plants by solving the regulation of Water Hammer as in his first publication in 1902 that was reprinted in 1903. In **Figure 4(b)**) is reported the tile page of the most distributed version in 1913. He continued to work the theory of Water hammer but he never considered again problems on Kinematics of mechanisms that were the subject of his first scientific publication, (Allievi 1895).

In his activity as engineer and industrial manager, he always paid attention also to the satisfaction of the employers since he considered the work of all as fundamental for achieving scheduled goals for the company and undergoing job. Since he was involved also in the Economy aspects, Lorenzo Allievi approached also subjects of Finance in articles that were published later in a volume 'Spunti polemici di attualità' in Rome in 1918.

Lorenzo Allievi carried out successfully activity as professional engineer and industrial director. But the activity that gave him international fame is the scientific study on the water hammer that he treated in several publications since 1902 until 1936 (Ceccarelli & Koetsier, 2009) and he was still investigating on the subject when he died in 1941.

His approach that is still today known as Allievi's Theory gave him several prizes in Italy, like for example the Jona Prize for Industrial Engineering achievements, and abroad, including immediate translations of his publications into French, German, and English. Significant is the Award that ASME, American Society of Mechanical Engineers, gave him as recipient for Honorary Membership in 1937, in a period of great international tensions before the Second World War.

3.4. Remarks

First, confirm that you have the correct template for your paper size. This template has been tailored for output the above three figures represent emblematic examples of the characteristics of the persons, who contributed to the Italian developments in the Industrial revolution. There were people, who once formed abroad, transferred the new ideas with personal understanding, like Borgnis; persons who matured their expertise with abroad influence by a formation within Italian frames and then shaped the academic and professional frames with their direct presence, like Colombo; persons who once formed in the university, worked to the industry shaping not only the management but even the new technologies with Italian creativity, like Allievi. Peculiar is the strong personality of each of those actors within the scientific community for the Italian industrialization who acted as leaders in well determined areas both in topics and geographical presence. Other characteristics is that, with exception of few cases, most of those influential figures have acted only with Italian frames and by using only Italian languages for dissemination of their works and ideas as a need to reinforce the nation characters but also producing a certain isolation from the international community.

4. Italian Machine Industrialization in 19th Century

The peculiarity of Italian industrialization can be outlined by looking at the experiences that started in the South and then the initiatives in the north of the country after the re-unification with strong state support and single entrepreneurs success, respectively.

In the following, we report three examples of those enterprises with significant activity in those past aspects

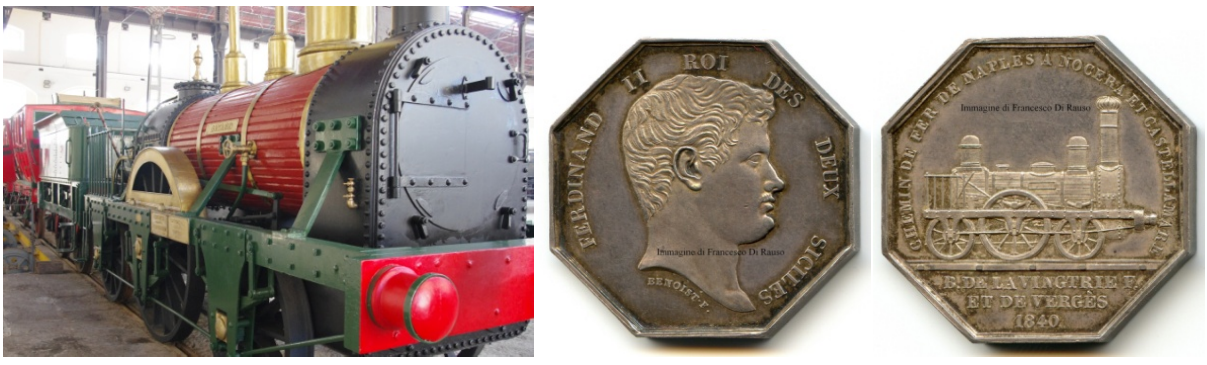
characterizing the time evolution in Italian industry, namely early initiatives with strong king support, large companies with strong governmental support, and small companies by creative dynamical entrepreneurs with very frequent relationships and mergers.

