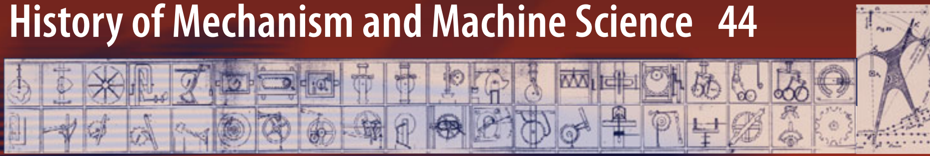
History of Mechanism and Machine Science 44



Dorel Banabic *Editor*

History of Romanian Technology and Industry

Volume 1: Mechanics, Processing Techniques and Construction

Springer

History of Mechanism and Machine Science

Volume 44

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History of Romanian Technology and Industry

Volume 1: Mechanics, Processing Techniques and Construction

Springer

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Preface

The purpose of publishing an abridged English version of the volumes titled *History of Romanian Technology and Industry* is that of disseminating internationally the Romanian achievements in the field of technology. The present book is the first work on the Romanian history of technology published in English. It consists of two volumes titled as follows: *The History of Mechanics, Processing Techniques and Construction* and *The History of Electrical Engineering, Energetics, Transport and Technology Education*, respectively. Each volume includes several chapters covering the fields referenced in the volume subtitle.

Over the decades, the history of Romanian technology has been tackled in Romanian specialized literature in several books authored by historians, engineers, industrialists and sociologists. Nonetheless, it is scarcely known about this field outside of Romania. This is due in part to, among other reasons, the insufficient popularization in world languages of the history of Romanian technology and of the main Romanian contributions to the global technology heritage. Romania is mentioned in the history of technology encyclopedias and in the encyclopedias dedicated to inventions across the world especially because of contributions in the fields of aviation and aeronautics. Missing, however, are numerous names of Romanian engineers and inventors who have contributed significantly to the development of both Romanian and world technologies.

The multidisciplinary approach of the volumes means that the field of technology had to be split into several branches. The present volume includes the following industries: mining, metallurgy, oil, natural gas, machine building, agricultural machinery, military, textiles and construction. Folk technology, the forming of the industrial system and mechanics are tackled in separate chapters. For each subfield, the best specialists in that field or authors who have already published histories of those fields have been invited to contribute to the volume. Some of the chapters have been authored by specialists who have acted as decision-makers in elaborating the development strategies of Romania, who are familiar not only with the facts and the history of their field of expertise but also with the ‘philosophy’ of that field’s development. Such is the case of the chapters on the history of machine building, the history of oil and the history of natural gas. Putting the spotlight on these ‘living archives’ contributes to the quality of the present book. This approach is new compared to those of the books on the history of technology written in the last 80 years. It has the advantage that the specialists in the field are in a better position to make a hierarchy in terms of the value of the technological accomplishments across the years. Now, in the age of the Internet, when it is not the retrieval of information that is a problem in documenting an issue, but rather making a hierarchy based on the value of the information, this approach is essential and adds to the value of the present work. One of the limits of this approach is that there are differences in writing style across the various chapters, due to the different individual styles of each chapter author(s)/editor(s), which is inherent to any book with a large number of co-authors. Another element of novelty in this book as compared to those published so far is the fact that the authors could make good use of the wealth of information available on the Internet, which is accessible to all, but was structured and hierarchized by the specialists in the respective fields.

The coordinator of the book is grateful to all of the authors who have contributed to the chapters of this volume. They all put in significant effort to complete this project in a timely and professional manner. A lot of gratitude also goes out to all those who have contributed to this book.

Cluj Napoca, Romania Dorel Banabic
November 2023

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Introduction

Dorel Banabic

Abstract The purpose of publishing this work is defined in the introduction. The arguments for publishing this history of Romanian technology and industry are listed. Then a brief history of the works in Romanian published over time in this field is presented. After which it was described how the history of Romanian technology and inventions is reflected in foreign literature.

1 Introduction

In 2018, the Romanian Academy started an ambitious program to publish a series of books entitled *Romanian Civilization.* The purpose of the program was to have a panoply of the most significant achievements of Romanian civilization throughout the ages. Why include *History of Romanian Technology and Industry* in the series titled *Romanian Civilization*? The first argument is that technological civilization is part of civilization in its broad sense. If civilization represents the level of material and spiritual development attained by a socio-economic entity, then technological civilization represents that part of civilization which corresponds to the material development of society. Industry is the characteristic form of production of our times and the whole of social life is being technologized.

The second argument is that there are few works in Romanian specialized literature in which the history of Romanian technology is tackled by specialists in the various branches of technology. The history of Romanian technology has been discussed along the decades by historians (Iorga 1927; Pascu 1954, 1982; Giurescu 1973; Wollmann 2010–2016), as well as industrialists (Furnică 1926), engineers (the collective volume of the Polytechnic Society 1931), Bălan and Mihailescu 1985), Răduleț 2000, Nicolae Iordăchescu 2007, Iancu 2009) and sociologists (Gusti 1939). Only three of the books written by the authors above feature a multidisciplinary approach: History of Technology Development in Romania (***1931) in three volumes, dedicated to the 50th anniversary of the Polytechnic Society in Romania, *Romanian Encyclopedia*

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(Vol. 3) (Gusti 1939) by Dimitrie Gusti, and the treatise by Pascu (1982). The history of technological development in Romania by sector is tackled in a comprehensive manner in the three volumes of (*** 1931), which constitute a veritable encyclopedia of Romanian industry up to 1930. The volumes add up to nearly 1500 pages and are structured into 77 chapters, each of them focusing on a specific field of technology and having been drafted by a specialist in the respective field. One cannot leave out the third volume of the *Romanian Encyclopedia* treatise, titled National Economy and edited by Dimitrie Gusti. Modelled after the *Encyclopédie Française* (de Monzie and Febvre 1935–1966), edited by Anatole de Monzie, this treatise is the most accomplished presentation of Romanian industry up to the beginning of World War II, with each chapter being authored by specialists in the field (74 specialists were involved in drafting the treatise). These two works have constituted the main source of information as to the time before World War II. The history of science and technology in Romania was approached in a multidisciplinary manner by Ștefan Pascu in his ambitious treatise *History of Romanian Scientific and Technical Thinking and Creation*, which, unfortunately, never went further than the first volume, thus only discussing the preindustrial age (before the 18th century). It is the intention of the present volumes on the history of Romanian technology and industry to continue this enterprise.

The third argument is that the history of Romanian technology is scarcely known outside the borders of Romania. This is due, among other reasons, to the insufficient popularization in widely spoken languages of the history of Romanian technology and main Romanian contributions to the world's technological heritage. A relevant testimony in that sense is the opinion of Jacques Attali, influential French thinker and former adviser to President Mitterand, who, in his Romanian edition of the book *A Brief History of the Future* (Attali 2007), mentions three reasons why '*Romania never managed to become a dominant power in Europe*'. Two of them have to do with the field of industrial technology, namely: *1. Romania has always privileged agriculture over the mobility industry, innovation, and technology; 2. Romania has not succeeded in forming a sufficiently numerous class of creative people (engineers, researchers, entrepreneurs, traders, etc.); it has never attracted enough scholars, bankers, and businessmen.* The English-language edition of the present work aims to bridge that gap.

The fourth argument is that studying and understanding the past is useful in prospecting the future, as Mihai Eminescu splendidly and concisely put it in his poem '*Glossă'*: *Both the future and the past/Are but sides of the same page;/In beginnings, ends are cast/For whoever can be sage.*[1]

The present volumes of *History of Romanian Technology and Industry* approach the field in the spirit of the treatise published under the aegis of the Polytechnic School in 1931 (*** 1931) and of the third volume of Dimitrie Gusti's *Romanian Encyclopedia*, adapted to present times, namely to the beginning of the fourth industrial revolution. This approach involved dividing the field of technology into multiple industrial branches, such as: mining, metallurgy, oil, natural gas, machine building,

[1] Translator's note: Translation source: http://luceafarul.com/Pages/sbsglossabantas.html.

agricultural machinery, military, textiles, construction, electrical engineering, energetics, biomedicine, naval transport, railway, automotive, aviation. Folk technology, the forming of the industrial system, mechanics, inventions, technological societies, higher education within technology are tackled in separate chapters. At the end of these volumes, a chapter was introduced which contains brief portraits of eminent figures in Romanian technology. The engineers who have contributed to advancing the fields of computers, automation, and electronics are not included here, as these fields are part of another work within the series. For each field, we engaged the collaboration of top specialists or authors who have already published a history of their field. Certain chapters were drafted with the aid of specialists who have played the part of policy makers in the elaboration of development strategies for Romania and who are familiar not only with the facts and the history of their field, but also with the 'philosophy' behind its development. Such is the case of the chapters on the history of machine building, the history of electrical engineering, the history of energetics, and the history of oil. Making the most of these 'living archives' adds to the quality of the present book. This represents a new approach as compared to the books on the history of technology written in the last 80 years, an approach which has the advantage that specialists in the field are more capable of correctly ranking the value of technological achievements along the ages. Nowadays, in the age of the Internet, when the issue is not about finding information when doing research, but about ranking it based on its value, such an approach is crucial and increases the worth of the present work. One limitation to this approach, which is inherent to any book with a large number of authors, is that the chapters are written in different manners, each author/chapter supervisor having a different style. Another element of novelty brought by the present work as compared to the ones preceding it is the fact that the authors have made full use of the extremely bountiful information found on the Internet, a source accessible to all, yet this time employed most fruitfully thanks to the ordering and ranking conducted by specialists in each field. Furthermore, archive documents published after 1990 were used, such as the ones included in the paper (Manole et al. 1991).

There is a wealth of world literature on the history of technology, published from the early 20th century onwards, first in Germany (Beck 1900; Darmstaedter 1908) and, after World War II, in Britain (Singer 1954–1978), France (Daumas 1962–1978), the USSR (Zvorikin 1963), the USA (Klemm 1964), Italy (Capocaccia 1973), Poland (Orlowski 2008). A vast five-volume treatise has recently been published in Germany by the Propyläen Publishing House (Konig 1997–2000), while in the USA, the publication of a treatise began in 2010, having now reached its fourth volume (Deming 2010–2012). These volumes mention but a few Romanian technological achievements, such as those of George Botezat (helicopters), Gogu Constantinescu (the theory of sonics and automatic transmission) and Hermann Oberth (interplanetary travel) in *A History of Technology* (Singer 1954–1978) and those of Oberth in *Propyläen Technikgeschichte* (Konig 1997–2000). Chinese technology, with its ancient traditions and remarkable contributions to the world heritage, is presented in a plethora of books on the history of technology in Chinese, some of which have recently been translated into English, such as the ample three-volume treatise called

A History of Chinese Science and Technology (Lu 2015). In the mid 1930s, historian Lucien Febvre, who, together with Anatole de Monzie, created the *Encyclopédie Française* (de Monzie and Febvre 1935–1966), said about the history of technology: *'Technique: un de ces nombreux mots dont l'histoire n'est pas faite' (Technology: one of the many words whose history has yet to be made).* These words have spurred historians all over the world to approach the topic of the history of technology, which has led to an avalanche of works from the 1950s onwards (as can be seen from the list above). Furthermore, series of books on the history of technology were published, by the VDI Publishing House in Germany (*** 1909–1919) in 1909–1919 and by the Springer Publishing House in the same country from 1938 onwards (Holey 1938). In 2007, the same publishing house began issuing a series of books titled *History of Mechanism and Machine Science*, which has reached 34 volumes so far (http://www.springer.com/series/7481?detailsPage=titles). In 1964, a series of books on the history of technology started to be published by the MIT Press in the USA (so far, it comprises over 250 volumes) (https://mitpress.mit.edu/category/discipline/science-technology-and-society/history-technology). In 1991, the Institute of Historical Research of the University of London began issuing a series of books titled *History of Technology*, which has reached its 33rd volume (Inkster 1991–2016).

As a result of the impetus given to the research on the history of technology, international professional associations were also created to bring together the efforts made by researchers in the field. The first and most well-known such association is the *Society for the History of Technology* (https://www.historyoftechnology.org), which was founded in 1958 and counts over 1,500 members. The society organises an annual conference, publishes a magazine titled *Technology and Culture* (https://www.historyoftechnology.org/publications/technology-and-culture/), and supervises a series of books in its field (https://www.historyoftechnology.org/publications/historical-perspectives-on-technology-culture-and-society/historical-perspectives-on-technology-culture-and-society-booklets-in-print/). Subsequently, in 1968, the *International Committee for the History of Technology* (ICOHTEC) (http://www.icohtec.org/) was founded in Paris, as part of the *International Union of History and Philosophy of Science* (IUHPS). The ICOHTEC issues an annual magazine titled ICON (http://www.icohtec.org/publications-icon.html). It is worth noting that Romanian Academy Member Ștefan Bălan was the president of ICOHTEC in 1981–1989.

In Romania, the *Romanian Committee for the History and Philosophy of Science* (CRIFS) was created in 1956, under the aegis of the Romanian Academy and upon the initiative of its president, Traian Săvulescu. The first person to be elected president of this committee was Romanian Academy Member Mihai Ralea, while Romanian Academy Member Remus Răduleț was head of the division of technological sciences. In 1957, this Romanian committee became part of the *International Union of History and Philosophy of Science*. The sustained activity of the Romanian committee within that international body enabled the former to organise the 16th Congress of the History of Science in Bucharest in 1981. In 1992, CRIFS is restructured into three divisions and its name is changed into the *Romanian Committee for the History and Philosophy of Science and Technology* (CRIFST). The three divisions are dedicated to: history of science, logic, methodology and philosophy of science, and history of technology, respectively. The latter division was headed by Romanian Academy Member Horia Colan from the time of its creation until his death (2017). CRIFST is editor to two annual publications: NOESIS, founded in 1972, and NOEMA, founded in 2002 (http://www.acad.ro/crifst/crifst.htm).

When it comes to Romanian inventions mentioned in books on the history of inventions, the situation is similar to that of the history of technology. For example, in the four-volume encyclopedia edited by Alvin Benson, titled *Great Lives from History: Inventors and Inventions* (Benson 2009), 413 inventors from 36 countries are presented, yet none of them is Romanian. Other recently published encyclopedias mention merely one Romanian each: in *Britannica Guide to Inventions* (Curley 2010), Hermann Oberth is included due to his contribution to interplanetary travel; in *Ancient Engineers Inventions* (Rossi and Russo 2017), Conrad Haas is mentioned for his invention of the multi-stage rocket; in the *1000 Inventions and Discoveries* (Bridgman 2014) encyclopedia, Steven Auschnitt is featured due to his invention of the ZipLoc for plastic bags. In *The Timetables of Science* (Hellemans and Bunch 1991), 5 Romanians are mentioned, 3 of whom are engineers: Traian Vuia (first flight in a self-propelling aircraft), Henri Coandă (the jet-engine aircraft), Gogu Constantinescu (sonics). In the *Larousse-Dictionary of inventors and inventions* (*** 2001), 8 Romanians are mentioned, 4 of whom are engineers: Henri Coandă (the jet-engine aircraft), George Botezat (the helicopter), Hermann Oberth (interplanetary travel), Gogu Constantinescu (sonics). The same can be noted with respect to the great thematic encyclopedias, such as *Mc Graw Hill Encyclopedia of Science and Technology* (*** 2007), or general ones: *British Encyclopedia, Encyclopedia Universalis, Larousse*, etc.

Romania is mentioned in encyclopedias of the history of technology and of inventions especially for its contributions to the fields of aviation and aeronautics. Such publications leave out numerous names of Romanian engineers and inventors who have had significant contributions to the development of global technology, such as: Petrache Poenaru (the fountain pen), Alexandru Ciurcu (applications of the jet engine), Lazăr Edeleanu (oil refining), Ion Basgan (sonic-vibration drilling), Aurel Perșu (the aerodynamic automobile), Dumitru Daponte (3D cinematography), Augustin Maior (multiple telephony), Constantin Budeanu (electrical engineering terminology), Nicolae Vasilescu-Karpen (the thermoelectric pile), Elie Carafoli (aerodynamics) and many more. An exhaustive list of Romanian inventors is featured in the work edited by the *State Office for Inventions and Trademarks* (Oficiul de Stat pentru Invenții și Mărci – OSIM) (*** 2002).

There are numerous solutions for increasing the visibility of Romanian technological achievements, such as: publishing a history of Romanian technology and industry on the website of the Romanian Academy and on that of Academia de Științe Tehnice din România (Academy of Technical Sciences of Romania); having Romanian specialists participate more frequently in conferences on the history of technology; introducing information on Romanian engineers into the English version of Wikipedia; publishing monographs on various themes in English, etc. Several commendable initiatives have been taken by the *State Office for Inventions and*

Trademarks (OSIM), such as the publishing of *In the World of Romanian Inventors* (*** 2002), and, more recently, by the Romanian Cultural Institute, which has lately published a book titled *100 Romanian Innovators* (Vișinescu 2018), both works having been issued as bilingual editions (Romanian and English). The present work aims to contribute to promoting the valuable achievements of Romanian technology both at home and abroad (through its English edition).

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History of Folk Technology

Cornel Bucur and Dorel Banabic

Abstract A fundamental category of historical civilization is the traditional popular civilization. This represents a multi-millenary synthesis, resulting from the grafting, on the ancient autochthonous background, of some elements mediated by ethnic contacts, temporary or long. These were caused by heterogeneous influences, caused by numerous and diverse political, socio-economic or ethno-cultural factors. This crystallized in a long process of ethnocultural osmosis, which generated that "ethnic specificity", invoked as a defining attribute in the effort to characterize the culture and civilization of peoples. In this chapter, the main folk techniques discovered in Romania starting with the Paleolithic period are reviewed. They are classified based on occupational specialization and are presented in their historical evolution. The most relevant artifacts are described in more detail, including sketches for understanding their operation.

1 Introduction

Technology is defined as the totality of production instruments (tools, machines, equipment) and methods developed throughout history that allow mankind to study and transform the natural environment in order to obtain material goods. **Folk technology** represents that part of technology which has been developed along the ages through the anonymous contributions of a community. Folk technologies have developed in time in order to reflect the evolution of occupations within communities. The main characteristics of Romanian folk technology are directly linked to those of Romanian folk civilisation, namely: the fact that it represents a collective heritage, the specific manner in which it appropriated values borrowed from other peoples

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and integrated them into its own creative efforts, its diachronic continuity achieved through the integration of new elements of technology alongside the old, traditional ones during each of historical stages, etc.

2 The Dawn of Folk Technology

The history of a people's civilisation universally overlaps the history of labour, and labour—a conscious activity of procuring materials from nature and transforming them into consumer goods—began once tools had been produced. The first tools, made by the *Paleolithic man*, performed basic functions such as striking, cutting, piercing, scraping, etc., thus confining man to the same cultural stage, defined by his role as mere 'gatherer'. The discovery and use of fire when it comes to *energy* and, in terms of instruments, the trap—described by J. Lips as 'the first machine in the history of mankind' (Lips 1958)—represent the most important cultural acquisitions of that age, which enhanced the initial act of conscious tool production and use. The sum of these achievements constitutes the mere overture to the great transformations of the age of polished stone (the Neolithic), which would impart upon this new historical stage the quality of the first revolution in the entire history of humanity. That which would bring about the first radical transformation of Neolithic communities' way of life, namely the discovery of agriculture through the cultivation of land with the aid of instruments to enable the natural reproduction of plants (a process doubled by the domestication of wild animals and their use in the work process), pushed mankind towards a superior stage, namely that of 'production', the main social outcome of which was the fact that communities became sedentary, while, from a cultural standpoint, it triggered the onset of the great chapter of folk architecture (Vlăduţiu 1973).

The 'Neolithic agrarian revolution' marked the disappearance of the benign savage and the emergence of the Neolithic grower who functioned within the organised framework of the sedentary village community. The range of instruments of the Neolithic Age, made out of bone, horn, and hardwood (Canarache 1950), was revolutionised in the Metal Age by the introduction of the metal axe, sickle, and ploughshare.

Of the manual means of *soil preparation*, the Neolithic horn mattock was replaced by the hoe and the forked mattock (*coaştă*), to which the spade was added. Mainly due to the use of animal power, agriculture was able to move forward to employing greatly superior means: the ancestor of the plough (*arat*), the harrow, and the roller. A tool rooted in archaic local tradition, the ridger, represents a faithful replica of the ancient wooden plough (*aratru*), which only served to split the soil without cutting and turning the furrows. Known to the Geto-Dacian community since as far back as the second-first century BC in its version without a sole shoe (*plaz*) and generalised during the Daco-Roman period in its sole-shoed version, the *aratru* (the archetype of today's ridger) constitutes a superior tool to those preceding it due to its more complex structure (the wooden plough-beam up to three metres long, the sole shoe with a symmetrical ploughshare, and the horns), thus paving the way, in turn, for the emergence of the plough. In some areas, the tool employed for *harrowing* (*boronit*) was the roller, followed by the thorned harrow (*boroană*), which was replaced by the version with wooden nails, and later, by the one with iron nails (not before the nineteenth century).*Harvesting* was traditionally carried out with the aid of the sickle, which originated in the Neolithic Age and consisted of lithic blades inserted into a curved piece of (jaw) bone or wood. The *threshing* of cereal grass has also preserved several extremely old procedures with a very long-going tradition, of which we would like to mention the ancient ones, such as having animals walk over the harvested crops, pressing them with a stone roller or flint sledge (called *dosca* or *dicania*)—all animal-drawn implements (Bucur 1981)—, as well as the medieval method of manual threshing with a flail. Aside from growing cereal and textile crops (flax and hemp), since time immemorial, man has also been concerned with *growing trees*, *grapevine*, and *vegetables*. The work techniques are specific to each branch, yet the set of instruments used does not exhibit significant differences in terms of the actual crops being grown. Two specific tools capture our attention due to their remarkable age, their autochthonous origin, and the millennial continuity of their employment: the pruning knife (*cosor*) and the dibble (*chitonog*), both used ever since the Bronze Age.

In parallel to agriculture, the Neolithic society also developed the branch of *animal rearing*. The simple technology of dairy processing and the ancient instruments still in use today—due partly to the conservative nature of this occupation, the main fief of which still consists of piedmont grassland areas and mountain pastures—allow us to determine, through analogy, a basic technical inventory of remarkable age and tradition: the milking cup and 'pail' (both monoxile, originally), the *crântă*, a vessel used for pressing the curd, and the *răvar*, a grooved piece of wood used for crumbling cheese, the churn for separating butter from cream through beating and, last but not least in terms of historical and cultural importance, the tally stick, the first system for quantitative recording of rights, which was necessary within a framework of co-possession or collective ownership.

One fundamental pillar of the 'Neolithic revolution' is the perfecting and specialisation of the processing of raw materials, both inorganic (stone, wood, clay) and organic (leather, bone, fibres), which, from a social point of view, led to the *emergence of the first craftsmen.* A decisive role in this respect was played by the discovery of circular motion (via the intermediary stage of the pendulating, oscillatory motion). Applying this method for the perforation of stone, the making of shaft-holes, the shaping of spherical clay vessels, or the spinning of textile fibres constituted an unprecedented innovation, matched only by the use of caloric energy to bake ceramic vessels in 'reverberating' ovens of remarkable perfection.Out of all these, the invention which 'gave human thinking and the forming of science a great push forward' (Childe 1966)—as V. G. Childe described the production of Neolithic ceramics—, pottery, unquestionably constituted 'the oldest fully conscious and calculated use that man has made of a chemical transformation' (Harţuche 1981). The pottery-baking oven in the making of ceramics, the spindle with large clay, stone, or bone whorls (*fusaiole*) in the spinning of fibres, the vertical loom, the drill for perforating lithic tools in stonemasonry, and the linear grinder in the milling of cereal are marks of fundamental progress as to instruments, which consists in the creation of the first tools and installations in the history of mankind intended for specialised forms of production: the drill, the loom, and the oven.

Due to its immediate quantitative, but especially qualitative implications in the area of material production, this technological process sowed the seeds of the second social division of labour to come. Thus, *the tool created the craft.* Archaeological finds peremptorily prove that certain Neolithic villagers were mainly specialised in weaving, pottery, stonemasonry, and even 'milling' (a necessity naturally experienced from early days by agricultural communities and illustrated by the discovery of the Neolithic mill of Hamangia (Harţuche 1981)).

The beginning of the Metal Age (Bronze, Hallstatt, and early Latin) brought with it notable technological progress. The most important development was undoubtedly *metallurgical technology.* Obtaining metals through the reduction of ore, which compelled the perfecting of Neolithic ceramic ovens and the adapting of bellows to raise temperatures to the melting point, followed by processing per se through pouring or hammering, required people to acquire very diverse and complex knowledge, which justifies the statement that metallurgy was 'the oldest specialised type of work' (Childe 1966). Producing metal tools and weapons of superior range and efficiency triggered profound transformations in numerous fields of activity. The most important of these, in our opinion, was the introduction of the *metal ploughshare in agriculture*, which generated a genuine 'revolutionary twist'. This event associated with the use of animal power in the preparation of agricultural land generated a profound mutation in the socio-professional structure of the age, as men definitively replaced women in agriculture.

From the point of view of instrument complexity, this age also stands out through its increasingly diverse applications of circular motion, many of the installations which appeared at this time being veritable inventions which emerged from the inexhaustible supply of folk ingenuity. Grouped under the label of 'simple installations', they ensure the debut of mechanical activity within numerous raw-material processing procedures. The potter's wheel for the crafting of ceramics, the horizontal lathe in woodworking and especially wheel making, the circular hand mill in the grinding of grains, they all have as a natural consequence the prevalence of male work, with its increased and necessary muscular-energy consumption, as opposed to creative female work.

From an energy standpoint, the most profitable acquisition was the generalisation of animal power, not only in agriculture, but also for transport. During the Bronze Age, approximately from the 1800s BC onwards, 'that brilliant crowning jewel of prehistoric carpentry' (Childe 1966), the cartwheel, became known on Romanian territory as well, as proven by the findings at Cuciulata. It revolutionised locomotion technology by virtually replacing dragging-based means of transport with rolling ones.

3 Folk Technology in the Geto-Dacian Period

The prevailing technological characteristic of this age consists in the intensification of the exploitation and reduction of ferrous and non-ferrous (silver, gold) mining, as well as of (ferrous, gold and silver) metallurgy. The consequence in terms of instruments, as revealed by the multitude and diversity of work implements made of iron, was the maximal specialisation and, implicitly, diversification of tools. Their vast typology, highlighted by numerous finds (among which it is especially worth mentioning the metallurgical workshops of Grădiştea Muncelului), demonstrates, in all objectivity, the existence of a developed 'Dacian iron civilisation' (Glodariu and Iaroslavschi 1979) comparable to the most developed metallurgical production centres across the continent, thus revealing the Dacians' genuine vocation for the craft of iron extraction and processing. Dacia's rich gold and silver production stimulated the development of goldsmithery and silversmithery, as the ornaments made of such metals which have been discovered illustrate the great skill employed in shaping noble metals using the most diverse technological procedures and a refined set of instruments suitable for this craft. The rich gold treasures of Hinova, dated ca 1500 BC, argue for the long history and value of Thraco-Getic goldsmithing traditions.

The *energy system* of the age is dominated by the general use of muscular energy, both human and animal. The imposing edifices of the time, be they military (fortifications, defence towers), cultic (the sanctuaries in the Orăştiei Mountains), urbanistic (pavements, stairs, tunnels) or social (aqueducts, cisterns, wells), are the products of great concentrations of force, such as are compatible only with state-based existence.

From the perspective of instruments, the Geto-Dacian society's development level in the field of energy makes their civilisation fall into the scope of the 'man-tool' system, defined by direct manual action exerted by the subject of the work, through the means of work, upon raw materials or semi-finite products. One initial breech into this formidable multi-millenary system seems to have most likely occurred at this very time, through the discovery and exploitation of the kinetic energy of watercourses for the processing of wool fabrics with the aid of a modest hydraulic installation the name of which hails from the Thraco-Illyrian linguistic substrate: the *ştează* (whirlpool) (Bucur 1980). The oldest hydraulic installation in the Carpatho-Balkan area, which has been preserved unaltered—in terms of its construction and function—to this day and exhibits a completely unitary character throughout the country, the *ştează* consists of a truncated cone-shaped basket with a strong water jet directed towards its base via a trough, as seen in Fig. 1.

In terms of autochthonous culture and civilisation, the partial incorporation of Dacia into the Roman Empire resulted first and foremost in the Romanisation of life on a number of levels. This process of overwhelming importance for the ethno-cultural profile of the Romanian people mainly resulted in an intense infusion of Roman technology, grafted on the millennia-old Thraco-Dacian foundation and mediated partly by the imports of instruments and partly by the frequent circulation of Roman workers, technicians, and 'engineers'. While, from the point of view of processes, we know of few new production sectors inaugurated after 106, with the

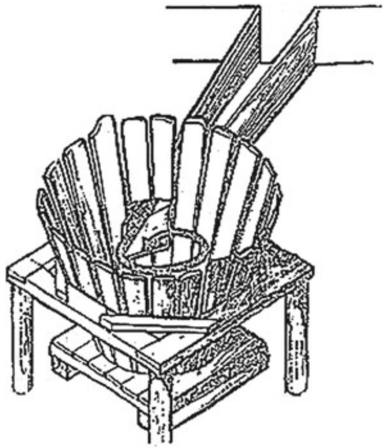


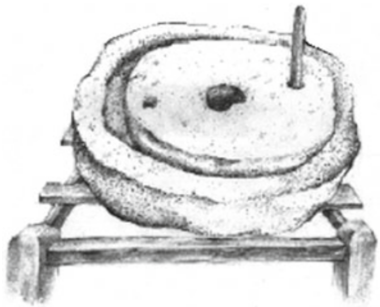
Fig. 1 The whirlpool

exception of urbanistic projects (river bridges, roads, Roman thermae, monumental public architecture and private architecture), from the point of view of procedures, there is an intensification of the exploitation of Dacia's mineral wealth, as the switch is made from the technique of surface or shallow probing to underground mining at great depths, which required mine gallery-draining procedures with the aid of elevating wheels manually operated by mineworkers whose names are attested by the famous *tabelae ceratae* (in other provinces of the empire, this was done by mine slaves, whom sources call 'damnati ad metala '). Vestiges of such mechanisms consisting of wheel hubs and a few spokes were discovered in the Roman gold-mine galleries of Ruda and Roşia in the Apuseni mountains (Christescu 1929).

The general technological characteristic of the age is the morphological and functional perfecting of the old types of manual tools and installations (called by Vitruvius 'moderationes machinationum' (Vitruviu 1964)). The most eloquent proof thereof is provided by the hand mill (mola manuaria) (Fig. 2), which evolved from the truncated-cone type, which was cumbersome and difficult to operate, to the concave-convex type, significantly flatter and therefore easier to handle. Another installation which was perfected during this period was the wine press. The screw press (called 'the vortex axis' by contemporary sources), attributed to Archimedes, appears and is generalised gradually, alongside older models, which relied on the principle of wedge beating or levers and weights (of the type discovered in Pompei). All these wine-press types and versions have survived in Romanian folk civilisation, forming an impressively diverse typology (Bucur 1982).

The hegemony over the Roman 'baking industry' continues to be held by the 'hourglass mill'. A fixed stone (*meta*) belonging to such an animal-powered mill (*mola asinaria*) was discovered on the premises of ancient Porolissum, thus proving that the use of animal power for mills was known in Roman Dacia. However, the most valuable technical achievement of the era is constituted by the use of hydraulic energy for the grinding of cereal. It seems that, no earlier than the late second century or early third century BC, the fist hydraulic cereal mills made their appearance in

Fig. 2 Hand mill



Dacia as well. The discovery in Micia, Apulum, and Napoca of ancient hydraulic millstones which were installed there and feature construction and functional particularities which place them, typologically and chronologically, into the system of Ancient Roman mills, as well as perfect similarities to the millstones discovered in other Roman provinces (Salzburg and Barbegal—second century AD—and Athens, fifth century (Bucur 1981), constitutes a peremptory argument in favour of the existence of the watermill in Roman Dacia. Typologically speaking, we are inclined to believe that these belong to a superior category, featuring a vertical hydraulic wheel and a transmission gear, called the 'Roman' or 'western' type and described in detail by Vitruvius as a veritable 'machina', that is a cutting-edge invention that is technologically superior and an extremely rare mechanism ('quae raro veniunt ad manus' (Sebesta 1977)), which appeared in Rome in the late first century BC and became slowly generalised throughout the first–fourth century AD (Vitruviu 1964) (Fig. 3 positions 3, 4, 5). As far as the second type is concerned, the one with a horizontal wheel (Fig. 3. positions 1, 2), it could not be less likely to exist on Dacian territory in the second and third century AD, as this type was known in Illyria as early as the second century BC. Universally called 'the Oriental type' and, on Romanian territory, 'the spinning-top mill' (in Vrancea), 'the axle mill' (in Oltenia) or 'the wooden-bucket mill' (in Oltenia, Wallahia, and Banat), this primary type of hydraulic mill was at its most common and widespread in the Romanian Subcarpathian area, from southeaster Banat to the Vrancea mountain curve, with hundreds of such items having survived to this day. The representativeness for the Romanian people of this hydraulic installation of brilliant construction (it would go on to inspire the physicist Pelton in constructing the first electric-plant turbine in the world) has been acknowledged through the fact that an authentic exhibit of its kind was transferred from Romania and presented as part of an exhibition at the Museum of Technology in Munich.

The invention and gradual generalisation (along more than three centuries from its first attestation) of the watermill in the world of Greek-Roman antiquity is due, in our opinion, to the fact that the gear system became known and virtually generalised in animal-powered irrigation installations. The rigorous framing and coordination of the energy system (the wheel), the mechanical system (stones), and the gearing system (with gear coupling consisting of toothed discs and their axles set at a 90°

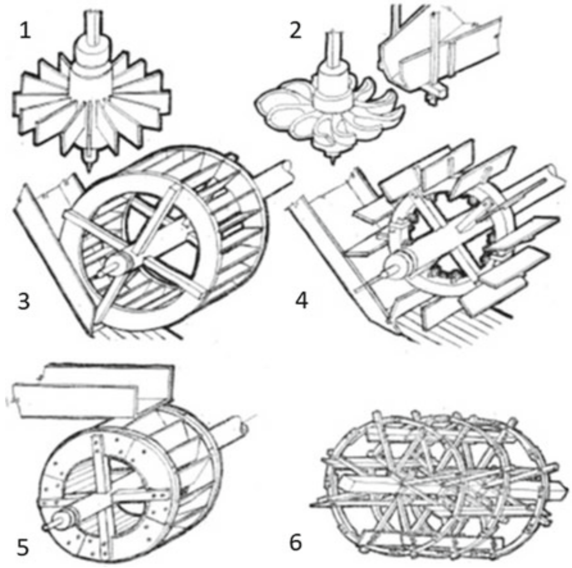


Fig. 3 Types of hydraulic mill wheels: 1—wheel with a vertical axle and horizontal trough; 2—wheel with a vertical axle and vertical trough (the axle mill); 3, 4—wheel with a horizontal axle and bottom water jet; 5—wheel with a horizontal axle and top water jet; 6—floating-mill wheel

angle) within the new technological structure of the ancient watermill had become reality as early as the first century BC, yet their generalisation came about only when, in the midst of an economic and social crisis, in order to meet the needs of the population of great cities, Roman economy imperiously demanded superior technical equipment, which, in fact, represents the embryo of a new manner of production.

In the field of textile processing, the manual beating of broadcloth is attested by the specialised workshops of the drapers' guild (*fulonica* (Tudor 1976)) preserved in situ in Ostia and Pompeii. The same procedure would be passed on to European medieval economy and consistently maintained in numerous ethnographic regions (in parallel with the hydraulic mill machine, known since the beginning of the 2nd millennium), even on Romanian territory, where it survived in certain enclaves until the twentieth century.

Based on the above, we may conclude that, although known and exploited in the context of cereal mills, hydraulic energy was unable to lead to modifications in the technological and social structures of Daco-Roman antiquity, thus only foreshadowing them.

4 Folk Technology in the Middle Ages

From the point of view of the history of civilisation, the period from the late third century to the end of the 1st millennium, filled with the great migration waves, represented a prolonged interval of technological regression at continental level, globally illustrated by the ruralisation of life. The decline of urban life, caused by shrinking trade due to unsafe commercial routes, caused a rapid drop in production and a considerable technological relapse. Within the economy of this period, these phenomena would cause the naturalisation and autarky of all production activities, as now 'the entire economic cycle, from production to consumption, is completed within the closed circle of the household, while the manner and extent of production are dictated by the consumption needs of the household members'. The process of autarky of the 4th–10th century should not be interpreted in an absolute manner. The discovery of the workshops for bone and horn processing in Valea Seacă (4th century) or the silversmith shops in Budureasca and Olteni (6th century) testifies to the continuity of specialised craft production in autochthonous centres, which served the needs of both the local population and the migrators.

In terms of energy systems, we believe that the—at least temporary—abandonment of hydraulic installations follows naturally, as they are exclusively compatible with a fully developing economy and required by the highly dense demographics of urban settlements. Under such circumstances, the ruralisation of economic life and the reduction of production equaled a generalisation of archaic manual procedures and instruments.

Towards the end of the 1st millennium, several remarkable technological advances occurred, such as: the generalisation of the fast (foot-activated) potter's wheel and especially the building and employment of the first steel furnaces with a smokestack for the melting of iron ore, such as the one discovered in Ghelar (Fig. 4), dating from the 9th century (exhibited in the form of a 1:1 scale model at the British Museum), which constituted a continental priority (Popescu and Popescu 2016).

The late 1st millennium registered two decisive processes which left a mark on the socio-political and cultural life of the population of the Carpathian–Pontic–Danubian region: the completion of the birth process of the Romanian people and the crystallisation of feudal relations. Such historical realities set the stage for the general revival of technological and economic progress at the beginning of the 2nd millennium, as, from the 11th–13th century onwards, technological developments appear to resume their ascending trajectory in most fields of social production. We may say that, from the point of view of medieval economy, that translated as: the perfecting of agricultural implements through the appearance of the dissymmetrical plough with wheels and a breast, the introduction of biennial and triennial crop rotation, the cultivation of high-energy plants (peas, lentils), the generalisation of the new system for harnessing and using animal power to operate various pieces of equipment for the carrying and processing of food, wood, textile raw materials, etc., the diversification of means of transport due to the invention of the wheelbarrow, the wooden-railway mine car and the perfecting of the other rolling stock, the perfecting of mechanical systems due to the generalisation of the coppice, the reinvention and common use of the camshaft and the transmission belt, and, finally, the appearance of new transmission systems: the crank and connecting-rod mechanism, with its diverse applications in simple, manually operated installations (the spinning wheel, the lathe, the grinding wheel, etc.) or in hydraulic saws, and the toothed-rack axle. Above all these, in terms of overall importance along this succession of medieval technological advances, we feel compelled to mention the generalisation of the use of hydraulic energy and

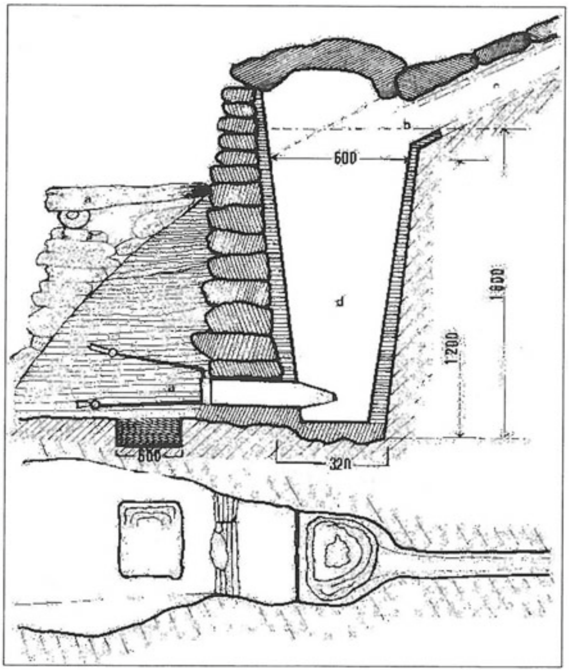


Fig. 4 The furnace of Ghelari

the discovery and application of wind power in grinding installations. As a general corollary of these substantial technological developments, we would like to stress the appearance of Romanian medieval towns in the 13th and 14th century.

The foremost characteristic of medieval craft production was the gradual accentuation of the social division of labour through the individualisation of branch craftsmen. The trade market and the perfecting of instruments to serve for specific operations led to an increasingly steeper internal division of labour within craft production through the ever starker distinction between certain types of raw-material processing and the more thorough specialisation of craftsmen. The objective cause of this phenomenon is the need to supply all the categories of consumer goods demanded by society in ever increasing amounts, while the subjective causes lies with Romanians' acknowledged creative propensities in both technology and art.

In his memoirs from his stay in Wallahia in his capacity as secretary to ruling prince Constantin Brâncoveanu, Antonio Maria del Chiaro proclaimed this to the entire world, as, in full objectivity, he wrote the following: *'As for the Romanian people in general, as soon as one has come to know them, one can see clearly that they are endowed with great skill and capable of succeeding in any trade they might take on… As for crafts, they carry them out wonderfully well. They can learn everything they see and there is no item made by human hand, be it in the Turkish fashion or in our own (Italian one) which they cannot replicate very well'* (Chiaro 1718).

In our opinion, there is nothing which can illustrate such a characterisation more adequately than the phenomenon of ‘craft-specialised villages’, which is particular to Romanian folk civilisation, especially in the case of hill and mountain regions. Given the demographic growth registered during the middle and end of the feudal period (the 17th and 18th century), many village communities in regions with rugged terrain that was either insufficient or inadequate for agriculture began to capitalise intensely on the raw materials abundant in their area, thus specialising in the production of certain use-values, which they sold on the regional, provincial, or even national market. Villages of potters and blacksmiths, stonemasons and limeburners, coopers and woodworkers, wheelwrights and trunk-makers, loom-makers and spoonsmiths, carpenters and shingle-makers, furriers and makers of *suman* coats, bag-makers and mat-makers, marc-collectors and candlemakers supplied traditional households—mainly rural ones—with the full array of products they required, which, for centuries, were obtained through bartering, as farmers offered their cereal and shepherds their cheese, wool, or hides in exchange. Artistic crafts make up a special chapter in the book of folk crafts. The decorating of the products or even means of labour (dippers, forks, cheese stamps, yokes, furniture, millstone holders, wayside crosses and more), as a manifestation of the Romanian peasant’s special inclination towards beauty, has led to certain folk centres and creators specialising in the crafting of such use-values featuring particular artistic qualities. Painting on wood or glass, both secular and religious, took folk visual art to an entirely superior level, thus contributing to the forming of veritable schools of icon painters, whose creations are part of today’s national cultural heritage.