4.1. The Start of Italian Industrialization in the Two Sicilies Kingdom

The Kingdom of the Two Sicilies was the first Kingdom in the Italian Peninsula since it was founded the day of Christmas of 1130. In the last 126 years of the kingdom, before the unification of Italy, the Kingdom was held by the Royal family Borboni-Due Sicilie and was composed by lands in the Centre-South of the peninsula, see **Figure 1**. During the last period of the Kingdom, especially when the last king Ferdinando II got the throne in 1830, a renovation process was implemented by the king who wished to emancipate the kingdom from the dependence on foreign military and technology. Steelworks, shipyards, and metal works were developed by using new equipments and manufacturing processes, which made the Kingdom of the Two Sicilies the birthplace of the Italian modern engineering industrialization. Among the king's industrial projects, the Pietrarsa workshop was undoubtedly an important symbol of such early process of Italian industrialization (Ceccarelli, 2014).

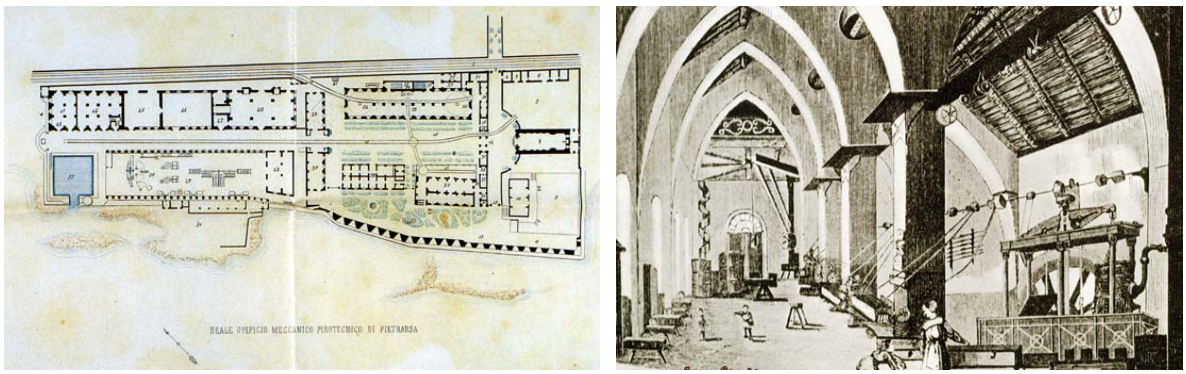
Pietrasa Workshop was originated from a small mechanical factory that was founded as affiliated to the military corps of the kingdom by William Robinson (a captain of Borboni navy) in Torre Annuziata near Naples. In order to form properly technicians for the factory, "Officers, smelters, county workers were shipped to France, Belgium and England to acquire not only knowledge, but also essential printed works, detailed data, and drawings." (Puca, 2011). In 1837, the factory was transferred to Pietrarsa in Naples that is the birth place of the first Italian locomotives. The first locomotive, **Figure 5**, served on the first railway from Napoli to Portici that was inaugurated on 3th October 1839. From the technological viewpoints the first two locomotives were Italian designs although they were built and assembled at the Pietrarsa Workshop. They were designed by French engineer Armand Bayard who was in charge of the construction of the railway Napoli-Portici, with structure that was based on a prototype by George Stephenson. The essential parts of the locomotives were produced by the British company Longride and Co. and then were shipped to Napoli, where they were reassembled by local works under the guidance of British technicians.

In order to meet the development of railway, the young king decided to construct a larger workshop on the seaside of Pietrarsa in 1939 or manufacturing locomotives as well as for their repair and maintenance. A British engineer, David Roberston was appointed to be the technology director of the workshop and the workshop started operation in 1942 with a successful period of expansion from 1843 to 1853 by the direct interest of Ferdinando II. A school for training machinists was also opened at Pietrarsa in April of 1841, but it was closed in 1848 partly since there were not enough students with employment opportunities. However, the expansion made Pietrarsa workshops the largest industrial pole in Italy in 1850s (**Figure 6**). As an advanced industrial site with foundries for iron and bronze casting in processing of boilers, several machine tools and hydraulic systems, the forge facilities with fans and the large steam hammers, and a great hall equipped with complete set of facility for locomotive construction. Almost 700 workers were employed there in 1853. Between 1845 and 1860, 20 new



(a) (b)

Figure 5. The first locomotive and railway in Italy: (a) The locomotive Bayard that is preserved in the national railway museum of Pietrarsa; (b) Silver Medal in 1840 for the inauguration of the railway Napoli-Castellammare-Nocera, including the portrait of Ferdinando II, and the drawing of the first locomotive. (From the collection of Francesco di Rauso, Caserta).