The most significant technological phenomenon of the age is the appearance of folk medieval industries, which, from a phenomenological point of view, is the equivalent of a genuine revolution in the field of technology and energy. The new work processes branched away from crafts due to their use of superior natural energies which allowed for a certain degree of technological-process automation, thus bringing about important economic, social and legal consequences which marked the shift from the ‘man-tool’ system to the more evolved ‘man–machine’ system. One first premise was the perfecting of hydraulic generators (waterwheels) based on specific hydrographical conditions, the energy required to power each type of installation, the material to be processed, and the procedure employed. Different models of mill wheels are shown in Fig. 3 (Pavel 1954).

The oldest installation for processing raw materials using hydraulic energy remains the grain mill. It became widespread at continental level during the 11th and 12th century (Gleisberg 1956). On Romanian territory, the two different types of hydraulic mill, the one with direct transmission (the bucket mill) (Fig. 5) and the one with transmission gear (the vertical-wheel mill), each dominated one side of the Southern Carpathians. With the exception of the Valea Streiului river basin, where the bucket mill is present, this type of mill does not seem to have spread northward, which raises the question whether the two types—eastern and western—may have been diffused simultaneously, with the inferior eastern type no longer having the power to expand into the distribution area of the more effective mill of the two.

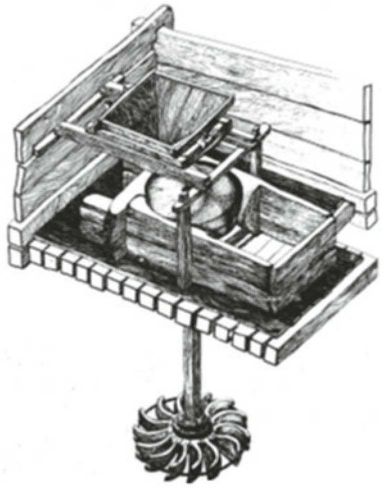


Fig. 5 The bucket (axle) mill

Of all the transmission-gear mills which gradually made their way into the southern territories as well, thanks to their superior technical parameters, special attention is due to floating mills. Two construction versions of such mills were developed on Romanian territory: one with two wheels positioned on either side of the boat (which carried the milling installation) and one with one large wheel placed on the drive shaft, which, in turn, was supported by two boats (the bigger of which carried the entire installation).

The true paragon of the medieval technological revolution, due to the diversity of its applications in the processing of the most diverse raw materials (oilseeds, broadcloth, gold ores, ferrous metals, etc.), is the camshaft, used in all work processes which require the transformation of circular continuous motion into alternative motion for the purpose of powering the mechanical systems specific to each process and adapted to each raw material (hammers and stamps for oil mills, mallets (*pisălogi*) for broadcloth mills, hammers for metal-processing installations, stamps for ore-crushing stamp mills, bellows for ore-melting furnaces or metal-processing workshops).

First documented in Romania as late as the 14th century (1342 for broadcloth mills (Bucur 1982) and 1392 for bellows at the foundries of Mircea cel Bătrân in Baia de Aramă (Panaitescu 1943)), these innovations may well have reached Romanian territory earlier, yet not before the second half of the 13th century.

As for the crank and connecting-rod mechanism, this ingenious medieval achievement revolutionised the technology of log cutting. Hydraulic saws spread quickly throughout the country, starting from Transylvania, and were known under the name of *joagăr*. By adapting ingenious solutions consisting of lever and chain systems, rolls, or toothed-rack axles to the need to transport the logs positioned on the saw carriage, an automation of the work process is achieved when it comes to moving the log towards the saw cutter.

Aside from these hydraulic installations, there were the stills for alcohol preparation trough the distillation of fruits or grains (by using large-sized hydraulic wheels to transport water to the cooling container) or the troughs for processing large pieces of woven wool fabric through thickening or napping within a functional complex that included the whirlpool.

One may conclude that, from the perspective of the history of civilisation, medieval industries represent the energy and instrument revolution which consecrates the superiority of the medieval manner of production in relation to previous ones in terms of production forces, while also marking the onset of the modern technological revolution of the 18th century.

Due to their intense diffusion throughout Romania, windmills are at the forefront of the development of the Middle Age's technological potential until late into contemporary times, as they were fully integrated into medieval industries. With a relatively late documentary attestation on Romanian territory (initially in a document regarding the establishment of borders dating from 1531 to 1532 and subsequently in 1585) (Giurescu 1973), the windmills in Romania fall into all the categories found in Europe (the central-pivot mill, the canvas-winged mill of the Mediterranean type, the 'hooded' mill, the western mill, also called the Dutch windmill. An atypical version, encountered exclusively near Clisura Dunării (the Danube Gorge), appeared due to an ingenious adaptation of the transmission belt that carries the motion from the wind generator, which is detached from the body of the mill, to the vertical axle of the mobile stone of the milling installation.

While the first technological revolution targeted the energy and transmission system, the mechanical system remaining the same (only oversized), the modern technological revolution initially preserved the classic energy generator (particularly the hydraulic one) and the classic name of 'mill' as well, yet radically transformed the mechanical system and, implicitly, the transmission system, by introducing the 'machine tool', which basically consisted of replacing the singular traditional device with one made up of active elements, which ensured higher productivity.

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History of Mining

Dumitru Fodor

Abstract This paper has as purpose the presentation of the activities of extraction and valorisation of the deposits of solid utile mineral substances on the territory of Romania, along four historical periods comprised between Paleolithic Era and the end of the Millennium II A.D. For each period of time, the exploited and valorised deposits are shown, presenting the utilised exploitation methods, utilized work technologies and the obtained economic results. Within paper, a special importance is given to the presentation of the main operations from the production process: ore excavation from the massif, loading and transport of the extracted material, water evacuation, ventilation and lighting of the mines, ore processing and utile substance obtaining. The evolution and spreading of the technical knowledge about mining was sustained by the activity of applicative research and by the specialty education and therefore the paper presents the existence and development of the research and mining medium and superior education of Romania. The chapter ends with the presentation of some actual tendencies of the Romanian mining industry.

1 From the Beginnings of Mining to the First World War

The extraction and processing of solid mineral raw materials have been known since ancient times on the territory of Romania. The archaeological research conducted across the country has highlighted man's work in extracting and making use of various minerals and rocks ever since the Paleolithic. Vestiges related to the exploitation and processing of flint, opal, obsidian, quartz, and various other rocks have been found in numerous Paleolithic sites that have come to light.

Mining activities intensified in the Neolithic. This is the age that marks the beginning of the exploitation and processing of metals. The first metals to be used were copper and gold.

The Bronze Age (Almăşan 1984, 1965; Abrudeanu Rusu 1933; Baron 1999; Fodor 2005, 2003, 1780; Haiduc 1940; Maghiar et al. 1970) is the time when, aside from

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extracting and processing stone, people move on to making bronze (copper + tin), an alloy which is superior to copper and gold in terms of hardness and potential uses. During the same period, gold, silver, amber, salt, and various hard rocks were exploited in various regions on the territory of Romania.

The Iron Age constituted a step forward in the development of human civilisation. The exploitation and processing of iron on current Romanian territory are attested as far back as 1000—900 BC in settlements in today's Dobruja (Babadag and Dervent).

After the conquest of Dacia by the Romans, the exploitation of underground resources registered a strong upsurge. Thus, during the Roman rule, over 20,000 people came to work in Dacian mines. The Romans, who were the greatest military force of the time, focused on the exploitation of iron in particular, thus maintaining the already known mines (Teliuc, Ghelari, Ocna de Fier), while also opening new ones. However, Rome's economy was in need of Dacian gold and silver. Given that the yearly production of pure gold was of 3,000 kg and that of silver double as much, during the 166 years of occupation, the Romans probably exploited approximately 500,000 kg of gold and 950,000 kg of silver (Wollman 1996; Roman et al. 2017) from the Apuseni Mountains.

The exploitation of metal ores in Dacia registered an unprecedented level of development after the Roman occupation, due to the opening of numerous mines and the introduction of perfected work tools and methods, as well as to the use of a vast specialised workforce recruited from among slaves and free men.

The Romans exploited other metals as well: lead, copper, mercury, etc. and the salt deposits in Transylvania and Maramureș.

Salt was mined both above and below ground. The former method was employed when the deposit was close to the surface or in the form of an outcrop; after the overlying soil or rock was removed, the excavation was initiated and advanced downwards, taking away bottom strips. Such a system had the advantage that it was inexpensive and allowed for massive extraction, but it could not expand to great depths and was subject to weather changes. The second method, that of underground exploitation, involved digging a vertical shaft in order to cross the gangue and then excavating the salt through the same descending method, as seen in Fig. 1 (von Fichtel 1780).

The Romans made openings into mines mainly through adits and inclines, which enabled them to reach the deposit. In the vicinity of the deposit, they continued their work either through directional galleries advancing along the direction of the lode, or through cross-cuts.

The galleries (*cuniculi*) were mostly carved through hard, compact rock by using a chisel and hammer or the fire method.

In those times, the main operations of the underground part of the production process were carried out as follows:

Water drainage was one of the most difficult and challenging technical issues given the day's technology. The Romans either designed special drainage galleries to collect the water, or equipped galleries with drainage canals. The water which gathered in the mine at one end of a gallery or at the bottom of a shaft was evacuated

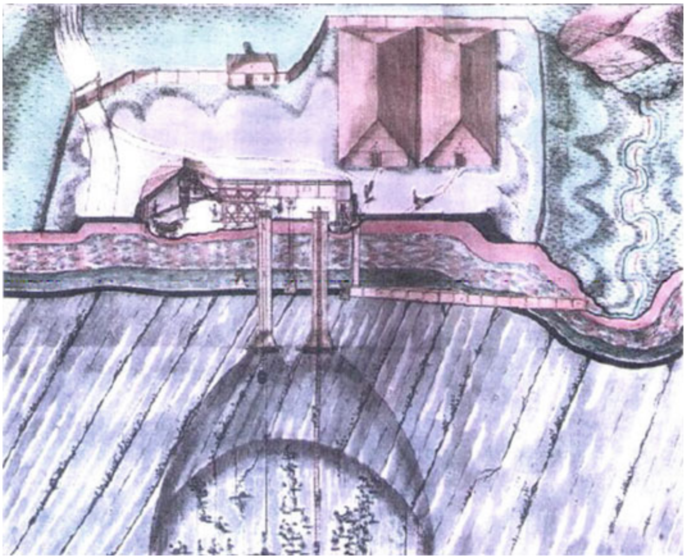

Fig. 1 Cross section through the salt mine from Turda (von Fichtel 1780)

with the aid of pails, buckets, cowhide waterskins, Archimedes' screw, or a hydraulic scoop wheel, as in Fig. 2 (Wollmann 2017).

The ventilation of mines in Roman times was carried out using three methods: carving secondary shafts alongside the central one, which ensured the access of fresh air inside and the evacuation of foul air; building parallel, overlaying galleries in combination with moving pieces of canvas or fabric—this system was mainly used in mines where the fire method was employed for dislocation purposes, as water vapours and smoke were evacuated via the currents generated by the movement of the pieces of canvas; maintaining a fire at the mouth of the shaft, which created the necessary depressurisation for the air inside the shaft to rise and for the masses of air inside the galleries to be set into motion.

The lighting of mines was achieved with the aid of oil lamps (*lucernae*). They were equipped with a tank—in which the oil or animal fat was kept—and one hole for taking out the wick and another for pouring the fuel into the tank.

Ore transportation and processing In the case of both above-ground and underground mining, the dislocation of the ores was immediately followed by an initial sorting of the pay-ore from the gangue at the bottom of the excavation, gallery, or stope, after which the pay-ore was transported in wooden troughs or baskets made of wicker or wood.

While iron or copper ores were carried directly to the furnaces and put through the reduction process, gold ores were submitted to a string of operations: first, they were crushed in stone troughs, then they were taken to the grinders to be milled; the resulting powder was then taken from the grinders by specialised workers who washed it on a slightly slanted plank covered in wool fabric to catch the specks of

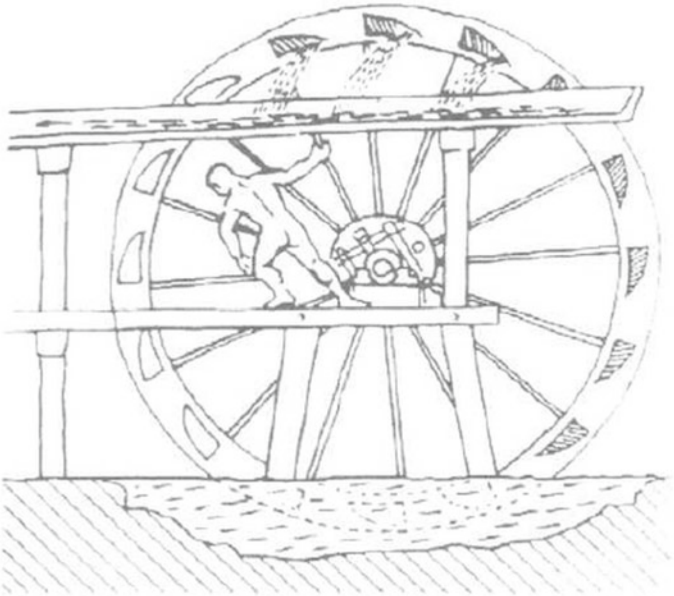

Fig. 2 Graphic reconstruction of the components of the water-evacuation installation, with its manually-operated scoop wheel (courtesy of Dr. V. Wollmann)

gold. In order to retrieve the gold found in alluvial sands, buddles were used. The specks obtained through washing were melted in white-clay crucibles and, in order to be purified, the gold was melted again mixed with salt and lead.

The withdrawal of the Roman troops from Dacia (271–275 AD) had a significant impact on the entire economic and social situation of the north-Danubian province. Deprived of the organisational framework previously provided by the Roman state, mining activities shrank. However, they did carry on in the field of iron and copper extraction for the crafting of tools and weapons, as well as in that of salt extraction.

It was not until the 11th century AD that a significant level of activity was registered on Romanian territory in the way of extracting useful mineral substances.

Circa 1300 years after the Roman withdrawal from Dacia, the methods of exploitation for gold and metal ores in general remained the same, the only noteworthy difference being that the mines were much deeper and more extended horizontally.

For hard rocks, the chisel and hammer continued to be used, and so did the fire and water method, yet notable progress was made in terms of ore transportation, water evacuation, mine ventilation, and ore processing.

In the 16th century, several more significant changes occurred regarding extraction and preparation technologies, which led to an increase in production and work productivity. For shaft-based extraction, animal-powered basic wooden winches (*crivac*) appeared, while inside mines, wooden-railway mine cars with wooden wheels were used, as well as points.

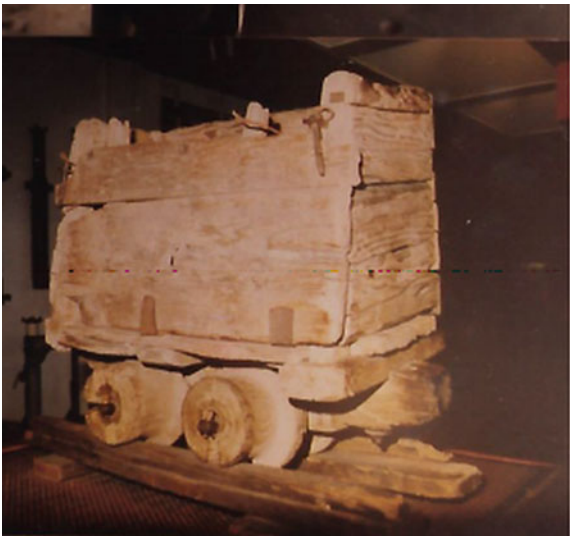

Fig. 3 Wooden mine car used to transport ores in the mines of the Apuseni Mountains (courtesy of Dr. V. Wollmann)

Wooden mine cars were rectangular in shape, featuring a slightly smaller section at the top and were bound with sheet-iron strips, as shown in Fig. 3. The bottom part was equipped with two metal axles at the ends of which wooden wheels were attached. Mine cars travelled along wooden tracks.

The oldest wooden mine car in the world dates from the 17th century and was discovered during mining work at Ruda-Brad, along with the transport line and a point, also made of wood. The original mine car is kept at the German Mining Museum in Bochum, while the point is found at the Transport Museum in Berlin.

The point was invented around the year 1600 by the miners of Brad. The use of explosives to extract rocks and hard ores, thus increasing work productivity, dates back to the 14th century as well.

In order to grind gold ores, the miners of Transylvania started using STAMP MILLS as early as the 14th century, first in the Apuseni Mountains, then in Baia-Mare, having borrowed the method from German miners sent to colonise the region. Stamp mills revolutionised gold-extraction technology by replacing mortars and grinders, thus becoming the only grinding machine to be used until the appearance of the mill. Figure 4 shows a stamp mill which was employed in the gold exploitation work in Săcărâmb.

The fierce battle against the hard rocks, the fouled air, and the greatest enemy of underground work—infiltration water—, the added difficulty of putting the extraction and processing installations into operation, particularly in times of draught, permanently stimulated and kept up miners' inventiveness. Aside from the specialists trained in mining and forestry academies, one cannot overlook the contribution to the field of simple people with a long-going tradition and experience in this kind of work, who, through their skill and abilities, added their valuable input to the

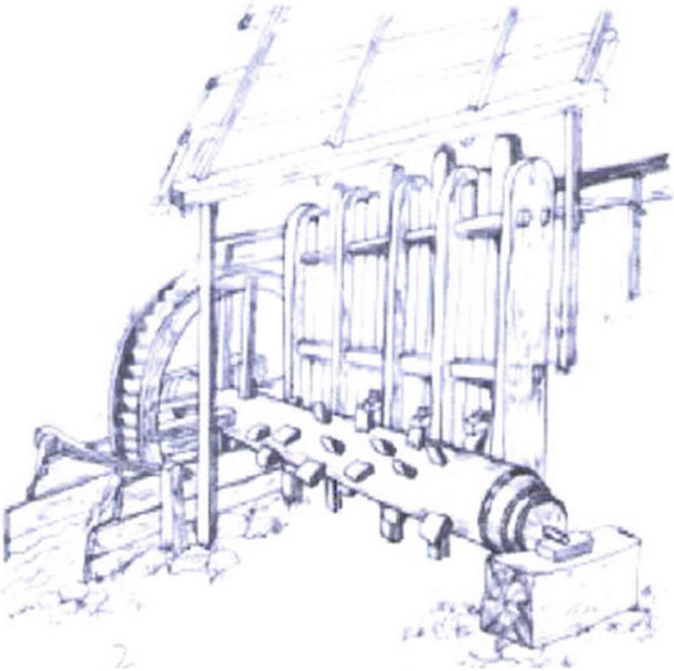

Fig. 4 Hydraulic stamp mill for grinding gold ores, used in Săcărâmb

development of mining technology, some of them making their mark as veritable innovators.

In the early 19th century, wooden stamp mills began to be replaced by metallic ones, called Californian stamp mills. Both the troughs and the stamps of these stamp mills were made of highly wear-resistant manganese steel.

New iron deposits were discovered and put into service all across Transylvania, Banat, Maramureș and Bucovina. The exploitation of complex ores in the Maramureș and Apuseni Mountains area continues, in a better organised form, while, in Banat, copper ore exploitation begins at Moldova Nouă and Sasca-Ciclova-Oravița (in 1719), as well as bituminous coal exploitation at Doman (in 1780), Secul (in 1782), and Anina (in 1790).

In 1838, the first steam-powered machine in Transylvania starts operating in Zlatna (power of 14 HP), shortly followed by the one in Baia Mare (of 30 HP). In 1843, the first attempts to reduce iron ores from Govăjdia-Hunedoara using bituminous coal extracted from Valea Jiului are made, while the first coal-mining sites are organised around Brașov in 1838.

The Valea Jiului mining basin started to be known for its coal deposits as early as 1780. The first mining activities are not conducted until 1840 and the first batches of coal are produced in 1868 (853 tons).

The technological revival of gold and silver mining was due, on the one hand to the introduction of electricity, extraction machines, explosives for hard-rock extraction, pumps, ventilators, and pneumatic drills and, on the other, to the modernisation of above-ground work through the use of Californian stamp mills and new types of shaking tables.

In the early 20th century, substantial progress is registered as to the modernisation of some of the basic departments of mining work. An important factor in that respect is the introduction into mining of new sources of energy to replace physical human and animal power: steam power—1838, electricity—1894, pneumatic energy—1900. Changes occur in the excavation and dislocation technique for rocks and useful mineral substances, as the use of explosives, drills, and scaling hammers gains widespread application. Important achievements are registered in the coal industry, where a series of exploitation methods specific to thin and medium beds, as well as to thick one, are applied, which involve the use of dry or hydraulic filling. The opening of mines via vertical and inclined shafts becomes increasingly common and great changes are made in underground and above-ground transportation.

Wooden winches are gradually replaced by hoists or high-capacity extraction machines equipped with steam-powered or electric engines. After 1900, electric, Diesel, compressed air, or steam locomotives are used for horizontal transportation. For transportation over uneven terrain, cableways are increasingly employed.

In the metal-ore extraction and efficient-use sector, changes occur in the crushing, washing, sorting operations, etc. Thus, old stamp mills are modernised by increasing the weight of the stamps and through the virtually general assimilation of Californian stamp mills, which featured greater battering force and frequency. Later on, jigging was introduced and modern preparation plants were built in Gurabarza and Maramureș.

The existence of a solid infrastructure and a large number of specialists and readers interested in learning useful information for their activities made it possible for the first technology book published on Romanian territory to be issued in Sibiu in 1717. It was titled *Auraria Romano-Dacica*, authored by Transylvanian scholar Samuel Köleseri (1780), himself an inspector of the Abrud-region mines, and comprised a short history of the old gold-mining sites in Abrud, Bucium, Vulcoi, Zlatna, Almaș, Hărțăgani, Trestia, Brad, Țebea and Baia de Criș, while also mentioning the method used to exploit gold through mining work and alluvium washing (Abrudeanu Rusu 1933; Haiduc 1940; Wollman 1996; Wollmann 2017).

The 20th century provided the most favourable conditions for the development of mining. Due to the accelerated rhythm of production, the rise in the number and size of mining companies, the increase of the exploitation depth, the large-scale introduction of mecanisation, and the need to ensure adequate work conditions, the science of mining is faced with a series of bigger and more complex problems than ever before.

2 The Interwar Period

During the interwar period, the Romanian state proceeded to rationalise and modernise the process of extraction and efficient use of deposits of useful mineral substances.

The production of various such substances increased constantly from year to year, new coal an ore deposits began to be exploited, the number of mining companies rose, and so did their level of technology and equipment.

In 1929–1930, the preparation plants in Petrila and Lupeni are modernised through the introduction of rheo washers into the technological process stream. The coal silts that result from both plants are processed through flotation. A briquette factory and a low-temperature carbonization installation are built in Petrila.

During the economic crisis of 1929–1933, the Vulcan, Dâlja, Petroșani Vest, Victoria and Carolina mines in Lupeni were closed. After the crisis, production recovered and reached its climax in 1943 of 2,755 thousand tons from Valea Jiului alone.

The economic crisis marked a new stage in the process of concentration and centralisation of production and capital. The crisis imposed a series of technical and orgnaisational reconsiderations, which were governed by the principle of 'rationalisation' and resulted in the implementation of certain modern technical elements (Baron 1999).

Following a drop in ore prices, iron-ore mines adopt the strategy of closing small mines and concentrating production exclusively in Ghelar-Teliuc, Ocna de Fier in Banat, and Lueta-Vlăhița. Precious-metal mines, most of which had been abandoned during the First World War, were gradually brought back into operation.

Rock extraction in galleries and stopes was conducted through drilling and blasting, or with the aid of coal augers and drill hammers, while using wood for support in underground mining. The transportation of coal through galleries was carried out by means of mine cars drawn by electric accumulator locomotives, electric winch locomotives, and Diesel locomotives. For shaft-based extraction, steam-powered extraction machines were employed. Power plants were built for the mines and preparation plants in Baia Mare and Brad. Water was evacuated from the mines by means of centrifugal pumps or piston pumps. The ventilation of mines was carried out with the aid of ventilators powered by electric or compressed-air motors, while the lighting of work spaces was ensured by gasoline safety lamps.

In the field of massif extraction, the drilling method for making shot holes became generalised in both coal and ore mines, and scaling hammers were introduced into most coal mines.

Chain coal-cutters were introduced in 1926 at the Lupeni mine for the extraction of thin beds and, from 1932 onwards, coal augers began to be used in salt mines as well.

During that time, mechanised items such as belt loading carriages, scraper loaders, and shovel loaders were used, which made it possible to attain a gallery-digging speed of up to 150–200 m/month.

During the interwar period, exploitation methods suitable for the specific characteristics of the deposits in Romania were developed and perfected. Thus, for the exploitation of hard-coal deposits, for thin or medium beds, either horizontal or low-dip, the method employed was that of the rance longwall, in the form of either strike or dip face. In the case of thick, high-dip beds, the exploitation method applied was that of horizontal slicing, with the coal being extracted in slices or by means of completely mechanical longwalls. For thick low- or average-dip beds, the dip slicing method was employed, combined with longwall-based coal extraction.

As far as ore deposits are concerned, the method of horizontal upward slicing combined with the filling of the mined space was used. When speaking of exploitation methods, it is also worth mentioning that the magazine mining method was introduced at the Săsar mine in 1938, having been applied in America merely a few years before.

In terms of stope support, one could name the building of powered support shields and their testing at the Petrila mine in 1942. The rise in stope efficiency at the Valea Jiului mines, combined with the concentration of production, imposed the increasing of the transportation capacity in order to evacuate the production, which gave rise to the intense use of modern extraction shafts and mechanisms.

In 1937–1938, a cyaniding installation was built at Săsar—Baia Mare, which was intended for the direct processing of green ore through cyanidation. Thanks to the new machines on the market, all the crushing, grinding, and classification departments in all the plants throughout the country proceeded to be modernised. At the same time, an electromagnetic preparation installation was built for the ores at Ocna de Fier.

In 1936, at Gurabarza, Societatea Anonimă Română 'Mica' (the Mica Romanian Anonymous Society) built a gold-refining installation, which was the second of its kind in Romania. The same society constructed a new flotation installation in 1938.

In 1937, the production of ores extracted and processed at the mines in the Apuseni Mountains tripled compared to the levels of 1928, thus registering the largest amount of noble metals ever attained in a European province, namely 5,465 kg of gold and 25,645 kg of silver. The total quantity of gold obtained throughout the centuries via the exploitation of the gold deposits on Romanian territory amounts to the significant level of over 2,200 tons of pure gold.

To summarise, one may conclude that, during the interwar period, mining made great progress in Romania, resulting in a series of technological achievements, of which we would like to mention the following as the most important: introducing electric mechanical-rotating drilling and pneumatic percussion drilling in both ore and coal mines; the generalisation of the exploitation method using large trapezoidal rooms in salt mining and the introduction of coal-cutters for the cutting of salt; applying the longwall mining method in the coal mines of the Valea Jiului basin; the extraction of coal in stopes using coal-cutters, drilling and blasting; the use of oscillating chutes and push conveyors to transport the production in stopes; using rings and prefabricated-block walls for gallery support and metal pillars for stope support; introducing the magazine mining method for certain deposits; building modern coal preparation plants in Valea Jiului and the ore cyaniding installation at Săsar; the introduction of electromagnetic separating devices in iron-ore preparation plants; the use of intermittent excavators in quarries.

3 From the Second World War to 1990

In the span of merely three years, from the end of the Second World War until 1948, the year of the nationalisation of the mining sector, almost all the useful mineral substances exploited reached the pre-war production levels of 1938.

Immediately after the nationalisation of the main means of production in Romania, a growth and development strategy was elaborated for the mining branch of the national economy (Almăşan 1984, 1965). However, what lay at the foundation of that strategy was an immense geological research, prospecting, and exploration effort, which spanned several decades. Thus, IGEX (Întreprinderea Geologică de Explorări—the Geological Exploration Enterprise) was created and tasked with conducting operations all over the country, while Institutul Geologic (the Geological Institute) was reorganised in the form of a government body called Comitetul de Stat al Geologiei (the State Geology Committee), which functioned as such for 16 years.

From the beginning, the geological research was conducted along three lines: improved knowledge of the reserve potential of the mining basins under exploitation; previously abandoned mining perimetres and areas; new, yet unresearched areas.

The great investments in the studying of Romania's underground resources were made until the 1980s. In view of identifying the reserves of useful mineral substances and of gaining better knowledge of the deposits, in 1950–1980, several thousands of surface drilling operations were conducted throughout the mining basins in Romania, adding up to a total of over one million linear metres in auger holes. Combined with the geological research carried out underground, these led to the accumulation of sufficient data to ensure good knowledge of the country's subsoil and its resources.

The greatest accomplishment in the field of 20th-century extractive industry was the fact that, from the exploitation of three useful mineral substances—coal, precious metals, and salt, seven sub-branches of the extractive industry were organised and developed, namely the extraction and preparation of coal, salt, ferrous ores, non-ferrous ores, precious-metal ores, non-metalliferous ores, rare-metal and radioactive-metal ores.

Iron ores continued to be exploited in Ghelari, Teliuc, Ocna de Fier and Lueta, while new mines were opened in Căpuș-Șatra and Băișoara. The exploitation of manganese ores expanded as a result of the efficient use of new sectors of the Vatra Dornei-Iacobeni deposit.

In the field of non-ferrous ores, the production capacity of extant mines was increased, while also opening new mines (Rușchița, Dognecea, Burloaia, Toroioaga, Muncelu Mic, Șuior, Ilba, Valea Blaznei, Deva, Baia de Arieș, Leșul Ursului, Moldova Nouă, Gura Băii, Fundul Moldovei, Altân-Tepe, Catarama, Băița Bihor, Pădurea Craiului).

The carbon sector registered a significant development, as did the sector of non-metalliferous ores. The most noteworthy increases occurred in the production of solid fuels: bituminous coal, brown-coal, and lignite. Some of the old mines in the Valea Jiului basin were modernised (Jieț, Petrila, Aninoasa and Lupeni), others were reopened (Cimpa, Lonea, Vulcan), while other mining perimetres saw their first opening works, followed by the swift entry into operation of several new mines (Livezeni, Uricani, Bărbăteni, Petrila Sud, Valea de Brazi).

The development of the extractive industry relied almost exclusively on machines manufactured at home. For basic mining operations, the following machines were produced in Romania: scaling hammers, pneumatic and electric drills, gallery loaders, hopper machines for stopes, raise-digging platforms, etc. Extraction machines and various hoists were manufactured, friction and hydraulic pillars for support, various types of push conveyors for mechanical transportation, belt ribbon conveyors, portable belt conveyors, scrapers, electric and Diesel locomotives, etc. Our own machine-building industry was also the one to supply compressors, pumps, ventilators, and the machines for the preparation installations (crushers, mills, flotation cells, filters, etc.).

There are three large mining basins in Romania which hold hard coal, namely: the Schela-Gorj basin—anthracite; the Banat basin—bituminous coal and brown-coal, and the Valea Jiului basin—bituminous coal.

Of the above-named basins, the most important one in terms of the reserves it holds and the level of production attained is the Valea Jiului mining basin. The bituminous coal production in Valea Jiului was constantly on the rise, reaching 11,194,435 tons of gross production in 1988.

The diverse characteristics of the deposits in the Valea Jiului mining basin led to the implementation along the years of a large number of exploitation methods and work technologies for the extraction and efficient use of coal. Supporting and controlling longwall roofs marked a turning point in the changing and modernisation of the work techniques employed in Valea Jiului. In 1960, the Petrila mine saw the introduction of hydraulic pillars of the Klökner-Feromatic type, which served as a basis for the design, construction, and use of autochthonous hydraulic pillars.

The first stopes to become operational and be equipped with powered systems were the ones in E.M. Paroșeni in 1970. The systems that the first stopes in Valea Jiului were equipped with were of soviet manufacturing, of the O.M.K.T. line. The O.M.K.T. powered support elements were used as part of a system in combination with the Polish-made KWB—3 RDS stoping machine.

The first indigenous powered support units (SMA—susțineri mecanizate de abataj) were introduced underground in 1978, while foreign ones were still being imported. During that period, the following types of power support units were brought into the country: Hemscheidt, Fazos and KM-87.

In order to put into action the vast programme of opening and preparation operations for the new faces of workings, it was necessary to increase the speed of heading work. Particular emphasis was placed on the mechanisation of loading, as it was the most exhausting operation and also the most time-consuming when performed manually. Loaders for galleries under construction made in Romania made it possible for the degree of mechanisation of loading operations to increase and, consequently, for the heading speed to rise by approximately 25–30% compared to the manual-loading procedure. Given the characteristics of the Valea Jiului basin, the maximum excavation speed of horizontal mining work reached 250–350 m per double-gallery month.

Romania possesses over 3 billion tons of industrial brown-coal and lignite reserves, found in ten different basins across the country. The most important of them are the mining basins of Rovinari, Motru, Jilț, Albeni-Seciuri, Cerna-Cernișoara, Berbești-Alunu and Husnicioara, which hold over 90% of the country's total lignite reserves.

Of the total approved industrial reserves of lignite, over 80% can be exploited through quarries, while 20% are exploitable through underground mining. In the last years of the period in question, nearly 90% of Romania's lignite production came from Compania Națională a Lignitului Oltenia (the Oltenia National Lignite Company), which coordinated the activity of 18 quarries and 12 underground mines.

Lignite extraction was conducted through both underground and open-cast mining, while brown-coal, which makes up only a small share of the production volume, was extracted exclusively through underground mining. Lignite production grew at a very fast pace from 1950 onwards, reaching over 50 million tons in 1989.

Non-ferrous ore deposits (copper, lead and zinc, gold and silver, and aluminium) are distributed across four geographical areas in Maramureș, the Eastern Carpathians, the Apuseni Mountains, and the mountain areas of Banat.

The thickness of the deposit bodies varies greatly, from a few centimetres in the case of lodes (gold ores) to over 10 m (complex ores). There are numerous ore bodies in the form of stock, deposits, or aggregates. Lately, large accumulations of low-content mineralisations of the 'porphyry copper' type (a mineralisation featuring strong vertical development and fine dissemination into the massif) have been included into the economic network.

Whether eruptive or metamorphic, mineralisations are generally irregular, in both strike and dip orientation. The cases where bodies and lodes are of consistent shape and size are rare.

In Romania, the size of metal-ore deposits varies widely. Many deposits can be deemed small, with ore reserves of under 10 million tons. Others can be considered medium-sized and only a few fit into the category of large-sized deposits. With the exception of the 'porphyry copper' type, large deposits, such as the ones at Bălan, Moldova Nouă, Baia Borșa, Rodna, are, in fact, made up of several separate ore bodies.

4 Scientific Research and the Application of Research Results onto Production

The first mining research and design activities were organised as early as 1949 within the former Institut de Proiectări Industriale (Industrial Design Institute) of Bucharest.

Once ministries focused on different industrial sectors had been created, new republican development institutes were founded and organised. Thus, it is in this context that Institutul de Cercetări și Proiectări Miniere și Metalurgice (the Institute for Mining and Metallurgy Research and Design) of Bucharest was founded in 1950.

In the summer of 1951, two research and design institutes dedicated to mining are created: ICEMIN and IPROMIN, which operated in Bucharest until 1973.

In 1974, mining research and design institutes focused on useful mineral substances were founded in Baia Mare, Cluj, Deva, Petroșani, Craiova and Bucharest.

After the year 1960, the organisation of the research institutes and the design ones was regulated, and so was their manning with key and auxiliary staff, while scientific research activities were made mandatory for higher education.

90% of the research funding came from economic contracts with productive units, which were under the obligation to take over and apply the results obtained onto production.

Higher-education scientific research was either fundamental or applicative and was mostly conducted based on contracts with productive units.

This form of organisation and coordination of scientific research in the field of mining led to important results at both regional and national level.

In the second half of the 20th century, over 100 mines and quarries were opened and put into operation in Romania. The production capacity of over 50 mines rose, over 30 preparation installations and plants were built, and more than 15 mining-machinery manufacture and repair plants were designed, built, and made operational.

5 The Period After 1990

The Romanian mining industry registered a constant increase until the last decade of the 20th century, but entered a period of profound transformation and adaptation from 1990 onwards, in view of the transition to market economy.

In order to attain that goal, along the years, a series of measures were adopted and several strategic concepts were formulated and put into practice as to the fundamental restructuring of the mining-industry system, which, among others, included:

1. *The restructuring of technology and production*, which resulted in: an increase in the share of quarry-produced lignite and a drop in underground production; the growth of the share of energetic bituminous-coal supplies and a decrease in bituminous coal prepared for coke; an increase in copper and precious-metal ore extraction and preparation; the initiation of the modernisation of the great lignite quarries in the mining basins of Oltenia, etc.;
2. *Organisational and managerial restructuring*, which consisted first and foremost in removing certain complementary or even basic activities from the mining units and organising them into separate companies;
3. *Personnel restructuring within mining units*, particularly in the form of massive reductions by means of three basic methods: removing certain activities and associated personnel and organising them into companies, early retirement, and redundancies with severance payments.

Up until December of 1999, approximately 85,000 miners of a total of 175,000 left the mining industry. Circa 70,000 of them accepted to be made redundant and receive severance payments, while another 15,000 left the industry either to retire or because their work activities were eliminated from the mining system.

4. *The reduction or discontinuation of productive activities* in certain mines with geological stock on the brink of exhaustion and particularly harsh geological and mining conditions, which incurred high and very high production costs.

The mining-industry restructuring programmes approved by the Romanian governments from 1998 onwards through 11 consecutive Government Decisions, authorised the definitive closing of 556 mining units located on the administrative territory of 28 Romanian counties, combined with post-closing conservation and monitoring of environmental factors.

So far, 250 units have been closed and greened, with the rest to follow in the future, depending on the funds allocated for this purpose.

In the exploitation of the deposits of useful mineral substances on Romanian territory after 1990, for both extraction and preparation, the same classic work methods and technologies perfected for the pre-1990 situation in Romania continued to be employed.

In the past few decades, the use of longwalls with individual support and mechanical cutting, as well as of longwalls equipped with stopping machines expanded into coal mining.

Ore mining on Romanian territory continues to be conducted within quarries and underground mines. The copper, manganese, and iron required by Romania's metallurgical industry are mostly produced by quarries. The mining method applied without exception in all the ore quarries in Romania is the method involving the transportation of gangue to external heaps. All the quarries employ work technology which ensures very high productivity.

Underground mining is mainly associated with lead, zinc, gold, and silver deposits, yet a significant part of the country's copper, manganese, and iron has nevertheless been exploited through underground mining. The mining methods applied underground in the few mines Romania still has are the same ones which were in used before 1990.

The ores extracted from underground units or quarries are processed in preparation plants where the basic technology employed is flotation concentration for non-ferrous ores, cyanidation for most gold ores, gravitational and combined procedures for non-metal ores.

Almost 40 sorts of non-metal ores are extracted from the several hundred deposits of such ores in Romania, to be used especially in the production of cement, glass, porcelain, fine ceramics, sanitary ceramics, stoneware, various fireproof products, enamels, paints, items used in the chemical industry, in metallurgy, or in foundries, etc.

Both dry and wet methods for the exploitation of salt deposits are still well-developed in Romania, the bulk of production being directed towards the chemical industry and household consumption.

The country has over 50 quarries of marble, limestones, granites, sandstones, conglomerates, breccias, calcites, travertines, tufas, gabbros, rhyolites, andesites, etc., which are extracted, processed and used in construction, as well as in interior and exterior decorative paving.

6 Trends in the Mining Industry

Today, Romanian mining is divided into three sectors: the exploitation and efficient use of energetic-substance deposits; the exploitation and efficient use of metal-ore deposits; the exploitation and efficient use of non-metal-ore and useful-rock deposits.

In the last 25 years, no investment has been made in any of the still operating units of the three sectors, the technical equipment has remained at its 1980 level, and activities have been reduced to a minimum.

At present, Romania's production capacity in the field of mining has decreased substantially compared to the period before 1990.

We would like to point out that current useful mineral-substance production is at a fifth of Romania's annual pre-1990 production levels.

In the future, Romania needs to channel its investment efforts into the field of mineral resources, with the particular purposes of: capitalising on low-content, yet high-volume deposits, which are suitable for quarry extraction; reprocessing mining refuse found in dumps and metal-containing sludge beds; reopening the reserves with economic potential using underground extraction methods; reopening the mines containing ore reserves with rare accompanying elements, which have become of great economic interest in the current technological and economic context.

Romania's extant reserves of most useful mineral substances can supply enough production for several decades, as they represent a reliable resource irrespective of the fluctuations on international markets, which justifies investments in the revival of mining and metallurgical activities.

The mining industry will require well-supported sustainable development in order to meet the necessities of our times without compromising the possibility for future generations to satisfy their own needs. Sustainable development must ensure economic growth, social progress, as well as the protection of the environment and of natural resources.

Looking at the overall situation of the exploitation and efficient use of solid useful mineral substances, the conclusion which ensues is that, given the new economic circumstances, it is necessary to reconsider the Romanian state's position and involvement in the field of mining, particularly in the way of improving institutional capacity so as to focus on the role of institutions in regulating and promoting the mining sector, while also providing a viable system for private entities to operate in, fund and manage. The state needs to make better and more efficient use of its capacity as owner of the mineral resources by instituting a stable, competent and fair association, taxation, and royalty system.

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History of Metallurgy

Iulian Ripoşan and Stelian Stan

Abstract The production and use of metals and metallic materials date back to very ancient times, which are difficult to pin down and differ from one part of the world to another. It started with the use of metals in their native state, and then moved on to their production by smelting ores from the surface of the ground and easily accessible ores from underground. It is estimated that in the area that includes the territory of Romania, the processing of metals in their native state began about a millennium earlier than in the area that includes most of Europe. The new discoveries regarding the beginnings of iron metallurgy in Romania are an additional argument, besides the general historical considerations, in favor of the idea that the first iron age began in the Carpatho–Danube area before 1150 BC. The metallurgical industry in Romania has evolved over the years, being in certain periods an important player in the field. The most important metallurgical areas in our country: Călan, Hunedoara, Reşiţa, Galaţi, Slatina, Bucharest. Along with the evolution of the metallurgical industry, the Romanian metallurgical education also developed in university centers such as Timişoara, Bucharest, Iaşi, Braşov, Reşiţa, etc.