(a) (b)

Figure 6. Pietrarsa Workshop in 1850s: (a) Map of Pietrarsa Workshop by Col. Cesare Mori at the time of completion of its final structure; (b) A drawing of the great hall for construction in Pietrarsa, with the Watts machine on the right side, (Gamboni, 2013).

locomotives were made in Pietrarsa as based on the license of Stephenson's model, (Puca, 2011). The first seven locomotives were produced under the direction of Robertson between 1845 and 1850, with materials partially stored in the military warehouse or bought in England, and partially made at Pietrarsa factory itself. The production of the second set of 10 locomotives was completely designed and made at Pietrarsa with the exception of axles. The final three locomotives with doubled power capability were finished before the fall of the Kingdom.

Since 1860 after the unification of the kingdom into the Italian Kingdom, Pietrarsa workshop was handed over to the Italian Government. Even though the locomotive industry in the North was under the way of significant growth after the unification, Pietrarsa was still the biggest locomotive manufacturer in the first 20 years of the united Italy; since it produced 148 locomotives from 1861 to 1884 as the 64% of the total Italian production, (Merger, 1986).

Pietrarsa Workshops can be regarded as a prime effort by a monarch in Italy toward industrialization. It was a personal initiative of the king without real industrial infrastructures and market backgrounds and needs. Nevertheless, this made south Italy to be the first area where Italian engineering industrialization occurred with also a stimulus in industrial development in other areas. The King's project was based on foreign technology not only in construction of the factory but also in the design and production of locomotives. However, although the limitation of market success due to the territory fragmentation, the initiative was relevant as a successful experience of technology transfer into a local production with independent capabilities. From this viewpoint, King Ferdinando II can be considered as a key visionary entrepreneur, who was able to form the earliest network which made the modern machine technology to be transferred and developed at the beginning of industrialization of Italy.

4.2. The Rise of Mechanical Engineering Giants in the North

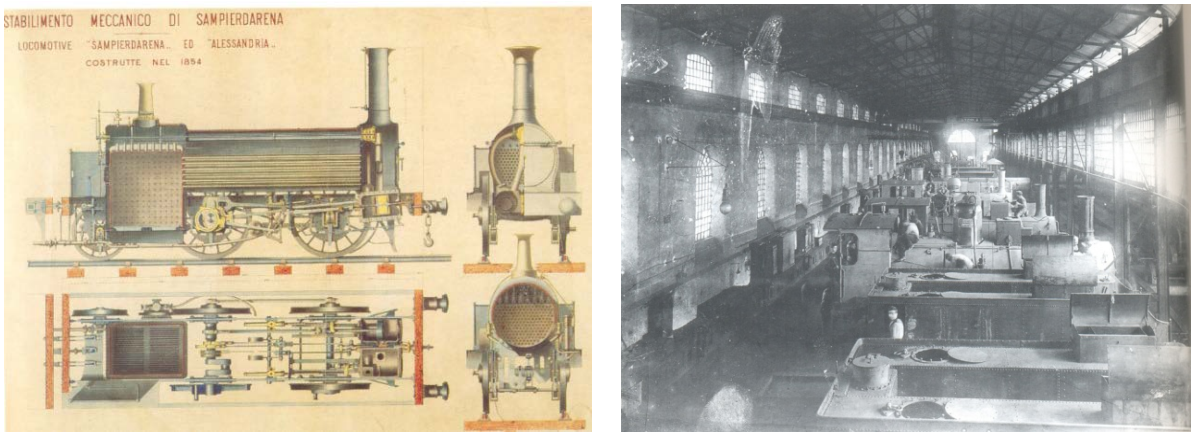
First, confirm that you have the correct template for your paper size. This template has been tailored for output More than from the history of technology and industry, the historiographical attention on nineteenth-century Italy is addressed to the political developments that are identified as the history of Risorgimento. The Risorgimento was initiated in the Kingdom of Piedmont-Sardinia by pushing the north of Italian Peninsula onto the way not only to struggle for the national political unification of Italy, but also to develop the nationalism idea in economic developments. Building a country railway network by the state was an important part of the progress in the economy of the unified nation. It was around 1846 that the Saubadi Kingdom in Piemonte started a large scale program of construction of the main railway lines and left the secondary lines to private companies, following the French example of the period, (Schram, 1997). The network was further developed in the 1850s with a state railway program that also initiated the industrialization of the mechanical engineering in the north Italy, especially in the field of the railway locomotives and facilities' manufacture. The Ansaldo Company in Genova was a typical case of this process with a company strongly supported by the governmental programs..