1 Genesis of Metallurgy on Romanian Territory

Due to its natural resources and geographical position at the junction between East and West, the current territory of Romania has had thorough knowledge of and an ample contribution to the emergence and development of metallurgy, having been, in some respects, ahead of many presently advanced areas. According to estimations, the processing of native metals in this region began approximately one millennium before it did in the area comprising most of Europe (Popescu and Popescu 2016; http:eurouniunea.blogspot.ro; Tylecote 1992; Hătărăscu et al. 1991, 2023, 1972; Romulus 2015; Iorga 1927; Glodariu et al. 1979; Istoria Românilor (2001–2003); Burileanu 1920; Chicoş 1925; Negrescu 1931; Stanescu 1931). The practice of metallurgy on the territory of today's Romania dates back to 2800–1900 BC for copper,

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1900–1700 BC for bronze and 1150 BC for iron [iron weapons and ornaments have been discovered dating from as early as the 12th–11th century BC, but they came from outside the territory in question].

1.1 Non-ferrous Metallurgy

Copper was, practically, the first metal to be actually used by man for his everyday needs, aside from including it, alongside gold, in the making of jewellery. The alloying of copper with small amounts of As, Sb, Pb and Sn, which appeared in the Neolithic, constituted prehistoric man's first metallurgical activity.

Cu-As alloys (<8% As) emerged during the 4th millennium BC, practically at the same time in the Near East and Europe, as representative metal materials for the Early Bronze Age. In the Ocniţa-Vâlcea area in Romania, they were made from a mix of Cu and As ore with 6.7% As (Bugoi et al. 2013), using the same technique as the ones discovered in the North-Pontic region, the Caucasus, or Central Europe. The alloys in Băile Herculane—Caraş Severin (6% As) and the Lower Danube area (5–10% As) date from the late Neolithic and early Bronze Age (Bugoi et al. 2013). Cu–Sn bronze is the representative material for the second (Late) Bronze Age; it has been found in southern Romania, along the Danube, as well as in the deposits of Predeal and Sinaia, which attest to the fact that Valea Prahovei was used as one of the current routes connecting Transylvania (mining area) and Wallachia (agricultural area) (Ursulescu and Zugravu 2016).

Dacian soil was rich in ores. Dacian-Getic craftsmen worked with Au, Cu, Ag and Fe. Rich copper-ore resources allowed bronze metallurgy to begin no later than the early Neolithic and to play an important part in the dissemination and use of this metal at European level. The first to be processed was arsenious copper in surface lodes, known in Transylvania from as early as the late 5th millennium BC. The Bronze Age would reach its heyday in the 12th century BC. In the region of Banat, metallurgical ovens dating back to the 18th–17th century BC (Dognecea-Ocna de Fier) are particularly noteworthy, as are the ones in Bocşa, Giurgiova, Ciclova, Moldova Nouă, Deva, Căzăneşti. Other areas in the country were of importance as well, such as Bălan (Harghita), Baia de Aramă (Chalchis), where the Scythians and the Romans opened many copper mines. In Moşneni, near Mangalia in Dobruja, an entire agricultural inventory of items was discovered, dating back to Roman times, the possible origin of the metals used for making them being the mines of Altântepe, near Hamangia, which were rich in surface deposits of Cu (malachite) and Fe (magnetite) ores.

During the Neogene, the Baia Mare depression (Maramureş, northern Romania) saw intense volcanic activity, which led to the development of a mountain range, with eruptive rocks containing gold and silver ores such as Pb, Zn, Cu, Au as free elements and Ag. The first attested mining activities in these areas date from the 2nd and 3rd centuries BC. Baia Sprie [Mons Medius in 1329] was an important mining centre as

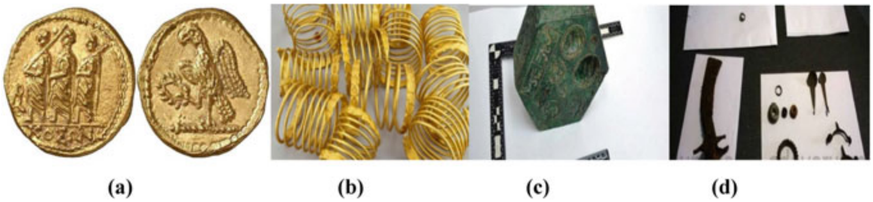


Fig. 1 Dacian artefacts: Koson coins (**a**), Gold Dacian bracelets (**b**) (Constantinescu et al. 2009), Mould for casting precious-metal pieces (**c**) (https://www.dzr.org.ro/matrita-bijutierilor-daci-de-la-sarmizegetusa-regia-descoperirea-unei-unelte-unica-in-lume-utilizata-pentru-turnat-piese-decorative-din-metale-pretioase) and the treasure of Petreni-Valea Streiului (Dacian Sargeţia) (**d**) (https://www.dzr.org.ro/comoara-antica-descoperita-pe-valea-streiului-in-hunedoara-inele-podoabe-cu-forme-ciudate-si-un-topor-vechi-de-peste-doua-milenii) (courtesy of Constantinescu B.)

early as in the Bronze Age. Gold and silver exploitation is mentioned around 1141 in relation to the Transylvanian-Saxon colonisation.

Gold metallurgy has a longstanding tradition on Romanian territory. The oldest ornaments were discovered in Moigrad (Sălaj) and date from the Stone Age, thus being 6,000 years old. Romanian gold deposits, mostly found in the 'gold quadrilateral', namely the perimetre of Baia de Criş, Săcărâmb, Zlatna, and Baia de Arieş, in the Apuseni Mountains, as well as in Maramureş, were exploited for a very long time, by the Scythians, Agathyrsi, Dacians, and subsequently by the Romans. A branch of the Greek people of the 7th century BC came to the Apuseni Mountains area for the organised exploitation and use of gold deposits.

The exploitation of alluvial gold in the Arieş, Mureş, Timiş, Dâmboviţa, Olt rivers appears to have been the Dacians' main source of the said metal. A few Dacian artefacts (Fig. 1) capture our attention, such as the koson coins, produced in Dacia towards the middle of the first century AD, and the Dacian gold bracelets (Fig. 1a and b) (Constantinescu et al. 2009).

Metallographic research has shown that the gold used to produce the first series of koson coins is similar to that employed by Pontic cities (the first half of the first century BC), while the gold used by the Dacians for the second series, the one without a monogram, is similar to that employed in the making of the Dacian bracelets (alluvial gold from the Apuseni Mountains area). A chemical analysis of a 'Dacian bracelet' (5–7 spirals, 682–1,196 g) made from top-quality gold in the region around Sarmizegetusa Regia, the capitalof the Dacian state in the first century BC-first century AD, showed that, aside from gold, it contained 11% Ag and 0.9% Cu, thus being different from natural gold, which contains up to 40% Ag and 1.0% Cu.

It was concluded that the material was obtained from a mixture of natural gold and primary gold from Transylvania (Constantinescu et al. 2009).

Another ancient treasure (10 ornaments and jewels, most of them made of bronze, but also an axe over 2,000 years old) (Fig. 1d) (https://www.dzr.org.ro/comoara-antica-descoperita-pe-valea-streiului-in-hunedoara-inele-podoabe-cu-forme-ciudate-si-un-topor-vechi-de-peste-doua-milenii), was discovered in the forest at the edge of Petreni village, on Valea Streiului (Dacian Sargeţia, known as ‘the Dacian Path’), along the river where the Dacian king Decebalus is said to have hidden his treasures. It is important to mention that Decebalus’s treasures, found on the bank of the river Sargeţia, following Bacilis’s betrayal, was evaluated by Jerome Carcopino to contain approximately 165 tons of gold and 331 tons of silver (Romulus VI 2023, Ursulescu and Zugravu 2016).

Once Dacia had been occupied by the Romans, miners were brought from Dalmatia, Asia Minor, and other regions and they perfected the methods for the exploitation and preparation of gold ores during the 166 years of Roman dominion. In Roşia Montană, Bucium, Zlatna, Almaş, Stanija, Ruda, and Caraci approximately 3,000 kg of pure gold/year and almost double the amount of silver were produced.

During the period immediately following the Roman withdrawal from Dacia, for over 100 years (272–395 AD), the production of gold dropped radically to a mere 100 kg/year. Mining began to be revived at the dawn of the 2nd millennium and registered great progress in Europe from 1320 onwards, when the exploitation of gold mines started in earnest in Transylvania. It is estimated that, during the long period of the Middle Ages (396–1492 AD), the gold production amounted to an average of approximately 450 kg/year. The year 1500 marks the debut of a sustained development of gold mining, thus reaching over 1000 kg per year (2012).

From the 7th–6th century onwards, the Greeks founded a string of colonies on the shore of the Black Sea, into which Scythians influences found their way. The city of Histria minted its own coin (the first one to be issued on Romanian territory). The treasure in a tumulus in Agighiol—Tulcea dates from around 400 BC and contains pieces made of silver, gilded silver, and gold.

1.2 Ferrous Metallurgy

N. Ursulescu and N. Zugravu, in their work (2016), provide a summarised presentation of the prehistoric and ancient civilisations on Romanian territory associated with the Iron Age, particularly its first (ca 1200/1150-450/300 BC—Hallstatt) and second period (450/300 BC-106/271 AD—La Tène).

The first people to base their development on their knowledge of iron were the Hittites of Asia Minor, starting from around 1400 BC (the zenith of the Hittite Empire). There are several paths via which ferrous metallurgy could have entered Romanian territory: *(a) the South path.* Several Balkan Thracian tribes set out on expeditions into Asia Minor, where they could have borrowed ferrous metallurgy and then spread it among the north-Danubian Thracians. It is also possible that it may have been developed by the south-Balkan Thracians under Greek influence. *(b) The north-western Balkan and Italic path* was active in the western part of the country. The influences stemmed from the Illyrian metallurgical centres, as well as from the pre-Etruscan ones (the *Villanova*-type culture) and subsequently from the Etruscan centres in northern Italy. *(c) the North (or Cimmerian) path.* The Cimmerians (an Indo-European population of the North-Iranian branch, related to the Scythians), found north of the Black Sea, would attack the eastern part of Asia Minor in particular, which is where they borrowed, among other things, the knowledge about ferrous metallurgy, which they went on to spread, during their warlike raids, towards East-Central Europe and, thus, into Romanian territory as well. The various paths of access were convergent and sometimes even synchronous.

On the territory of today's Romania, the Iron Age began with the arrival of the Scythians, in the 7th–4th century. Later on, the Celts introduced an improved version of the craft, which the Dacians learned as well. The oldest whole iron object discovered on Romanian territory up to the present appears to be a *Celtic*-type axe found in the tumular necropolis of Lăpuş-Maramureş, probably dating from the very end of the 13th century BC (Bugoi et al. 2013). Traces of iron exploitation and processing were also found in Almaşul Mare and Ghelari. Iron objects began to be produced locally, in various areas, important findings in that sense being the pieces of iron slag in Susani (Timiş County) and the iron ore-reduction workshops in Baia de Fier (in Oltenia), Cernatu de Sus and Sâmpetru (in Transylvania), and Babadag and Dervent (in Dobrogea).

Aeschylus (525–456 BC) remarked on the fact that the land of the Scythians, which were tribes that had come into Dacian territory and been assimilated by the locals, was also called 'the motherland of iron', with one of its largest centres in the Paranx (Parâng) Mountains, in the vicinity of 'the violent river that is difficult to cross' (Olt), namely in today's Baia de Fier (Popescu and Popescu 2016).

Ferrous metallurgy was predominant in the mountains of Banat (having begun at the end of the 2nd millennium BC), as vestiges of such activities were found in various places, such as Ocna de Fier, Bocşa, Berzovia, Broşteni, Brebu, Ezeris, Sosdea, Fizeş, Ramna, etc. (Popescu and Popescu 2016). The number of such centres increased radically, particularly after the introduction of the procedure for obtaining iron through the melting of ores on open hearths or in ovens. The continuity of metallurgy in this area and of activities in this field, which have also evolved technologically, is highlighted. Mined iron was processed either at the extraction site or elsewhere.

A significant part of the iron used by the Geto-Dacians came from the area of the Orăştiei Mountains, more exactly from around the capital of the Dacian state. It is thought that the largest workshops for the extraction and processing of iron in South-Eastern Europe in the La Tène age operated at Sarmizegetusa. Some of the items from the said workshops are specific to the Dacians, among which the massive iron pieces ending in two wings bent in the form of a conical sleeve, which protected the mouth of the bellows, massive unclogging tools which served to remove the deposits of slag and impurities (Popescu and Popescu 2016).

In the Transylvanian part of Dacia, the Celts would have a beneficial influence on metallurgy, as they added to an existing autochthonous form of it, which had already reached a certain level of development, new elements which were disseminated over a large Dacian territory. One might say that the Celts brought a boost of civilisation to the Geto-Dacian region. After the occupation of Dacia (106 AD), the Romans introduced their own administration (conductores ferrariarum), which materialised, among other things, into a new manner of organising metallurgy. The result was an intensification of the exploitation of metalliferous mines and of metallurgical activities. As they were interested in the mining and metallurgy conducted on these territories, the Romans focused on the metalliferous areas in Transylvania and Banat, which, at the time, were deemed to be 'inexhaustible'.

In the Medieşu Aurit—Şuculeu area, there were several hundred ovens (associated with the ceramic ones), which are certain to have operated in the 2nd–3rd century AD. Consequently, this area must have played a very important part in the lives of the free Dacians, as it is unique in Central Europe (http:www.cunoastelumea.ro). Ferrous metallurgy registered a fairly large-scale expansion in Scythia Minor as well, namely in Roman Dobruja, as traces of ovens carved in rock were identified in the area, in Teliţa (Wollman 2010).

Iron extraction, both worldwide and on Romanian territory, evolved in parallel with the development of related systems, especially those which ensured the introduction of air (oxygen), as well as with the quality improvement of the fuel used to supply the necessary energy. From that point of view, one can identify two main periods, namely one when (a) open hearths and ovens were used to reduce iron ores and one characterised by the use of (b) furnaces.

2 Open Hearths and Ovens for the Reduction of Iron Ores

Early procedures of metal-ore melting relied on the use of open hearths (Fig. 2a) (Popescu and Popescu 2016), with charcoal as fuel, which was added in consecutive layers [charcoal—iron ores—unslaked lime], and forcefully inserted air as a source of oxygen. The resulting 'ball lumps' (iron clumps that included slag) were reheated and submitted to processing through beating, which led to the removal of the slag to obtain the desired metal items.

The oven's limited thermal regime, together with the restrictive iron-carbiding conditions caused the resulting ferrous product to be low in carbon, classifiable as steel, malleable, yet with limited strength.

Towards the end of the Hallstatt period, open hearths were replaced by **metallurgical ovens**, which constituted a particularly important step in iron extraction: the burning was carried out in a closed space and the air was blown in at the bottom of the burden (as opposed to the top, as in the case of open hearths). Thus, the temperature in the space where the iron ores were reduced grew, which brought a series of notable advantages: the increase of the percentage of iron extracted from the ores, the reduction of the duration of a burden and the rise in the carbon content dissolved into the iron—in other words, the production of what we, today, call steel. In European countries, the shift from open hearths to vertical ovens took place during the transition from the first period of the Iron Age (Hallstatt) to the second (La Tène), namely at the end of the 1st millennium BC.

The items which are representative for Romania are the ovens discovered and reconstructed in Doboşeni-MiercureaCiuc (Fig. 2b, 2nd–1st century BC) and Șercaia-Făgăraş (Fig. 2c, 1st century AD) (Popescu and Popescu 2016). The Orăştiei

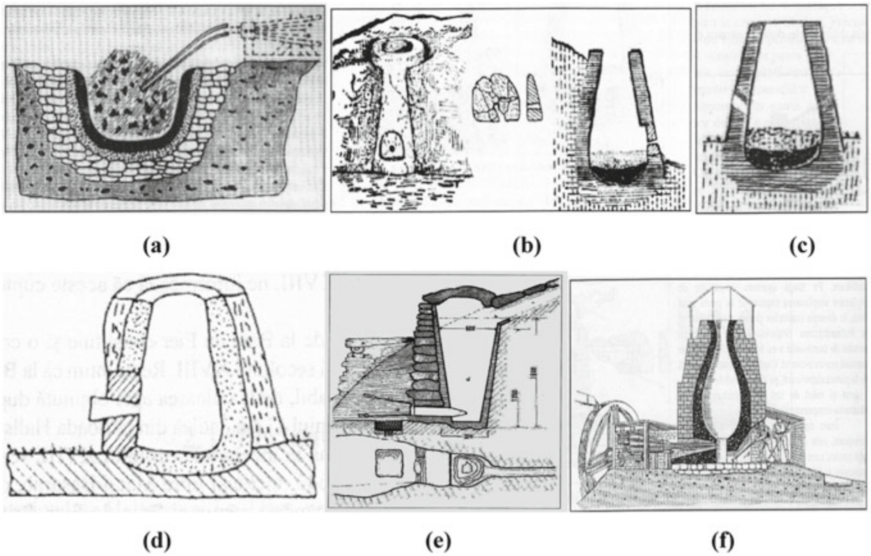
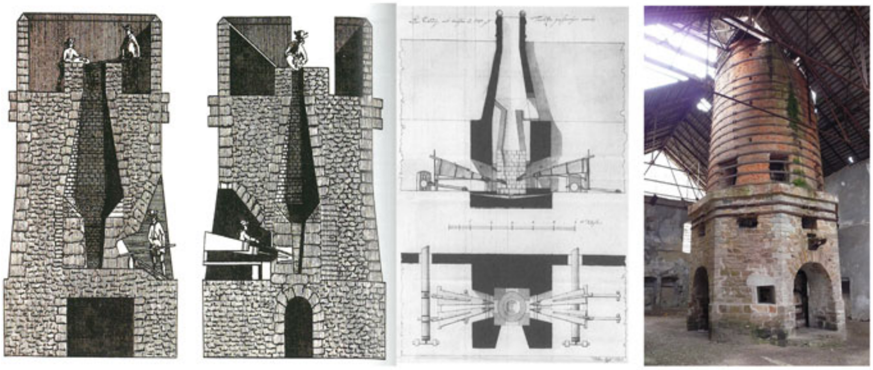


Fig. 2 Iron-ore reduction systems along the centuries, with an open hearth (**a**) and oven-based (**b**–**f**): **b** Doboşeni, 2nd–1st century BC; **c** Șercaia, 1st century AD; **d** Fizeş, 4th century AD; **e** Ghelari, 9th–10th century AD; **f** representative for the 16th century AD (Popescu and Popescu 2016) (courtesy of Popescu C)

Mountains area comprised several iron extraction and processing centres, such as the ones in Sarmizegetusa, Grădiştea Muncelului, Dosul Vârtoapelor, Valea Tâmpului, Căprăreaţa, etc., which continued to operate into the Roman period (Popescu and Popescu 2016). Vestiges from the 2nd–3rd century AD were found in other metalliferous areas in Transylvania (Ghelari-Teliuc, Hunedoara), as well as in the Bocşa-Reşiţa region, in Ocna de Fier and Dognecea, Berzovia, Șoşdea, Fizeş (Fig. 2d), etc. In the late 1st millennium AD, larger metallurgical ovens appeared (Ghelari, 9th–10th century AD, Fig. 2e). The extraction of iron remained important during the period of advanced feudalism and in hill and plain areas as well, such as in Moldavia, where it was carried out in Dacian-style ovens.

As they possessed significant iron and fuel (wood/coal) resources, Transylvania and Banat maintained a significant level of activity throughout the known duration of iron metallurgy, that is, namely from the late 2nd millennium BC to this day. The representative areas in these regions are the Poiana Ruscă mountain area (Ghelari and Teliuc, from the late 1st millennium BC to the mid 20th century AD), Harghita and Ciuc in Transylvania, and Dognecea and Anina in Banat. Less important were the areas of Baia de Fier, Birtin, Halmagiu, Vaşcău, Baia-Fălticeni, Iacobeni, Rimetea, in Transylvania, Oltenia, and Moldavia.



(a) (b) (c)

Fig. 3 Furnaces in the first period of their construction (**a** Bocşa, 1725; **b** Topliţa, 1787; **c** Govăjdie-Hunedoara, 1813) (private collection)

3 Iron Extraction Using Furnaces (18th–21st Century AD)

Iron ore-reduction ovens were abandoned in favour of furnaces. On the territory of Romania, they began to be used in the mountain area of Banat, which fulfilled the three simultaneous prerequisites: metal ores (Fe), forests to produce charcoal (fuel), and running water featuring sufficient level differences to enable hydraulic operations (supplying the air, or, more exactly, the oxygen required for the fuel to burn).

Thus, from 1718 (Oraviţa) until 1884, circa 60 furnaces were built in 45 locations. The efficient volume of these furnaces increased gradually, from circa 7 m^3 for the first ones found in Oraviţa, Bocşa (Fig. 3a), Dognecea, Topliţa (Fig. 3b), Govăjdie-Hunedoara (Fig. 3c) to 10–50 m^3 in 1800–1850, then to over 80 m^3 after 1850, culminating at 350 m^3 for the furnace in Călan, in 1871.

4 The Representative Metallurgical Areas on Romanian Territory

4.1 Ferrous Metallurgy

The reorganisation of mining and metallurgy sites constituted a priority for the region of **Banat** immediately after the Austrian–Hungarian Empire took over the area from the Turks (the Peace of Passarowitz,1718) and was carried out by colonising it with German workers. In 1719, the first tall oven that used charcoal for fuel was built in **Bocşa**, followed by furnaces in various locations in Banat, which remained functional for a long time (Fig. 4) (Wollman 2016).

(a) (b) (c) (d)

Fig. 4 Views of the furnaces: Bocşa (**a**), Dognecea (**b**), Anina (**c**) and Reşiţa (**d**) (Wollman 2016), (courtesy of Dr. V. Wollmann)

The expansion of ferrous metallurgy within the region of Banat occurred in **Reşiţa** (Cimponeriu 1930; http://www.csr.ro.50megs.com/istoricr.htm; Jurma 1996; Perianu 1996; Malinschi 1964; Haşeganu 1957; Nicolescu 1940; Ministere de l'industrie, La Roumanie Economique 1921). The construction of the furnaces there began in 1769 and was completed in 1771. The place became known for its cannonball exports (to Napoleon and the royal court of Naples).

Part of the production was supplied to other, neighbouring centres to be processed, such as to Bocşa, Ciclova, Rusca and Văliug.

Puddling furnaces were introduced (replacing refining fires) and the first rolling mill in today's Romania appeared here in 1846, thus providing the rails for the country's first railway (Oraviţa-Buziaş, 1854). The steel produced in Reşiţa was used in the building of the Eiffel Tower in Paris.

Then Bessemer converters appeared (1868), followed by Siemens-Martin furnaces (1876), crucible furnaces (1889) and electric furnaces (1894). Production continued to grow until 1913, then dropped upon the outbreak of the First World War, after which it registered a revival until 1918, followed by another drop until 1920. In the years that followed, there was a general ascending trend, which turned into a linear one in 1948–1980, then started dropping in 1980–1989 (by 43% for cast iron, 30% for steel, 12% for rolled steel). The post-1989 restructuration and retechnologisation programme aimed to eliminate the use of furnaces, reduce steel production to half (electric furnaces), implement continuous casting and the development of secondary-metallurgy technologies.

Hunedoara and its surroundings constituted a remarkable hub for ferrous metallurgy, which has been practiced there from the middle of the 1st millennium BC to this day. In the seventeenth century, the Corvin Castle, a wonderful piece of medieval architecture, became the administrative seat of the smithies on the Hunedoara domain. The castle yard was organised as a market for iron trading, hence the German name for Hunedoara, which is **Eisenmarkt**.

Cast-iron production began in **Topliţa** (1754), expanded into **Govăjdia** (1837) and eventually reached **Hunedoara** (1884), due to its proximity to the iron-ore sources of Ghelari and Teliuc. In a relatively short period of time (1884–1903), 5 furnaces were put into operation, the cast iron being intended to be turned into steel, as well as used as such by casting it into various pieces, either directly in its liquid state or after it has been remelted in foundry-specific furnaces (initially cupolas), either their own or belonging to other beneficiaries. The melting of steel began in 1892. There was an expansion of production operations based on plastic deformation, namely those categorised as forging or lamination. Cast-iron production grew constantly during the early part of the period during which the ferrous-metallurgy platform in Hunedoara was operational, reaching its peak around 1900. The interval between 1949 and 1989 can be divided into three subperiods: (a) 1948–1960, significant increases in production; (b) 1960–1980, a surge in production, for cast iron, as well as steel and rolled steel; (c) 1980–1989, a drop in production below its rated capacities. After 1990, activities were carried out for the restructuring of production, so that, after the privatisation of 2003, only one electric steel plant, a continuous-casting one, remained in operation.

Situated near Hunedoara and practically capitalising on the same resources, **Călan** lies on ValeaStreiului (the Dacian Sargeţia, possibly the location of Decebalus's treasure). Its charcoal furnaces became operational in 1871 and 1875 (82 m^3 of efficient volume, 10,000 tons/year each). In 1990, annual production capacities amounted to 1,170,000 tons of first-fusion cast iron for foundries (practically the sole significant producer of this material in Romania) and circa 100,000 tons of second-fusion cast iron (cast pieces).

Călan also saw the development of the manufacturing of cast pieces made of cast iron (1877), general-use pieces, ingot moulds and moulding beds, rolling mill cylinders for machine tools. Thus, in the second half of the 19th century, Călan produced over 350 types/versions of heating and cooking stoves, some of which were veritable artworks (Fig. 5a) (Wollman 2016).

Cast pieces of the same category were also produced in Anina, Vulcan, Ruşchita, Vlăhiţa, Nădrag, some of which are hosted by museums around the country, such as the ones in Hazsmann Pal, Cernatu de Sus (Fig. 5b–e) (Wollman 2016).

Located in Banat, near Lugoj, **Nădrag** (Fig. 6a) has had a metallurgical industry since 1845, including iron-ore reduction ovens and heating ovens, as well as hydraulic lift hammers. Charcoal furnaces were to follow (1846, functional until 1916), accompanied by refining fires for the production of steel [in 1848 even puddling furnaces]

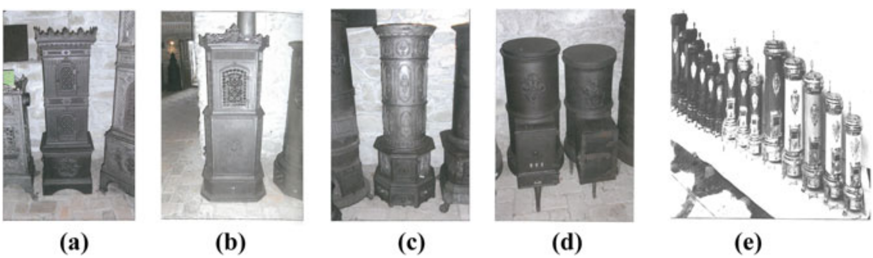
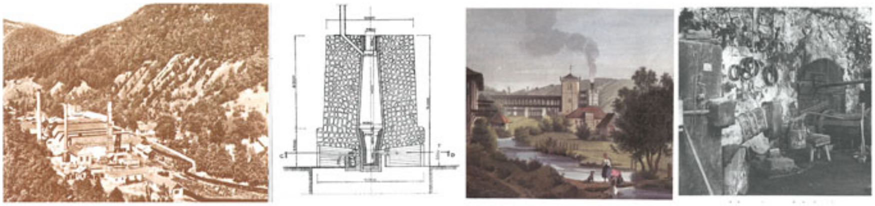


Fig. 5 Cast stoves made of cast iron in the 19th and 20th century: [**a** Călan (Wollman 2016); **b** Nădrag (Wollman 2016); **c** Ruşchiţa (Wollman 2016); **d** Vlăhiţa (Wollman 2016); **e** Anina (Wollman 2016) (courtesy of Dr. V. Wollmann)



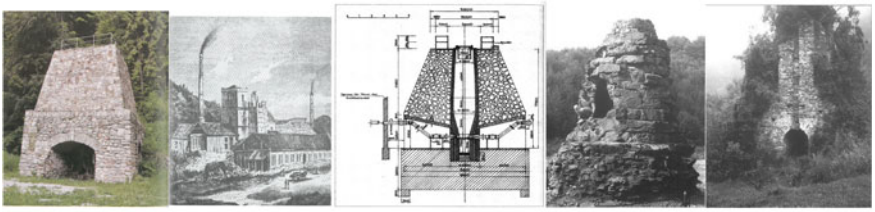
(a) (b) (c) (d)

Fig. 6 The Nădrag plant, early 20th century: (**a**) (Wollman 2010); furnace built in 1860 (**b**), view of the plant in 1864 (**c**) and the hydraulic hammer (**d**) of the Vlăhiţa Iron Plant (Wollman 2010) (courtesy of Dr. V. Wollmann)

and a rolling mill for the processing of steel. The 1924 merger and creation of the Titan [Galaţi]—Nădrag [Banat]—Călan [Hunedoara] concern, which operated until 1948, relaunched metallurgical production (Wollman 2010). After nationalisation (1948), the cast-iron, steel and non-ferrous-material foundry is re-established and new departments are created, such as the ones for various chains. The concern ceased its activities in 1999.

In a different geographical region, yet still in Transylvania, lies another hub of ferrous metallurgy, namely **Vlăhiţa**—Harghita (Fig. 6b–d) (the village of the ancient Vlachs), which has the iron ores in the area at its disposal (abundantly used ever since antiquity by the Dacians and Romans), as well as the deciduous forests and the force of the Homorodul Mic river. The first furnace that became operational in 1825 (21 m^3, open crucible, charcoal) functioned without any essential modifications for over 100 years. The supplying of iron ores, charcoal, and flux was performed by means of carriages, which ran on wooden tracks (a procedure used in this country ever since the fourteenth century, with a series of technical improvements) on a platform situated at the level of the furnace mouth. A classic foundry appeared in 1950 (cupolas, electric ovens), next to which a foundry for rolling mill cylinders (electric ovens) was built. The year 1977 came with a new foundry, very modern for its time (Disamatic automatic casting line), mainly intended for cast-iron pieces for the electrical engineering industry.

Other operational furnaces, located south of Vlăhiţa, were found in **Herculian** (Fig. 7a, from the beginning of the second half of the 19th century to 1950), **Filia** (Fig. 7b, 1854), **Doboşeni** (Fig. 7c), **Zălan**, all in Covasna County. A centre of renown which used locally extracted iron ore (oolitic ore, 40% Fe) was found in **Rimetea,** in the Trascău Mountains; it employed miners who had come from Austria even before the Tartar invasion (1241). Ferrous metallurgy was present in **Maramureş and Bucovina** as well, in the 18th–19th century AD, in places such as **Lăpuşul Românesc—Păduroi—Strâmbul**. The same can be said about **Borşa**, which hosted two operating furnaces in 1866. In **Iacobeni**, Suceava County, 3 furnaces and a foundry were in operation in 1784, using iron ores from Mestecăniş and Valea Fierului, and manganese ore from Arşiţa. In the same area, on the Bistriţa Aurie river, iron was processed in a two-hammer forge which was hydraulically operated (by means of



(a) (b) (c) (d) (e)

Fig. 7 The reconstructed furnace of Herculian: (**a**), the appearance of the Filia plant in 1868 (**b**), the Doboşeni furnace (**c**), the ruins of the furnaces of Răşchirata (**d**) and Zimbru (**e**) (Wollman 2010) (courtesy of Dr. V. Wollmann)

its own sluice). **In western Romania (Bihor, Arad)** (Wollman 2010, 2016) where sources of iron of the oolitic-ore type were found, in the 18th–19th century, iron metallurgy developed in centres such as **Vaşcău** and **Pietroasa** in Bihor, as well as **Moneasa** (1853–1855), **Dezna-Răşchirata** (1849, Fig. 7d), and **Zimbru** (1844–1865, Fig. 7e) in Arad. Iron-processing workshops operated in Donceni, Zugau, Brezeşti, Sebiş.

Starting its activity in 1966, on the bank of the Danube, the **Galaţi Steelworks** was designed to produce 10,000,000 tons of liquid steel per year and began with the heavy-plate rolling mill (1.2 mil. tons/year). The first furnace (1,700 m^3) began production in 1968, followed by another three until 1975. Larger furnaces would follow in 1975 (2,700 m^3) and 1981 (3,500 m^3). Thus, the production capacity for first-fusion cast iron reaches over 7.5 million tons per year, using furnaces built at the latest technological standards of the time. For the direct processing of furnace liquid cast iron into steel, several LD converters are built [1968–1979], and, for special-property steels, arc furnaces (50 t/burden) are constructed in 1974.

In 1970–1987, other rolling mills are added, amounting to a total capacity of 10 mil tons/year. In 1968–1989, production practically registers constant growth, reaching 6.5 mil. tons of cast iron and 7.5 mil. tons of steel in 1989, making it the largest steel producer in Romania.

The 1990 restructuration aimed to reduce production capacities and conduct retechnologisation and modernisation operations, including the intensification of furnace use, the introduction of new, high-performance installations for liquid-steel processing, the modernisation of the carbonisation plant and rolling mill departments, etc. Three furnaces, along with the steelworks with three LD converters and continuous casting, and the lamination departments for heavy plate, hot and cold-rolled strips (including zinc-plated ones) remained operational.

Located on the banks of the Danube, the **Călăraşi Steelworks** was designed as an integrated flow, with a production of 4 million tons a year for medium and heavy profiles, including rails weighing between 49 and 75 kg/LM. It became operational in 1980, when its electric steelworks started to be used (400,000 tons/year, continuous casting), followed by the light-profile rolling mill (350,000 tons/year) two years later. In 1986, it produced the coke furnace block, with its associated chemical sector.

In 1991 it became a company, SC SIDERCA SA Călăraşi, with the electric steel-works and medium-profile rolling mill running, while the other departments were in various phases of execution, some already in the technological-testing phase. The restructuration programme envisaged discontinuing the production of furnace cast iron, coke, sintered iron ore, and converter-made steel.

The accentuated growth of metallurgical production in Romania, especially after 1965, led to an increasing need for ferro-alloys, all imported. The first burden of Romanian ferrosilicon was produced in 1976, at the **Tulcea Ferro-alloy Plant Complex**, which reached 80,000 tons/year in capacity four years later. Maximum production is registered in 1988, amounting to 250,000 tons of ferro-alloys with silicon, manganese, chromium, and complex ferro-alloys such as FeW, FeSiMg, FeSi TE (electrotechnic sheet) (www.feralrom.ro).

4.2 Non-Ferrous Metallurgy

In the **Baia Mare area** in northern Romania, significant metallurgical activities have been conducted ever since the Bronze Age, as its rich non-ferrous metal resources including Cu, Pb, Zn, Au, Ag, etc. have been known and exploited by all the populations which passed through it along the centuries. The Phoenix Baia Mare Plant Complex was founded in 1907 as a sulfuric acid factory, then it was expanded in 1925 to include the neighbouring glass factory, after which it entered the market for non-ferrous metal metallurgy (copper wire, gold and silver ingots, of the raw materials on the Romanian market). During the interwar period, Romania was one of the main producers of precious metals in Europe. Moreover, the copper produced in Baia Mare was traded on the markets in Romania, Czechoslovakia, Poland, or Germany. The plant was nationalised in 1948 and became a private company once again after 1989. Every year, it produced 40,000 tons of refined electrolytic Cu (99,99% Cu), 120 tons of Ag and 12 tons of Au. Gold was extracted from the mining concentrates coming from the county mines and from other places, such as Satu Mare, Alba, Harghita, Mehedinţi (Pantea 2017; https://ro.wikipedia.org/wiki/Cuprom; www.cuprom.ro). Pb was produced in Baia Mare ever since the mid 19th century, out of selective Pb concentrates, through the dry-metallurgical processing of concentrates in a vertical flowing furnace of the Watter Jacket type.

The **ALRO Slatina Company** (Fig. 8a and b) was founded in 1963 through the building in Slatina of the first and only Romanian aluminium plant, with a capacity of 50,000 tons/year Al, which gradually went up to 263,500 tons a year. In 1996, ALRO was turned into a joint-stock company and subsequently privatised, undergoing significant investments in the way of environmental protection. It is the only producer of primary aluminium and aluminium alloys in Romania and the largest aluminium producer in Central and Eastern Europe (except for Russia). Its production capacity makes it possible to obtain 265,000 tons of electrolytic Al, 300,000 tons of primary-Al castings, and 120,000 tons of processed Al products every year. In 2006, ALRO merged with **ALPROM Slatina**, a company in Slatina

Fig. 8 ALRO Slatina (a and b) (www.alro.ro) and ALTUR Slatina (c and d) (www.altursa.ro) (courtesy of ALRO and ALTUR)

which produced Al alloys, and with **ALUM Tulcea** (founded in 1973, the largest producer in Romania and South-East Europe of calcined alumina, which is used to obtain Al) (www.alro.ro).

Slatina is host to another metallurgical company which is emblematic for the efficient use of Al, namely **ALTUR Slatina** (Fig. 8c and d), which was founded in 1979 and turned into a joint-stock company with private Romanian capital called SC ALTUR SA in 1991 (www.altursa.ro. xxxx). It is an important supplier for several industrial sectors, such as the auto sector (on-road and off-road automobiles, freight and passenger automobiles), tractors and agricultural machinery, the electrotechnical industry, natural-gas heating systems, etc., items made through gravitational casting (74%), die casting (19%), and machine-work (finite) items (7%).

Another area with longstanding activity in the field of non-ferrous metallurgy, particularly that of Pb, was **Copşa Mică**, where the company SOMETRA Copşa Mică (abbreviation of Societatea Metalurgică Transilvană) was active, producing Pb, Zn; and other non-ferrous metals. The ingots made here were used in the automobile industry, in electronics, electrotechnics, electroplating, car batteries, etc. (www.sometra.ro) Founded in 1939 (metallurgical-zinc production, 4,000 tons/year), it was nationalised in 1948 and, in 1950–1960, produced up to 28,000 tons of Zn a year. Complex installations for the simultaneous extraction of Zn and Pb from mining concentrates [30,000 tons/year of metallurgical Zn and 20,000 tons/year of decopperised Pb] were set up, thus diversifying production. Along the years, the plant bore different names: SONEMIN, U.C.M., 21 DECEMBRIE, I.M.M.N, and, from 1991 onwards, SC SOMETRA SA. Its production included: electrolytic Pb—ingots, Ag-Au alloy (D'ore alloy), Zn oxides (Waelz oxides—powder), clinker Waelz (Waelz slag—granules).

SC ZIROM SA Giurgiu is a company in Romania which produces strategic metals. Its main activity is the production and commercialisation of Ti, Zr, and their alloys, as well as the microproduction of non-ferrous and ferrous metals. It was founded before 1989, as a division of the Giurgiu Chemical Plant Complex. SC ZIROM S.A. appeared as a result of the reorgnaisation of Regia AutonomăZirom, which was created in 1990. At present, the company produces titanium ingots and alloys (www.zirom.ro).

5 Metallurgical and Mechano-Metallurgical Plants and Companies

Aside from the traditional metallurgical centres with a long track record (Reşiţa, Hunedoara, Călan, Vlăhiţa, Nădrag, Baia Mare) or more recent ones (Galaţi, Slatina, Călăraşi, Tulcea, Giurgiu, Copşa Mică), many other companies used to make or are still making 'metallurgical history', thus providing vital support for various fields of metal-item manufacturing, for various purposes.

Among the representative **metallurgical plants and companies** we can include the following (with their year of founding): the Oţelul Roşu Plants (1795), Industria Sârmei Câmpia Turzii (wire industry) (1920), the Titan Galaţi Plant (192)], the Griviţa Bucureşti Plant (1921), Întreprinderile Metalurgice Dunărene (the Danubian Metallurgical Companies) (1923), Întreprinderea Industria Sârmei Brăila (wire industry) (1930), the Malaxa Tubes and Steel Plant of Bucharest (1938), Uzina de Țevi Roman (pipe plant) (1957), Combinatul de Oţeluri Speciale Târgovişte (special-steel plant) (1973), Uzina Oţel Inox Târgovişte (stainless steel plant) (1974), Întreprinderea de Țevi Zalău (pipe company) (1980).

The representative **mechano-metallurgical plants and companies** would be: the Lemaitre Plant (Timpuri Noi) in Bucharest (1874), the Aversa company of Bucharest (1882), the Aiud Metallurgical Plant (1884), the Vulcan company of Bucharest (1904), the Fabrica de Locomotive Malaxa (Malaxa 23 August / FAUR) Locomotive Factory) of Bucharest (1921), the Progresul company of Brăila (1921), the MaşiniGrele (Heavy Machinery) company of Bucharest (1966), Combinatul de Utilaj Greu Iaşi (Heavy Machinery Plant Complex) (1977), Combinatul de Utilaj Greu Cluj-Napoca (Heavy Machinery Plant Complex) (1979).

Another category of metallurgical companies includes **producers of cast metal pieces** for other users, namely cast iron, steel, and non-ferrous-alloy foundries other than those which are part of metallurgical and mechano-metallurgical plants and plant complexes, which put to use the cast pieces produced mainly for internal processing. Examples of companies which can be included in this category are the ones in **Alba Iulia** (1972—MECANICA/SATURN), **Câmpina** (1971—Întreprinderea de PieseTurnate (the Cast Piece Company) / ORION), **Olteniţa** (1978—Întreprinderea de Construcţii de Nave şi Piese Turnate Olteniţa (the Olteniţa Ship-Building and Cast-Piece Company) / TUROL), **Băileşti** (1975—Întreprinderea de Piese Turnate (the Cast-Piece Company) / FONTANEF).

6 Metallurgical Education in Romania

The tradition of metallurgical education in Romania goes back a long way, having originated in the development of ferrous and non-ferrous metallurgy on the territory of this country (Universităţi cu învăţământ Superior Metalurgic in Romania). After the occupation of Dacia, within the framework of the Roman organising structure, an important part was played by the craftsmen's 'colleges', which had their own schools for the training of specialists in the field. 'Schola fabrorum' was the blacksmithing school, organised by the Romans at the same time as the 'college', and contributed greatly to the development of the field. After the appearance of the first metallurgical industrial units in Banat, in the 18th century, on January 23rd, 1729, the Mining and Ferrous Metallurgy School of Oraviţa was founded, to be subsequently transferred to Reşiţa 60 years later (1771).

The first notions of metallurgy are introduced by Gheorghe Asachi into the engineering classes of the Greek School of Iaşi in 1813; in 1842, a metallurgy course is introduced in the 3rd-year curriculum in the Exploitation Engineers' section of the same school. In 1867, the School for Bridges, Roads, and Mines is founded by decree in Bucharest, with a five-year course of study, the 4th year of which includes metallurgy courses for the Mining section. From 1881 onwards, the school grants engineering diplomas in the field of metallurgy as well.

In June 1920, the Polytechnic School of Bucharest is created out of the former National Bridge and Road School, including the Mechanics and Metallurgy section and the Mining and Metallurgy section. In the same year, the Polytechnic School of Timişoara is founded. Both establishments train metallurgy engineers for the country's ferrous and non-ferrous industry. In 1928, an Iron Metallurgy Conference is born, which turns into Iron Metallurgy and Metallurgical Machines, which, in 1933, becomes a department in itself, to be merged with the Metallurgy Department led by Traian Negrescu in 1939. It is noteworthy that the first engineering PhD of the Polytechnic School of Bucharest was granted to the American engineer Welton Crook from Stanford University in California in 1936, having Traian Negrescu as dissertation supervisor.

In 1948, the Mining and Metallurgy faculty sections were dissolved and replaced by the Iron Metallurgy Institute of Timişoara. During the academic year of 1949–1950, the 3rd and 4th years of study in the field of metallurgy are created, pertaining to the Mechanics Faculty, yet administratively part of the Iron Metallurgy Institute of Timişoara. During the academic year of 1952–1953, the 1st and 2nd years of study which used to be carried out in Timişoara were transferred to Bucharest and, in combination with the Non-Ferrous Metallurgy section of the Industrial Chemistry Faculty, formed the Metallurgy Faculty, the 6th faculty of the Polytechnic Institute of Bucharest.

The academic year of 1990–1991 marked the beginning of a complex process of reformation in the field of metallurgical education in the way of the modernisation of education technology and the broadening of the scope of knowledge in the field of metallic, ceramic, carbonaceous materials, high-performance materials (composites, intermetallic compounds, amorphous materials, etc.). As a result of these considerations, in 1990, the Metallurgy Faculty of the Polytechnic Institute of Bucharest became the Materials Sciences and Engineering Faculty, a change which was registered in other academic centres in the country, where faculties with this specialisation were founded (Braşov, Cluj Napoca, Iaşi, Galaţi) in 1990. Sub-engineers' institutes were created, such as the ones in Reşiţa (1971—a sub-engineers institute;

1990—an engineers institute; 1992—the 'EftimieMurgu' University) and Hunedoara (1970—a sub-engineers institute; 1990—an engineers institute, the POLITEHNICA University of Timişoara).

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History of Oil Industry

Gheorghe Buliga

Abstract In the present chapter, the evolution of the oil industry in Romania is presented, starting with the 19th century until today. Romania was one of the first countries to refine crude oil, starting with 1857 when the first refinery was established. Rich in oil resources, Romania has made the most of this advantage, developing a powerful oil exploitation and refining industry. The evolution of exploitation and refining technologies is presented in the chapter, marking the significant stages of this development as well as the scientific personalities who marked it. The Romanian School of Petroleum formed its specialization at all levels: conception, management and execution, which produced technologies, machinery and specific equipment at world technical level. Engineers, geologists, other Romanian specialist and researchers, in addition to developing the appropriate technologies, have made important contribution to the global progress of geophysical investigation methods by electrometry in geophysical prospecting and electric core drilling, deep well drilling technologies; substantiated and successfully experimented with the technology of extracting heavy and viscous crude oil by in situ combustion; they experimented with many unconventional methods for increasing recovery factor from the fields; built plants for machinery and equipment, so that between the 1970s and 1980s Romania became the second world exporter of oil machinery.

1 The Period Before the First World War

Today oil is the main energy resource in the world. In Romania petroleum industry started in 1857 when brothers Marin and Theodor Mehedinţeanu from Ploiești, distilled, in the plant they conceived, 275 tons of lamp oil, used in the street lighting of Bucharest city (Buliga 2007). The year of 1857 also marked the birth of the world's petroleum industry (Buliga 2007; Ivănuş et al. 2017).

In the Romanian territories, petroleum springs covered a large surface. Crude oil has been used since antiquity in the form of bitumen for water tightness in ships, as a

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Fig. 1 The beginning of the world oil industry 1857: Ploiesti—the first oil refinery in the world 1857: Bucharest—the first capital in the world to be illuminated using lamp oil

medicine, to ignite wicks, and to ignite the fire at the fortress. In the Middle Ages oil continued to be used for the same purposes, and the Romanian Principalities were exporting large amounts of crude oil. Until 1855 oil production had not come out of the primitive phase, still being extracted by the local peasants who had acquired some skills and also learned how to sell it.

The extraction was made through shafts (fountains) dug by hand or from pits (dug at the surface of the ground and sealed with the earth resulted from the excavation) (Fig. 1).

The success of Mehedinţeanu brothers encouraged the replacement of rapeseed oil with lamp oil in many countries (Buliga 2007). At the same time, 1857/1858 in the U.S.A., a certain entrepreneur, Kier, set up a boiler for distilling lamp oil.

The increase in oil demand is supported by the discovery of 'Colonel Drake' who digs a well using, for the first time, a mechanical rig of its own design through which oil shot out.

In Romania the oil shafts were manually dug and supported with planks or wicker, under high risk for workers, including danger of asphyxiation, collapse of shaft walls or free eruptions, whether or not accompanied by fire. Both the drill cuttings resulting from manual digging, and the oil extraction were carried out using a wooden bucket connected to a rope which at the surface was passed over a beam or pulley manipulated by hand or by two horses (Fig. 2).

The first well in Romania was made in 1861, in Mosoare, near Tg. Ocna (Buliga 2007).

The rig was executed by the French company Huig. A drill bit was used for drilling, as well as wooden rods rotated manually reaching a depth of 150 m, but the well proved to be unproductive.

In 1889 the Romanian Society of Petroleum Industry and Trade was founded with the support of Offenheim and Singe banks in Vienna, and it owned refineries

Fig. 2 A 'hecna' device operated by horse

in Câmpina and Bucharest, as well as private fields in Moinești and Solonţ (in the region of Moldova).

Due to the lack of capital and experience, only 134 wells were drilled in the period up to 1896, out of which only 71 were productive (most of the production was obtained from 1,215 shafts dug manually).

Even with all the difficulties encountered in oil extraction, and with the challenges due to the lack of capital and sale logistics, the production increased from the 275 tons refined by Mehedinţeanu brothers to 81,570 tons.

The participation of foreign companies to oil extraction in Romania has stimulated innovation in drilling, so that in 1895 the first metal drill rod was used, and in 1896 the percussive drilling system was used to drill the wells in Poiana Vărbilău, Poiana Câmpina and Băicoi.

In 1896, the Romanian United Petroleum Company introduced Fauwelle's hydraulic drilling system. The principle consisted in the permanent cleaning of the well bottom with a powerful jet of water.

In 1897 the Dutch company Amsterdam Câmpina dug, for the first time in the world, on the strand of Prahova River, three wells with the help of electric power, and in 1899 the Bucea rig (Câmpina) became the first electrified rig. In 1899 German drilling systems started to be used (Thuman, Trautzl, Vogt), as well as the Romanian systems Raky and Alianţa.

The results of the wells drilled with these systems led to lengthy disputes on inserting the column casing in the hole, and how to achieve a sealing against the waters from aquifers. In 1901, the Colix Drill drilling system was used in Cosmina, the drilled well having a depth of 300 m.

An important event in the history of Romanian oil industry is the inauguration of the technical, scientific and commercial periodical titled *Monitorul petrolului român* published by the Association of Oil Prospectors and Manufacturers of Romania. The periodical appeared continuously until the nationalization in 1948. Its publication was resumed in 2002 (being re-established by Dr. Eng. Gheorghe Buliga and economist Violeta Dumitriu). The publication retains the initial structure of *Monitorul petrolului român* and it is published by the Society of Petroleum and Gas Engineers (SPIG) (Buliga et al. 2016, 2017).

The accelerated rhythm in which the oil demand developed could no longer be sustained using unqualified workers and improvised equipment, and in anticipation of the new industry, the year of 1900 marked the World Exhibition held in Paris, as well as the first World Petroleum Congress.

In 1904 the School for Drilling and Refining Foremen (FOREMEN) was founded in Câmpina. The first director of this school was Dr. Eng. Vasile Iscu, subsequently professor at the Academy of Commercial and Industrial High Studies in Bucharest. The study period was set at 22 months: the first 6 months were dedicated exclusively to practical work, the next 10 months to classroom theoretical study, and the last 6 months the students had to fine-tune their practical abilities with the theoretical knowledge. In July 1906, 56 graduating students received their diplomas, being the first series of Romanian welding foremen (masters in drilling).

The third World Petroleum Congress is held in Bucharest in 1907, under the high auspices of Prince Ferdinand, the successor to the throne. It was the first Congress to be organized in an oil producing country. Renowned personalities in the fields of industry and science in Romania were members of the organizing committee, among whom C. Alimănișteanu (Director of Industry, Trade and Mines within the Ministry of Industry and Trade), Ludovic Mrazec (renowned Romanian geologist, member of the Romanian Academy), Dr. Eng. Lazăr Edeleanu, and Anghel Saligny (professor at the School of Bridges and Roads) (Buliga et al. 2008). The Congress was structured into three sections: Section I Geology, exploration, exploitation, Section II Petroleum chemistry and technology, and Section III Legislation and trade. The Congress was honoured with the participation of personalities from England, Austria, Galicia, Belgium, France, Canada, Germany, Italy, Mexico, Holland and Portugal.

In 1901, the American rotary system is introduced at the oil drilling rigs in the Prahova Valley, and in the year of 1906, the drilling of the wells in Neamţ and Prahova counties was experimented using the rotary mass hydraulic system. With the rotary system, the first production well (7 Astra Română) is drilled at a depth of 1,170 m, in Filipești de Pădure (Buliga et al. 2017). The rotary hydraulic drilling system was tested in Texas (U.S.A.) in 1901, and was generalized in Romania during 1925–1927; however with one exception: the depth of the wells did not exceed 700-800 m in this period of time. For wells that no longer had an eruptive charge, the deep pumping method was applied starting with 1909 (Fig. 3).

The Romanian chemist Lazăr Edeleanu patented, in Romania, the 'Edeleanu technique of refining petroleum with liquid sulphur dioxide' which he successively patented in countries producing and consuming lamp oil. Thus, the Edeleanu technique was patented in England in 1908, in the United States in 1909, and in the Austria-Hungary in 1910. Based on this patent band on his lab research, Dr. Lazăr Edeleanu, as manager of Vega refinery, built the first pilot plant and then a distillation plant of two tons/day, whose capacity had afterwards tripled (Buliga et al. 2008).

Fig. 3 Lazăr Edeleanu

In 1908, the company Societatea de reparat foraj (in short the 'drilling plant') was established in Ploiești, having 65 Romanian shareholders. The plant was taken over first by the company Creditul Petrolier, and then by the company Concordia. After the nationalization in 1948, its name was changed to 1 Mai Ploiești, and in the end to UPETROM 1 MAI—Ploiești.

The increasing demand for Romanian oil has prompted the Ministry of Public Works to organize a commission tasked with the study of petroleum-bearing regions. The report drawn up in 1909 by the most renowned experts of that time (C. Alimănișteanu, L. Mrazec and Vintilă I. Brătianu) included general geological considerations and statistical data on the deposits in Romania, the extensive geological map of the territories between Nistru and Tisa rivers on a scale of 1:330,000, as well as the map of petroliferous areas.

In 1912, the financing of a pipeline for crude oil and lamp oil transport was approved, based on a project of the Romanian engineer Anghel Saligny, on the route Băicoi-Ploiești- Constanţa (Palas), with a total length of 300 kms.

When Romania entered the First World War (August 30, 1916), the pipeline construction had been completely accomplished except for the sections crossing the Danube River.

During the German occupation, 40 kms of the pipes for lamp oil were dismantled in order to be used in building a new pipeline on Baicoi-Giurgiu route, to intensify the export to Germany by the Danube River.

In 1913, Romania had the largest production before the First World War, amounting to 1,885,619 tons, the domestic consumption being of about 811,200 tons, while the quantity exported was of 976,045 tons (Ficsinescu and Dobrescu, 1940; Buliga 2016)

2 The Romanian Oil Industry in the Interwar Period

For the petroleum industry in Romania, the interwar period begins with a negative balance due to the great destructions caused by the First World War. According to the statistics, the 104 oil companies which existed in Romania in 1919 did not drill any wells, and the production already in decline dropped to 920,488 tons of crude oil extracted.

After the Great Union, the difficult situation could be overcome only through the industrial capitalization of the soil resources, and especially the mineral resources. For mining, in the context of the recovery of an oil industry which developed over 59 years, the regions of Țara Românească, Banat and Transilvania were the main pillars on which Greater Romania would be built.

Even before the First World War, the National Commission for the Unification of Petroleum Testing and Testing Methods was established in order to uniformly define the qualitative parameters, to have a unique procedure of technical assessment of products in the international oil trade.

The Romanian geophysicist Iulian Gavăţ was the first specialist in the world to highlight the characteristic effect of gravimetric anomalies in prospecting gas fields and petroleum fields. The gravimetric prospects carried out by Iulian Gavăţ during 1928–1938 revealed the oil-bearing structures in Aricești, Florești, Băicoi-Țintea, Siliștea Dealului, Măgureni, Tufeni, Novăcești, Viforâta-Teiș, Lăculeţe-Târgoviște.

Another great personality of this period was Sabba S. Ștefănescu. Born on July 20, 1902 in Bucharest, he attended the St. Sava High School in Bucharest and St. Louis High School of Paris, and graduated the Paris School of Mines. Attracted by the perspectives of geophysical investigations, based on field measurements of rock characteristics, he followed an internship at the Schlumberger brothers' company, in collaboration with whom he researched and laid the theoretical basis of electrometric measurement methods in vertical bore holes. The method of electrometric measurements (electric bore-hole logging) of well holes was introduced and generalized in Romania and worldwide.

Returned in the country, between 1937 and 1987, Sabba S. Ștefănescu worked at the Geological Institute of Romania as chief of the geophysical prospecting department and chair professor of the Institute of Oil, Gas and Geology (1950–1967). He continued his research activity in the field of prospecting, by means of electrometric measurements and magnetometry among others. He published numerous works of reference in earth's field theory: gravitational, magnetic, seismic and radiometric. He was a member of the Romanian Academy, chairman of the National Geodesy and Geophysics Committee, and honorary member of the American Geophysical Union.

The Romanian specialists' interest in the improvement of drilling performances has been materialized in some inventions remarkable for that period. It is worth mentioning the invention of engineer Petre Oteleșteanu called 'dry rotation survey for oil—Romanian system' (1921), and the invention of engineer Eugen Mărdărescu named 'a rotational drilling system' (1925) (Figs. 4 and 5).

The technical progress of this period includes:

Fig. 4 Well 5 Steaua Română, 1929

Running and cementing an 11-inch casing at well 2904 Astra Română, using Perkins method (with two cementing plugs and hydraulic mixer);
Use of the first BOP (blast out preventer/eruption preventer) at well 100 Astra Română in Moreni (1926);
The application of electric bore-hole logging to a drilling hole for the first time in the world by the Schlumberger Company (1927);
The first use, by the Romanian refinery Astra Română, of internal combustion engines in the drilling the well 2 Iordăchioaia (1928);
The refinery Steaua Română drilled and ran a unique 8.5/8-inch casing at a depth of 1,900 m.

As the drilling depth increased, the risk of violent free eruptions also increased. Such an eruption occurred at the well 298 AR in 1928. The eruption was stopped by Andreescu brothers.

Fig. 5 Eruption (Blast out) at the Romanian-American well 298 (Moreni 1929)

The most spectacular and destructive eruption, accompanied by a large scale fire was the eruption at the Romanian-American well 160, which broke out on May 28, 1929, while the drill was operating at a depth of 1,460 m. The free eruption blew up the drilling rig and burned it down. The height of the flame reached 100 m, making it visible from a distance of 80 to 100 km. Other 25 wells in the vicinity were damaged and stopped their production, and the population in the area was evacuated. The fire allowed the international teams of reputed specialized fire-fighters and oil workers to come no closer than 300 m. The well continued to burn until November 4th, 1931, when the eruption stopped on its own and the flame extinguished. The human lives lost and the damage caused to the environment were unprecedented. The estimates have shown a burned quantity of nearly 20 million tons of crude oil, along with expenses of 5 million USD.

The drilling systems used in the first part of this period were the Canadian system, the Pennsylvanian system, the Alianţa system, and the rotary system. These systems are maintained until around 1933.

A 1931 statistics on the use of drilling systems shows that:

The rotary swinging system was used in drilling 144 wells, totalling 142,068 m;
The Canadian system was used in drilling 6 wells, totalling 984 m;
The hydraulic system was used in drilling 3 wells, totalling 721 m;
The Alianţa system was used in drilling 2 wells, totalling 468 m;
The Raky system was used in drilling only 1 well at 33 m.

In the 1930s the maximum depth achieved by different systems was as follows:

700–900 m with the Canadian system;
900 m with the Pennsylvanian system;
1,800–2,000 m with the rotary system. The cost of drilling one meter with a rotary system up to a depth of 1,800 m was of 140 LEI-gold, and a well amounted to 240,000–260,000 LEI-gold, the equivalent of 2,300 wagons of crude oil.

A number of upgrades are performed at the oil sites: the company Astra Română built a mechanical workshop at Ochiuri, and in 1928 it introduced separate gases into the household consumption of Ploiesti city, the gases being separated in the nearby separation plants.

During 1933–1936, the rotary drilling system was generalized in Romania, replacing the percutaneous system and Alianţa system.

The technical activity in the oil industry was led by engineers trained at the Mine Departments of the Polytechnic Schools in Bucharest and Timișoara, geologists and chemists, most of them graduates of the Polytechnic or Natural Sciences Faculties of the Universities of Iași, Bucharest and Cluj, or graduates of foreign specialized schools.

The rotary drilling technology has been revolutionized thanks to patents registered in Bucharest and at the U.S.A. Patent Office by the Romanian Ph.D. Eng. Ion Basgan.

Ion Basgan's Patent No. 22789 on 'Proportional Heavy Oil Drilling Rods and Sonic Drilling' was registered in Romania in May 1934, as well as the application for 'the Basgan effect'. The same year, the invention was sent to the American Petent Office, and in December 1937 Ion Ștefan Basgan received the Invention Patent (Letters Patent 2,103,137).

Since 1935 Ion Basgan had been applying the new Basgan drilling methods at the oil fields of the Romanian Oil Society with exceptional results (Fig. 6).

Ion Basgan's patents have had an overwhelming importance for the further development of the oil industry, as they allowed the drilling depth to safely exceed 2,000 m, making vertical holes, increasing the drilling speed, and discovering new deposits of oil and gas.

Fig. 6 Dr. Eng. Ion Basgan

Although the patent offered the owner guarantees that the invention would not be used without the owner's consent, the American drilling companies made profits of billions of dollars out of using the invention, and the owner did not receive anything from the U.S.A. Patent Office in the City of Washington.

The extent of the petroleum industry in Romania is revealed also by the weight of petroleum products exported in the total foreign trade of Romania; from this perspective the weight during 1932–1940 was as follows: 1932—43,1%; 1933—55.3%; 1934—52,8%; 1935—51,7%; 1936—41.35; 1938—43.24%; 1939—41,87%; 1940—62,4% (Ficsinescu and Dobrescu 1940; Buliga 2016).

3 Oil Science and Technology After the Second World War

On August 23, 1944 Romania breaks the Alliance with Germany and with the Axis powers. A government of national unity is formed, which decided to cease the military operations with Germany, and to intensify the fights against Germany and Hungary on the Allies' side, under the command of the Soviet Commandment. The Armistice Convention stated that in the field of petroleum Romania had to supply oil and petroleum products for a period of 6 years as war damage compensation, including a compensation in other goods that had to be delivered, as well as to unconditionally supply petroleum products to the Red Army at the price level of 1938 (which represented just a third of the real prices of that time).

On October 25, 1945, the Council of Ministers of Romania approved the creation of the Soviet-Romanian joint company Sovrompetrol, a public limited company. Its share capital amounted to 5 billion Lei consisting of 5 million shares. The equity participation was 50% each (Buliga 2007, 2016).

In April 1948, the New Constitution of the Socialist Republic of Romania was approved. According to it 'the subsoil resources of any type, the mining ores, the natural energy, the communication means, the railways, the roads, the air and the water, the mail, the telegraph and the telephone belong to the state as common possession by the people".

In the same year, on June 11, the Law on the nationalization of industrial undertakings, banks, insurance companies, and mining and transport companies also stated that 'all the resources in the soil that are not in the property of the state on the date when the Constitution of the Socialist Republic of Romania comes into force are nationalized, as well as any other individual undertakings, companies of any type and private industrial associations (Buliga 2007). Any shares in such companies and associations become the property of the state, free of any obligations, as common possession by the people, and controlled by the Ministry of Finance'.

After the nationalization, the undertakings with national or foreign private capital, as well as the state capital companies were reorganized by the Ministry of Mines and Petroleum.

According to the Decree no. 263327/1948, the Institute of Oil and Gas was established in Bucharest. It is the first higher education institution in Romania and Europe (with the exception of the Soviet Union) which focused only on petroleum. The Institute included four faculties: the Faculty of Geology, the Faculty for Prospecting, Exploration and Exploitation of Petroleum and Gas Deposits, the Faculty of Oil Technology, and the Faculty of Tools and Machines for the Oil and Gas Industry.

The first annual plan of the Socialist Republic of Romania for 1949 stipulated that both the level of the oil production registered in 1948, and the research for the discovery of new deposits continued to increase. Drilling increased by 48.2% compared to 1948, out of which 83.3% was exploitation drilling, and 31.3% was exploration drilling.

In 1949, research and design centres/institutes are created in Câmpina and Ploiești.

In the field of drilling, at the old drilling rigs Aideco, Emsco, Wulfel, Trauzl (in Germany), Reșiţa or Concordia, multiple-chain transmissions with wood derricks are replaced by guyed derricks built in Reșiţa, driven by steam engines. In the early 1950s, the first Soviet Uralmash-type drilling rigs appeared in Romania, equipped with 4 type 4D tank engines, out of which two for driving the pulley, and two for driving the mud pumps. The tools and devices were still made in Concordia workshops or in the workshops of oil companies (Strungul and Steagul Roșu in Brașov).

The well drilling goes beyond the artisanal 'art and science' stage to specific operations and rigorous research in order to improve and increase the success in obtaining the established objective.

Drilling is done based on projects developed by complex teams of design institutes, including geologists, drilling engineers, chemical engineers specializing in drilling fluids and cement pastes, etc. The permanent supervision of drilling is entrusted to foremen and drilling engineers.

In the context of the national industrialization policy of that time, research and design institutes were established for all the branches of the national economy. In the petroleum extraction industry, the Institute of Research and Design in Câmpina, the Institute of Drilling and Petroleum Exploitation (the current PETROSTASR) in Ploiești, and the Institute of Research and Development of Oil Equipment (IPCUP) in Bucharest/Ploiesti were established.

After 1962, the company 1 Mai continued the manufacturing of drilling rigs and succeeded in producing 147 pieces of the 5D-150(R) drilling rig and 450 pieces of the 4LD-150 drilling rig. It also carried out and developed the manufacturing of the drilling rigs 3DH-250 and 4DH-250 for well depths up to 4,000–5,000 m. Until 1965, a complete family of drilling rigs was produced for drilling wells of depths between 2,000 and 8,000 m: 2DH-75 and 2DH-100 were manufactured at the IUP plant in Târgoviște, while 3DH-200, 4DH-415 (with the alternative 4DH-450) and others were manufactured at 1 Mai plant in Ploiești, completely equipped with all driving, rotary and circulation systems, hydraulic coupling converters between Diesel engines and drilling intermediary, and equipped with the necessary control, adjustment, auxiliary and other devices.

In 1971, 1 Mai plant achieves—for the first time in Romania, based on a design of IPCUP and PETROSTAR—an offshore drilling rig (FOMAR) for depths of up to 6,000 m, which was set up on the offshore drilling platform Gloria in the Black Sea. This was the first sea platform designed and made in Romania. Subsequently, this

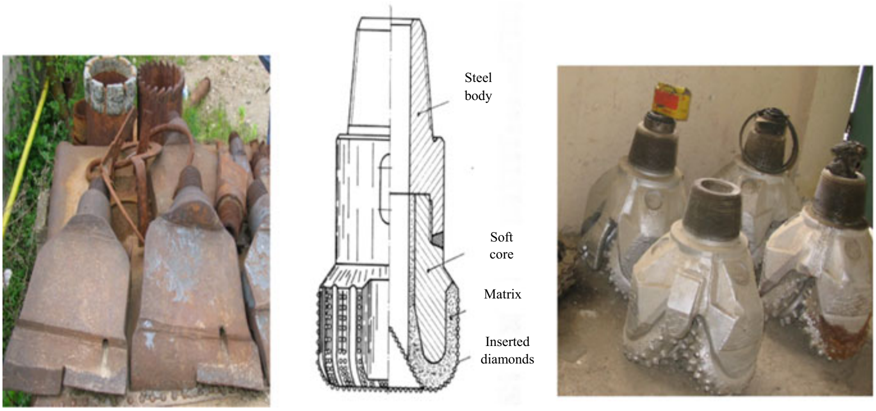

Fig. 7 Drilling bits

rig was set up on all the other offshore drilling platforms designed and manufactured in Romania, namely Orizont, Atlas, Prometeu, Jupiter, Saturn and Fortuna.

A new family of drilling rigs (with the code name 'F') was designed by IPCUP, namely F-80, F-100, F-125, F-200, F-320, F-400 and F-500, with hook load between 80-500mt, and driving (action) power between 800 and 3,000HP. It was available in diesel-hydraulic, diesel-electric or mains power versions, performing well drilling at a depth between 1,000 and 10,000 m (covering almost all of the drilling depths available worldwide at that time) (Figs. 7 and 8).

The drilling rig F-400 (well number 7000) drilled in Băicoi at a depth of 7,012 m was the deepest well in Europe since 1983.

The specific machinery for oil and gas exploitation (workover hoist, pumping units, Christmas trees, roller rock bits, core barrels, diamond crowns, blow out preventer units, cementing and hydraulic fracturing aggregates), and the ensemble of tools and devices for drilling and extraction activities were designed and manufactured in Romania.

With the start of drilling in the Black Sea, on the first offshore drilling platform named Gloria, the Romanian foreman faced with new and difficult scientific, technical and logistics problems to solve.

The Romanian engineers from the Marine Drilling Group within the company Special Drilling and Geological Works Enterprise (IFLGS) (formerly known as ISEM and ACEX, and recently FORADEX)—initially specialized on the American platforms in the Gulf of Mexico—started working on Gloria drilling platform under the leadership of engineer Ion Floarea, platform leader, and then on other platforms under the leadership of the chief engineer and technical director Septimiu Seiceanu (Fig. 9).

The engineer Septimiu Seiceanu and other brilliant Romanian drilling engineers have brought fame to the Romanian drilling specialists. Septimiu Seiceanu was born on September 14, 1926 in Deleni (Mureș County). In 1950 he graduated from the

Fig. 8 Drilling rig F.200

Fig. 9 Gloria platform

Fig. 10 Septimiu Seiceanu

School of Mining, Metallurgy and Petroleum within the University Politehnica of Bucharest, in the last class of the faculty, while his father—Zaharia Seiceanu—had graduated its first class, being the first scholar sent by the Management Council to the University Politehnica of Bucharest (Buliga et al. 2014, 2016).

His dream of drilling in the Black Sea became reality the moment the construction of Gloria Marine Drilling Platform began. He led and supervised the construction and transport from Galaţi to the site of the Lebăda geological structure, and he was involved in great detail in the positioning of the platform and the organization of the drilling crew.

In charge of acquiring the license of the drilling platform, supervising its technical execution, as well as the design of the drilling technology, Septimiu Seiceanu proved his high professionalism, requiring that the highest world standards are applied in all of the activities.

The extraordinary end of his engineering activity and as director of the drilling operations of Petromar Constanţa, before his retirement, was the construction in 1994 of the first horizontal oil exploitation well in Romania, LO-1 well, drilled based on an original design, with the support attached to the existing jacket, the well having a horizontal segment of 600 m. Until 2005, this well produced 128,000 tons of oil from a deposit considered to be unexploitable by vertical wells (Fig. 10).

4 Research and Technological Design in the Period of the Planned Economy

The technological/technical research in the field of oil extraction was carried out mainly at the Institute of Research and Technological Design in Câmpina. The Institute started its activity in 1950 under the name Câmpina Central Research Laboratory, created on the structure of the former Technical Division of the former company Astra Română, a subsidiary of Royal Dutch-Schell (founded in 1910), and in 1974 became I.C.P.T. Câmpina.

For more than four decades, the Institute has played a leading technical and scientific role in the oil and gas extraction industry. His role was of the highest importance in initiating geological prospecting programs and grounding of the economic and technical decisions regarding oil exploration and exploitation in Romania and in other countries having commercial and scientific relations with Romania.

Within the I.C.P.T. Câmpina, the many problems of the petroleum industry have been tackled through the research and development of new and improved technologies, products, and new or improved methods, some of which are subject to over 500 patents, part of these with wide application, due to their economic effects.

At I.C.P.T. Câmpina, a new interdisciplinary field appeared: engineering of hydrocarbon deposits having as main representatives Dr. Eng. Gheorghe Aldea, Dr. Eng. Nicolae Cristea, Dr. Eng Alexandru Vernescu, Dr. in geology Traian Mocuţa, Dr. Eng. Paul Călin, Dr. Eng. Aurelia Panaitescu, and many other researchers and specialists. Professor Dr. Eng. Constantin Popa worked in this field at the Petroleum and Gas Institute of Ploiești (Buliga et al. 2014).

The Institute has initiated, designed and conducted experiments and industrial processes for increasing the final factor of oil recovery in crude oil deposits in correlation with the physicochemical characteristics of the deposit and the saturation fluids, such as injection of water, injection of polymers, injection of alkaline solutions, methods of bacterial displacement, and others.

The Romanian Petroleum School organized within I.C.P.G.T. Câmpina has won one of the most successful international projects by initiating, researching and developing the industrial experiment for 'the exploitation of heavy and viscous crude oil' via the underground combustion method applied on the deposit in Suplacu de Barcău. In solving the complex theoretical and practical problems regarding in-situ combustion, a special contribution was made by engineer Valentin Petcovici, Dr. Eng. Gheorghe Aldea, Dr. Eng. Alexandru Turtă, and Eng. Mircea Zamfir.

5 The International Cooperation in the Field of Science and Technology

Romania was a prestigious participant and partner at the International Oil Conference of 1900 (in fact the first World Petroleum Congress), being well represented through lectures that sparked the interest of foreign scientists and specialists. At the second edition of the International Oil Conference—held in *Liège* (Belgium) on June 13–26, 1905—, the representatives of the Conference Committee included Romanian scientists and oil men Dr. Lazăr Edeleanu, Ludovic Mrazec and engineer C. Alimănișteanu. The participation was renowned thanks to the lectures of Romanian participants on geology, chemistry and the rational use of products, as well as through the Romanian Exhibition Pavilion.

The Romanian participation was such a remarkable success that the next Conference was held in Bucharest in August 1907, when the Conference was transformed into the World Petroleum Congress. The Congress in Bucharest was accompanied by the Petroleum Exhibition rigging at Filaret, and was followed by visits to some fields, especially in the Câmpina area. Romanian scientists, engineers and national authorities were welcoming the hosts and active participants to the success of the high level technical and scientific meeting.

The event was largely publicized by the young periodical making its appearance at the beginning of 1905, titled *Monitorul petrolului român*, a bilingual magazine (printed in Romanian and French) that appeared continuously until 1948, and was the mirror and the complete and competent tribune of all oil-related events in Romania, being a part of the world's broad oil movement as well.

More than half a century after the publication *Monitorul petrolului român* ceased, at the initiative and under the supervision of Dr. Eng. Gheorghe Buliga, in March 2002 it resumed its place among the Romanian periodicals, under the title *Monitorul de petrol și gaze.*

In 1979, Romania hosted the 10th edition of the World Petroleum Congress in Bucharest—the first recurrent World Petroleum Congress to be organized for almost three quarters of a century—, a prestigious event much appreciated by participants coming from around the world. Over the years, Romanian specialists have had great contributions in oil extraction technology and processing of oil.

The oil specialists were trained by the Institute of Petroleum, Gas and Geology in Bucharest (currently Petroleum-Gas University of Ploiești) (the training covered the entire field—from exploration to the marketing of finished products). Over the years, thousands of students from different countries in Europe, Asia, the Middle East, Africa, Indonesia, and South America have studied, have been trained and have acquired a graduate engineer or doctor engineer diploma at the Institute, as well as hundreds of engineers attending the UNESCO postgraduate training organized by the University (Buliga et al. 2008).

The consultancy and technical assistance activities have been another part of the cooperation between Romanian specialists and companies from different countries around the world. Research and development activities have been carried out in countries such as Albania, Bulgaria, Russia, Greece, Algeria, Nigeria, Libya, Egypt, Turkey, Syria, Jordan, India, Ceylon (Sri Lanka), Pakistan, Colombia, Sudan, Madagascar, Angola, Yemen, Venezuela, Ecuador, Vietnam, France, Canada, USA, Italy.

Through ROMPETROL's foreign trade company exploration, exploitation-drilling oil pipelines, liquefied gas tanks were carried out after 1990. The technical and scientific collaboration in the field of oil materialized in the preparation of two advisory studies on the *Evaluation of Romanian hydrocarbons potential* carried out in collaboration with the American Society Harms and Brady from Denver, Colorado (project manager Dr. Eng. Gheorghe Buliga).

The study evaluated the total amount of organic matter (total organic carbon, TOC) that could have been bituminous organic matter in geological periods, and the prospective areas to be prospected and explored.

The second study was titled *Romanian Oil Gas Reserves and Evaluation of Production Practices*, and was contracted to the company Interra-Bergerson from

Denver, Colorado (project manager Dr. Eng. Gheorghe Buliga). The study was the foundation for the preparation of Romania's 20-year oil strategy.

6 The Technological Development of the Romanian Oil Industry After 1990

During 1990–2000, in a complex internal and international context, Romania faced a series of structural changes, reorganizations and privatizations.

After the entry into force of the Law no. 31 of 1992, the oil industry was reorganized into two autonomous companies ('regii autonome'): Petrom R.A. and Romgaz R.A. The activities, such as drilling, and undertakings specializing in services have been outsourced and privatized. Six of the seven drilling platforms were sold to the company Grup Servicii Petroliere.

Over time, the company Grup Servicii Petroliere operated on platforms acquired in the Persian Gulf and the Black Sea, in the economic zone of Turkey.

Petrom (Petrom-OMV after the privatization at the end of 2004) operated on Gloria Platform transformed into a production platform.

Prior to the privatisation, Petrom having a scientific from ICPT Campina and the university profile education requested and supported the company Prospecţiuni S.A. in acquiring two geophysical seismic stations, together with the specific interpretation software, in order to create 2D and 3D (two dimensional and three dimensional) seismic profiles. Based on the recorded seismic profiles, corroborated with the modelling software for sedimentation basins and the new concepts of 'petroleum systems' in petroleum geology (introduced in Romania by the geologist Nicolae Constantin Balteș and Dr. Eng. Gheorghe Buliga), it was possible to make an evaluation of the potential petroleum generated and have a possible identification of new areas for discovery of new petroleum deposits.

The last decade of the 20th century brought about a revolution as regards the 'guided/directional drilling' through the development of technology and manufacturing/acquiring new equipment such as bottom hydraulic motors, devices for the continuous measurement of deviation and bore hole orientation, together with automatic fault correction devices and software for the planned route, which allowed horizontal wells to be made on long-distance routes in oil/gas fields, greatly increasing the drainage area around the well bore (Fig. 11).

Important improvements have also been made to surface equipment in drilling rigs such as the top-drive replacing the rotary table, the use of automated tools, the continuous recording of drilling parameters on computer-assisted Martin Decker devices (six to nine parameters), the improvement of the mud cleaning system using the Swaaco screens, the use of desanders, desilting devices for the geological geoservice cabins. The crude oil extraction fields of the company Societatea Naţională a Petrolului PETROM was provided with a large number of cooling-tubing replacing the classic tubing. Also, a large number of classic pumping units were replaced

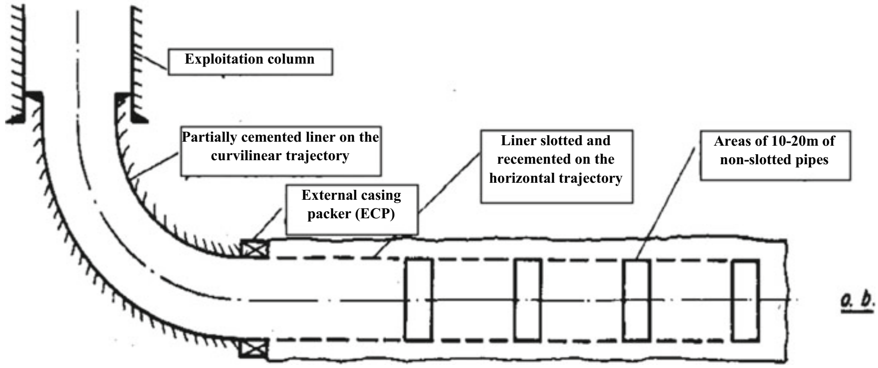

Fig. 11 Horizontal well

with ‘moino’ helical pumps operated electrically from the surface by an engine via sucker rods. A careful consideration was given to filtering in extraction wells by using Johnson filters and graving-packing systems. Environmental problems have been solved by building upstream treatment plants and the injection of extracted waste waters into the deposit.

As far as oil deposits in Romania are concerned, most of them are mature, with a high degree of exploitation. The current recovery factor is below 30%.

By developing secondary recovery processes, an increase of 5% in the oil recovery ensures a Romanian oil production for 10 more years. If one takes into consideration the possibility of discovering new deposits on land and in the economic area of the Black Sea pertaining to Romania (even though in the present the oil extracted does not belong entirely to Romania), the experience and the talent of the Romanian oil men justify the conclusion that oil is still a hope for the Romanian economy.

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History of the Natural Gas Industry

Dumitru Chisăliță

Abstract 114 years ago, the accidental discovery of gas accumulations in the layers of the Transylvanian earth, led to the name of this new form of energy "natural gas", a name kept for many years. The identification of the main gas component as methane brought a new name: "methane gas" and only a few years ago, with the globalization and universalization of products, the name "natural gas" was established. Regardless of the name that bore it, gas has influenced and influenced the economic, energy and even political and geopolitical sectors of the world. All this was possible due to the ingenuity and evolution of the track and the technique specific to the action of resource identification, drilling and exploitation of wells, tartarization and conditioning, transportation and use of gases in the industrial and domestic sector. The natural gas industry in Romania started in 1909, once natural gas was discovered here, this sector being one which registered important European and world firsts.

1 The Dawn of the Natural Gas Industry and Use up to the First World War

Since time immemorial, countless peoples of Antiquity mentioned a substance which was emitted from the ground and caught fire because of electric discharges in the atmosphere.

On the territory of Romania, there were numerous accounts of natural gas, testimonies which were passed on orally (Fig. 1). The first written accounts (Velescu and Bondoc 1978) regarding the existence of natural gas in Romania come from some shepherds who, wishing to extinguish the fire they had made the day before to keep warm during the night, witnessed a veritable miracle: no matter what they threw onto the fire, even loads of soil, it would only burst out more forcefully.

Natural gas is thought to have been officially discovered on 19 April 1909, when a powerful eruption caused by a drilling operation in the Sărmășel area (Mureș County)

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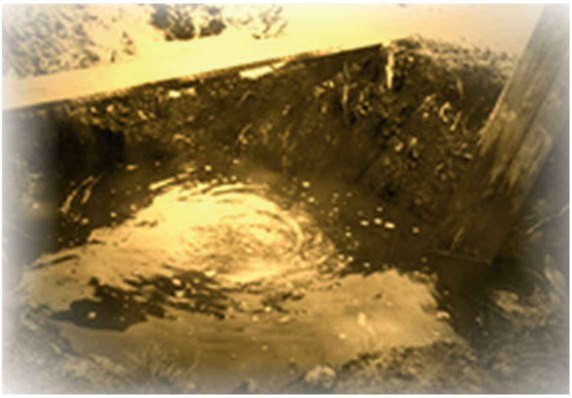

Fig. 1 Gas emissions in Cojocna, Cluj County

revealed an enormous amount of flowing gas, which made the Sărmășel well the fourth largest one in the world at the time in terms of the volume of free-flowing gas (Fig. 2).

In the early stages of the gas industry, when wells were drilled using primitive means (Fig. 3), due to the reduced levels of technology at the time and to the socio-economic system within which these activities were conducted, all the accomplishments in those days were attained while taking great risks as to people's lives and the safety of the deposits.

There is an interesting account in a Hungarian newspaper from the early 19th century which compared the drilling equipment in Romania to that in America: *'American drilling elements were fairly rudimentary, much simpler than those in*

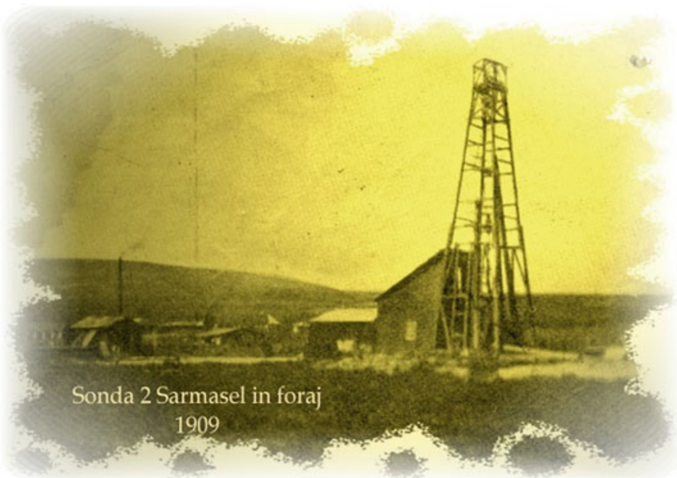

Fig. 2 The drilling of well 2 in Sărmășel

Fig. 3 Drilling rig with a wooden derrick

Europe, yet very practical and efficient. The most conspicuous aspect is that a mere 2–3 people worked around a drilling rig, while, in Europe, aside from the 1–2 qualified workers, another 8–10 day-labourers worked around one' (Kozlony 1912).

After the Unification in 1918, two trends took shape in the Greater Romania (Axenciuc 1977): the unreserved acceptance of foreign capital by the conservatives and the consolidation of Romanian capital. The liberal governments which took the reins of Romania after 1918 preferred a '*collaboration*' (Motaş 1936) between national capital and foreign capital, the purpose being that *'…the domestic capital invested in industry and finances, insignificant at first, should increase gradually, bring profits through broadened capitalist production, so that, in a few decades, it should come to hold a dominant position in the country's economic life, thus outweighing foreign capital'* (Motaş 1931).