The origins of the Ansaldo Company may be traced back to 1846 when the English engineer Philip Taylor and the Piemontese Fortunato Prandi established a workshop for the construction and repair of railroad machi-

nery in Sampierdarena near Genova with a state loan. Philip Taylor was one of the typical British engineers in the period of industrial revolution initiated in England, who seeks aboard the chance to make success by running business with their own technical skill or invention in the field of vapor engines or other machine manufacture. He was involved in research on the improvement of steam engines by designing a new type of boiler for a horizontal engine, and the relative research result was published in 1822 (Taylor, 1822). He founded a mechanical workshop in London and then in Paris to exploit his patent and sold steam engines in his early time but was not enough successful. In 1834, he went to Marseille to continue his entrepreneurial career with great success in increasing exports in the Mediterranean basin, especially in Italy, as reported in (Raveux, 2000). In 1846, Philip Taylor was called by the Sabaudi Kingdom of Piemonte to establish a mechanical factory in Genoa for manufacturing activities for the railway of the state. But Taylor's factory got into a financial difficult situation soon since the ambitious initiative of the British engineer was largely discrepant to the program of the Piemonte Kingdom that preferred the locomotives' production of British and Belgium manufacturers.

In 1853, the workshop was taken over by four new Italian entrepreneurs, namely Giovanni Ansaldo (1814-1859), Carlo Bombrini (1804-1882), Raffaele Rubattino (1810-1881), and Giacomo Filippo Penco (active in the Kingdom parliament in 1848-49). The new company was founded with the name Giovanni Ansaldo & C because Ansaldo was the only person who had specific technical skills for machinery engineering. It is to note that Ansaldo Company was founded in a transformation time for Italian peninsula undergoing profound political and social changes that were motivated by national consciousness not only at the political levels due to the unification of Italy, but also at the economical levels. The founders of Ansaldo were representative of a new class of Italian entrepreneurs who recognized the close ties between unification and economic developments, as pointed out in (Row, 1988). For example, Giovanni Ansaldo was a professor of Mechanic Applied to Arts and Infinitesimal Calculus at Genova University where he received his PhD degree of Mathematics in 1845. He successfully visited some industrial districts in England and France before he moved his life to the industrial activities to design a locomotive by himself, (Lacaita, 1994). The other three founders of Asnaldo company were also from Genova with a vision to fulfil the need of a strong industry for power machines in the united Italy.

Anslado Company was the first locomotive manufacturer in the north Italy. In 1854, Ansaldo Company began to produce its first two locomotives, **Figure 7(a)**). They were designed by Giovanni Ansaldo himself with a number of design adjustments to increase speed, to reduce fuel consumption, and to solve problems in the mountain railway routes. All the essential parts of the locomotive were made at Ansaldo workshops with original solutions for steam generator, motor engine and mechanism system (consisting of a cylinder with piston engines linked to the apparatus for the transmission of motion and the mechanism for steam distribution), and locomotive wagon, (Lacaita, 1994). These two locomotives were completed at the end of 1855 and they immediately started the service in Torino-Rivoli railway. The two locomotives were successful so that Ansaldo company was committed for construction of 20 more locomotives that were produced in Ansaldo up to 1895 when Giovanni Ansaldo died.



(a) (b)

Figure 7. Locomotives by Ansaldo Company: (a) The design of the locomotive Sampierdarena, in 1855; (b) The construction line of Locomotive FS290 and FS870 in 1907.

Even though the political unification brought a brilliant prospect to the railway developments, the domestic market was still underdeveloped for Italian engineering industry because of free-trade policy that was adopted by the Italian government. During the first twenty years after the unification, around 1,297 locomotives were put into service in Italy, but over 80% of them were produced by foreigner manufacturer; and only 68 were made by Ansaldo company. It was in 1880s when the Italian state was to be the "agent of development" for Italy's heavy industries by adopting a protectionist policy and Ansaldo company go the state support to experience a rapid development, as pointed out in (Row, 1988). Because of the support of Italian government within strategic plans for industrial developments and military updates, the Ansaldo company increased the industrial capability up to be even a competitor of large European companies, as demonstrated by a contract that was made in 1910 for a destroyer ship with the Chinese emperor Navy, **Figure 8** (Ansaldo, 1910). By the end of the First World War, the company was developed into one of Italy's largest industrial corporation that was engaged in railroad machinery, shipbuilding, armaments manufacturing, and steel making.

Ansaldo company can be regarded as a typical successful case of a national plan for Italian industrialization. At the foundation Ansaldo company was very limited but thanks to the Italy re-unification it could benefit of strategic plans that were mainly based on North Italy. Even the more consistent academic technical frames in North gave large support to the rapid growth of company with well educated professionals and engineers. In South Italy Pietrarsa Workshop was a brilliant isolate initiative that because of lack of surrounding professional frames and governmental support after re-unification, very strongly reduced the activity with a loss of a promising regional development up to a minimum by the end of 19th century.