Constantin Ioan Motăș, the man who laid the foundations of the natural gas sector, for the first time in Europe, was a patriot and promoter of domestic capital, as he built the first private–public mixed-ownership natural gas company in Europe. Ever since 1918, he had been invited to join the Specialised Committee of the Sibiu Board of Directors and, on 30 June 1919, he was appointed by the board as 'Receiver-Manager' for the Hungarian gas company (Ungarische Erdgas-Gesellschaft AG) in Budapest.

2 The Interwar Period

The discovery of natural gas and the awareness of their benefits led to the ‘birth’ of a new industry: the natural gas industry. While the period immediately following the discovery of natural gas is characterised by the exploration and exploitation of certain deposits using primitive equipment, the transportation of natural gases across small distances being considered a local industry, during the interwar period there is a leap from an industry of the local kind to one of a regional and national kind. 1931 is the year when the Rotary drilling system is used in gas-related activities in Romania, at the Dumbrăvioara deposit (Ciupagea and Vancea 1933). The system consisted of a wooden derrick, the Rotary table, the rig, which was activated by a steam machine, mud pumps, water pumps, a power unit, drilling pipes, and drilling bits.

A drop in the pressure of the natural gases in the first gas field discovered in Romania—the Sărmășel field, due to the increase in methane gas consumption and to the reduction of drilling works caused a need for compression in order to supply the town of Turdawith gas, which came from this deposit. Thus, in 1927, a natural gas compression station was installedin Sărmășel, equipped with 3 Ingersol Rand horizontal motor-compressors (Figs. 4 and 5) (Chestiunea gazului metan din Ardeal 1929).

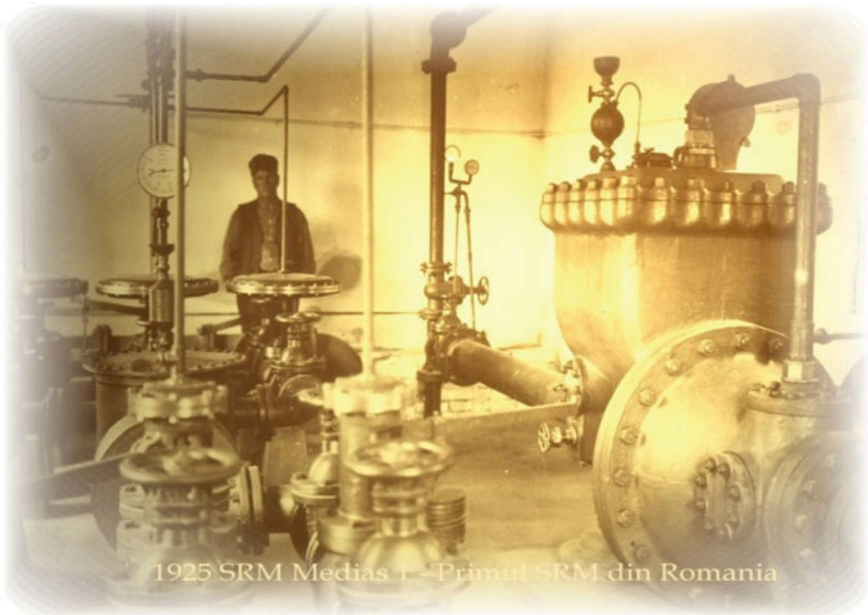

Fig. 4 The first gas regulation station in Europe

Fig. 5 The first gas compression station in Europe

3 From the Second World War to 1990

In 1947–1962, the deep exploitation of old fields starts, as well as the opening of new fields, both in the Transylvanian Plateau and outside the Carpathians. The first geophysical operations in Transylvania were the gravimetrical ones started in 1906. These works were conducted using a torsion balance up until 1936, when they began to use static gravimeters of various types (Thyssen, Truman, Carter, Graf-Askania, Boucher, etc.) (Vancea 1960). In 1959, the ground-current method was introduced and, in 1963, the cross-transmitter method. After the year 1947, the geological research carried out in the Transylvanian Plateau covered the entire surface of the depression (Fig. 6).

Excess Russian natural gas, together with the economic development programmes implemented by Balkan states in 1970–1995, justified and determined the creation of an international transport corridor intended to supply natural gas to countries such as: Bulgaria, Turkey, Greece, etc. The Government of the Socialist Republic of Romania and that of the People's Republic of Bulgaria signed a convention for the construction of a pipe on the territory of the Socialist Republic of Romania to transport gas from the Union of Soviet Socialist Republics to the Republic of Bulgaria (Fig. 7).

The increased demand for gas in Romania due to the reduced volume of new gas discoveries led the Romanian Government to initiate natural gas imports in 1979, via the completed gas importing station in Isaccea, in eastern Romania.

Fig. 6 The construction of transport pipes in Transylvania

Fig. 7 The undercrossing of the Danube enabling gas imports from the former USSR (1979)

4 The Period After 1990

The vertical integration of the company operating in the gas industry determined the continuous development of the natural gas sector along its 95 years of existence. The changes in the years following the revolution, the natural depletion of the deposits, the obsolete installations and technology, the economic recession of 1996–1997, all led to major changes in the activity of this industry.

The economic conditions subsequent to the collapse of the communist regime were more difficult in Romania than in Poland, Hungary, and Czechoslovakia. The great production losses came with a change in prices and a market-oriented economy. The new path that Romania decided to follow, namely the transition from a centralised to a free economy, caused major economic problems.

The greatest first by far, even at European level, one might say, was the legal separation of the gas company, which integrated vertically its exploration, exploitation, transport, storage, and distribution activities into 5 different entities specialised in those specific operating segments: production—SNGN ROMGAZ SA Mediaș, transport—SNTGN TRANSGAZ SA Mediaș, storage—SC DEPOGAZ SA Ploiești, and distribution—SC DISTRIGAZ NORD SA Târgu Mureș and SC DISTRIGAZ SUD SA Bucharest (ROMAZ Archive).

5 Trends in the Natural Gas Industry

The events of the last few years have led to the erosion of trust in nuclear power plants, which translated into a decrease in the level of investments in such plants, as the energy strategies of the world's countries seek to promote natural gas as the leading source of primary energy. These strategies envisage natural gas as the world's most used form of energy in the 2030s. Thus, it is expected that, in 2020, natural gas should account for 27% of the total primary energy consumed in Europe. This primacy of gas, should it become a reality, will be short-lived, as, on the one hand, the secure natural gas reserves are estimated to last 50 years (worldwide) and, on the other hand, the main reserves are found in several regions of the world which are often unsafe and lack the specific infrastructure (Azerbaijan, Turkmenistan, Iran, Iraq, Algeria, etc.).

6 Research Institutes and Professional Associations in the Natural Gas Industry

The Natural Gas Central Agency (Centrala Gazelor Naturale) included a Natural Gas Research and Design Centre (Centru de Cercetare și Proiectare Gaze Naturale) founded in 1971, which operated until 2000, when it was dissolved, without there being any other such institute left in Romania.

In 1939, the first Association of Engineers and Technicians in the Mining Industry (Asociația Inginerilor și Tehnicienilor din Industria Minieră) was created in Mediaș and functioned until 1947. It resumed its activity in 2005 through the founding of the Natural Gas Engineers' Society (Societatea Inginerilor din Domeniul Gazelor Naturale), which operated within the General Association of Engineers in Romania (Asociația Generală a Inginerilor din România) until 2010, when it was dissolved. 2015 saw the creation of the Intelligent Energy Association (Asociația Energia Inteligentă), which set to disseminate and produce know-how, mainly aimed at the participants on the market: consumers, suppliers, producers, operators, designers, builders, employees, and citizens.

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The Shaping of the Industrial System

Victor Axinciuc and Dorel Banabic

Abstract The chapter presents the formation of the Romanian industrial system starting with the nineteenth century until the end of the First World War. The historical context of the development of the Romanian industrial environment is mentioned, the politicians who influenced this development as well as the industrial policies from the end of the nineteenth century and the beginning of the twentieth century. The development of the industrial environment is exemplified with numerous statistical data for different industries.

The traditional Romanian industrial system of the early nineteenth century—the household, crafts, and handmade industry –, eminently manual, scaled to the reduced needs and the required quality and diversity of the rural market (the rich and urban classes consumed mainly imports), was unable to actively generate and host modern production-technology elements. In that given stage of development, a few steps behind the West, Romanian industry could only be renewed and revolutionised through the import of production forces; moreover, in fact, the premises of such a solution were themselves deficient—the absence of adequate paths and means of transport, of capital accumulation, of a specialised workforce, and the profile of the internal market. These would be the main reasons behind the loitering transformation of the old manual system into the mechanised industrial system.

The institutionalisation of market economy after 1859, the creation of an infrastructure and of the other premises facilitated the process of industrial transformation, yet not without the inherent difficulties and accomplishments. Romania's national development in the decades which followed the creation of the national state (1859)

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occurred in the context of the expansion of the industrial revolution and of the industrialisation of Western Europe, the processes and outcomes of which would determine the manners, paths and means of the industrial transformation of this part of the world as well. However, the extent, depth and pace of industrial changes would also depend on domestic circumstances.

The analysis below is carried out in the following historical context: the unification of Moldavia and Wallachia occurred in 1859, thus forming Romania, which became independent in 1877. Transylvania, Banat, Basarabia, and Bucovina became united to Romania in 1918. Before these events, Moldavia and Wallachia were part of the Ottoman Empire, while Transylvania, Banat, and Bucovina were included in the Austrian-Hungarian Empire, and Basarabia was part of Russia. Consequently, until 1877 and 1918, respectively, the Romanian provinces developed in different political and economic contexts, which is why there were significant differences between them as to their level of industrial development. The mechanisation of production processes and services would also bring about the most profound transformations in the Romanian society of the late nineteenth century and of the twentieth century. Although delayed by half a century, the machine revolution did spread into Romania as well, attempting to make up for lost time and reduce the economic setback. Under the partial spur of the Western industrial revolution and fuelled by it, mechanised industry performed the greatest leap in Romania's economic evolution up to that time.

Modern industrial policies. Three decades after the 1859 Unification of Moldavia and Wallachia, in 1886 and 1887, the foreign commercial policy of free trade was suspended and the policy of customs protection of the domestic market was introduced, as well as that of state support for the mechanised industry. A slow, lagging evolution was replaced by a quick industrial kickoff. Thus, the *age of industrial protectionism* (Gheorghiță 1998) and of support for the industry was born and would continue without interruption in Romania for over a century (1886–1989); the role of the state became decisive in the promotion of the industrial revolution and of the process of industrialisation and transformation of Romania from an agrarian into an agrarian-industrial country. Protectionist policies were implemented as a reaction to the undermining of the domestic industry by foreign competition and were aided by the free-trade-based commercial conventions with the Austrian-Hungarian Empire and other states. Progressive circles stood firm in the defence of industrial interests. The liberal government initiated and adopted a protectionist customs tariff in 1886, thus marking the beginning of a long period of protection for the domestic industry, which it will support consistently against external pressure and internal conservative forces. The protectionist customs tariff of 1886 replaced the single customs duty according to the "free-trade" tariff of 7% for all imported industrial products with higher duties, ranging from 8 to 20%; it was an initial, moderate form of protection, yet one that would stimulate the future domestic industry. Subsequently, the customs tariffs underwent various changes as they grew and functioned under that regime for two decades (1886–1906).

Meanwhile, in Western Europe, under the offensive of industrialisation, the assault launched by industrial countries to conquer foreign markets skyrocketed and competition became steeper. Romania was forced to adapt its industrial policies and to increase measures for the protection of its developing industry. In that sense, in 1904, a new customs duty was negotiated by Emil Costinescu, liberal minister of the industry and great industrialist. The new tariff, a remarkable feat of research and elaboration, was applied from 1906 onwards; it differentiated and upped protection, with average import duties of 10–30%, yet going up to 80% of the value of the goods, thus intensifying the defence of domestic industry. This tariff, with certain modifications, would apply until 1924. In parallel with customs protection, *measures of state support for the industry*(Arcadian 1936) are implemented by means of the General Measures for Supporting National Industry Law of 1887, also elaborated by the liberal government upon the initiative of eminent economist P.S. Aurelian. The law granted all industrial companies which met the stipulated conditions substantial advantages for a period of 15 years, among which: *exemption from any direct duties or taxes* owed to the state or commune; the ceding of land of a surface area up to 5 ha for building factories to be owned by domestic capital and used by foreign capital; a deduction of up to 40% of the tariffs for the transport of goods via Romania's railways; exemption from duties for imported machinery and equipment for factories and for imported raw materials unavailable internally; preference over foreign offers with respect to state orders of supplies.

Starting with the year 1912, a new law for the support of the industry is enforced, one with a broader scope, aiming to extend support to include the industries which employed agricultural raw materials produced by the great landowners and leaseholders. The criteria for granting the advantages were modified: a certain level of capital was no longer required, but one was supposed to use at least 20 workers or engines of over 5 HP driving force. The law required that 75% of the workers and at least 25% of the technicians should be Romanian, thus promoting the employment and training of domestic personnel in industry. It also enlarged the range of companies which could benefit, thus including mills, beer and spirits factories, and craftsmen's cooperatives. *The advantages were largely the same*, but they were granted in a diversified manner and for varying periods of time, from 21 to 30 years. The previous support laws only concerned manufacturing branches. However, laws are also passed regarding the extractive industry. The Mine Law of 1895 established the mining regime in Romania for the first time in the modern age; it made the distinction between surface ownership and ownership of subterranean space, which now belonged to the state, along with all its resources, with the exception of oil, which belonged to the land owner. Freedom is thus granted to oil exploitation at a time when large companies were increasingly interested in crude oil extraction and refinement, as a result of the growing demand for petroleum products generated by the invention and spreading of the internal combustion engine, the automobile, etc. However, state royalties would vary between 18 and 24% of the amount of crude oil extracted. The Romanian oil industry would register great progress due to massive foreign investments which would remain dominant in this branch until the mid-twentieth century.

Aided by the general context of the country's modernisation, by protectionist policies, and by state support, machine use quickly makes its way into the branches of the economy: transport and communication, much more intensely in the industry and less so in agriculture. The industrial revolution—in the sense of replacing manual technology with machine activity, which, initially, had a timid start in Romania (Constantinescu 1957) during the period of free-trade policies, expanded during the subsequent period of protectionism, after 1886, into the industrial branches and sub-branches, yet with uneven intensity and distribution. The foundation for building the mechanised industrial system in Romania was constituted by the industrialisation effort, which gave rise to the modern structure of national industry and economy.

Romania's industrial system, which underwent changes from manual technology and labour to mechanised technology, accelerated the expansion of its mechanised component. Based on the industrial survey of 1901–1902 (*** 1904) and on other statistical information, we estimate that the industrial system of the early twentieth century had roughly the following structure: the factory industry, called the large industry at the time, produced approx. 20% of the total; the small industry, that of crafts, mainly manual, had a share in the general industrial manufacturing production of approx. 35%, while the household industry, completely manual, accounted for around 45%. Thus, as it turns out, the Romanian industrial system at the beginning of the period and of the kickoff of machine use appeared to be based mainly (80%) on manual technology and labour. Within three decades, after 1890, fast development led to the mechanised industry outweighing the others in the industrial system; the factors which determined such a growth are analysed extensively in consecrated works.

A series of external and internal stimulating factors combined in order to generate a striking industrial development: the industrial momentum registered by developed countries; large surplus capital on the European market, which stormed into Romania with reduced interest (4–5%); the country's natural riches—oil, forests, agricultural products, animals, etc.—with great export opportunities; very low wages for workers, and especially the laws for the support and protection of national industry, which were applied without any kind of restrictions, ensuring great privileges for foreign investors.

This period remained in history as the most fruitful one for the industry of the first half of the twentieth century. It is the time when industrial machine use set off the quickest, when great investments were made in production capacities, with massive imports of modern machines and installations for the new branches. Foreign capital created hundreds of factories which employed techniques and technologies contemporary to those of Western industry. Investments in the mechanised manufacturing industry increased considerably, as did production, as shown in Table 1.

The statistics of the year 1915, however, include mills and beer and alcohol factories as well, which were not included in the previous data. This shows that the size of the mechanised industry is underestimated in the data of the years 1893, 1906, and 1910.

Returning to the table, what draws one's attention is the boom of newly created mechanised factories between 1893 and 1915, as their number increased from 113

Table 1 The manufacturing industry during the period of 1893–1915 (Arcadian 1936; *** 1904; Păianu 1906; *** 1915; Axenciuc 1992, 2008)

Years	Number of factories	Fixed capital mil. lei	Personnel thousands	Production value mil. lei
1	2	3	4	*5*
1893	113	29.0	7.7	*44.9*
1906	294	111.0	37.6	*239.5*
1910	472	281.5	46.3	*349*
1915	*837*	*361.0*	*60.9*	*584*

Table 2 The installed capacity and the driving force production in industry in 1900–1915

Years	Installed capacity thousand kW				Driving force production MWh	Production per industrial worker Wh
	Total	Extractive industry	Manufacturing industry	Electric power industry		
1	2	3	4	5	6	7
1900	46.5	1.0	35.5	10.0	88.1	14.6
1908	103.5	12.3	63.3	27.9	193.0	28.5
1915	238.3	24.8	116.6	96.9	494.9	62.7

Sources See Table 1

to 837 and the fixed capital from 29 mil. lei to 361 mil. lei, while the personnel grew from 7.7 to 61 thousand. The most important indicator available as to the increase in industrial capacity is the installed capacity and the driving force[1] produced by the power plants (Table 2).

Installed energy capacity means and represents the production capacities of the industry, as, by consuming driving force, the operated equipment and machines produced goods and services at least in the same proportion. In reality, production became proportional to the energy consumption; the installed capacity of the three industrial sectors—extractive, manufacturing, and electrical—increased over five times—from 46.5 thousand kW to 238.3 thousand kW; at the same time, due to the greater usage of installed capacity, the energy produced and consumed rose over 5.6 times—from 88.1 MWh to 494.9 MWh.

The boosts were registered by the extractive industry—particularly that of oil, which became dominant in Romanian economy, as well as world economy, having significant importance, and by the electricity industry. The oil extraction and refinement industry, the production of which was mainly intended for export, would have a powerful influence on the country's industrial economy for half a century. This

[1] The installed capacity and the driving force production, expressed in horsepower in the statistics of the time, were transformed into kW according to the known ratio 1 HP = 0.736 W (Ghiorghita, 1998).

Table 3 The personnel employed in the mechanised industry in 1902, 1906 and 1915 (thousand individuals)

Years	Total	Extractive industry	Manufacturing industry	Share of employed population out of 100
1	2	3	4	5
1902	26.1	5.8	20.3	0.8
1906	47.8	10.2	37.6	1.3
1915	75.7	14.8	60.9	1.5

Sources See Table 1

natural resource, massively capitalised on ever since the early twentieth century, would constitute an important driving factor for the national economy.

The electric power branch appeared in Romania a mere decade after it was put into industrial production in the developed world, once it had been discovered. Although power plants initially produced electricity for lighting, they announced the future process of electrification of the national economy as part of industrialisation. Both sectors, which had great future potential and importance in the building of the industry, the modernisation of the country, and the acceleration of economic progress, registered the most intense growth at the beginning of the century: the first one, of an extractive nature, became 25 times larger, while the second, electrical one increased 10 times. The energy production per inhabitant stands out as significant, as it grew 4.3 times in 15 years, a characteristic fast pace of an industrial kickoff.

The workforce, a decisive factor for industrial production, also registered an expansion, yet much more reduced, which proves that machine use would save a significant part of industrial personnel (Table 3).

In the 13 years, the total personnel of the two sectors increased almost threefold compared to the installed driving force, which increased fivefold. This confirms a process which would accompany Romania's entire industrial development during the first half of the twentieth century, namely attracting into the industry a relatively more reduced personnel contingents compared to the work means put into operation; hence the incapacity of the industrial sector, as it was structured in the first half of the twentieth century, to build a broad outlet and diminish the massive, chronic overpopulation in agriculture.

The result of the accumulation and development of technological production factors was the creation of the **matrix** of most modern industrial branches and the increase in the amounts of manufactured goods. The pace of production was considerable, both for extraction products and for cement, the latter being a manufactured product and one of significance in the context of the expansion of urban construction works at the time. By 1914, Romania became the fourth largest oil producer after the USA, Russia, and Venezuela, yet with a share in the world production of 2.5%.

The main operational factors of the industry highlight an increase in fixed capital 14 times, in personnel 8 times, and in production value over 13 times in those two decades. This proves that there are high-efficiency ratios perceptible in the pace of index growth and of factor usage. However, the fixed capital per worker went up 1.5 times compared to work productivity, which grew 1.7 times, thus confirming the rising efficiency of invested capital. According to statistical sources and consecrated studies, the profit rate, which was of 16–20% on average, varied upwards to 30–40%, hence the possibility of significant capital accumulations and increases. The great financial advantage during this spectacular period of industrial development came from the cost of capital, which was of 6–10% on the internal market and 4% on the external market, and from the profit rate, which was two–three times higher in Romania. These would be the general results of the growth of mechanised industry.

Qualitative development materialised intro the essential, namely the matrix of the mechanised industrial system, with most of its basic branches: food, textiles, leather, wood and furniture, paper and printing, glassware and ceramics, metalworking, construction materials, the electric industry, the extractive industry. As to mechanised industry, from 1913–1915 onwards, it was characterised by a modern structure in the process of forming its branches and sub-branches. However, no branch was complete in terms of capacities and technological and economic components; most of the goods required by the internal market were not produced, neither from the point of view of quantity, nor of range. On average, the mechanised manufacturing industry covered 25–30% of the demand of the consumer goods' market, as mentioned; of these, a larger share, of up to 80–95%, was supplied by certain branches of the food industry, the oil industry, etc., while the smallest share was accounted for by the textile, metallurgical, electrotechnical, chemical branches, etc.

Up until 1914, the industrial revolution and industrialisation were carried out based on imported machines, equipment, and technologies, as Romanian economy was entirely dependent on external suppliers. On the other hand, the oil and forestry industrial branches supplied the external market not with manufactured goods, but with raw materials: crude oil, petroleum products, logs, timber. Thus, the factory industry was structured in such a way as to prioritise the light and extractive industrial branches and missed the backbone of any developed industry, which was considered a standard in the nineteenth and twentieth century: machine, installation, and equipment building. Given the state of the Romanian economy at the time, it had not been possible yet to create and develop these branches. Thus, the industrialisation process in Romania in the second decade of the twentieth century was in its beginning stage and consisted of an industrial structure which covered merely a limited part of the need for industrial consumer goods and mostly approx. 4/5 of the necessary agricultural and extractive raw materials it used came from internal sources. The main branches and sub-branches mainly produced goods of reduced technicity and complexity: sugar, pasta, beer, alcohol, vegetable oils, sweets, cans, bricks, cement, nails, wire, packaging, rope and twine, candles and soap, tanned hides, timber, cereal flour, printed matter, joinery, etc.

Towards the end of this period (1915), the young mechanised industry engaged in its production process approx. 76 thousand people out of an active population of around 3.5 mil., which is merely 1.5% of Romania's workforce, yet accounted for approx. 15–20% of the country's material production. The capital invested in the large public companies was 81% external and 19% domestic; there were also branches with 90% foreign capital: the industry of oil, electricity, cement, sugar, etc. Furthermore, 42% of the engineering and technical personnel and 30% of the administration personnel came from abroad, brought in by foreign companies. Both the capital and the technical personnel at the time appeared to be a stringent necessity, as Romanian economy was still lacking in these respects.

Thus, while the general beneficiary of the mechanised industry was the national economy—the founding of the industry, the efficient use of certain raw materials and of the workforce, etc. –, the main financial beneficiary was external capital, which owned over 4/5 of industrial investments and the same share of the annual profit mass, 40–50 mil. golden lei. In the Romanian provinces found under foreign dominion until 1918, the industrial revolution and the beginning of industrialisation occurred in different way, exhibiting particularities, as they were either more intermittent or more accelerated in relation to the raw-material resources, the capital and the market, the industrial policies.

In Transylvania and Banat, machine use was introduced much earlier, in the 4th and 5th decade of the nineteenth century, mainly in railways, in the coal-extracting industry, as well as that of ferrous and non-ferrous ores, due, among other things, to natural underground resources. The Habsburg Empire founded mines and plants for the exploitation of coal and iron resources with the purpose of developing the industry of ferrous metallurgy which produced metal for railways, machines, and armament in Reșița and Hunedoara, as well as for the exploitation of gold and silver in the region of Abrud and Baia Mare. In 1881–1890, the industrial policy promoted involved laws which supported the industry and was based on general principles for the stimulation of this sector. Consequently, certain branches of the light industry developed as well: broadcloth, paper, glassware, milling, wood, leather processing, etc. The large capital investments mostly belonged to Austrian, German, and, to a lesser extent, Hungarian companies. The branches which registered the most significant growth were the ones that used natural resources of raw materials. Nevertheless, Transylvania remained one of the less industrially developed provinces of the Austrian-Hungarian imperial complex.

Bucovina also underwent industrial transformations, particularly regarding the exploitation of certain ores and the great wood reserves, but they were mainly limited to the production of raw materials. Basarabia, however, was dominated by the household and crafts industry until the Unification.

Up until the national Unification and integration of 1918, on all Romanian territories, the process of transforming the old mechanised industrial system was in various stages of transition, yet far from relying completely on machines. After the unification of all Romanian territories within the unitary national state of 1918, the industrialisation process would enter a new phase of evolution. The forming modern industrial system, in parallel with the technological and economic transformations, necessarily acquired new forms of organisation and management as well. Thus, the transition was made from sole proprietorships, characteristic of the old forms of capital, to collective entrepreneurships—associations, companies—capable of mobilising and utilising capitals dozens of times larger than individual ones.

Starting with the early twentieth century, joint-stock companies, generalised in Western economy, become widespread in the Romanian industrial sector as well, yet the most common form of economic organisation was the sole proprietorship. In 1914, 132,431 units in the fields of industry, trade, credit, and other services were registered with the financial agencies, where they paid taxes (patents). In that same year, the social companies, such as general partnerships, cooperatives, and joint-stock companies in all the economic fields amounted to 6,875 units. Of these, in 1913, the joint-stock companies were 474 in number, of which 168 were industrial.[2] Although much fewer, the joint-stock companies owned approx. 80% of the share capital—637 mil. lei, while the other collective and individual ones accounted for merely 169 mil. lei, or 20% of the total capital.

The mechanised industry during this kickoff period was described in the specialised literature by means of economic and technological indices. However, the analysis of the industry's financial indices, which were widely used in the literature of other countries where such information is available, is especially important. In Romania, the official statistics up until 1913 did not publish the financial situation of the industry according to the balance sheet account. However, the primary data needed are found in the Official Gazette, where each company had the obligation to publish its annual balance sheet, including the data regarding the assets and liabilities accounts, as required by law. The data collected from the Official Gazette show that the assets of industrial joint-stock companies, expressed as assets and liabilities accounts, increased tenfold, as did the share capital; however, the other own funds and especially the borrowed funds amplified even more; benefits, as one of the sources of own-fund increases, reached the highest levels, growing 18 times, from 4.5 to 82 mil. lei. The importance of financial accounts as to the evolution of the large mechanised industry resides in two categories of information. In the official statistics and studies up to this point, the power of the industry was represented by the fixed capital of the supported large manufacturing industrial companies, the only index regarding capital; in 1915, the 847 units had a fixed capital of 329 mil. lei and, together with the working capital, they amounted to 735.4 mil. lei. According to the statistics on balance sheet accounts of 1914, which we have drawn up, the share capital of the industrial companies consisted of 556 mil. lei, while the total working capital was of 1,176 mil. lei. Thus, the financial potential of the large industry in the researched period is seen in its real form and dimensions. As a comparison, in the same year, the revenues of the country's state budget were estimated at 600 mil. lei. Translated into weight in gold (1 kg = 3,100 lei), the industrial assets were equal to 380 tons of gold.

The building stage of the modern industrial system. Having gone through the development of the industrial sector and its economic and social results, we will now present the main overall conclusions. Once the country modernisation process was initiated, the economic, technological and social transformation of the old industrial system also began; the transition from the old system to the modern one occurred

[2] The data according to the first official statistics regarding companies: the Statistics of Joint-Stock Companies in Romania, Ghiorghita (1998).

in a specific way in each of the three forms of industry, the central axis of the changes being the factory industry, a product of the industrial revolution and of the onset of industrialisation. The mechanised industry, supported and protected by the state, became the leading and driving sector of the entire industrial system; it took first place in terms of importance, technological and economic function and becomes dominant, in the view of the twentieth century, as a field which carries the most efficient material progress of Romanian society and the capital remedy to eradicate Romania's throwing-back. The mechanised industry, due to its technological and economic superiority, would radiate its influence over the manual forms of industry inherited from the old system, thus stimulating their transformation or hastening their extinction. At the end of its first stage of development in the twentieth century, Romanian industry presents an industrial system in which the transition to full mechanisation was far from being complete. Its contribution to the country's overall industrial production can be estimated in the most general terms to be of an average of 50% for the large mechanised industry, 20% for the middle-sized industry, and 30% for the household industry. Thus, the manual components supplied approximately half of the country's overall industrial production. An important role in the process of industrial transformations was played by Romanian education and sciences. To that purpose, dozens of trade schools, both middle and high schools, the Polytechnic School and various faculties of physics, chemistry, geology, etc. were founded, where thousands of bodies of personnel consisting of Romanian workers, technicians, and engineers were trained. The Romanian Academy stimulated scientific creation through scholarships, research, etc. Research institutes and scientific societies were founded.

The position of the industry within national economy. Although the expansion period of the machine-using industry was relatively brief, this modern, advanced sector stood out clearly dominant within the economic-social organism. Its share in the social product was of 20–25%, resulting from the activity of 1.5% of the employed population. The mechanised industry, large and small, on the other hand, benefitted from the prevalent installed driving force—68.7%—in the branches of material production, namely 246.1 thousand kW out of a total of 358.4 thousand kW. The superiority of industrial activity, especially that of the mechanised part, stood out within the national economy through the high productivity of machine work, which was far ahead that of agriculture. In 1913, the value of plant and animal agricultural production was estimated at 1,906.7 mil. lei, while the population engaged in agriculture counted 3,390 thousand people, so that the annual production per employed person was of 562 lei. For the same year, the value of the production of the supported and unsupported large industry, together with that of the state and middle-sized industry amounted to 811 mil. lei and was produced by approx. 97 thousand people, which meant 8,381 lei per person (calculated according to (Arcadian (1936); *** 1904; Păianu 1906; *** 1915; Axenciuc 1992; Axenciuc 2008). Thus, there was a disparity of 1:15 between the productivity of industrial activity and that of agricultural activity, which stressed the indisputable advantage of the industrial one for economic operators and for the national economy. Another priority element of

Table 4 The employed population in the main sectors of the economy in Romania, Germany and France, in 1911–1913 (*** 1916)

Employed population, total shares			
Country	Large and small industry	Agriculture	Services
1	2	3	4
Romania	8%	80.5%	11.5%
Germany	40.9%	36.8%	22.3%
France	36.1%	41.1%	22.8%

industrial activity is that the capital market, in a still immature economy, was dominated by industrial capital. According to the statistics on joint-stock companies, in 1913 (*** 1915), the total share capital represented 722.1 mil. lei, of which 436 mil. lei or 60.4% belonged to industrial companies, 215.8 mil. lei or 30% formed the banks' share capital, while the rest, nearly 10%, was distributed among insurance, commercial, and real estate companies. Thus, even if the large mechanised industry contributed to a limited extent to ensuring the products required by the internal market, it had become important and even accounted for the majority of the volume of certain products, as well as of the share capital; through its petroleum and forestry products, the industry supplied over 20% of the total exports. The data and arguments invoked to illustrate the industrial kickoff confirm that the vision of the supporters of promoting the industry and industrialisation process in order to reach a superior step in terms of progress and civilisation and turn Romania into an industrial country was starting to materialise in the country's agrarian and traditional reality through significant results. Nevertheless, the level and structure of Romanian industry, which was at the beginning of its journey towards industrialisation, were far behind those in Western countries.

The population employed in the industrial sector in agrarian Romania was 4–5 times more reduced than in the two industrial countries (see Table 4); this share registered by Romania in 1913 had been attained by France and Germany 120–150 years before. The driving force with which a country is equipped is also a comparable index; in 1910, for every 100 inhabitants, there was a machine-based driving force of 12 HP in Germany, 9 HP in France, while, in Romania, it was only 1.6 HP.

Consequently, in spite of this, Romania's young modern industry evolved at a quick pace and expanded its scope, thus becoming vigorously dominant within the economic-social organism, being the sector which carries economic progress with assured perspectives of the country's machine-based transformation. The process of industrial transformation of the economy, was, however, triggered; its premises turned out to be favourable due to natural resources, as well as to the external influx of cheap capital, imported technologies, projects, specialists, and industrial managers who came to support the new industries. If these favourable conditions had persisted for several decades, Romanian industry and economy would have made significant steps towards the industrialisation and transformation of the country into an industrial-agricultural one. However, the ideal was not accomplished. A world war followed—the first one—which caused great destruction for the recently constructed industrial assets and cancelled out much of the advances made. The Great Unification of 1918, as a historical accomplishment consisting of the unification of the entire territory, population and natural, technological, and economic heritage of the Romanian nation within its functional organism created favourable conditions for the continuation of the country's industrial transformation and industrialisation process, with all the expected transformative outcomes. However, the external factors of the three decades after 1920—the world economic crises, the Second World War with its tragic consequences for our country—slowed down or even obstructed the alert course and great expectations of Romania's young industrialisation during the kickoff period of 1890–1914.

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History of Machine Building Industry

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Abstract The chapter is structured in four parts. In the first part, the beginning of industrialization in Romania is presented. The industrialization of Romania begins in the first part of the eighteenth century, when the demand for mineral resources (coal and iron) of the western European countries increased considerably. These resources began to be exploited in the "Banatul Montan" area, where the first furnaces appeared. Later these were extended to other areas of Transylvania. If initially the production was predominantly focused on the metallurgical sector, starting from the second part of the nineteenth century it was expanded in the field of machine construction (household and agricultural tools, cast iron objects, locomotives, etc.). The second part presents the development of the machine industry in the period between the two world wars. The formation of Greater Romania, after the First World War, strongly boosted the development of Romanian industry, especially by supporting domestic capital. During this period, the first Romanian entrepreneurs appeared who strongly developed the metallurgical, railways, armaments, and aviation industries. The third part of the chapter analyzes the development of the machine industry after 1945 until 1989. After the Second World War, the political reality changes completely through the change of the political regime and the entry of Romania into the Soviet occupation zone. During this period, part of the Romanian industry is abolished (the aeronautical industry, armament industry) and the industry of agricultural machines, energy equipment, transport equipments, consumer goods, textile equipment, etc. is developed. From the 1960s until the beginning of the 1980s, a strong industrialization took place throughout Romania, trying to cover all the industrial needs of the country. After 1989, with the fall of the communist regime, the machine industry was affected by several major events: the transformation of state enterprises into commercial companies; the privatization of commercial companies; the decline of the export market to former communist countries, Arab countries and African countries; globalization,

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through the emergence and development of subsidiaries of large international companies; the opening of borders to foreign products; the rapid increase in interest rates. These events led to crucial changes in the Romanian industry, the context in which the new enterprises operated being completely changed compared to the one before 1989. The reindustrialization of Romania after 1989 occurred mainly through two mechanisms: the first, through the purchase, restructuring and re-engineering Romanian enterprises by the big players on the world market or by Romanian investors with an entrepreneurial spirit; the second, by setting up enterprises of foreign companies in locations with skilled labor or in geographical areas with a surplus of (cheap) labor that do not require a high qualification. At the end of the chapter, a panoply of research and design institutes in the field as well as higher technical education institutions in the field of machine construction technologies is presented.

The industrial revolution reached the Romanian territories with a delay of over half a century compared to Western countries (England, Germany, France, the USA). Entry (Imreh 1955) of the bibliography presents in great detail the process of the passage from manufacture to industry in Transylvania. The Imperial Patent of 1851 (an official document issued by Emperor Franz Joseph) led to a new administrative redistribution of Transylvania, cutting back on the privileges of guilds (abolished in 1872). The Chambers of Commerce of Cluj, Brașov and Timișoara were established in the same year, resulting in an impetus given to manufacture and opening the way to industrialisation in Transylvania. The first *steam engine* was used in the mining industry, in Zlatna, set up in 1838 (Imreh 1955); in 1846, another such machinery (imported from France) was also set up at the mill of Păcurari, Iași (*** 1963). Some years later, in 1853, the Assan mill was built in Bucharest, operated by a Siegel type steam engine, brought from Vienna (Assan 1904). However, the first signs of the industrial revolution did not show until the late nineteenth century, at the time of the reforms of Alexandru Ioan Cuza, of the formation of the independent state, and of the law of 1887 meant to encourage the national industry (entitled '*General measures to assist the national industry*'). It was at this time that the industry witnessed a significant growth as a result of the introduction of machines as the driving force in production. Towards the end of the nineteenth century, these machines, imported from England, Germany, Austria and France, started to be used in mining, oil industry, food industry, forestry, transportation, textile industry, etc. (for details, see Chap. 6, Formation of the industrial system). In the first stage of machine building in Romania, the machine production mainly covered agriculture, railway industry, naval industry, oil industry, and military equipment. In what follows, the main machine building factories on the territory of Romania will be presented in the course of their history.

1 The Beginning of Machine Building Industry Before the First World War

After the Passarowitz Peace Treaty of 1718, the Banat region was placed under Habsburg rule, as an estate of the Crown. The Transylvanian Court Chamber (the governing body which connected the Court of Vienna and the Transylvanian local authorities) approved, in 1725, the project of Governor Mercy to establish manufactures and produce locally the goods necessary for consumption. As a consequence of the Austrian state's interest in making the most of the potential of this region, important economic changes (mainly in mining and metallurgy), as well as social changes had taken place. *The first iron ore melting furnaces* on the territory of Romania were built by melting masters from Tyrol and Bohemia at *Ciclova* (1718)*, Oravița* (1718) and *Bocșa* (1719) (*** 1996). *Thus, the mountainous Banat region became the oldest industrialised area on the territory of Romania.* In 1756, the furnace of Bocșa was moved to *Reșița,* where the first furnace was built in 1771 (*** 1996) (Fig. 1). This area is also one of the first regions of Europe in this respect, preceding the establishment of famous factories such as Krupp (1811), MAN (1834), Škoda (1851), etc. Due to the rich iron ores and coal resources of the area, the Austrian Empire (which was ruling over Transylvania and Banat until 1918) invested massively and introduced state-of-the-art machinery and technology. *The first steam engine-driven rolling mill* was built in 1845 and the *first steam engine operated presser in Romania* was set up in 1846 (Imreh 1955). This presser was set up at Reșița shortly after it was invented by the Englishman Nasmyth (in 1830) and built by the French Bourdon (in 1839). Such types of pressers were also built at Plosca (Dolj County) in 1851, Vlăhița (Harghita County) in 1856 and Filia (Covasna County). Consequently, while the industrial production originally focused mainly on metallurgy, later, in the second half of the nineteenth century, it was also extended to machine building (household and agricultural tools, nails, cast iron objects, etc.). Such a factory existed in Rușchița, in the area of Poiana Ruscă mountains, in 1834. In 1854, the works at Reșița were moved from the ownership of the Austrian Treasury to that of the Imperial Royal Privileged Austrian State Railway Company (StEG, Staats-Eisenbahn-Gesellschaft). This had resulted in a major change of the production profile, focusing on railway services: railway equipment, rails, crossings, etc., and later wagon and locomotive maintenance. The experience gained in the process led to the manufacturing in 1872 of the *first steam engine on the territory of present-day Romania.* It was a narrow-gauge locomotive named Resicza 2, used for transportation within the premises of the factory. The engine was designed by the famed English steam engine designer John Haswell, who had been working at the StEG Locomotive Works since 1839. Before 1918, seven more such locomotives were also produced at Reșița (*** 1996).

After the First World War, in 1920, the works from Reșița were transformed, becoming the Steel Works and Domains of Reșița (U.D.R.), and the largest inter-war company in metallurgy and iron and steel industry (employing almost 23,000 workers in 1948) (Chicoș 1925; Popescu 1929). During this period, the works were equipped with modern machinery, such as a high power press. Until 1940, the U.D.R.

Fig. 1 Reșița before the First World War (*** 1996)

had a successful administrator: Max Ausschnitt. Ausschnitt and Malaxa were representative figures of the Romanian industrialists between the two World Wars. The production profile of the factory extended to the military as well (making anti-tank and anti-aircraft guns, shell throwers, etc.), metal works, oilfield equipment, and electric equipment (electric motors, transformers, etc.). In 1948, the Steel Works and Domains of Reșița were nationalized, and the establishment has repeatedly changed its name until taking its current denomination, the Reșița Machine Building Factory. In 1969, the *Reșița Plants Group* was established, which also comprised: The Bocșa Metalworks, the Caransebeș Machine Building Works, the Timișoara Mechanical Works and the Reșița Research and Design Institute for Hydroelectric Equipment. The factory's field of production extended and became more and more complex, covering also the building of hydroelectric equipment (the first Francis turbine for a 100 kW hydro-aggregate was built in 1946, as an *industrial premiere* in Romania). In addition to various kinds of hydraulic turbines (Pelton, Francis, Kaplan), beginning with 1977, it also produced thermo-energetic equipment (steam turbines, turbo generators and other associated equipment), naval engines, and large size reducers (at the new reducer factory at Reșița-Renk, established in 1973). The plant was reorganized in 1991 to become a joint-stock company, then in 2003 it was privatised and bought by the Swiss INET company. In order to showcase the importance of this plant for Romanian economy, some significant numbers for production volume by various fields will be presented: 1,461 locomotives, over 6,000 industrial air compressors, electric motors with a cumulated power of over 1.5 million kW, thermo-energetic equipment with over 1 million kW of installed power, Diesel motors for locomotives and ships with a cumulated power of over 10.8 HP, hydro-aggregates (hydraulic turbines/electrical generators) with over 6.2 kW power (Wollmann 2010–2018).

The Ferdinand Plants (named after the first owner, Ferdinand Hoffman) were founded by German colonists in 1796 (*** 1996). In the second half of the nineteenth century (1861) the plants were extended, and a jobbing mill, a five-stand rolling mill for making rails, and a light sheet rolling mill were built (Fig. 2). In 1924, the plants became part of the United Metallurgical Works *TITAN-NĂDRAG-CĂLAN SAR* founded by Max Ausschnitt. After the nationalisation, the town changed its name to Oțelul Roșu (1964) and the Ferdinand Plants to *Oțelul Roșu Steelworks* accordingly. The works was privatised in 1990, sold to foreign investors in 2000, and eventually it was closed in 2012. Another important steelworks centre in the mountainous part of Banat was Anina. The ironworks were built here in 1861, and in 1872 a *Screw factory* was built, producing assembly elements (screws, rivets, etc.). The factory worked until after the First World War. In 1872, the Nădrag Industrial Society for Iron was established, where several furnaces, steelworks, a foundry, a rolling mill, a factory for rolls, a machine factory and one for agricultural machinery and tools were built between 1880 and 1918. In 1924, the society was integrated into the *TITAN-NĂDRAG-CĂLAN SAR*. A *Factory of agricultural machinery and tools* was functioning in Bocșa, in 1898. Later it was renamed the *Bocșa Metal Building Company (CMB)* and focused on metalworks for industrial, public and thermo-energetic use (metal bridges, tower cranes, elements for nuclear power plants, etc.).

Another traditional centre dating back to the eighteenth century in the field of metallurgy and machine building in Transylvania was Cugir. In 1799, an *iron factory* was established here which processed the iron ore mined at Govăjdia, near Hunedoara (*** 1974). The factory was extended and modernised repeatedly, in 1850, 1873

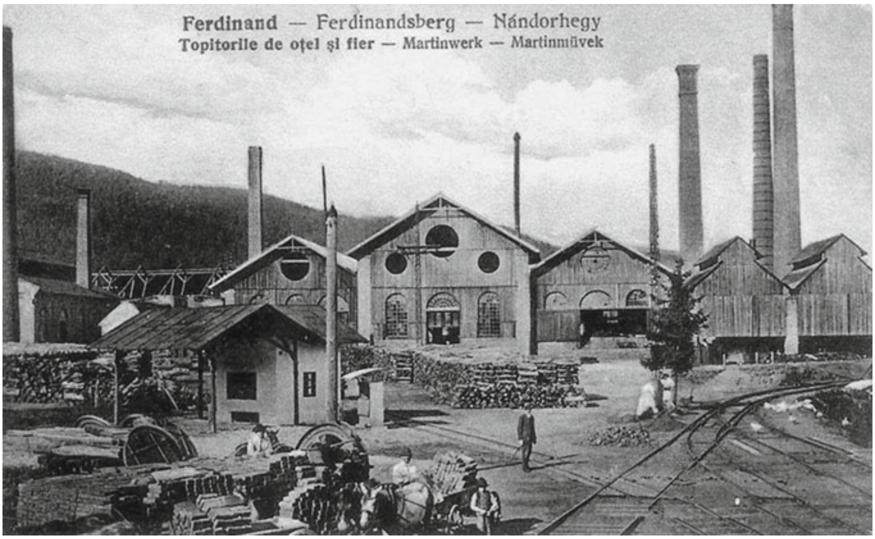

Fig. 2 The Ferdinand plants in the nineteenth century (Wollmann 2010–2018)

and 1898 (Fig. 3). In 1873, the factory had 106 employees, in 1900 it had 500 employees, and in 1913, after it was connected by railway to the Deva-Sebeș railroad, it reached almost 1,000 employees (*** 1974). In 1920, the factory in Cugir was nationalised. A significant time in the history of the factory was the year 1925, when, following the Paris Convention, the factory of Cugir began producing ammunition, purchasing equipment from Vickers in England and Skoda from Czechoslovakia. The first Romanian automatic pistol, designed by Captain Marin Oriță, was also produced in this period, in 1941. In 1948, the factory was renamed the *Cugir Mechanical Works*. The production covered the manufacture of machine tools, becoming one of the largest machine tool designers and producers in Romanian in the 1950–1970 period. This is where *the first machine tools in the country were made in 1946: machine tools for grinding, milling (1948), drilling and tool sharpening machines, and the first gear milling machine (1963).* After this pioneering period of machine tool building, the production was transferred, beginning with the 1970s, to other factories in the country: the milling machines to the Brotherhood (Înfrățirea) company in Oradea, grinding machines to the Tools and aggregates factory of Bucharest and then to the Grinding machine factory in Cluj Napoca, the tool sharpening machines to the Plopeni Mechanical Works, etc. Based on this, one might say that the Cugir Mechanical Works was the main provider of machine tools for the Romanian industry in the 1948–1965 period and this factory was the *cradle of machine tool production in Romania.* Starting with 1946, household machines were also built at Cugir. This is where the *first industrial sewing machine from Romania called MCI-1 was built* in 1946, and the production of household sewing machines began in 1948. The first type was *Casnica*, followed by many other types, with millions of such machines being built before the factory was closed. Another household machine which was produced beginning with 1961 was the washing machine, the first type in production being the *Albalux 1*. This was the *first washing machine manufactured in Romania.*

The first machine building factory from Romania (agricultural tools) was established by the Solymos brothers in Arad in 1825 (Wollmann 2010–2018). In 1891, the Austrian Johann Weitzer founded the *Johann Weitzer Wagon and Engine Factory* (Fig. 4). The factory was founded in order to cover the needs for rolling stock (wagons, carriages, locomotives, electrical tramways, but also military equipment, field kitchens, agricultural machines) (Fig. 5) for the eastern part of the Austro-Hungarian Empire. In 1909, the *MARTA Automobile Factory* was founded (Magyar Automobil Részvény Társaság Arad, the Arad Hungarian Automobile Joint Stock Company), a branch of the American Westinghouse company. The machines produced here were engines for locomotives, buses, lorries, etc. In 1910, it also made *the first car produced on the territory of Romania,* called MARTA. In 1912, the factory was taken over by the Austrian company Austro Daimler, continuing to make cars (called Daimler) as well as lorries and buses (Wollmann 2010–2018). After the union of Transylvania with Romania, in 1921, the *Johann Weitzer Wagon and Engine Factory* and the *Marta Automobile Factory* merged to establish the ***ASTRA*** society. This was the first Romanian factory to *manufacture railway vehicles, as well as automobiles, lorries, tractors, agricultural machines, airplanes and other aircraft equipment.* The portfolio of the factory diversified and the number of employees increased, becoming eventually one

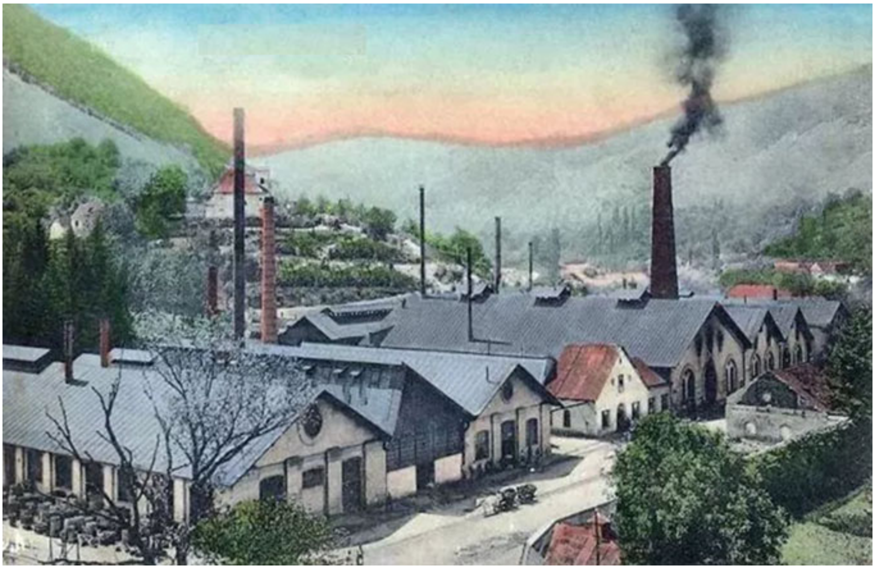

Fig. 3 Image of the Cugir Plant in 1912 (*** 1974)

of the largest factories of Romania (with 2,120 workers employed in 1926) (Fig. 6). Due to the experience in manufacturing the Daimler airplane engines, an airplane factory was founded in 1923. This was the *second industrial unit in Romania where airplanes were built. The first airplane engine produced in Romania, called Marta-Benz,* was made at the ASTRA Airplane Factory. This engine was used for the Astra-Șeșefschi airplane, designed by engineer Șeșefschi in 1923. Three airplane models were produced here: Astra-Șeșefschi, Proto-2 and Astra-Proto. The airplane factory was moved to Brașov in 1925, establishing the *Romanian Aeroneutics Industry—IAR* Brașov. At ASTRA Arad, precision lathes and power presses were being build already in 1924 (*** 1924). The factory was extended to Brașov, Bucharest and Satu Mare. After the Second World War, the company was nationalised, keeping its main profile in the interwar-period: the building of wagons. When the subway in Bucharest started to be built, it also produced subway cars for the METROREX company, which oversees the Bucharest subway. In 1990, the factory transformed into a joint stock company under the name of S.C. ASTRA Vagoane Arad S.A, keeping its production profile.

The first mechanical/metal works workshop was established by Joseph Franz Teutsch in Brașov in 1833 (*The brass and bells foundry*) (Wollmann 2010–2018). Initially, it produced bells for churches, candlesticks, scissors, irons and other household goods. After the dissolution of guilds, the workshop was changed into Iulius Teutsch Company in 1868, extending its profile starting from 1882 to the production of parts for different kinds of factories (sugar, textile, distilleries, sawmills, water mills, steam mills, etc. The factory profile did not change significantly after the First World War. In 1927, the factory changed its name to Teutsch Foundry and

Fig. 4 The Johann Weitzer Wagon and Engine Factory at the end of the nineteenth century (Wollmann 2010–2018)

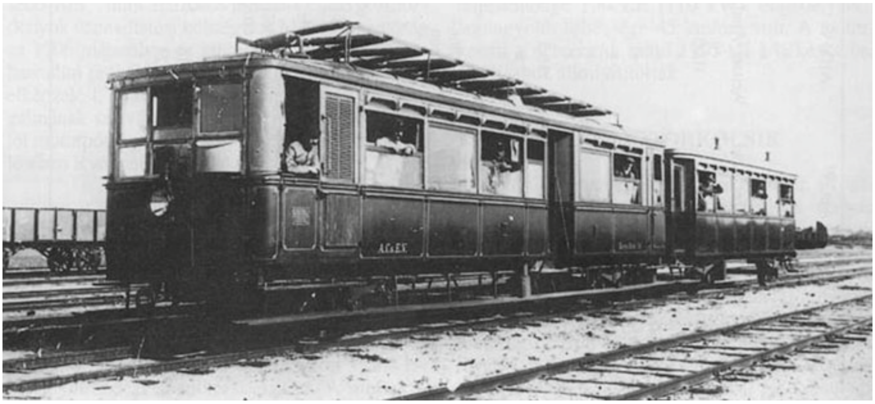

Fig. 5 One of the first railcars built at the *Wagon and Engine Factory* (courtesy of Dr. V. Wollmann)

Tool Factory, a name it kept until 1948, when it was nationalised. This is where *the first high-power presses of 30–60 ton-force in Romania* were built beginning with 1936, and *the first lathe frame (a national premiere)*. Because of these successful enterprises, beginning with the same year, the factory started reorganizing its profile to produce machine tools (lathes, drilling machines, presses), becoming the *first factory in Romania which manufactured such equipment*. After the 1948 nationalisation, the factory merged with two other factories of Brașov, forming the Tools

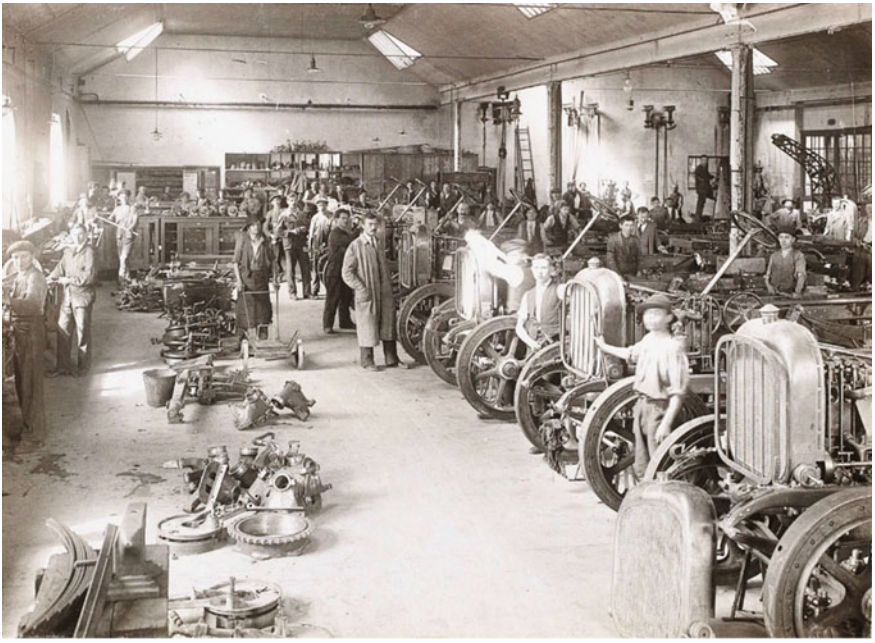

Fig. 6 Image of the assemblage department at *ASTRA* Arad (1921) (courtesy of Dr. V. Wollmann)

Factory (Întreprinderea de Unelte și Scule, IUS). In 1880, the brothers *Karl and Samuel Schiel* founded an *iron casting and processing workshop* in the *Schei Gate* area (Wollmann 2010–2018). In 1919, the factory turned into a joint stock company, taking the name of *Schiel Brothers* s.a.p.a. The factory extended its activities to locomotive and wagon repairs, equipment and parts for mining industry, building machines, mechanical transmissions and lathes. In order to reduce the costs of equipment acquisition, the factory *decided to produce its own machine tools* needed in production, specialising in this field. Figure 7 presents the image of a complex milling machine manufactured in 1942. In 1925, they started producing bodies for Fiat buses and later for Citroen buses. In 1924–1926 the Schiel Factory *designed and built the first airplane made in Brașov, Ra-Bo.* After the nationalisation of 1948, the factory was renamed *The Lathe (Strungul).*

The beginnings of machine building in Cluj are connected to a legendary figure of the town, Rajka Péter (Imreh 1955). He was the son of a gunsmith from Târgu Mureș and a student of Farkas Bolyai, who graduated from the Technical University of Vienna. In 1840, he founded at Cluj a *workshop for agricultural tools* making straw choppers (with an original design, highly efficient), sowers, threshers, etc. He designed and manufactured a reversible plough with a new concept, which was considered *one of the best ploughs in the world* in that time (the 1870s). Rajka opened in his business a school as well, which trained craftsmen from all over Transylvania for several decades. After Rajka's death, the factory repeatedly changed

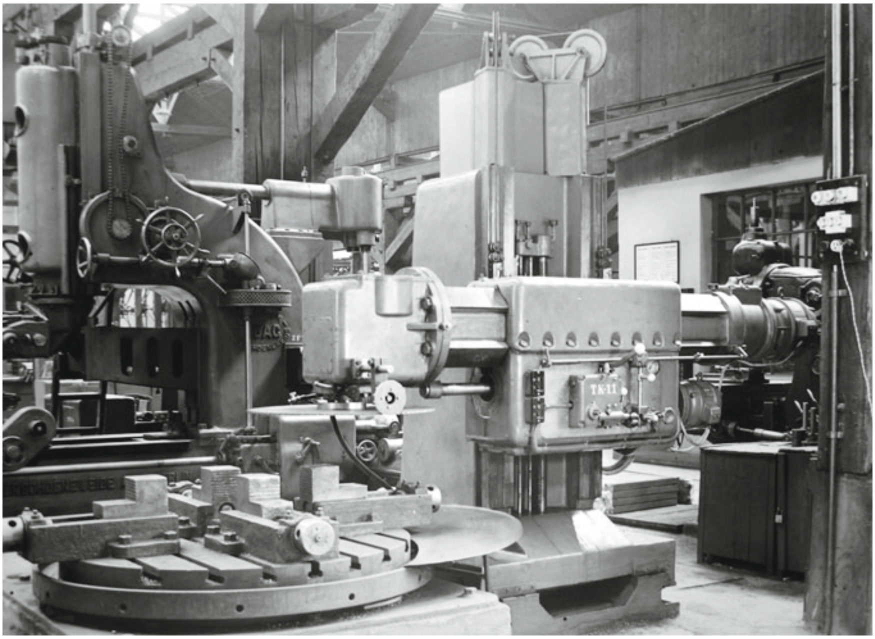

Fig. 7 Milling machine manufactured at Schiel Factory in 1942 (courtesy of Dr. V. Wollmann)

its name to *Wagner and Dietrich*, then in 1904 to *Junász Metalworks and Machine Building Factory*, specialising in hydraulic machines, heaters, mine lifts, etc. (Imreh 1955). In 1919, the factory was taken over by a Romanian society and changed its profile to producing charcoal irons, pressure tubes, etc. Beginning with 1933, the factory started producing the first machines for textile industry: mechanical looms, warping machines, recoilers, etc. (Giddo 2014; Pascu 1974). After the 1948 nationalisation, the factory changed its name to *Union (Unirea)* and produced machines and equipment for the textile industry (mainly looms). In 1870, the *Railways Workshops* were founded in Cluj with over 150 employees. The workshops underwent continuous development, so that in 1938 there were already 1700 employees, making it the largest machine building business in Cluj. After the 1948 nationalisation the workshop changed its name into *16 February* and currently it is named *Remarul 16 February*.

As there was a shipping route on the Danube with exit to the Black Sea which brought on the need to repair (and later build) commercial and military ships, dockyards were also established. The Treaty of Adrianople from 1829 ended the Turkish monopoly over the economy of the Romanian Principalities and opened the way to international navigation on the Danube and the Black Sea. As a direct consequence, it led to a major development of dockyards for repairing and building ships. The first ones were established on the Danube (Brăila, Turnu Severin, Galați, and later

Oltenița, Tulcea, Giurgiu) and then on the Black Sea shores (Constanța and later Mangalia).

The *dockyard of Brăila* was established in 1840 under the name *Romania Dockyard*. It was an important site for building ships for river and sea (cargo ships, barges, lifeboats, pilot ships, tugboats, etc.). Beginning with the end of the nineteenth century, by connecting the port of Constanța to the Romanian railway by the Saligny bridge (inaugurated in 1895), the ports and dockyards of Brăila and Galați gradually lost their importance. After the nationalisation, the shipyards from Brăila merged into one single site, the Brăila Dockyards. In the early twentieth century (in 1907) the first metalworking company of Brăila was founded with the name of *Triumph Metalworks (Întreprinderile metalurgice Izbânda).* Its main profile was to produce iron laminates, and after the nationalisation it was incorporated into the Rolling Mill (Laminorul) company.

In *Iași*, the Italian I. Saketi founded in 1843, on the initiative of Ion Ionescu de la Brad, *the first factory of agricultural machines of Moldavia and Wallachia,* called the *Factory of Instruments (Fabrica de Instrumenturi).* At the beginning, he employed German and French workers (Ghitoiu 1924). The factory produces tools for agriculture and threshers for cereals.

The Austrian shipping company D.D.S.G established in 1852 the *Turnu Severin Dockyard*. In 1893, the dockyard was transferred to state ownership and changed its name to *SEVERNAV Dockyard.* In 1977, a factory of forged parts was built there, which merged with the dockyard and formed the *Drobeta Turnu Severin Naval Construction and Hot Working Company*. In 1882, a *Wagon and Locomotive Repairs Workshop* was founded at Turnu Severin. After it was nationalised, for a while (1960–1968) it merged with the dockyard of the town, forming the *Turnu Severin Mechanical Works.*

In *Oradea*, the first workshops for the production of agricultural tools were founded in 1844 and 1847, by *Gitye* and *Perge and Roszlay*, respectively (Hochhauser 2010). In 1860, *Daday* established a locksmith's and clock making workshop (Hochhauser 2010). In 1902, *Tátrai and Klier* as associates established a small company made up of a locksmith's workshop and a foundry, making metalworks and tinware (Hochhauser 2010). This workshop was the forerunner of *metal and mechanical works in Oradea.* After 1908, the company began to extend, reaching 120 employees and taking on the name *The First Foundry and Machine Factory of Oradea.* After the Great Union of 1918, the company was reorganized and in 1926 it took the name *Phoebus Iron Foundry and Machine Factory.* It began producing internal combustion engines for threshers, pumps, generators, etc., and later, from 1930, also equipment for oil industry (Hochhauser 2010). In 1936, the company was taken over by the French-Romanian Society (Societatea Franco Română, and in 1940, when Northern Transylvania was attached back to Hungary, the factory was evacuated and moved to Brăila, where it became the *Progress Plant (Uzina Progresul).* In 1947, some smaller workshops in Oradea merged, re-establishing the *Phoebus* company (Hochhauser 2010). In 1948, following the nationalisation, the Phoebus and some other smaller workshops were merged into a new company, the *Brotherhood (Înfrățirea) Oradea*, profiling on machine tool production (milling machines, drilling machines, processing centres).

The *CFR Timișoara Railway Rolling Stock Repairing Workshop* established in 1858, was *the oldest mechanical workshop in Timișoara* (Munteanu and Munteanu 2002). In 1960 it merged with the *Banat Metalworks* to become the *Timișoara Mechanical Works.* At the beginning, this company produced fire trucks, isotherms, rolling stock, naval winches, equipment for food industry, forestry tractors, etc. After 1970, the factory changed its profile to the production of transporting and lifting equipment (overhead cranes, forklifts, cranes). Later, after 1980, it started the production of mining equipment (rotor excavators, mechanized felling supports, and equipment of coal mines). In 1991 it became the joint stock company UMT SA and in 2000 it was bought by the PROMT SA company from Timișoara, making parts and subsystems for the well-known Caterpillar company. The first *metalworks company in Timișoara* was the *Bozsák*, established in 1869 (Munteanu and Munteanu 2002). It produced metal furnishing and metal nets. After the 1948 nationalisation, it changed its name to *Tehnometal*, and produced machines for agricultural products (selectors, sorting machines, threshers, seed driers, etc.). In 1980, it started producing low power tractors. In 1985 it changed its name to *Car Factory Timișoara (Autoturisme Timișoara)* and produced the low capacity car Dacia 500 Lăstun. It merged in 2006 with the Electrotimiș SA company, and took over the latter's production portfolio. In 1900, the *Iron Factory* was founded at Timișoara, which, after the 1948 nationalisation, merged with the *Iron Industry* company to form the *ELECTROMOTOR,* a company producing electric motors. This was the oldest electric motor factory in Romania. The *Friedrich Factory*, producing subsystems for locomotives and agricultural machines, was founded in 1900. The industrialist Schmitzer founded in Timișoara in 1908 the *Chain Factory*, which merged in 1944 with the *Britania Factory* (a producer of electric motors), founded by Zoltán Erőss, and the *Friedrich Machine Factory*, under the name of *Iron Industry* (Munteanu and Munteanu 2002). This factory produced mid-power electric motors, small compressors, machines for food industry, grain mills, oil presses, etc.). It was nationalised in 1948 and merged with the Iron Factory to form the ELECTROMOTOR company.

In Sibiu, a weapon making and repairing workshop existed ever since the mid-fifteenth century as part of the *Castle Arsenal*. For a period after 1529, the arsenal master was Conrad Haas, the crafter of the first multistage rockets. In the period between 1848 and 1918, the workshop became the *Army's Repair Workshop.* A major change in its profile came about in 1948, when it started to produce industrial equipment as well in addition to military equipment, and started to make repairs for tractors and railroad wagons. In 1964, the company changed its name to *Sibiu Automechanical Works (Uzina Automecanica Sibiu)*, focusing on the production of car parts, and in 1969 it merged with the Elastic Works (Uzina Elastic), forming the *Sibiu Car Parts Company (Întreprinderea de Piese Auto Sibiu, IPAS). The first machine building company in Sibiu* was the *Fabritius Iron Works (Fabrica de construcții de fier Fabritius)*, established in 1855 (http://patrimoniu.sibiu.ro/istorie/industrie/38). In 1868, Andreas Rieger founded the *Andreas Rieger Machine*

Factory (Fabrica de mașini Andreas Rieger) (http://patrimoniu.sibiu.ro/istorie/industrie/38). The *Andreas Rieger Machine Factory* started out as a forged iron workshop, making horseshoes and repairing agricultural tools and machines. It specialised in producing ploughs, including the widely known Rieger system plough. This was the *first reversible plough produced in Romania, with cast iron stilts.* It worked as the *First Transylvanian factory of agricultural machines and iron foundry* until 1921, when the machine factory *Fabricile de mașini Andreas Rieger S.A.* joint stock company was founded. The new factory extended its line of production to hammer mills, cranes, pumps, threshers, mechanical saws, and from 1938 it also started producing spark ignition engines and Diesel engines, used with threshing machines. Also in 1938, the production (under licence) of textile machines also started (for instance, the Wolf weaving machine). In 1948, the factory was nationalised and, merging with the Virola company (founded by Friedrich Fabritius in 1855), they founded the *Independence Works (Uzinele Independența).* The new company made equipment for metalworks, considered the 'chief mechanic' of Romanian industry. In 1886, József Datky founded in Sibiu a craftsman's workshop with the name *József Datky and Sons Bodyworks (Atelier de Caroserii Datky Iosif & Fiii)* (http://patrimoniu.sibiu.ro/istorie/industrie/38). In the beginning, it produced lamellar springs for coaches, forged parts, household tools, etc. From 1920 it changed its name to A. Datky Elastic (Elastic A. Datky), and extended production to parts for cars and wagons. The factory specialised in producing spiral springs, as the first factory in Romania to make such products beginning with 1932. Figure 8 presents a body produced at this workshop. In 1948, the factory is nationalised and renamed the *State Elastic Company (Întreprinderea Elastica de Stat)*, producing files, springs and forged parts until 1960. In 1969, it merged with the Sibiu Automechanical Works (Uzina Automecanica Sibiu). The new factory was called, until 1991, the Sibiu Car Parts Company (*Întreprinderea de Piese Auto Sibiu, IPAS*) and became one of the main producers of car parts for the Romanian car industry, making shock absorbers, brakes, cardan transmissions, steering gears, springs, etc. In 1991 the factory was transformed into a joint stock company and was renamed SC COMPA SA, and in 1999 it was privatised, becoming one of the successful private-owned companies of Romania. In 1902, the *Benker and Jickeli Machine Factory of Iron Foundry (Maschinenfabrik und Eisengieserei Benker und Jickeli)* was founded in Sibiu, which first specialised in automobile repairs, and after the First World War, on building machines for the textile leather processing industry (http://patrimoniu.sibiu.ro/istorie/industrie/38). Another important stage for the industry of Sibiu was the foundation of *the first balances and scales factory.* It was founded in 1905 by Johann Hess and produced medium and large weighbridges mostly for railroads and food industry factories. Later, after the First World War, they also produced small household scales or shop scales, and semi-automatic balances (http://patrimoniu.sibiu.ro/istorie/industrie/38). In 1930, the factory changed its name to *Hess Factory.* After the 1948 nationalisation, it maintained its original profile but extended it to the production of measuring devices as well, and changed its name to *Balance Company (Întreprinderea Balanța).* In 1975, the factory also started to produce hydraulic and

Fig. 8 Car body produced at the A. Datky Elastic Factory (http://patrimoniu.sibiu.ro/istorie/industrie/38)

pneumatic equipment under Bosch licence, as the main producer of such equipment in the country and one of the few in Eastern Europe.

In order to better supply the Army with modern equipment, Prince Alexandru Ioan Cuza founded in 1861 the *Direction of the Establishments of Artillery Materials*. Within this institution, the army's *Pyrotechnics* and *Building Arsenal* were founded in 1862. These were *the first metalworks in Bucharest* (Manole et al. 1991). Initially, they produced metal tubes for cartridges and shells, and later light infantry armament. Until 1950 it was a military company, but later it started manufacturing equipment and parts for the building material industry, changing its name to *9 May Works. (Uzinele 9 Mai)*. After 1990 it changed its name to *PUMAC*. In 1864, *Louis Lemaitre* opened *a foundry in Bucharest*, which later became the New Times (Timpuri noi) factory (Manole et al. 1991). In 1891, the Lemaitre works produced the first row seed drills. In 1898, the Lemaitre works were transformed into the *Romanian Metallurgical Joint Stock Company (Societatea Anonimă Metalurgică Română)*, and extended the production to stationary engines, threshing machines, steam engine activated mills, spray pumps, barometric vessels and pumps, public hygiene equipment, etc. (Manole et al. 1991). Figure 9 presents the department of stationary engine assembly. In 1948, the Lemaitre works were nationalised and changed their name to *Fabrica Timpuri Noi*. The production profile was changed to compressors, pumps and assembly materials. The Swiss *Erhard Wolf* (who came to Romania in 1877) opened a *foundry in 1886* (Manole et al. 1991). At first, he produced warheads for the Ministry of War, but then built a brass foundry for metal fittings (hinges and locks). He was the *first to build filling stations for steam locomotives* (Manole et al. 1991). In the 1900–1910 period he manufactured oil industry equipment, central heating equipment, metal railroad bridges, and also military equipment during the First World War. After the nationalisation, the company was divided into two factories: one fore pumps (later named *Aversa*) and one for hydraulic equipment (later named *Red Star*). The

1887 Law for Encouraging National Industry stimulated the industrial development, including metalworks and machine building. Consequently, several companies and workshops emerged, such as: the *Weigel in 1889*, the *Haug in 1890* (producing iron works), the *Rășcanu foundry in 1900* and the *Botez Bodyworks* in 1901 (Manole et al. 1991). *Abonyi*, a representative of the *Brünn-Königsfelder Maschinenfabrik* of Brno, founded in 1904 a branch of the company in Bucharest. In 1908, it became a joint stock company, one of the stockholders being the Romanian state, and took the name *Vulcan Society—Machine Factory (Societatea Vulcan – Fabrică de mașini)* (Manole et al. 1991). This factory started to produce *equipment of oil industry and tank wagons.* The main profile of the factory was to make boilers for various industries (oil, chemical, etc.) as well as lifts and compressors. The name and profile of the company were also maintained after the 1948 nationalisation (except for 1950, when it was called Mao-Tze-Dun, MTD). This is where the *first Romanian buses* called *MTD* were made in 1955. Beginning with 1984, the Vulcan factory produced parts for the Cernavodă Nuclear Power plant. After the Romanian state took over the railways built by foreign concession-holders (under the 1883 law), the *Grivița Railway Repairing Workshops were founded in Bucharest in 1897* (Manole et al. 1991). The reason why the workshop was founded was the maintenance of steam locomotives and carriages of the Romanian Railway Company (CFR). After the nationalisation in 1948, part of the Grivița CFR Workshops were transformed in the *Grivița Chemical Equipment Company.* This company became the main producer of equipment for chemical industry platforms in Romania. In 1899, the *FELD et BUDICH Device and Machine Production and Trade* company was established in Bucharest (Manole et al. 1991). The workshop specialised in making equipment for factories of food industry (canneries, distilleries, etc.). After several name changes (in 1906 and 1915), in 1930 it took on the name of *Paul Budich coppering and boilermaking works, device and machine factory* (Manole et al. 1991). In 1948, the workshop was nationalised and changed its production profile to equipment for chemical, petrochemical and food industry (pressure vessels, cooling columns, distilleries, heat exchangers, etc.). In 1973, it was renamed the *Mechanical Factory for Chemical Equipment,* and after 1989 it changed into a joint stock company with the name *Mechanical Company of Chemical Equipment UMUC Bucharest.*

The beginnings of commercial vessel building in Galați are reported as early as the beginning of the nineteenth century, following the Treaty of Adrianople (1829). In 1839, there is evidence of building five 'commercial ships' (Păltănea 1994, 1995). In 1867, the *Military Marine Arsenal* was founded in Galați. At the beginning, barges and flatboats were built there, and from 1907 military monitor ships built at the Trieste dockyards (then part of Austro-Hungary) were assembled here.

In 1870 the German firm Strousberg founded in Galați the Workshops of the Romanian Railways which produced equipment and parts for the railway network (Păltănea 1994, 1995). In 1887, the *Bee chemical factory and tin packaging company* was built in Galați, which produced packaging for the cannery that had been working there since 1844 (Păltănea 1994, 1995). In 1888, the first nails and wire factory called *Wolff et Comp* was founded, followed by some more factories in the same field (Păltănea 1994, 1995). Max Ausschnitt (Fig. 10) established in 1920 the *Titan Works*,

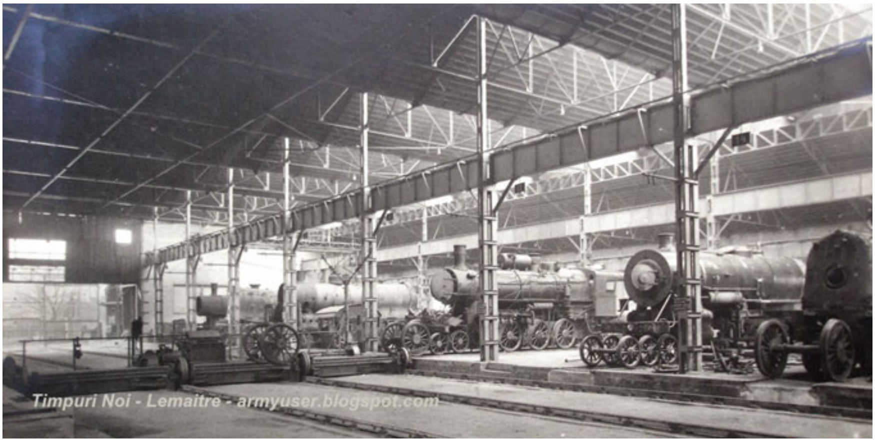

Fig. 9 The Lemaitre Works (1923) (courtesy of Dr. V. Wollmann)

producing hot rolled steel sheet, built upon the structure of his father's nail factory (founded in 1906). Later on, this factory extended to establish, in 1924, the *TITAN-NĂDRAG-CĂLAN SAR United Metal Works*, with the head office in Bucharest. After the nationalisation, the *Galați Titan Works* became the *Sheet Rolling Mill Company Galați. G. Fernic* established at Galați in 1893 the *Mechanical Construction Works and Iron and Brass Foundry*, which was transformed, in 1897, into the *Galați Dockyards* (Shipyards had been reported to exist in Galați as early as 1784.) (Păltănea 1994, 1995). *The first oil tank was built here in 1947*. After the nationalisation, in 1950, the dockyard merged with the former *Military Marine Arsenal*. It was then extended and technologically upgraded, allowing for the building of larger and more complex ships. In the period of 1974–1988, seven marine platforms for oil extraction were built at the Galați dockyards, the first of which was the *Gloria* platform.

In *1897*, the *Giurgiu Dockyards* were established, mainly for repairing river ships. Someships representative for the Romanian fleet were launched on water here

Fig. 10 Max Ausschnitt

even before the establishment of the dockyards: *Romania—the first warship of the Romanian principalities*, *Ștefan cel Mare* and *Fulgerul.*

After the War of Independence of 1877–1878, when Dobrogea was attached to Romania, and its railroad network was connected to the Romanian one by the Saligny bridge at Cernavodă (inaugurated in 1895), the freight traffic via the port of Constanța increased considerably. Therefore the need emerged to build another *dockyard* in *Constanța.* It was founded in *1899* and functioned until 1962 as a ship repairing workshop. After this date it also worked as a ship building factory for oil tankers, bulk ships, etc. The *Independence* oil tanker was built at this dockyard in 1977, while in 1984 *the largest Romanian oil tanker* of 163,000 tdw, called *Victory (Biruința).*

The development of the Moldavian railroad network made it necessary to establish repair workshops for locomotives, wagons and rolling stock in this part of the country as well (Pașcani in 1869, Galați in 1870, Iași in 1892). These, together with those of Constanța (1865) and Bucharest (1897), ensured the maintenance of the locomotives and wagons on the territory of the Romanian Kingdom. *The first such establishment* was in *Pașcani*, on the Roman-Suceava railway, founded in 1869 (Botez and Esanu 1970). Figure 11 presents this workshop. The Pașcani repair workshops rapidly developed, and both the number of employees and the technical level of the equipment and machines increased (Botez and Esanu 1970). The workshop in Pașcani continued its intense development even after the Second World War (when it got almost completely destroyed) and extended its profile, building freight wagons, ore transport wagons, and bogies.

Fig. 11 Photograph from 1873 of the repair workshop of Pașcani taken by Károly Papp de Szathmary (Botez and Esanu 1970)

Due to the extension of the railway network, another repair shop for rolling stock was needed in this part of the country. Thus, in *1892*, the *Frumoasa CFR Workshops* were established in *Iași*. This was the *first machine building factory in Iași*. (Botez et al. 1972). Later, in Păcurari-Iași, the *Vulcan SA* society was founded, specializing in repairing agricultural vehicles and equipment, and owning also a foundry and the *Biruința* factory. The production of wheels, assembly, etc. actually started in the *CFR Iași Workshops* only in 1905 (Botez et al. 1972). In 1921, the company changed its name to *Nicolina Iași CFR Workshops* (Botez et al. 1972). In 1967, the Nicolina CFR Workshops extended its production profile to building equipment and road building works (static and vibration rammers, asphalt mixture finishers, blade graders, front loaders, etc.) and changed its name to *Nicolina Iași Mechanical Works*.

Costinescu, a Romanian businessman, built *a factory for nails, screws and screw nuts* at Sinaia in 1892, as part of the *Emil Costinescu Company Sinaia*, transformed in 1913 into the joint stock company *Emil Costinescu SA*. In 1938, it started producing armament. After the nationalisation in 1948, it changed its profile and started producing equipment for precision mechanics, and beginning with 1953, also injection pumps for cars and tractors. The name of the company changed to *Sinaia Precision Mechanics Factory*.

In 1909, the *Petroșani Central Workshops* were built in order to provide mechanical and electrical repair services to the mines in the area. After the foundation of the *Romanian Joint Stock Company Petroșani*, they extend their business by upgrading their equipment. This is where Constantin Brâncuși cast the elements that compose the Endless Column.

In *September 1916*, the *General Reserve of the Aviation* was founded in *Iași*, by transferring the workshops existing in Cotroceni and Băneasa. This was *the first Romanian aeronautical industrial company in Romania*. Its role was the maintenance, repair and improvement of Romanian war planes. The factory functioned in Iași until 1919, when it was transferred to Bucharest, changing its name to the *Bucharest Aeronautical Arsenal* in 1920. Captain Ion Gudju established here the first laboratory in Romania for studying and testing the materials used to build airplanes. The Aeronautical Arsenal built *three self-designed models of airplanes* before 1939: Brandenburg, Proto 1 and Aeron.

In 1864, Prince A I. Cuza's Council of Ministers decided to establish a *foundry for armament industry in Târgoviște*. The *Arsenal of Târgoviște* was inaugurated in 1872 in the presence of King Carol I. This factory produced cannons and cannonballs until after the Second World War. Later, in 1945, it changed its name to *CFR Workshops*, and became a machine and equipment building company. In 1950, the profile and name of the factory changed, and it started to produce drilling machines, equipment for geological surveys, etc. The name was changed to *Târgoviște Oil Equipment Company*. Beginning with 1960, the drilling equipment T50-B was produced here, a state-of-the-art machine for that time on a global level. The company specialised in this field, becoming an internationally recognized company in the field due to the quality of its products.

In Craiova *the first workshop that produced and repaired agricultural machines* was established by *Mihail Nasta* in *1878*, as a branch of the British Clayton & Shuttleworth Company. In *1910*, the *Brătășanu Workshop* was established, in the beginning as a repair shop for agricultural and industrial machines. After the nationalisation, the factory started producing modern agricultural machines for working large surface areas. The name of the factory changed to *Craiova Tractors and Agricultural Machines Factory.*

At *Aiud*, Alba County, a *locksmith's workshop* was established in *1894*, transformed in 1931 into the *GENIUS Factory for Technical Articles.* After 1948, the workshop was nationalised and took on a new name, the *Rapid Factory Aiud,* and in 1951 it extended its profile to the repair of locomotives and wagons. In 1954, it changed the name again to *Aiud Metalworks,* and in 1958 started building machines and equipment for metalworks, ironworks and machine building industry, having been considered the *Chief Mechanic of Romanian Metalworks and Ironworks.*

The first factory of Satu Mare was founded in *1906* and named *Princz.* In time, the factory had repeatedly changed its name and production profile, and after 1948 it started producing household machines (especially gas stoves). The first Romanian gas stove was produced here in 1952. In *1911*, the *UNIO* factory was established here, specialising in furniture manufacturing. After the First World War the factory changed its profile, producing freight wagons and carriages (*the first Pullmann type coaches in Romania*). After the nationalisation, the company changed its production profile and, after 1950, it started producing mining equipment (minecarts, conveyor belts with scrapers, ore loading machines, etc.).

Because of the developing oil industry in the Prahova region, a group of oil industrialists founded the *Drilling Repair Company in Ploiești in 1908* (Pintilie 2007). Later, in 1913, it was transformed into the *Drilling Repair Company*, extending its profile to making reservoirs, pipes, faucets, etc. After the First World War, in 1922 it changed its name to *Ploiești Metalworks*, also manufacturing drilling and extraction equipment. It also extended to the field of the military before the Second World War, manufacturing *automatic anti-aircraft guns under Schneider licence* (Pintilie 2007). It was nationalised in 1948 and renamed the *May 1 Works Ploiești,* becoming *the main supplier of deep drilling equipment of the Comecon countries.*

The *Roman Mechanical Works (IMR)* was founded in 1916 as part of the Army Arsenal, specialising in military equipment. After the nationalisation in 1948, the company profile diversified, specialising in producing machine tools for wood processing, carousel lathes, overhead cranes, cranes, forklifts, etc. The ONSAL Roman (detached from the IMR) *produced in 2013 Europe's largest carousel lathe,* with the maximum diameter of the turning part of 17 m and weighing 450 tons (Fig. 12).