4.3. Small-Medium Mechanical Enterprises in the North Italy

Beside large scale companies such as Ansaldo, a lot of small and medium size mechanical enterprises started thanks to the dynamic behaviour of local entrepreneurs in north Italy during the second half of 19th century. According to the statistics of the time, the medium-size mechanical enterprises accounted for the largest share of the total number of the existing mechanical enterprises in 1864 as reported in **Table 1**. The success of these companies was different because of the difficult and complicated situations of the evolving mechanical market in Italy. Bankruptcy and merger happened very frequently. Nevertheless, such an active entrepreneur behaviour, no matter what the result was, made Italian mechanical technology well developed and be independent from the advanced countries in several special production sectors, such as the production of turbines and precise instruments. Riva Company and its predecessors in Milan can be considered a typical example of entrepreneurial activities in turbine manufacture during mid 19th century.

The first activities of Riva Company, as a plant established by Antonio Paolotti and some others for the "manufacture and sale of machinery and steam centrifugal action and any other", dates back to September 29,

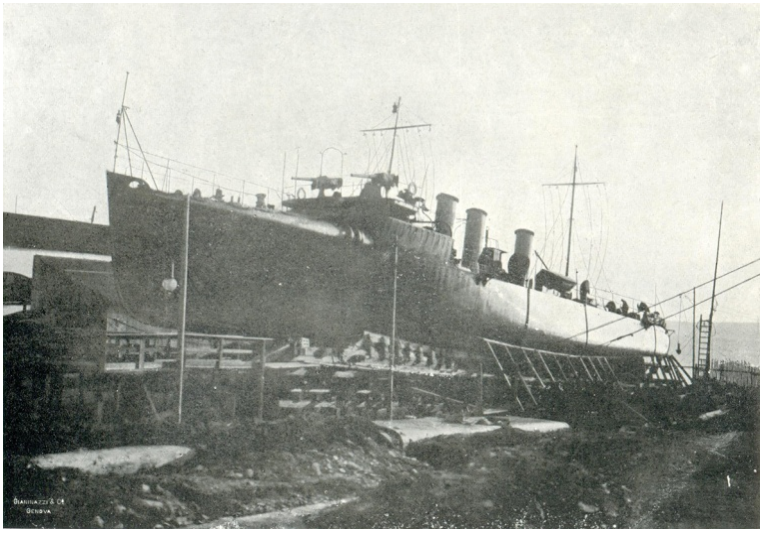


Figure 8. The destroyer "Qing po" built by Ansaldo company for the navy of Chinese imperial, (Ansaldo, 1910).

Table 1. Existing mechanical factories in Italy, 1864. (Giordano, 1864). (LE is for enterprise with more than 250 employees; ME is for enterprise with 50 - 250 employees, SE is for enterprise with less than 50 employees).

Province	Ancona	Bergamo	Bologna	Brescia	Gagliari	Como	Cuneo	Firenze
LE	1	0	0	1	0	0	1	1
ME	1	0	2	0	0	3	0	3
SE	0	1	0	1	1	0	0	0
Total	2	1	2	2	1	3	1	4
Province	Genova	Livorno	Lucca	Milano	Modena	Napoli	Novara	Palermo
LE	4	0	0	2	0	3	0	1
ME	3	0	1	3	0	2	3	0
SE	1*	3*	0	1*	1	2*	5	1*
Total	8	3	1	6	1	7	8	2
Province	Placenza	Pisa e Prato	Siena	Perugia	Torino	Others	Total	
LE	0	0	0	0	2	5	21	
ME	0	0	1	2	4	3	31	
SE	1	2*	0	0	0	4*	24	
Total	1	2	1	2	6	12	76	

Note *:The figures with *are estimates because of the lack of employee data.

1861 with a location at no. 3711 Road Corso Vettabbia in Milan. In 1876, Hercules Porro, a brilliant engineer, who was graduated from the Politecnico di Milano, joined Paolotti's company with a considerable financial support of 25,800 lire. The arrival of Porro marked a turning point of an influential effect in the technical management of the workshop. The workshop's production was limited in the locomotive Stigler system with the boiler for power at that time. It is notable that the two partners of the company had completely different background. Paolotti was an illiterate, who spend a long time as a military artisan, and the second was an engineer trained in mechanical engineering at the Polytechnic schools, a member of the new manager class capable of technical knowledge transfer to production processes, as pointed out in (Bigatti, 1998).

Thanks to the skills of young engineer Porro and the favourable economic situations, the plant ran well. In 1874 a limited partnership Paolotti, Porro & C was formally established with a capital of 105,000 lire. In 1875 Porro took over the share of Paolotti and changed the company's name into E. Porro & C. Unfortunately Porro died suddenly in August 1876 and his widow decided to entrust the management of the company to the engineer Giovanni Morosini. Morosini was a professor of agricultural mechanics at the Agronomy School of Milan, who used his expertise to develop the agricultural equipments for the surroundings of Milan. The company's name changed into Porro & C. di Colombo & Galimberti soon later. In 1879, Ernesto Galimberti, the brother of one of the company's owners, joined the company and became the technical director, while Morosini took charge of the management work.

Porro & C. di Colombo & Galimberti was a typical small-medium size mechanical company of Milan at the end of 19th century that without governmental support needed to survive by self finance. In 1880s, the Colombo and Calimberti group hold one third of the capital share of the company, while most of other members were from the world of professions (engineers) and traders, who were bound by ties of kinship, friendship or acquaintance with the managers. In the late 1880's the fortune of the company went worse gradually; and even the start of production of hydraulic turbines in 1887 could not change such bad situation. At the end of 1888, the capital share of the company was reduced to 246.000 lire, which led Ernesto Galimberti to put the company into liquidation and to negotiate for an agreement with the company A. Riva & C. for merging of the two companies and the reduction of the nominal capital share of Galimberti to 50%.

The company A. Riva & C. was founded in 1872 by Alberto Riva (1848-1924), a young man who also gradu-

ated from Politecnico di Milano and gained his first work experience in Switzerland, in the industrial company of Caspar Honegger. In 1887, Ugo Monneret joined Riva's company as technical director. In 1894, the Company's name changed into A. Riva, Monneret & C. In 1889 the company began the construction of hydraulic turbines that was so successful that the company s gradually abandoned other productions.

In a report of the Italian industry which was written by the representative of the British Journal "The Engineer" in 1906, Riva Monneret and Co. was considered as "one of those who have specially contributed to render the hydroelectric science in Italy an absolutely national one in its application, and to eliminate the necessity of foreign aids for machinery and its accessories.", (The Engineer, 1906).

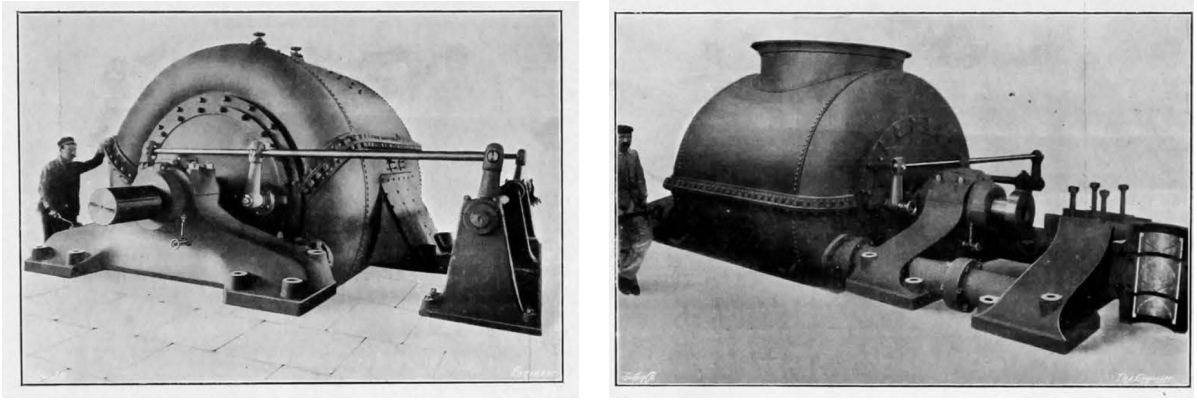
In 1893, Riva company equipped the power central station at Pordenone, in north east of Italy, with turbines of 450 horse-power that were built for driving dynamo machines by using the Francis reaction turbine type with horizontal spindle and direct-coupling. Two years after they equipped the hydro-electric central station of Castellamonte near Turin, the first large station in Italy for the distribution of electrical energy with five turbines, three of which were of 750 horse-power and two ones of 100 horse-power. The installation was so successful that they received commitments for other plants.