In order to examine the situation of the industry in Romania at the beginning of the twentieth century, the Minister of Agriculture, Trade, Industry and Estates initiated in October 1901 a census (industrial survey) of production companies which was carried out in 1901–1902. Its results and analysis were published in 1904 in two volumes under the title *Ancheta Industrială din 1901–1902* (*The Industrial Survey of 1901–1902*) (*** 1904). The first volume is dedicated to the major industry. The

Fig. 12 Europe's largest carousel lathe, produced at ONSAL Roman (Photo from the author's collection)

major industry, according to a law from 1887, meant the industry that comprised companies which met three conditions cumulatively: a fixed capital of over 50,000 lei, over 25 employees, and the use of modern machinery. The results of the survey showed that Romania had, in 1901, a total of 62,188 production units in the major and minor industry combined, with a driving force of 60,744 horsepower (HP), employing a number of 169,198 workers. In contrast, the processing industry (sawmills, metalworks, mechanical factories, glassworks, pottery, brickyards, cement factories) only comprised 127 factories with a driving force of 8,310 HP and employing only 10,990 workers. The textile industry included 49 factories with a driving force of 2,507 HP, employing 5,449 workers. The food industry included 35 factories with a driving force of 4,611 HP, employing 2,172 workers. The paper, cellulose and typography industry included 21 factories with a driving force of 4,783 HP, employing 2,587 workers. The chemical industry (including oil industry) comprised 51 production units with a driving force of 1,025 HP, employing 2,264 workers. The two electrical power plants operating in the period had an output of 4,800 HP, employing 60 workers. Another category were the companies which processed agricultural products (food industry: mills, distilleries and breweries). These comprised 126 items in all (86 mills, 28 distilleries and 12 breweries) with a driving force of 13,874 HP, employing 4,431 workers. The third category were the state or communal companies (tobacco factories, match factories, military factories, typographies, dockyards, railway workshops, electric power plants, water power plants, etc.). These comprised 52 items with a driving force of 9,230 HP, employing 9,742 workers. The major industry comprised a relatively low number of companies, only 471, with a driving force of 49,140 HP. It employed 37,695 workers. The data analysis shows that the major industry only accounted for less than 1% of the production units but had an installed power of 80%. The major industry employed over 22% of people working in industry. The analysis also proves that *at the beginning of the twentieth century the Romanian industry was primarily based on minor industry (manufacturing), with a low technical capacity (less then 20% of the driving force—steam engines, internal combustion or electrical machines) and employing 78% of people working in industry.* An excellent analysis of the data of the Industrial Survey from 1901–1902 was published by N. I. Păianu in his work *Major Industry 1866–1906* (Păianu 1906).

Before the First World War, in 1914, there were 83 metal processing companies on the territory of Romania, with an installed power of 9,600 HP (Păianu 1906). Transylvania and Banat had an important contribution to Romanian industry after the 1918 Union (Table 1) (Popescu 1929).

The data presented in Table 1 displays a significant difference in the distribution of industry within the historical provinces of Romania, highlighting the very low prevalence of industry in Bessarabia. Taking into account strictly the metallurgy and machine building industry, the installed power of the factories of Transylvania and Banat was 57,836 HP of the total Romanian installed power of 86,714 HP, which means 66.5% (Popescu 1929). The geographical distribution of the extraction and processing industry of Romania after the Great Union of 1918 was very uneven across the country (Gusti 1939; Georgescu 1941; Malinschi 1964). These branches of industry were almost completely absent in Bessarabia and Moldavia, and strongly localised to some key areas: Banat, Central Transylvania, Bucharest and the Prahova Valley, as well as Galați and Brăila. The Great Romania formed after the Great Union of 1918 had to respond to two great challenges in the field of industrial development, both caused by the aforementioned inequalities: that of the major and minor industry, and the unequal geographical distribution across the country.

Table 1 The distribution of driving force of industry in the Romanian provinces (Popescu 1929)

Province	Horsepower (HP)	No. of inhabitants per HP
Transylvania and Banat	210,115	26
Bucovina	20,640	39
Wallachia and Moldavia	171,340	46
Bessarabia	9,580	302

2 Machine Building Industry in the Interwar Period

The Great Union of 1918, which resulted in the annexation of Transylvania, Banat, Bucovina and Bessarabia, had a significant impact on the social and economic life of Romania. The Malaxa Workshops were founded in 1921, specialising in locomotive repairs. Drawing on the provisions of the law for the encouragement of industrial development, Nicolae Malaxa (Fig. 13), an excellent engineer trained at the Technical University of Karlsruhe, Germany (currently the Karlsruher Institut für Technologie) and a visionary entrepreneur, began building a factory for railway equipment in 1923. In 1928, he started making steam engines, railcars, carriages, Diesel engines, etc. At that time, the Malaxa Factory was Europe's foremost rolling stock factory and of the most modern ones from an architectural point of view (Fig. 14). In 1928, the first steam engine was built there. Between 1932 and 1934, locomotives went into production, and in 1931 the first Diesel locomotive was built. It took over the novelties of the field in a very fast pace, proved also by the fact that in the period of 1934–1940 seven generations of railcars were designed and produced at the factory. Malaxa used a revolutionary patent of Gogu Constantinescu in railcar building, called the *Sonic Couple Convertor.* This patent was used for the first time in the world for the building of locomotives at the Malaxa Factory. Consequently, Romania did not have to import any locomotives after 1930. In 1939, the most powerful steam engine in Romania was built here (Fig. 15). After the 1948 nationalisation, the factory became the *23 August Factory*. In 1938, Malaxa established, as a part of the rolling stock factory, the factory of artillery ammunition and armament, producing, in addition to artillery ammunition and armament, tankettes as well (designed also group). In the same year the production of optical equipment for military use also started. It also produced tanks under Renault licence. In 1938, Malaxa also built a factory for making seamless pipes, which was later renamed *Republica.* This factory was, at the time of its inauguration, the most modern factory of laminated pipes in Europe, using the American Stiefel lamination method for the first time on the continent. When pipe production for oil industry was at its best, this factory was the fifth largest producer of seamless pipes in the world. Beginning with the 1970s, the factory started producing parts for the Cernavodă Nuclear Power plant. In addition to the factories in Bucharest, including IOR Bucharest (Romanian Optical Industry), the Malaxa concern also included factories in different locations throughout the country: the Astra Arad, Unio in Satu Mare, the Tohan Factory of Zărnești (founded in 1938 for making bicycles, and later artillery ammunition). The UDR Reșița built in 1945 the Malaxa car, which was the first Romanian-designed automobile. It can be said that in the period 1921–1945 Malaxa managed to build an industrial complex for Romanian machine building, which became the main pillar of Romanian industry between the two World Wars. What's more, it was considered one of the great industrial complexes of Europe as well, as an example for a successful use of national capital. The words of one of Malaxa's collaborators are meaningful: '*He was the man and engineer who had the courage, skill, and patriotism necessary to demonstrate to the world the* *industrial vocation of the Romanian people, considered by foreigners to be nothing but ploughmen and shepherds'*.

In 1923, the engineer Grigore Zamfirescu founded in Bucharest the *Society for Technical Explorations*. This was *the first airplane building company in Bucharest* (Manole et al. 1991). At the beginning, the company repaired and maintained the military aircrafts of the Romanian army, then it started to modify the bombing planes, and in 1926 it started to design and produce its own airplanes. In 1927, the *Proto-SET* model was built, and in 1928 the *SET-3*, later starting the production of the latter.

Fig. 13 Nicolae Malaxa, the founder of modern national industry

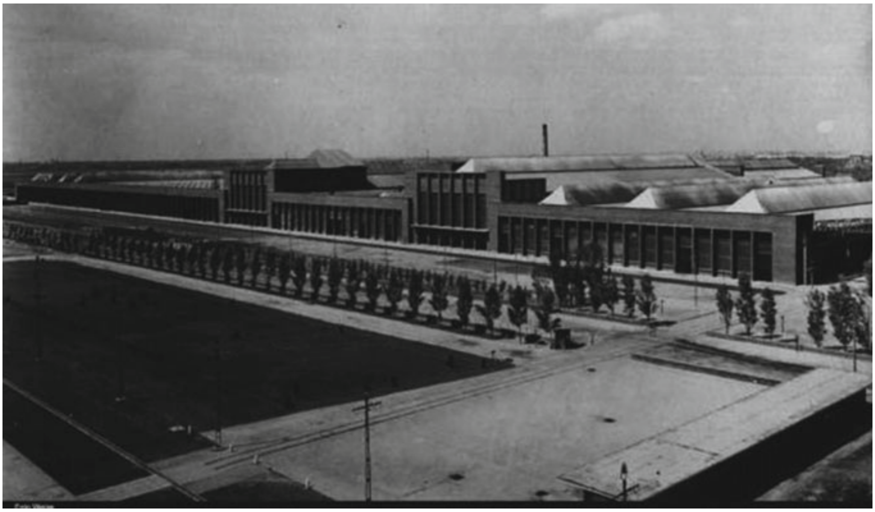

Fig. 14 The Malaxa Factory in 1933 (design by architect Horia Creangă) (courtesy of Dr. V. Wollmann)

Fig. 15 The most powerful steam engine in Romania, produced by the Malaxa Factory in 1939 (Photo from the author's collection)

In 1931, the SET changed its name to *Grigore Zamfirescu Airplane Factory S.E.T. (Fabrica de avioane S.E.T. inginer 'Grigore Zamfirescu')*, and developed production by designing and making new airplane models, especially for military industry (Manole et al. 1991). In 1953 the factory upgraded its technology and changed its profile to the production of measurement and control devices, renamed to *Precision Mechanics Company.*

The Ford Factory of Bucharest was established in 1935 under the name Ford Romania SAR, with the purpose of producing car body parts and to repair automobiles. This was where the *Ford V8 Fordor Sedan* car was built. In 1948 the factory was nationalised and closed down. In *1926*, the *Leonida Workshops* were established in Bucharest. At first, it was a *truck assemblage* shop, *the first of its kind in Romania.* Later it became the Romanian representative of the *General Motors*, changing its name to Leonida S.A.R. (Manole et al. 1991). In 1921, the *Fichet Factory* was established (Manole et al. 1991) which built safe boxes, cash registers and other steel sheet products. In 1949 the *Semănătoarea Factory* was built on the structure of the former. In the first period of its existence it produced trailed harvesters and sowers, and after 1955 it moved to a different level, producing trailed combine harvesters and precision sowers. Beginning with 1969, it started producing self-propelled combines, the first of these being the Gloria C12. This was a great success for Romanian agriculture, as it greatly increased the productivity both for straw cereals and corn harvest. In 1936, the *Romanian Optical Company IOR* was founded in Bucharest, as the first Romanian factory that produced optical equipment. During the war, in 1941, the company started to produce military equipment (binoculars, telescopes, telemeters, etc.). After the nationalisation, beginning with 1949, this is where the first eyeglass lenses, the first didactic microscope (1951) and the first Romanian photo camera called OPTIOR (1954) were produced. Later the production extended to the field of medical equipment for ophthalmology (1959), equipment for dentist's offices (1961), binocular microscopes (1960) and research microscopes (1962), cinema projection equipment and camera lenses (1967).

In 1920, a joint stock company was founded in Câmpia Turzii (Ghiriș) with the name *Wire Industry*, which produced dead-drawn wire and nails. After it was nationalised in 1948 it changed the name to *Câmpia Turzii Wire Industry Factory*.

The *Romloc* company was founded in Brașov in *1921*, as a locomotive and wagon repairing workshop. In 1935, the ***Astra Wagons Arad*** company extended its activity to Brașov, on the Romloc territory. In 1938, Romloc changed its profile to armament production. After 1948, the factory was renamed **the *Red Flag (Steagu Roșu)***. In 1953 the *Steagu Roșu* factory produced the first Romanian truck, SR (Steagu Roșu) 101, while in 1958 the first lorry, SR-131 Carpați, and at the beginning of the 1960s, the SR-114 Bucegi were built. In 1978, the factory reached its production record of 30,000 lorries, and a number of 26,000 employees. In 1922, the *Dumitru Voinea Machine Factory and Foundry* was established in Brașov for rolling stock repairs. In 1936 the factory changed its name to D. Voinea Metalworks S.A.R. Brașov, and started producing military technology (Brandt grenade throwers), becoming one of the main Romanian weapon producers. After 1965 it changed its profile and produced carburettors, oil and diesel filters, oil, fuel and water pumps, becoming the main supplier for the Romanian car and tractor industry. The Romanian-Austrian *Farola* company was also founded in *Brașov* in *1923*, manufacturing wire, steel sheet and copper cables for the engines of railway equipment. In *1935*, the *Metrom* factory was established, which, beginning with 1938, produced steel sheets, tapes, strips, bars, formed panels, copper and copper alloy tubes. *The airplane production in Brașov began in 1927, under Morane-Saulnier licence.* Engineer Elie Carafoli together with Lucien Virmoux, French engineer and technical counsellor at the IAR, designed the first Romanian fighter jet called *IAR C.V.-11*. It was built and tested in 1930. It was a monoplane with low wings, considered to be one of the best aircrafts of its category in the world. The design and production of new airplanes continued throughout the years with types IAR-16, IAR-39, IAR-80, and IAR-81, and the research aircraft IAR-47. *In 1928, the IAR started the production of airplane engines. The first mass-produced engine of Romanian design* was the *IAR-K-9*, with a performance similar to foreign models, produced in *1937*. Figure 16 presents an overview of the IAR factory in Brașov from 1932 (Stoica and Antoniu 2020).

The *Benker&Jickeli Machine Factory and Iron Foundry* was established in *1920* (http://patrimoniu.sibiu.ro/istorie/industrie/38). In the interwar period it produced machines and parts for the textile industry. After the 1948 nationalisation, the factory changed its name to *Sibiu Metalworks*. Beginning with 1961, the factory's profile was the production of pressing machine tools. In 1965, the factory changed its name to *Sibiu Mechanical Company*, and it had continuously diversified and extended its production profile before 1990. At first, it produced a large variety of hydraulic

Fig. 16 Aerial photograph of the IAR factory in Brașov-1932 (courtesy of H. Stoica)

presses for cupping, sheet bending presses, plastic extrusion machines, precision cutting presses, etc. The GRATIOZA company, which was founded in Sibiu in 1922 with Austrian capital, produced envelopes and paper as well as parts and equipment for paper factories. After the nationalisation it changed its name to *Flamura Roșie State Industrial Company*, becoming the largest producer of office and school supplies in the country. *This was the first company in the country to make plastic products.* After 1960, it also produced plastic processing machines first for utility vans, then also for sales, and extended production also to equipment for the textile industry.

In 1921, the *Westen Modeling and Enameling Works* was founded in Mediaș, as *the first Romanian factory to produce enameled pots for household use* and other sheet products. It was nationalised in 1948 and renamed *Red Enamel (Emailul Roșu),* maintaining its production profile and becoming the largest Romanian producer of kitchen supplies made by pressing. The *State Aeronautics Workshops* were founded during the Second World War (in 1941) in Mediaș for the repairing and maintenance of airplanes. After the nationalisation, it changed its production profile to a car repair company, and successively changed it name as well to *Central Car and Tractor Repair Workshop* (1957), then *Automechanics (Automecanica)* (1962).

As a result of the union of Transylvania and Romania and the new political, judicial and economic situation, the Romanian industry of Transylvania underwent a full reorganization. The same happened in Cluj as well, with many new companies, mainly joint stock companies (SA) appearing especially in the field of metallurgy and machine building. The Orion company, founded in 1924, made household products. After the nationalisation, it changed its name to *Red Metal (Metalul Roșu).* It became a producer for equipment and machines for food and textile industries. In 1929, the *RAVAG Metal Industry SA* was founded, which after the nationalisation became the *Armature (Armătura)* Company. The new company's production profile was sanitary fittings of non-ferrous materials.

Timișoara in the interwar period had more than 10 workshops and factories specialised in machine building. The most important of these were: *The Mecher Sheet Factory* (sheet products), *the Herman Scales Factory* (scales, bascule bridges, weighing machines), *Marki Workshop* (industrial repairs), *Friedrich Brothers Machine Factory and Foundry, Dura SA Factory, Jakabffi Cash Register Factory, Fabrica de lanțuri 'Timișoara' S.A. (chain factory)*, etc. (Munteanu and Munteanu 2002).

The *French-Romanian Company for Railroad Materials SA* was founded in Brăila in *1921.* The company was initially founded as a locomotive repair workshop. In 1940, it merged with the Phoebus company of Oradea. In 1948, the company was nationalised and renamed the *Progress Heavy Equipment Factory Brăila,* including the production of machines used in constructions. It was here that the *first Romanian cable excavator was built in 1952, and the first compression roller in 1953.* Later on, the production got more diverse, it produced excavators, vibrating roller compactors, crushers, vibrating plates, bulldozers, etc. In 1972, it produced the *first hydraulic excavator* (under Liebherr licence), in 1980 *the first telescopic arm excavator,* in 1987 *the first electrical excavator, tracked excavators,* etc. The experience gained in the process led to the production, in 1974, of *the largest speed reducer produced in Romania*, weighing 80 tons and 6 m high, made for the Galați Steelworks. Also after the First World War, in *1923*, the *David Goldenbers and Sons* company was founded in Brăila, producing *drawn wire, nails and metal products.* After 1927, other products were made as well, including chains, screws and screw nuts. In 1931 a rolling mill was built for making wire and reinforced concrete. The company was bought by Max Ausschnitt in 1933 and joined the TITAN-NĂDRAG-CĂLAN consortium. In 1938, it was renamed the *Danube Metalworks (I.M.D).* In 1930, the Wire Industry company of Câmpia Turzii built the first wire rolling mill in Brăila. Both companies were nationalised in 1948 and worked independently until 1959, when they merged under the name of *Brăila Rolling Mill.* The factory grew continuously, making rolling mills for various sizes and shapes of profiles for the entire range of profiles necessary for machine building industry.

In *1937*, the *Mărgineanca Factory* was established in *Plopeni, Prahova County,* to produce *ammunition.* After the nationalisation, it extended its production profile to civil industry products: bearings, parts for oil industry, pumps, engines and hydraulic cylinders for vehicles and machine tools, etc.). The *Plopeni Mechanical Works* was one of the *most important producers of armament in Romania,* reaching a number of 19,000 employees before 1990.

In 1938, there were 366 machine building companies in Romania, with an installed power of 152,100 HP, representing 10.2% of the global industrial production value (after food and fuel industries) (Gusti 1939; Georgescu 1941; Malinschi 1964; *** 1940, *** 1941; Constantinescu 1997).

3 Machine Building Industry in the 1948–1990 Period

The 1944 occupation of Romania by the Soviet Union marked the beginning of a nationalisation process of all companies on the territory of the state. In order to pay the war compensation to the USSR (which amounted to 300 million dollars, i.e. 55% of Romania's national income in 1945), there started a process of transferring certain production lines to the Soviet Union (such are the cases of IAR Brașov, some tobacco factories, steelworks, typographies, etc.). In 1948, the main companies of Romania were nationalised ('individual businesses, companies of all kinds, and private industrial associations'), with 20 companies of steelworks, non-ferrous metalworks, and rolling mills, and 115 metal processing companies, dockyards, precision tools and electrotechnical material producers, and car repair workshops (*** 1948). Several companies with equal mixed Romanian-Soviet capital were founded in the 1945–1956 period (the so-called Sovroms) in the most profitable fields of industry. These companies had the purpose of facilitating and controlling the payment of war compensations. It has been assessed that over 30 billion dollars at the present rate were paid to the USSR. This led to the exhaustion of the country's natural and financial resources (strongly affected because of the war) and to a drastic fallback of industry, which decreased 45% compared to the 1941 production. The solution of the Romanian governing party (borrowed from the Communist Party of the USSR) to stimulate the economical growth of the country was to introduce a central stage-based planning (the so-called five-year plans). The first five-year plan was implemented in the 1951–1955 period, and the system was in place until the fall of communism in 1989. Before 1951, the Romanian economy was planned on a yearly basis. When the five-year planning was introduced, the reconstruction of Romanian economy was coordinated by a State Planning Committee. The five-year plans stipulated huge investments in industry, mainly in heavy and chemical industry. Two industrialisation periods can be distinguished for the 1945–1990 period: the first before 1965, and the second after 1965. The first period is characterised by rebuilding the Romanian industry, subordinated (especially in the 1950–1960 period) to the economical and political interests of the USSR. The second period after 1965 was characterised by the principles of multilateral development (first and foremost of steelworks, chemical industry, oil industry and machine building) and equal geographical distribution. Consequently, in 1989 the proportion of industry in the GDP was 46.2%. The intense industrialisation process led to a significant rise in the number of industrial companies, from around 1,000 units in 1945 to 1,568 in 1965, and 2,102 in 1989. In the same period the total industrial production of the country increased 44 times. In what follows, the history of machine building will be presented according to the two historical stages, distinguished mainly by their investment priorities and the criteria behind these investments.

3.1 Machine Building Industry in the 1945–1965 Period

This period is defined, on the one hand, by the technological upgrading of companies founded before the Second World War, and on the other hand by the establishment of new machine building companies in the areas where machines and equipment were lacking (chemical industry, heavy machines industry, steelworks, vehicle building, food processing, etc.). The following pages present the main companies in the field of machine building founded in the 1948–1965 period in the chronological order of their foundation. In *1946*, the production of the *IAR Brașov* factory was changed to *tractor production.* The *first Romanian tractor, IAR 22*, was built in the same year. The IAR was closed down the next year and the factory was renamed the *State Metalworks*, and later (1948) the *Tractor Plant Brașov (UTB).* The first tractor designed completely in Romania was produced beginning with 1960 (U650). IN 1990, the factory had 23,000 employees and produced 50,000 tractors, more than half of which was exported. The *Sinterom* in *Cluj* was founded in *1948* as the nationalised *Triumf* company, established in 1936 for making chemical products. After the nationalisation it changed its production profile, making spark plugs for engines. One of the first companies established after the Second World War was the *Electroputere Craiova,* founded in *1949.* At first, it produced high power energetic equipment, and from 1960 it moved from the production of diesel-electric locomotives to electric locomotives (from 1966), under licence of the Swedish ASEA company and cooperating with the Reșița Machine Building Factory for the mechanical part. In the course of time it also produced electric railcars. The *Tehnofrig company* was founded in *1949* and used the equipment of the Hungarian industrialists of *Cluj.* It produced machines and technological equipment for food industry and refrigeration installations. In 1949, the IMATEX Textile Machine Company was founded in Târgu Mureș which produced automatic looms, winding machines, etc. In 1952, the Metalotehnica Company came into being, specialising in the production of machines and equipment of knitwear industry, industrial sewing machines, etc. The Arad Lathe Factory was established in 1949, as a merger of several factories and workshops. Later it took on different names (*Iosif Rangheț Plant, the Lathe Plant, the Arad Lathe*), and extended to nearby areas with departments in Lipova and Chișineu Criș, Arad County. In *1951*, the *Victoria watch factory* was founded in *Arad*, the *only factory of its kind in Romania.* It produced over 1 million watches before 1990. In addition to watches, the Victoria Factory also produced mechanisms and parts of precision mechanics for Romanian industry. The building works of the Danube-Black Sea Canal started at the beginning of the 1950s made necessary to build also a repair shop for the building equipment used at this construction site. The workshop was built at *Medgidia in 1951.* In 1958, after the construction of the canal was given up (1955), it was extended and started producing trailers and agricultural machines under the name *Medgidia Mechanical Equipment Factory (IMUM). The first independent bearing factory of Romania was established in Bârlad, Vaslui County, in 1951:* the *Bârlad Bearings Factory*. (Bearings were also produced in Brașov, but as a department of the Steagul Roșu Lorry Factory.) The production of bearings, using a Russian technology, began in 1953. The factory developed in time and extended production by diversifying the size and construction range of the products (from 4 type-dimensions to over 13,000). The *Airplane Repair Plant* was established in *Bacău* in *1953*. It was a military-type company. Later it changed its name to the *Airplane Repair Company* (1970), the *Airplane Company* (1978), and in 1991 it turned into a joint stock company with the name *AEROSTAR SA Bacău*, producing, repairing and modernising military aircrafts and producing and repairing hydraulic aviation equipment. Also in *1953* the *Tudor Vladimirescu Company* was founded in *Bucharest*. It produced threshing machines for cereals and freight trailers. The first *TV-type* (Tudor Vladimirescu, the name of the factory) bus was produced there in *1957*. Later the plant changed its name to *Autobus Plant* and produces buses, trolleybuses (1957), microbuses, coaches and utility vans. The *Mangalia Military Dockyards* were established in *1956* to *build military ships*. The *Drobeta-Turnu-Severin Freight Wagon Factory* was founded in *1956* and became one of the largest rolling stock producing factories in Romania. The *Electromureș of Târgu Mureș,* founded in 1957, *produced mechanical calculators*. Later, the production profile of the company extended and included electric heating products (electric heaters, electric hotplates, irons, etc.) and, from 1970, electro-mechanic calculators and cash registers for shops. In *1959*, a part of the the Red Flag (Steagu Roșu) Plant of Brașov was detached, and it became an independent factory called *Bearing (Rulmentul) Factory*, one of the main suppliers of bearings for Romanian industry. In *1960*, the *Mechanical Factory for Mining Machines and Equipment (IMUM)* was founded in *Baia Mare*, specialising in the production of *equipment for mining industry* (floaters, filters, crushers), building materials, metalworks and chemical industry. The *Steelworks Constructions and Fixtures Company (ICMSG)* was founded in *Galați* in *1960* in order to provide materials for the construction of the Galați Steelworks Company, one of the major industrial investments of Romania (a construction started in 1962). Due to the development of wood and paper industry in Suceava, it was necessary to establish a factory for the repairing and maintenance of mechanical equipment. Thus, the *Suceava Regional Factory for Maintenance* was founded in *1963*. Later it changed its name to *Suceava Mechanical Factory (IMS)* and extended its profile to metal constructions. In 1980, IMS was transformed into the Suceava Machine Tools Factory (IMUS), focusing mainly on the production of heavy duty parallel lathes, drilling machines, band saws and circular saws, aggregate making machines, etc.

The Bucharest Heavy Machines Factory (IMGB) was founded in 1963 to produce large forged parts, chipped processing, etc., needed in metalworks, hydroelectric and thermal industry and later nuclear industry (Babici 2017). When Romania started its nuclear programme with the introduction of technologies from the US (General Electric) and Canada (the CANDU technology), it opened the way to the processing of very large and extremely heavy parts (up to 400 tons) through pressing and forging.

This was a real challenge for the machine building industry of Romania. IMGB was the main pillar for processing of such parts. Based on the IMGB's experience in making large forging presses, in 1978 they started the production of the 120 MN (12,200 force tons) press, which was finished by the end of that year. In order to manipulate the semi-products of 400 tons on the forging press, special manipulators were needed. Such a manipulator was designed and produced at the IMGB as well. The manipulator and the 120 MN press were the most complex pieces of equipment produced in Romania for the metal processing industry, placing Romania as one of the top three countries in the world to have such technology. Figure 17 presents the 120 MN press and manipulator for forged parts. The IMGB also produced other large parts, like crankshafts, transmission shafts, and rudder spurs for heavy ships. One of the parts made for metal processing industry worth mentioning is the continuous casting installation for the Galați Steelworks (Fig. 18). *One of the most complex products of the Romanian industry was the main circulation pump of the nuclear reactor of the Cernavodă power plant.* These pumps were only made in three places in the world, one of which was the IMGB. Figure 19 presents its structure and size. The mass of the pump's cast shell processed at final dimensions, was 125 tons. The *Machine Tools and Aggregates Factory IMUAB* was founded in Bucharest in 1963. The reason for the foundation of this factory was to make Romanian-built machine tools, high precision aggregates, and numerically controlled cars for machine building companies (Sandu et al. 2018).

3.2 Machine Building Industry in the 1965–1990 Period

In the period of 1965–1990, the machine building companies had their part in achieving Romania's strategic objectives. Such objectives were: the building of the Galați Steelworks, cement factories, chemical factories, hydroelectric and thermal power plants, modernisation of the factories of airplanes, locomotives, buses, lorries, tractors and agricultural machines, the building of Dacia Pitești and Oltcit Craiova car plants, the building of Cernavodă Nuclear Power Plant, etc. The achievement of these objectives was a challenge for Romanian industry, requiring the combined and well coordinated effort of all actors involved. Therefore, a comprehensive industrialisation programme started, which claimed the construction of new factories or the technological upgrade and adaptation of existing ones. In order to better coordinate the machine building companies, and to achieve the strategic objectives of Romania, industrial centres were built which comprised several factories and research and design institutes with identical or similar profiles. The strategic objectives to supply machines and equipment for the various branches of economy were: making use of the country's natural resources and raw materials especially with regard to oil and gas, coal, ferrous and non-ferrous materials, building materials and wood; the development of the electric power supply to support this rapid industrialisation agenda, based mainly on Romanian raw materials (coal, gas, uranium), and making the most of the country's hydroelectric potential; the development of agriculture and food industry by

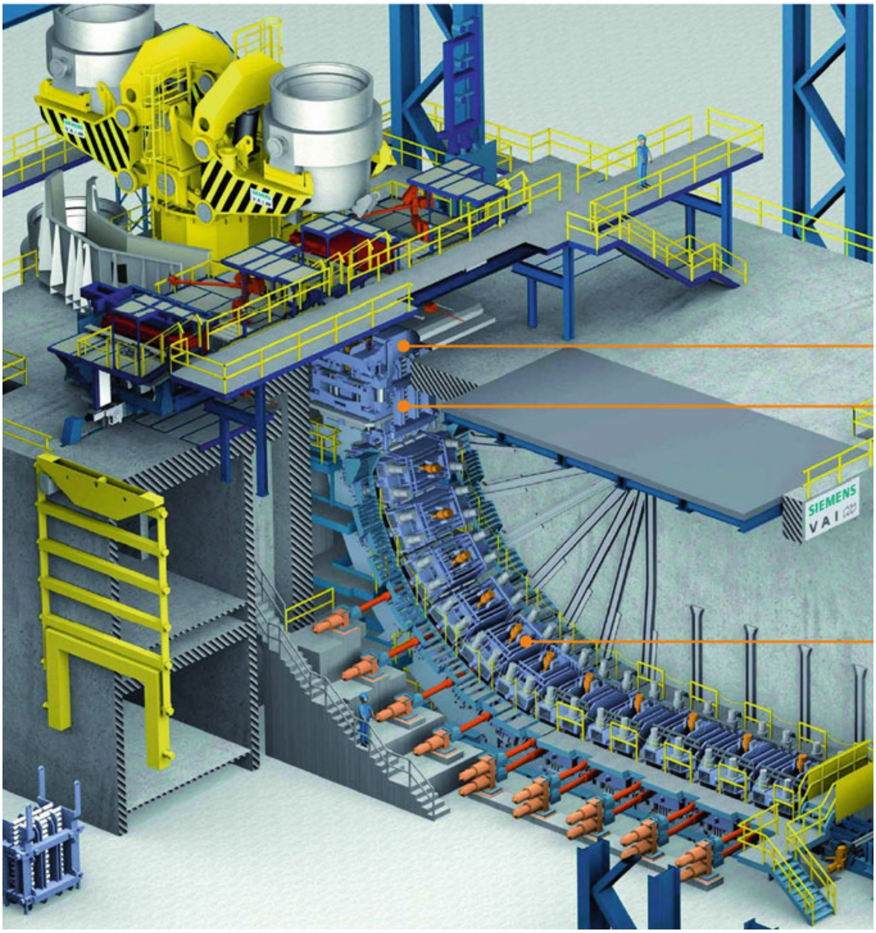

Fig. 17 A 120 MN press and forged parts manipulator produced at IMGB (Babici 2017)

the mechanisation of production, the irrigation of areas with water deficit (Bărăgan, the south of Moldavia, Dobrogea, Oltenia, Banat), the industrialisation of Romanian agricultural products; the development of new branches or processing industry, especially metalworks and petrochemistry; the development of building materials in order to supply the materials needed for the construction of these establishments, especially cement; the support of the development of transportation, mainly road and railroad transportation, but also water transportation by river and sea; the development of fields of processing which had a high rate usage rate in machine building (electrotechnics, electronics, precision mechanics, aviation and military industry); the development of light industry and the branches of consumer goods industry.

In what follows, the establishment and development of companies in the various branches of machine building industry will be analysed for an easier and more

Fig. 18 The continuous casting installation made by IMGB for the Galați Steelworks (Babici 2017)

coherent presentation of the industrialisation process of this period. The first *machine tools* were produced in Romania since the interwar period in factories with a technology high enough to build such equipment. The first machine tools (lathes, drilling machines, milling machines, presses) were produced by these factories for their own equipment. Such examples are presented in the previous chapters: the ASTRA company of Arad, the Schiel company of Brașov, the Zamfirescu workshops in Bucharest, etc. After 1945, some companies specialised in producing machine tools in order to sell them. In 1965, there were just a few companies in Romania which produced machine tools, some of them built on the structure of other companies founded before 1945 [the Cugir Mechanical Works, the Sibiu Mechanical Works, the Brotherhood (Infrățirea) company in Oradea, the Arad Lathe Company, the Roman

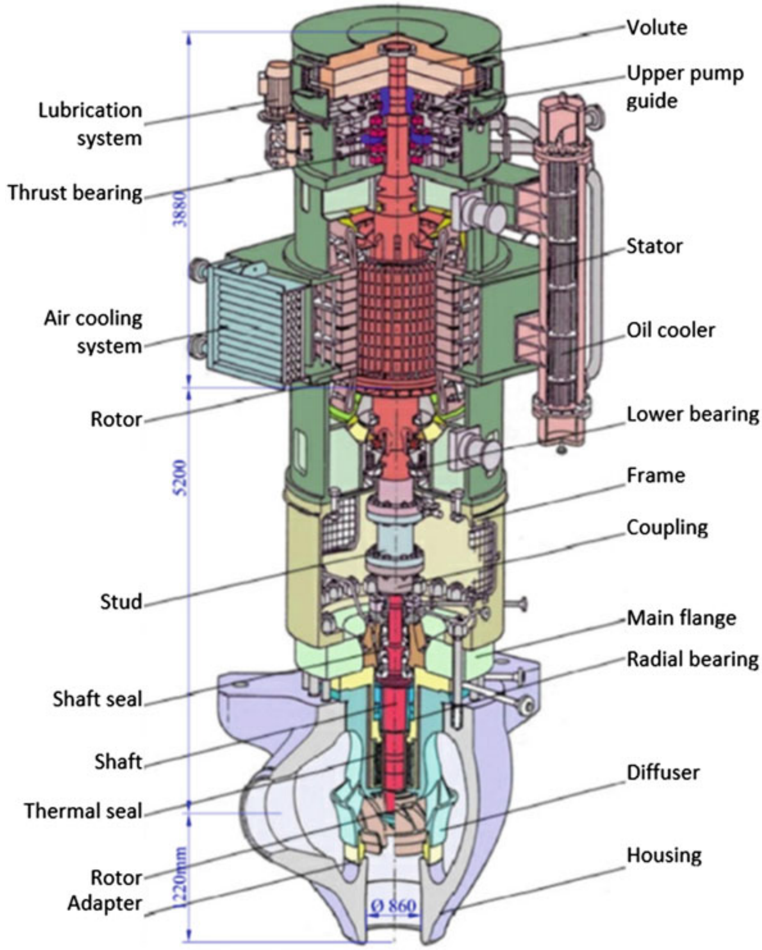

Fig. 19 The main circulation pump GTN 195 M of the 1,000 MW group of Cernavoda Nuclear Power Plant (Babici 2017)

Mechanical Works], others founded after 1945 (the Bucharest Machine Tools and Aggregates Company, the Suceava Machine Tools Factory). In order the catch up with other countries more experienced in this field, documentation and licence agreements were signed with companies from Germany, France, Italy, USA, Japan. A large number of machine tool factories were founded in this period, specialising in different types and sizes: The SARO Târgoviște Lathe Company (1969); Bacău Machine Tools Company (1971); Alba Iulia Mechanical Works (1972); Blaj Company for Machine Tool Accessories (1972); Electrotimiș Company Timișoara (1973); The Mechanical Rectifier Factory Cluj-Napoca (1973); the Iași Factory of Machine Aggregates and Special Machine Tools (1974); the Craiova Heavy Equipment Company (1975); Factory of Machine Tools for Pressing and Forging IMUPF Târgu Jiu (1975); Baia

Mare Machine Tools, Accessories and Tools (1977); Machine Aggregates and Parts Company (IMASA) Sfântu Gheorghe (1977); Dorohoi Heavy Machine Tools for Plastic Deformation Processing Company (1979), etc. In addition to these machine tool factories, the industry of tools and devices was also developed and new factories were founded: the Râșnov Tool Factory, and the Brașov Tool Factory presented before. The Focșani Device, Dies, Moulds and Cutting Tools Company was founded in 1971 (Sandu et al. 2018).

In order to support the objective of raw material usage, the industry of mining equipment and machines especially for surface mines was also extended and developed. For surface mines, large capacity system equipment was developed. Apart from large capacity transporters, other equipment was also designed and produced in the country, at the Mârșa Mechanical Works: 25 tons, 50 tons and 100 tons dump trucks, built with the American WABCO technology. The Faur Company Bucharest designed and produced mine gallery drilling machines, used both in mining industry and for building the underground in Bucharest.

The *metal processing industry* witnessed explosive development in this period, which needed to be supported with *adequate equipment*. The objective of the metal industry was to reach a production of 13 billion tons (starting from a yearly approx. 2 million tons in the 1960s). In order to achieve this objective, the Romanian machine building industry had to assimilate a complex range of metalworks equipment. For this reason the older steelworks, like those of Reșița, Câmpia Turzii, Oțelul Roșu, Brăila, were modernised, and the newer factories at Hunedoara, Galați and Călărași were developed. Equipment for furnaces, steelworks, coking, rolling mills, continuous casting machines, heavy presses for adjusting high capacity heat treatment furnaces were also produced. The main producers for metalworks equipment were Reșița, Faur Bucharest, Progresul Brăila, the Heavy Equipment Factory of Cluj and Iași, and a series of other factories in their horizontal industry (Sandu et al. 2018).

In the 1980s, Romania was the third producer in the world in the field of oil industry equipment. It supplied the whole range of drilling and instrumentation equipment from geological drilling to deep drilling for oil and gas. These were produced at the May 1st Factory Ploiești, the Oil Industry Equipment Company from Târgoviște, and the pumps at the Vulcan Plant in Bucharest. In 1976, a new plant was built in Giurgiu, the Machine Building and Heavy Equipment Company (Antonescu 2018).

After 1950, and especially after 1965, an extensive construction programme started for building a chemical and petro-chemical industry in Romania. The chemical equipment and machine building companies had a crucial role in this programme. In addition to the factories with a history in the field (like the Grivița Chemical Equipment Factory in Bucharest, the May 1st Factory in Ploiești), new companies also had to be founded for various fields of chemical industry. The Technological Equipment Company in Buzău, the Chemical Equipment and Forging Company of Râmnicu Vâlcea, etc. were founded at this time (Ivănuș 2016).

In the field of the *development of the electric power supply*, the machine building industry had to make the four types of equipment for *thermal power plants*, for *hydroelectric power plants*, for *nuclear power plants* and the beginning of equipment production for the field of *unconventional energy resources*. The thermal power plant programme started in 1965–66, when licences were bought from Alsthom France (330 MW plants produced at the Heavy Machines Company in Bucharest) and from Babcock Germany (the boiler of 1,000 tons of steam per hour made at the Vulcan Plant in Bucharest). The production of these required the adaptation of existing factories and the building of new ones. To achieve this new, ambitious programme, a new integrated industrial platform was needed. Accordingly, the IMGB heavy machine building industrial platform was built in Bucharest. This platform was a European-level accomplishment in the field of machine building because it brought together the newest European technologies for classical power plants and the American and Canadian technologies for nuclear power plants. The hydroelectric equipment programme was achieved at the Reșița Mechanical Works and some other companies in the Banat area (Caransebeș and Timișoara). The whole range of hydraulic turbines were produced here: Kaplan, Pelton, Francis, and horizontal turbines. Apart from turbines and generators, the entire set of hydromechanic equipment was made there: valves, dams, cofferdams, sluice gates, cranes for dams and sluices (Sandu et al. 2018).

In the field of *agricultural equipment,* an entire industry was built that could produce all the agricultural machines necessary for the mechanisation of agriculture. As a result of this programme, Romania was one of the top ten tractor producers of the world (with over 75,000 tractors produced per year). In addition to the Tractorul Brașov, which was developed and modernised, and became the main producer of tractors and parts, other new companies were also built and modernised: The Miercurea-Ciuc Tractor Company, the Craiova Tractor and Agricultural Machine Company, etc. The horizontal industry for tractors and agricultural machines also evolved, with new establishments in Codlea, Întorsura Buzăului, Rupea, Sfântu Gheorghe and Buzău.

Railroad equipment was produced in factories with a history, such as: The Faur Factory in Bucharest (Diesel locomotives, railcars), Electroputere Craiova (hydraulic and electric Diesel locomotives), February 16th Cluj Napoca (hydraulic Diesel locomotives), Arad Wagon Factory (railway and underground coaches), Drobeta Turnu-Severin Wagon Factory, Nicolina Mechanical Works Iași, and newly founded companies. Such companies were built after 1965 in several places in the country: Roșiorii de Vede Rolling Stock Mechanical Works, Balș Factory of Axles and Bogies, etc.

In the field of road transportation, the production concentrated to some large companies: Autocamioane Brașov (lorries and dump trucks), Mârșa Mechanical Works (high tonnage dump trucks), Automecanica Mediaș (cisterns for the transportation of liquids, vehicles for urban sanitation, special vehicles for constructions—concrete mixers), Timișoara Mechanical Works (refrigerator trucks, firetrucks). Buses, trolley buses and microbuses were produced at the Autobuzul Bucharest, and the underground coaches at the Arad Wagon Factory. The car industry evolved on two platforms: Pitești, for Dacia cars under Renault licence (beginning with 1966), and Craiova, for Oltcit cars under Citroen licence (beginning with 1977). At Câmpulung Muscel the IMS off-road vehicles were produced under Russian licence (beginning with 1957, and the ARO off-road cars since 1972. The automobile production of Romanian was integrated to a proportion of 85%, based on a strong horizontal industry producing parts or subassemblies.

The machine building industry also ensured the *building of ships* for river and sea transportation, and the oil platforms for oil extraction in the Black Sea. The main dockyards on the Danube were those at Galați, Brăila, Oltenița, Giurgiu and Turnu Severin, and on the Black Sea those at Constanța and Mangalia.

As for the bearing industry, there were six bearings factories with a total of around 20.000 employees before 1989, and a research institute in Brașov. *Romania was one of the top bearing producers at international level.* In addition to the factories built at the beginning of the 1950s, the Brașov Bearing Factory and the Bârlad Bearing Factory, new ones were also built: Alexandria Bearing Factory (1974); Suceava Bearing Factory (1979); Ploiești Heavy Bearing Factory (1979); Slatina Bearing Factory (1990).

The *assembly body industry* also underwent significant development, the existing factories of Brașov, Mediaș, Bacău and Cernavodă were modernised, and new factories were built at Târgu Secuiesc (1970), Botoșani (1975) and Sighetul Marmației (1975).

The precision mechanics, watchmaking and measurement and control device industry also developed in Bucharest (Reseach Device and Equipment Company), Otopeni (Measurement and Control Devices Company), Bârlad (Pneumatic Elements and Measurement and Control Devices Company), Suceava (Measurement and Control Devices Factory), etc.