In a short time, the company provided the power plants for the important stations of Bussoleno, Paderno, Vizzola, Lanzo Torinese, Pont, St. Martin and Ala Ceres, by using Francis turbines with controllers by automatic water pressure governors, **Figure 9**. Rapidly, the name of the company was appreciated for its honesty and good work so that in 1899. It was even committed by the Hanniton Cataract Power Company of Canada to construct a power station at Niagara falls with two 3000 horse-power Francis turbines of horizontal spindle for high fall (78 m.) and high operation (286 revolutions per minute, **Figure 10**. These great engines were sent to Canada without mechanics belonging to the constructing house, and, in spite of this handicap, they ran successfully from the first without a hitch.

In addition to the construction of Francis turbines for large or small volumes of water, and to falls from 2 m to over 100 m, the Riva company was renowned for its Pelton turbines that they specially modified for applications with water-pressure governors, and for automatic oil regulators, of their own patent. This original governor was exported all over the world during the beginning of 20th century. It was said that this application solved a problem which for many years had puzzled hydraulic engineers. According to a report of "The Engineer" magazine in 1906, Riva Monneret Company "has been able to solve, by its patented oil regulator, the problem of the governing of the turbine wheel, and has constructed more than 1200 turbines of an aggregate power of nearly 300,000 horse-power".

In 1911, under the suggestion of the engineer Guido Ucelli (1885-1964), Riva started also to develop pumps in addition to turbines, in order to complete the production of large hydraulic machines for hydroelectric stations. The long success of the pump production is demonstrated also by a brilliant pumping station in the digging out antique Roman ships from Nemi lake (near Rome) in early 1930s' with only Riva installations.

In 1923, Calzoni family established a cooperation agreement with the Company Riva which led the biggest turbine maker in Italy named as "S.A. Costruzioni Meccaniche Riva Ditte reunite A. Riva–A. Calzoni". The



(a) (b)

Figure 9. Hydraulic turbines by Riva Monneret and Co at the end of 19th Century, (The Engineer, May 11, 1906): (a) At Paderno station; (b) At Vizzola station.

company A. Riva-A. Calzoni totally produced 2,669 turbines by the end of 1923, being 35% of total production in Italy, **Table 2**.

New solutions were developed which gave rise to patents over the years, such as the switch of the jet in 1908, the rectilinear introducer in 1947 and the hydraulic reflector in 1960, (Ucelli, 1961).

Riva Company in its early stage can be considered as a typical example of the active small-medium companies in new areas of machine manufacturing in the north Italy during the second half of 19th century. In general, these companies were founded and developed without governmental support by requiring self finance, with differences from large-scale company like Ansaldo. Having strong relationship with the main engineering educational institutes of their city, such as the Politecnico in Milano, was another remarkable character of these companies. For example, in the city of Milan, the professors or students graduated from the universities with new technical knowledge became an active group of new entrepreneurs who were called "Milanese entrepreneurs" in mechanical engineering industry after the unification of Italy, as shown in the photo group in **Figure 11**. They made the city of Milan became a centre of manufacturing of turbines, science instruments, and railway accessories. These companies showed more innovative and flexible ability than the big companies since they didn't have financial and policy support from government, as it represented by the high numbers of their patents. They developed enhancements or new solutions for specific machinery and application in Italian frames, mainly in north Italy.

On the other hand, the case of Riva Company also represented a typical path of the new emerging industries

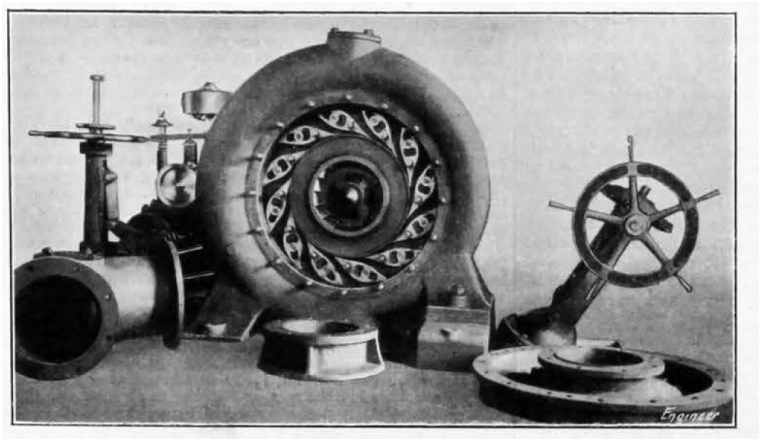


Figure 10. 3000-H.P. Francis Turbine for high falls by Riva Monneret and Co., (The Engineer, May 11, 1906).

Table 2. T Italian manufacturers of Hydraulic Turbines at 1923 as production for both Italy and abroad, (Ucelli, 1924).

Firms	Location	Start of producing	Number of turbines	Total power produced till 31-12-1923 (HP)
S. A. Costr. Meccaniche Riva & Ditte Riunite A. Riva-A. Calzoni	Milano	1885	2669	2,258,729
S. A. Franco Tosi S. A. San Giorgio	Legnano Sestri P.	1913	204	567,000
S. A. Officine Calzoni-Parenti	Bologna	1885	2218	288,575
Ing. S. De Pretto & C. & S. A. De Pretto-Escher Wyss	Schio	1893	936	157,038
S. A. Cantieri Navali-Acciaierie	Venezia	1908	300	22,000
S. A. Ing. Moncalvi & C.	Pavia	1905	719	19,427
S. A. Officine Riunite Italiane	Brescia	1892	349	14,705
S. A. Off. Meccaniche e Fonderie Ing. Pietro Veraci	Firenze	1905	164	9800
Total			7589	3,337,274

Figure 11. A group of graduates of politecnico di milano, including several founders and leaders of north-italy industry. from left to right, standing: alberto riva, bartholomew cabella, colombini, carlo salviotti, giovan battista pirelli, rasura, saldini cesare, angelo salmoiraghi; sitting pius borghi, tommasini.

such as the hydropower and electrical industry in the period of Italian Industrial Revolution. Actually most of the Italian small and medium size machinery enterprises emerged in the late 19th and the early 20th century were mainly belong to the new industrial sectors which rose in the second stage of the European industrial revolution. The lack of coal resources promoted the rapid development of hydropower industry in Italy since the late of 19th century and undoubtedly provided a big business opportunity to the new class of engineers and entrepreneurs who mastered the advanced technology in the north Italy. Compared with the large machinery companies which could develop under the strong support of the Italian government, those small and medium size companies survived and developed with more dynamic innovation activities and more active personal networks within the academic and business circles. It is notable that the active personal networks in Italy is an important factors to help Italian small and medium enterprises to overcome financial difficulties, which became a special peculiarity of the industrialization in Italy from 19th century up to today.

The dynamic behaviour of those small-medium companies can be highlighted by their initiatives also in abroad markets and challenging projects, like for example in the contributions to the constriction of the early Chinese railways by the companies of names, (Xu & Liu, 2013).

4.4. Remarks

The above three cases of enterprises represent emblematic examples of the characteristics of the industrial companies, who contributed to the Italian developments in the Industrial revolution. There were the big companies who received strong support from Italian government with the aim to determine and reinforce and Italian presence in the machine technology with independence from abroad influence and serving standard solutions within the whole national territory. Peculiar is the fact that the Italian industrialization started in the south that very often lost this prominence for lack of infrastructures and indeed proper industrial dedication. The Italian creativity expressed its success with the small enterprises that with flexibility could follow the uncertainty of the Italian industrial evolution with those characters that are still the peculiarity of Italian design. These small enterprises were very dependent of the vision of their founders and managers and suffered continuously alternant crisis that made the bankrupt, merge and new restart, but also very successful productions that were recognized even abroad.

5. Conclusion

The proposed outline presents Italian peculiarities in the history of industrial Revolution by discussing examples of figures and enterprises as typical Italian developments of machine technology in 19th century. The university frames with renewed visions evolved from segmented varied organizations towards a unified system with practical implementations of the produced knowledge and formation. Industrialization was experienced with a special start with support by King Ferdinando II in the south before the political unification, and the strong state support for big companies and dynamic behavior by small/medium enterprises in the north after the unification. The reported cases of study on figures and companies are emblematic examples of variety of situations and experiences that make the Italian Industrial Revolution peculiar with respect to the European developments.

In particular, the following peculiarities can be stressed out:

Although Italian Peninsula had a long history and tradition of prominence in machine technology since the Roman times toward the Renaissance, it was only till the second half of 19th Century that the modern Italian system of machine technology and industries could be established thanks to the uniformed Italian infrastructures in social and scientific aspects after re-unification.

Using Italian as main language for publications and work disseminations was an important means to build an Italian national scientific community in machine technology and industry. Several Italian figures from academic frames were influential in the industrial developments by transferring the new ideas and knowledge even from other countries with their own understandings in Italian language so that they created a modern Italian community of machine science and technology since the early process of Italian Industrial Revolution in 19th Century.

The industrialization of machine technology in Italy was closely related to the transformation of political situation in Italy in the 19th Century. Those situations motivated the birth and growth of few big industries with governmental support and a large group of small companies with the different types of entrepreneurs who played different key roles successively in the development of machine technology during the process of Italian Industrial Revolution in 19th century.

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