After 1968, it has been decided to increase production and production capacity of the *defence industry* for making armament in the country (over 70%) and become independent from Russian armament import. The list of products was enlarged, new products were made, raising the army's equipment standards. Licence agreements were signed and the efforts to design and produce new equipment based on local research were increased. The production of armoured vehicles, tanks, military trucks, infantry fighting vehicles, sophisticated armament and ammunition, new battleships both for river and sea, war aircraft and helicopters, military logistics, and many more. All this required, of course, a rapid development of production capacity along with the modernisation of factories like those of Plopeni, Zărnești, Sadu 1, Cugir, Brașov. New factories were built, like the Reșița Cannon Factory, the Moreni Armoured Vehicle and Fighting Vehicle Factory, the Tank Factory of the Faur Plants in Bucharest, the Uzina 2 Plant of Brașov, etc. With partners from Yugoslavia, the Airplane Factory was built at Craiova, where the first war aircraft were made for the army. The airplane factories in Bacău and Codlea Brașov were modernised, the Bucharest Băneasa platform was built for short courier planes, as well as the Bucharest Militari platform plane engine and aviation equipment production. The Bucharest Turbomecanica Plant was founded in 1975 for the production of turbine engines for aviation and mechanical transmissions for helicopters. This continued the tradition of Romanian aviation in making airplane engines, which was interrupted for a long while, like the Viper turbo-engine under Rolls Royce licence, or the Turmo IV CA turbo-engine for PUMA helicopters under Turbo Meca licence. In 1980, the licence for the Spey double flow turbojet engine for the ROMBAC 111 aircraft was bought also from the Rolls Royce.

The Bucharest Airplane Company was founded in 1978 under licence of the British BAC company to produce the ROMBAC 1–11 airplanes, in the place of an aircraft equipment repair company founded in 1950. *The first airplane was completed in 1982 and flew on the Bucharest-Timișoara route.* Nine airplanes were built there before 1990 (and two more were under construction), after which date the production came to an end.

The number of factories which produced *consumer goods* (the washing machine and sewing machine factory at the Cugir Mechanical Works, household appliances for heating at Electromureș Târgu-Mureș), was extended and new factories were built, like the refrigerator factory at Găești, the household appliances factory at Curtea de Argeș, etc.

New factories were also established in the field of textile machine industry, in addition to old ones: *Electrotehnica Company, Târgu-Mureș (1965), Botoșani Equipment and Parts Company (1970), Lugoj Equipment and Parts Company (1974).*

The establishment of the *Heavy Equipment Companies* was a special moment in the history of machine building industry. The decision was made at the beginning of the 1970s, and implemented by the establishment of three such companies: at Craiova, at Cluj-Napoca, and at Iași. The *Craiova Heavy Equipment Company* was founded in *1975* for the production of heavy machine tools and technological equipment. The Cluj-Napoca *Heavy Equipment Company* was founded in 1976 for the production of equipment for chemical industry, metal processing industry (steel ingot manipulators, thermal treatment furnaces, casting equipment, rolling mill cylinders, rolling boxes), mechanical presses for stamping bodies, cutting presses, hydraulic presses, mechanical presses, stamping hammers, etc. In 1976, the Iași *Heavy Equipment Company* also began to operate. It produced equipment for metal works and nuclear power.

In what follows, some of the companies founded in this period will be presented chronologically, though not exhaustively, as the first mechanical works in their respective settlements, putting them on the map of Romanian industry. The establishment of these factories also had an extremely important social and economic impact in the respective settlements. In 1969, the *Cast Iron and Steel Industrial Fittings Company (IAIFO)* was established in Zalău for the production of industrial fittings and safety valves used in oil industry. The *Râmnicu Vâlcea Chemical Equipment and Forging Company* was founded in 1970 for the production of large parts by forging and/or stamping, specific to chemical, petrochemical and metallurgical equipment as well as energetic equipment. In *1981*, the *Hydraulic Equipment Company* was founded in Râmnicu Vâlcea, which produced technically highly sophisticated proportional electro-hydraulic equipment (servovalve). The first machine building company of *Bistrița* was the *Factory of Equipment for Construction and Refractory Material Industry,* founded in *1971*, and transformed in 1977 in the Industrial Company for Machine Building with a very large field of activity: the production of machines and equipment for construction and refractory material industry, machines and equipment for forging and foundry, equipment for metal works, etc. Based on this data, it can be said that *the machine building industry became a fundamental branch of national economy after 1965.* The following pages present the arguments supporting this claim. The machine building industry covered over 70% of the machines and equipment required on the internal market, and it also had a substantial proportion of the Romanian export market. The field of machine building comprised over 220 industrial companies, employing almost 1,100,000 workers, which accounted for approx. 30% of the national income. Many of the new production capacities were placed in counties with a lower industrial development and with available workforce, but also in the proximity of the traditional industrial centres like Bucharest, Brașov, Ploiești, Reșița, Galați, Arad. A local research and design base was created by the foundation of a network of research and design institutes both with departmental and product profiles (see Sect. 5). 20 industrial centres were organized, inspired by the organization and leadership systems of major Western industrial concerns as integrated units, comprising the productive plants with their own research and design institutes, technical training schools for their staff, possibilities for internal sale and direct export, and some of these organized as general suppliers for an entire industrial process. Each industrial centre worked by the principle of self-management and self-finance, with their very own investment, research and design programmes, export programmes, and their own technical, economic and management teams. The proportion of machine and equipment export reached almost 30% of the entire production; the products were exported to over 120 countries all over the world.

4 Machine Building Industry After 1990

After 1990, the machine building industry was affected by some major events: the transformation of state companies into business entities or autonomous public entities; the privatisation of commercial companies; the fall of the export market to members of the Comecon countries, the Arab and the African countries; globalisation, with the appearance and development of branches of some major international companies; the frontiers opening for foreign products; the rapid growth of interest rates. These events led to crucial changes in the Romanian industry, as the new companies had to function in a context which was utterly different from the pre-1990 one. As a result of the law on the transformation of companies into business entities, the state gradually withdrew from industrial activities, which meant the lack of financial support, consulting in strategic marketing and management, etc. All these events led to the collapse of the pre-1990 Romanian industry. The proportion of industry in the GDP decreased significantly in the 1989–2014 period from 46.2 to 25.2%, due to the collapse of some of the most important branches of industry, many of them also competitive on an international market. The forced industrialisation placed the economy under great strain, as it oversized some of the branches without having the necessary reserves of raw material resources. In the preceding period, especially before 1965, the norm was an industry with high energy and raw material consumption and intense use of an often poorly trained workforce. The development came to a halt because of the lack of modern equipment and computing, the failure to use foreign capital and the lack of economic competitiveness. Romania's re-industrialisation after 1990 happened, largely, through two mechanisms: buying, restructuring and technological upgrade of Romanian companies by major players on the international market (Dacia-Renault, Daewoo, Ford, Damen, Timken, KOYO, etc.), or by Romanian investors with an entrepreneurial vein (Comelf Bistrița, Compa Sibiu, RAAL Bistrița); founding companies of foreign businesses in places where trained workforce was available (Schaeffler Brașov, Continental Timișoara and Sibiu, Star Transmission Cugir, Emerson Cluj) or in areas with cheap workforce which needed no special training (Leoni Bistrița and Târgu Jiu, Draexlmaier Satu Mare, Pirelli Slatina, Autoliv Onești, etc.). As regards the field of production, the Romanian machine building companies operate in some basic areas: *automotive industry, aeronautical industry, machine tools industry, agricultural machines industry, bearings industry, naval industry, railway industry, consumer goods industry*, etc.

5 Research and Design Institutes in the Field of Machine Building

After 1948, and even more so after 1965, a local research and design base was created by the foundation of a network of research and design institutes both with departmental and product profiles. The institutes with departmental profile were as follows: Technological Research and Design Institute or Machine Building (ICTCM) Bucharest; Hot Technologies Institute Bucharest; Welding and Metal Testing Institute Timișoara; Thermal Engines Institute Bucharest; Special Production Institute Bucharest; Design Institute for Electrotechnical and Electronic Industry Bucharest. In addition to these, institutes with product profile were also founded to conceive and test certain specific products (airplanes, vehicles, wagons and locomotives, energy equipment, bearings, agricultural machines, ships, etc.). These institutes primarily supported the companies of that particular production profile, ensuring expert assistance in the research, design and testing of the products made in these companies. The institutes of this network provided a strong technical know-how, being equipped with research and testing laboratories. Almost all of these institutes closed down after 1990 or significantly reduced their activity, this way a huge amount of expertise accumulated in decades of experience has been lost. Research and development centres were established also after 1990 by many multinational corporations established in Romania: RTR Bucharest and Titu, Continental in Timișoara and Sibiu, Bosch in Cluj, Autoliv in Brașov, Schaeffler in Brașov, Preh in Iași, Honeywell in Bucharest, etc., which absorbed many highly trained Romanian engineers.

6 Higher Education in Machine Building

Before 1948, design and execution engineers working in the field of machine building were trained either at the general (electromechanical) profile departments of technical universities in Romania (Bucharest, Timișoara, Iași) or at technical universities abroad. It was *only after 1948 that the faculties of mechanics with specialised machine and machine tools building technology departments (TCM) were created* after the Soviet model (BAUMAN). *The first machine tools departments* were founded by the decree of the Minister of Public Education in 1948 at the *Technical Institute of Bucharest, the Technical University of Iași, and the Mechanical Institute of Cluj.* As a result of this decree, departments of Machine Tools and later of Machine Tools and Instruments were founded in all three universities. These departments were headed by Professor Emil Botez in Bucharest, Professor Gheorghe Cașler in Iași, and Professor Wilhelm Rohonyi in Cluj. Professor Emil Botez is considered the founder of the Romanian School of Machine Tools. In *1949*, the *Machine Tools and Devices Department* was founded at the *Mechanical Institute of Brașov*, headed by Professor *Silviu Crișan.* This department was the predecessor of the Department of Machine Building Technology. In 1954, the *Department of Metal Processing Technology and Machine Building* was founded at the *Mechanical Faculty of the Technical Institute of Bucharest. Professor Constantin Popovici* was appointed as Head of Department. At the *Technical Institute of Brașov* (which changed into the University of Brașov in 1971), the first *Department of Metal Processing Technology and Machine Building* was founded in 1954, by the transformation of the *Department of Machine Tools and Devices.* This department was headed from its foundation by *Professor Silviu Crișan* until his death in *1965.* The Department of *Machine Building Technology* at the *Technical University of Cluj* was founded in *1955*, headed by *Professor Ion Lăzărescu.* The first *Department of Machine Building Technology* at the *Technical University of Timișoara* was founded in *1960*, headed by *Professor Gheorghe Savii.* The machine building technology specialisation (TCM) of the *Technical Institute of Iași* existed since 1954, but the *Department of Machine Building Technology and Agricultural Mechanics* was founded only 10 years later, in *1964*, with *Professor Constantin Picoș* as the first Head of Department. At the *Technical Institute of Galați,* today the University of Galați, the courses in the *Technology of Machine Building* were introduced in *1963.* The first Head of Department was *Professor Mircea Manolache.* The first Departments of Machine and Machine Tools Building Technology were founded at the most important industrial centres in the country (Bucharest, Cluj, Iași, Brașov, Timișoara, Iași, Galați) and were coordinated by experts trained at prestigious technical universities from Germany, Sweden, USSR, and experienced in production as well. The fast growth of production capacities in machine building posed a complex problem regarding the training and expertise of the production staff. Therefore, in addition to the main technical institutes of Bucharest, Cluj, Timișoara, and Iași, because of the demand on the labour market, new departments of engineering were founded and developed at certain Higher Education Institutes or Colleges. *Machine*

Building Technology Departments and specialisations were created in several industrial centres where such kind of institutes existed already or were created at that time: *The University of Pitești (1972), the University of Sibiu (1976), the University of Bacău (1976), the Ștefan cel Mare University of Suceava (1976), the University of Craiova (1977), the University of Târgu Mureș (1977).* After 1990, Departments of Machine Building Technology were created at the universities of Oradea (1990), Târgu Jiu (1991) and Arad (1999).

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History of the Agricultural Machinery Industry

Vergil Găngu, Ion Pirna, and Bianca Bădănoiu

Abstract The first factories for the construction of agricultural machines were established on the Romanian territory in the first half of the nineteenth century. Later, in the second part of the nineteenth century, after the establishment of the Institute of Agriculture, there was an intense development of companies repairing and manufacturing agricultural machines on the foundation of Romania's economic growth. After the Second World War, radical social transformations took place through the collectivization and nationalization of land, which necessitated the construction of an agricultural machinery industry suitable for the new conditions. Enterprises producing tractors, seeders and grain harvesting machines, as well as plants for industrial use, were mainly developed.

1 Beginnings and Preceding Events

In 1835, the testing of agricultural tools and machines imported from the West was initiated within the Muntenia Society of Agriculture (Societatea de Agricultură Muntenia) (created through the care of ruling prince Al. Ghica (1795–1862), in order to determine their manner of use and the way to adapt them to the conditions of the country's own agricultural land (Popescu 1944). Ploughs with iron ploughshares and other animal-drawn machines had already appeared in the West.

The first workshop for the making of agricultural machines and tools was founded in Bucharest by Dr. Zucher, of German origin, in 1840. In 1840, Petru Rajka, a graduate of the Polytechnic School of Vienna, started a workshop in Cluj which produced trailed sowers and ploughs with iron ploughshares, stationary threshers and straw choppers. He invented a plough with a curved supporting axle, thus enabling the ploughshare to maintain a constant ploughing depth (Imreh 1955), which gained him appreciation at the time.

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In 1843, in Iași, Grigore Avram invented a ploughing machine which required the traction power of 12 oxen. In 1844, an agricultural tool factory was founded in Oradea by Gille and a new factory for the building of metal and wood agricultural tools was opened by Parge and Roszlay (Imreh 1955) in the same city in 1847. The first book on agriculture was published in the same year; it was titled *Ferma model* (*The Model Farm*), written in Cyrillic script and included, among other things, descriptions of agricultural machines of the time.

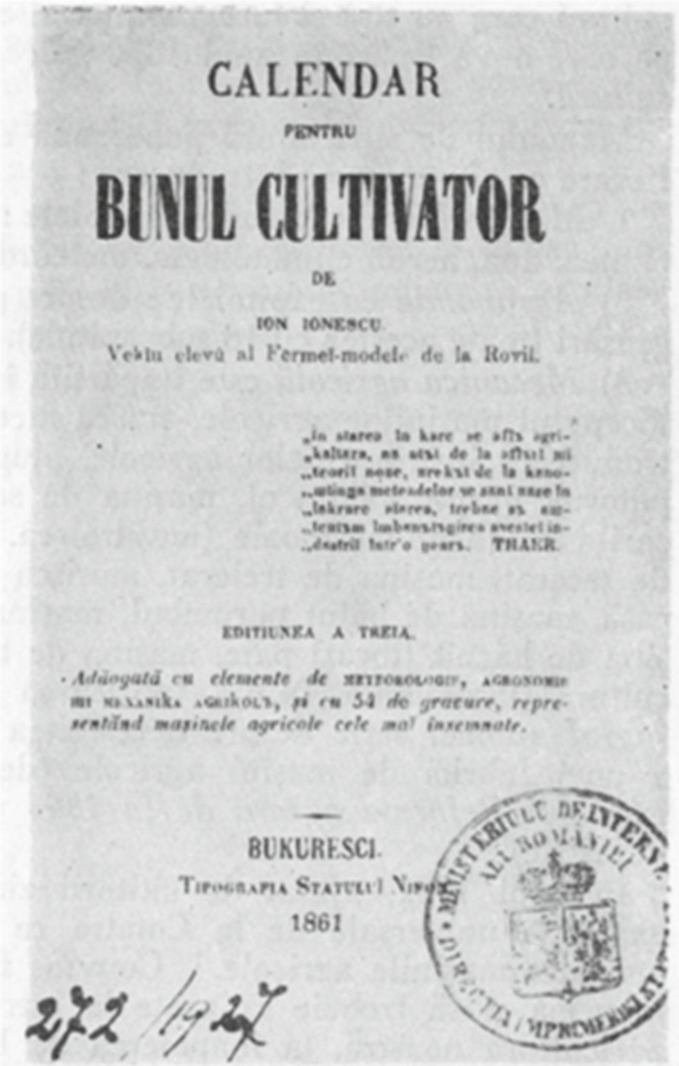
In 1852, the ruling prince of Wallachia, Barbu Dimitrie Știrbei, commissioned Alexandru Slătineanu, who had just completed his studies in agronomy in Paris, to create the Pantelimon Agricultural Institute (Institutul de Agricultură de la Pantelimon, the precursor of the University of Agronomic and Forestry Sciences and Veterinarian Medicine of Bucharest). Thus, the factory for agricultural machines and tools was built on the Pantelimon estate (www.usamv.ro).

In 1859, the Mechanical Institute founded by Gheorghe Asachi in Iași was turned into an agricultural machinery factory. Two years later (1861), the use of the iron ploughshare became common in the country, while Prof. Ion Ionescu de la Brad (Fig. 1) elaborated a manual of folk agriculture (*Manualul de agricultură poporană*), which contained 53 figures showing the most modern agricultural machines (Vasiliu 1967) of the time: 'the plough, the loosener, the extirpator, the harrow, the roller, the sower, the hoeing machine, the ridger, the mower, the threshing machine, the transport machine, the portable engine', etc. He also published *The Good Grower's Calendar* (*Calendar pentru bunul cultivator*) (Fig. 2) in the same year.

Constantin Râureanu, graduate of the Bucharest School of Arts and Crafts (Școala de Arte și Meserii), who had been sent to France to acquire specialised knowledge, built a plough in 1852–1864 which earned him a silver medal from the Paris Academy of Agriculture. In the same year, 1964, the workshop in Zvoriștea, Suceava, began producing a new ridger model for the hoeing of crops.

'The first Transylvanian factory for agricultural machines and iron foundry (Prima fabrică ardeleană de mașini agricole li turnătorie de fier)' (http://www.patrimoniu.sibiu.ro/istorie/industrie/UzineleRieger), under which name it operated until 1921, was founded in Sibiu in 1875 by master ironsmith Andreas Rieger. At first, its activity

Fig. 1 Ion Ionescu de la Brad (1818–1891)



CALENDAR
PENTRU
BUNUL CULTIVATOR
DE
ION IONESCU
Vechiu elevŭ al Fermei-modele de la Rovil.

EDITIUNEA A TREIA.

Adăogată cu elemente de meteorologie, agronomie şi mecanica agricolă, şi cu 54 de gravure, representând maşinele agricole cele maĭ însemnate.

BUKURESCI.
Tipografia Statuluĭ
1861

Fig. 2 The cover of *The Good Grower's Calendar*

consisted in repairing tools and simple agricultural machines, as well as producing horseshoes and stub nails. It is also the place where Rieger made the first plough with a changeable iron ploughshare and a steel sole shoe, known as a Rieger System plough, as well as the plough with 'an iron head and a steel foot', used for the ploughing of sloping terrain. The product range diversified to include ploughs, harrows, animal-drawn wheat and maize sowers, beet and feed choppers, maize threshers, and other products (for textiles, hydrants, water pumps). In 1914–1916, the factory was militarised and switched to producing military equipment and, in 1938, by assimilation into the manufacturing process, it produced five types of spark-ignition and Diesel engines, which were used to power machines for stationary threshing, then it was nationalised in 1948.

The first foreign-capital investment in Craiova was made in the field of agricultural machine use in 1877, thus enabling the founding of the first workshop for the building and repairing of agricultural machines, as a branch of the Clayton-Shusslliwort company of Lincoln, England and of the Mihai Nasta metallurgical company, which merged in 1884, benefitting from the Romanian company law passed in that same year. In 1893, the factory partnered with Richard-Graepel, an Austrian-Hungarian company, and in 1910 it began the construction of new, high-performance workshops and industrial halls, thus making it possible to start manufacturing more complex agricultural machines. This constituted the foundation of the subsequent building of modern agricultural machines in Oltenia. Thus, the 7 Noiembrie Plant and then Uzina de Mașini Agricole și Tractoare - MAT Craiova (the Craiova Agricultural Machines and Tractors Plant) has been including high-performance agricultural machines (www.matcraiova.ro) (Fig. 3) for tractors of varying power levels in its range of manufactured products since 1951.

A remarkable event in the existence of the Craiova plant took place in 1974, when it produced the first hydraulic tractor loader TIH-445 (Fig. 4) and the name of the factory was changed into Mașini Agricole și Tractoare - MAT Craiova (Craiova Agricultural Machines and Tractors). The mass manufacturing of the TIH-445 was the result of a collaboration with specialists from VEB Land Maschinenbau 'Rotes Banner', Döbeln in the German Democratic Republic and from the Tractorul Plant of Brașov - UTB (Uzina Tractorul Braşov). In 1976, the specialists in Craiova developed the manufacturing of the high-power tractors on wheels A 1800 and A 1800A. A

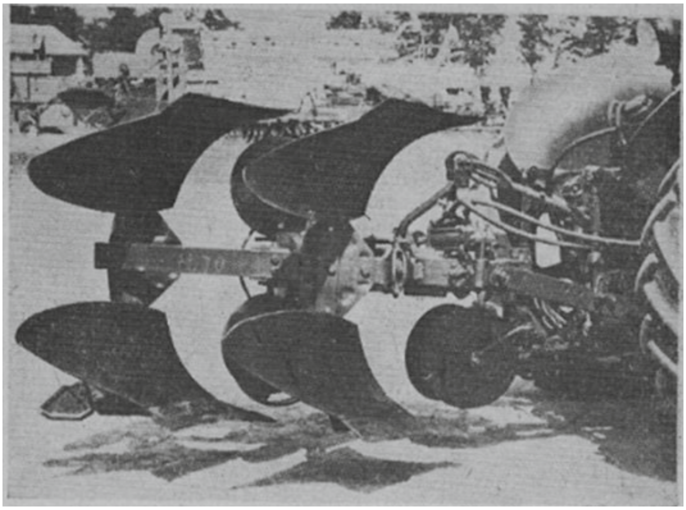


Fig. 3 The portable reversible plough PRP-2–35

Fig. 4 The hydraulic tractor loader TIH-445

noteworthy achievement of Romanian designers and engineers was the range of ploughs for high-power tractors (ICPITMUA (Institutul de Cercetare, Proiectare și Inginerie Tehnologică pentru Mașini și Utilaje Agricole - the Institute for Research, Design and Technological Engineering for Agricultural Machines and Equipment Bucharest + MAT Craiova) with 4, 5, and 7 plough-bodies in classic or reversible form, perfectly adapted to Romanian soils.

In 1992, SC MAT Craiova, together with a group of Italian companies, founded the MAT MAGRIT Craiova joint venture and, for the first time on the Romanian market, tillers and cultivators meant for working small pieces of agricultural land were introduced (www.matcraiova.ro).

2 The Agricultural Machinery Industry in 1921–1945

At the end of 1921, in Piatra Neamț (www.mecanicaceahlau.ro), industrialist Socrat Lalu founded a company with 16 employees and 3 lathes who performed repairs on agricultural and household tools. Within a short period of time (5 years), the company developed and reached 130 employees who repaired passenger carriages, locomotive injectors and produced commercial cast-iron products.

C Starting with the year 1953, the main activity of the company Mecanica Ceahlău Piatra Neamț (www.mecanicaceahlau.ro) became the production of agricultural machines. In 1972, following a transfer from the Semănătoarea Plant in Bucharest, the factory started manufacturing the SPC-6 six-row precision sower for row crops, a representative product due to its reliability and work safety (Fig. 5). In 1993, in order to meet the demands of the market, SC Mecanică CEAHLĂU SA Piatra

Fig. 5 SPC-6 sower

Neamț (www.mecanicaceahlau.ro) acquired a Kleine licence (Germany) for precision sowers and a Lemken licence (Germany) for the manufacturing of reversible ploughs and compactors. Starting with 1999, when the plant became a company with fully private capital, it entered a stage of modernisation and adaptation to the new manufacturing technologies. From 2017 onwards, the company developed its manufacturing of agricultural trailers with a transport capacity from 4 to 20 tons (www.mecanicaceahlau.ro).

3 The Agricultural Machinery Industry After 1945

After 1945, measures (Scurtu and Buzatu 2010) were imposed in Romanian agriculture which, among other things, established the expansion of the arable areas of peasant households smaller than 5 ha. During this stage, the Romanian rural environment was submitted to a powerful social and economic transformation process:

- the collectivisation of agriculture (1949–1952) and the creation of State Farms and fellowships;
- industrialisation and urbanisation.

A significant spur forward in the agricultural-machine building industry was provided by the creation of the first Romanian tractor in Brașov (Mihalache and Croitoru 2006) in 1946 – IAR 22 (power of 38 HP; mass of 3.4 tons, traction power of 1,225 Kgf; fuel: petrol-Hanomag model). The conversion of the airplane production of the Romanian-French joint-venture (Industria Aeronautică Română - IAR (Romanian Aeronautical Industry, Brașov) into one of tractors took place in 1946.

Thus, the IAR was dissolved and, in 1947, the plant was transformed into the State-Owned Metallurgical Company (Întreprinderea Metalurgică de Stat) and, through the nationalisation of the industrial and banking companies in 1948, it became the Tractorul Plant of Brașov - UTB (Uzina Tractorul Brașov).

In 1960, the designing of the first tractor of the 65 HP range (U 650) as a fully Romanian concept began and mass production was initiated in 1963. What followed was the inclusion in the manufacturing process of the FIAT licence for 45 HP tractors in 1968, based on which the 25 HP, 70 HP, 80 HP, 100 HP tractors were developed, and the creation of original projects for S-1300, S-1500, A-1800, A-3600 engines/tractors on wheels/tractors on high-power tracks. In 1963–1990, the Tractorul Plant in Brașov—UTB produced 1.2 mil. tractors, of which 670,000—of 53 types and various versions—were exported to 105 countries.

The Semănătoarea Plant in Bucharest was created in 1948 out of the former Fichet company, which specialised in metal furniture, cabinets, doors, shelves, wrought-iron ornamental fences, and Fichet Warthein-Vienna-model safety deposit boxes. The Fichet factory merged with the Romanian Arms Society (cartridges) and the file factory in the same area.

The first agricultural machines manufactured between 1949 and 1955 were two-row sowers for row crops (Fig. 6) and trailed mechanical harvesters, 24-row sowers for straw cereals and harvester-binders for straw cereals.

The level of performance in terms of the productivity and quality of agricultural operations emerged once self-propelled aggregates appeared, so that, in 1970, the plant produced the first harvesting combine for straw cereals—the Gloria C12, with a Laverda licence from Italy (Fig. 7).

Based on the experience gained by assimilating this licence, Romanian specialists designed and started manufacturing the first Romanian maize-harvesting combines, which solved the most complex issue with this crop (grain harvesting, husked-cob

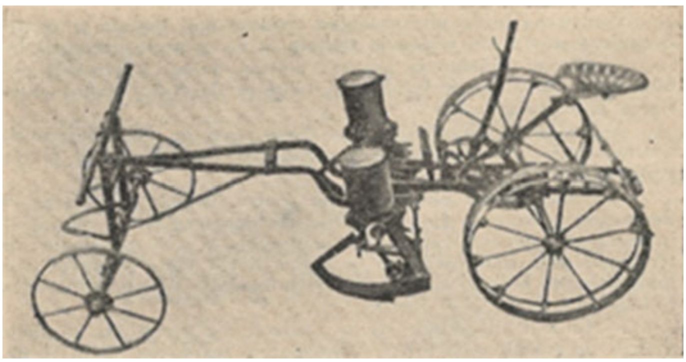


Fig. 6 SP-2 animal-drawn maize sower

Fig. 7 Gloria C 12 (Laverda licence)

and unhusked-cob harvesting, maize irrigation, in-the-field bean threshing), in 1969–1980. Thus, from 1989 onwards, the plant manufactured new self-propelled combines for the harvesting of straw cereals as a result of two years of research: SEMA 110, SEMA 140 M, SEMA 80 and subsequently the second modern range of cereal-harvesting combines, the DROPIA and the new GLORIA.

In 2009, S.C. Semănătoarea S.A. in Bucharest stopped manufacturing 'cereal-harvesting combines'.

In 1958, in Medgidia, the repair workshops founded in 1951 for the equipment used in the digging of the Danube-Black Sea Canal was turned into Întreprinderea Metalurgică de Utilaje (the Metallurgical Equipment Company), which manufactured agricultural machines. It produced disk harrows, agricultural trailers, cardans and cardan joints, yet its flag products were its PPF 1,2 and PPF 1,8 agricultural straw and hay presses, its root-vegetable and potato-extracting machines, and its agricultural trailers.

In 1972, in Iași, Întreprinderea Mecanica pentru Agricultură IMA Iași (the Mechanical Agricultural Company of Iași) was founded, its purpose being to manufacture machines and installations for agriculture and the food industry (through the reorganisation of the Tractor Repair Centre).

In 1990, Întreprinderea Mecanică pentru Agricultură Iași was turned into the joint-stock company SC IMA SA Iași, after which it was privatised in 1992 via the MEBO method. After the transition to market economy, SC IMA SA Iași developed its manufacturing nomenclature by adding agricultural machines (reversible ploughs, agricultural cutters with a vertical rotor, machines for phytosanitary treatments), as well as equipment for the food industry.

It became insolvent in 2010.

In 1977, the local industry company for repairs, metal constructions, and wood processing in Băilești was turned into Întreprinderea Mecanică de Mașini Agricole (the Mechanical Agricultural-Machine Company), subordinate to the Ministry of the Machine-Building Industry through the Agricultural-Machine Company Group (Grupul Întreprinderilor de Mașini Agricole), the headquarters of which were at the Semănătoarea Plant in Bucharest.

The first products to be included into mass production were the cabins for the cereal-harvesting combines made by the Semănătoarea Plant in Bucharest, the amendment-spreading machine, the straw and hay gathering and stacking machine (MAC), and the disk harrows in four standard sizes (3.4, 4.4, 4.7, 6 m). In 1989, the company had 1630 employees.

Întreprinderea Mecanică Băilești (the Băilești Mechanical Company) was turned into SC Subansamble, Unelte și Mașini Agricole - SC SUMA Băilești in 1991. This is where a series of technical execution projects created by the National Institute for Research & Development of Machines and Installations Designed for Agriculture and Food Industry—INMA Bucharest were implemented. In 2000, SC SUMA Băilești was privatised. Limited possibilities of procuring raw materials and other materials caused the company to become insolvent in November 2004.

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The History of the Military Industry and Operative Technology

Ghiță Bârsan, Adrian Stroea, and Dănuț-Puiu Șerban

Abstract The chapter presents relevant aspects of the national defense industry, with emphasis on armament evolution, the technology used in manufacturing it, the equipment needed, and the factories which produce it. Beyond the chronological aspects, the authors have highlighted the capacity of the national defense industry to adapt to the technological developments that impacted the modernization of the equipment produced in the country or abroad. Furthermore, the chapter presents the adaptability and flexibility of the Romanian factories to produce military equipment with the help of various research institutes, given that the role of innovation in this area is focused on responding to the capability requirements of national defense. At the end of the chapter, the evolution of the operative technologies used by the intelligence services to protect Romania's national interests is presented.

1 History of the Military Industry

Infantry armament was the first type of armament that the armies of the two Romanian Principalities were equipped with after their creation in 1830. They initially received armament (mostly) of Russian origin, but also Austrian (in Moldavia), Belgian, and subsequently, after the 1859 Unification, French and Spanish. The first piece of infantry armament produced in Romania was the 10.8 mm calibre 1876 model revolver (Fig. 1), made by Artillery Captain Vasile Buescu (Stroea 2017). This revolver, intended for officers, was created by modifying the Belgian 11.3 mm calibre 1874 model Lebeau revolver. Its technical characteristics resembled those of the Belgian model.

The first technological accomplishment in the field of artillery featuring a substantial Romanian contribution was the manufacturing of the 75 mm calibre 1904 model

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Fig. 1 The Buescu revolver (Stroea and Ginoiu 2012, p. 53)

Krupp cannon, based on the specifications formulated by a group formed of Romanian officers Toma Ghenea, Dumitru Iliescu, Eugeniu Lucescu, Vasile Rudeanu and Gabriel Negrei. Thus, an improved version of the 1889 Krupp model was made. Romanian technical creativity also stood out through Major Toma Ghenea's creation of this cannon's elevation indicator, called 'the Ghenea goniometer'.

Another original-system piece of artillery, completed at the end of two years of experiments and modifications by Romanian officers, was the 105 mm calibre 1912 model Krupp howitzer, with a range of 6,500 m (Fig. 2).

An exclusively Romanian accomplishment was the 'quick-fire' cannon prototype, designed by Colonel Perticari in 1898, which, however, was not mass produced.

An excellent achievement of the Romanian military industry was the 250 mm calibre 1916 model Negrei mortar. The barrel was placed on a carriage which served for firing from the ground, on the one hand, and for transport, on the other, as on the opposite side it had a two-wheeled axle.

An eloquent example proving Romanians' capacity for innovation in the military field at the time is the transformation of the 210 mm calibre 1891 model Krupp

Fig. 2 The 105 mm calibre 1912 model Krupp Howitzer (Stroea and Băjenaru 2010, p. 50)

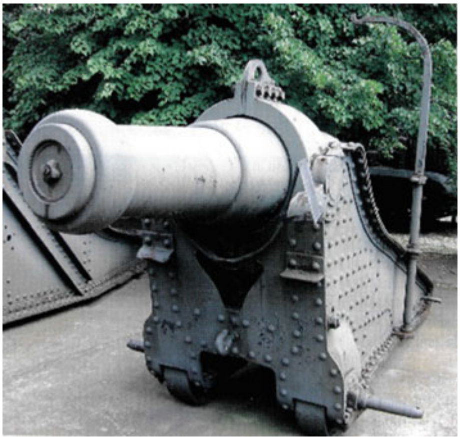

Fig. 3 The 210 mm calibre 1891/1918 model Krupp Howitzer (Stroea and Băjenaru 2010, p. 59)

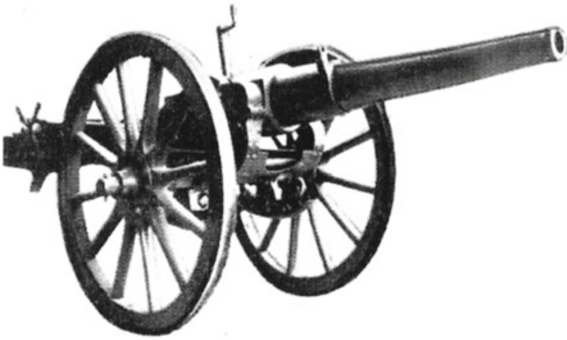

Fig. 4 The 57 mm calibre 1888/1916 model Hotchkiss cannon (Stroea 2017, p. 32)

howitzer from a fixed, fortress howitzer, into a field one (Fig. 3). It was the only large-calibre piece of artillery with a rigid carriage which could fire while on wheels (Bărboi et al. 1996).

By the time the First World War began, Romanian specialists had transformed the 57 mm calibre 1888 model Hotchkiss cannon (Fig. 4) as well, which was placed on an embrasure carriage, into ellipse rotating turrets or used as a mobile piece for flanking in infantry-accompanying cannons (79 pieces), mountain artillery (36 pieces) and anti-aircraft cannons (132 pieces).

1.1 The Interwar Period

In 1919, the Romanian Army was equipped with its first *tanks*, as a result of acquiring 76 such pieces of the Renault FT-17 model. During the interwar period, some of these were reconditioned by Romanian specialists in the Army Arsenal and the Leonida

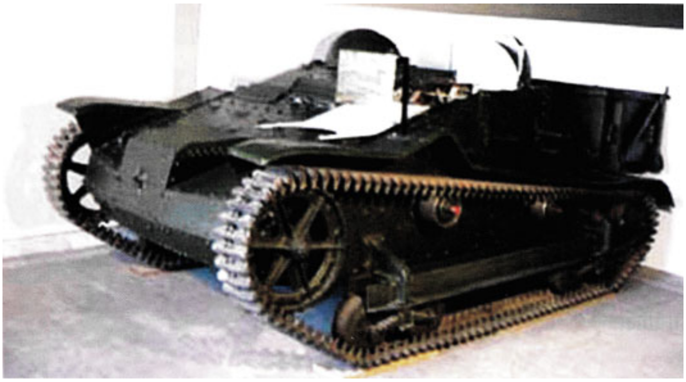

Fig. 5 UE-type Malaxa tracked tanks (Stroea and Băjenaru 2010, p. 90)

Workshops. Although it represented a genuine revolution in the field of military technology, the Renault FT-17 tank exhibited low performance and reliability. Hence, the Romanian state ordered the acquisition of the licence required for the production of 300 Renault UE tracked tanks at the Malaxa Works. Up until 1941, the Malaxa Works produced 126 UE-type Malaxa tracked tanks (Fig. 5), after which production stopped due to the cessation of the delivery of parts by the French (Stroea and Băjenaru 2010).

As far as *artillery armament* is concerned, at the beginning of the period under analysis, the Romanian army was equipped with a diverse range of artillery gun mouths (154 models), of foreign origin, enhanced by the ones received from allies and those captured during the war.

Another example of creativity was the TACAM R 2 self-propelled gun (Fig. 6). It was produced by transforming Czechoslovakian Skoda LT 35 (R 2) tanks. The prototype was made at the Leonida Works by a small team led by Lieutenant Colonel Constantin Ghiulai (Bărboi et al. 1996).

During this period, the Romanian military industry registered significant instances of success in the production of armament and anti-aircraft artillery devices. Among its important achievements, which made it into standard army equipment, are the '1935 model simplified central device', 'the 1938 model Major Bungescu device' and the 'Bungescu fire-control system'.

1.2 From the Second World War to 1990

Naturally, during this period, the production of the national defence industry was strongly influenced by the war conditions.

During the Second World War, army equipment consisted of *infantry armament* which had been used in the First World War as well. One important moment in

Fig. 6 Tacam R-2 tank destroyer (Stroea and Băjenaru 2010, p. 103)

the timeline of equipping the army with infantry armament was in 1943, when the Romanian-made 9 mm calibre, 1941 model Orița submachine gun (Fig. 7) became part of the standard equipment.

As far as the *tank corps* is concerned, it is of relevance that, in 1944, 30 R-35 tanks were rearmed by Romanian specialists with 45 mm calibre anti-tank cannons captured from the Soviet forces, the new resulting system being called 'the R-35 tank destroyer' (Bărboi et al. 1996).

Even as the war was raging on, Romanian specialists registered notable achievements with respect to *artillery armament.* The most important Romanian accomplishment in the field of artillery during this time was the 75 mm calibre 1943 model No 26 Reșița DT-UDR anti-tank cannon (Fig. 8).

Another technological success of the national armament industry was the 120 mm calibre 1942 model Reșița launcher (Fig. 9).

One period during which the Romanian army was intensely equipped with armament and military technology was that of 1969–1989. These two decades were the most prolific for the national defence industry. Gradually, the *infantry armament* that

Fig. 7 The first Romanian-design machine pistol, the Orița (1941) (Stroea et al. 2010, p. 261)

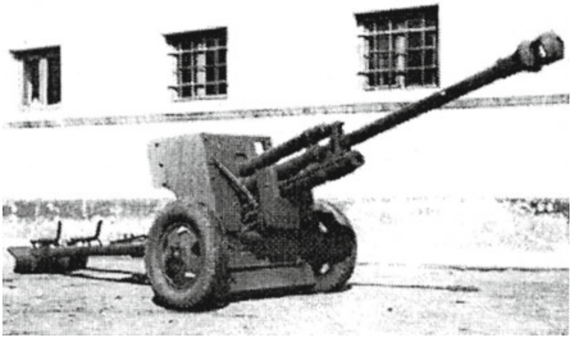

Fig. 8 The 75 mm calibre 1943 model No 26 Reșița DT-UDR anti-tank cannon (Frunzeti and Stroea 2008, p. 168)

Fig. 9 The 120 mm calibre 1942 model Reșița launcher (Stroea 2017, p. 58)

constituted standard equipment, which had been used in the Second World War, was initially replaced by either Soviet pieces or armament produced in the member states of the Warsaw Pact. Subsequently, most of it came to be produced in Romania.

Among the most important infantry armament systems produced under licence were the ones mentioned below. The 7.62 mm calibre 1933 model Tokarev-system T.T pistol is a powerful semi-automatic pistol which is accurate and easy to maintain. It was produced in Cugir in its TTC version. Moreover, the Cugir Mechanical Factory produced the 7.65 mm calibre 1974/1995 model Carpați pistol, an efficient individual anti-personnel weapon for self-defence and security (Fig. 10). An important and relatively recent achievement of the domestic defence industry is the 9 mm calibre 2000 model pistol (Fig. 11). It is a semi-automatic pistol produced by the Cugir Mechanical Factory, a modernised version of the 1995 model semi-automatic pistol, which replaced the 7.62 mm calibre 1933 model TTC pistol and the 7.65 mm calibre 1974/1995 model Carpați pistol as the standard equipment of the Romanian army (Stroea 2017).

Cugir is also the place where the 7.62 mm calibre 1963 model submachine gun (Fig. 12) was produced. This is an autochthonous version of the automatic AKM

Fig. 10 The 7.65 mm calibre 1974/1995 model Carpați pistol (Stroea 2017, p. 67)

Fig. 11 The 9 mm calibre 2000 model pistol (Stroea 2017, p. 67)

of Soviet manufacturing. It was produced at the Cugir Mechanical Factory starting with the year 1963, when it became standard army equipment. Several versions of the submachine gun were produced: the 1965 model, the 1990 model, and the 90 carabine model. The grooveless submachine gun allowed it to be equipped with the AG-40 hand-grenade launcher (Stroea 2017).

Fig. 12 The 7.62 mm calibre 1963 model submachine gun (Stroea 2017, p. 68)

Fig. 13 The 5.45 mm calibre 1986 model automatic rifle (Stroea 2017, p. 69)

Towards the end of the period under analysis, the Cugir Mechanical Factory manufactured the 5.45 mm calibre 1986 model automatic rifle (Fig. 13). This individual firearm is the standard weapon of Romanian troops in theatres of operations.

An excellent accomplishment of Romania's defence industry is the 7.62 mm calibre 1974 model semi-automatic sniper rifle (PSL) made by the Cugir Mechanical Works (Fig. 14). It is a gas-operation-based resetting firearm. The LPS T2 (type 2 telescope for semi-automatic rifle) gun-sighting telescope is manufactured by the Romanian Optica Company.

Another successful weapon produced by the Romanian defence industry is the 7.62 mm calibre 1964 model machine-gun (Fig. 15). It was manufactured under licence in Romania using the 7.62 mm calibre Soviet machine-gun designed by Mikhail Kalashnikov as a model.

The 7.62 mm calibre 1966 model machine-gun (designed by Mikhail Kalashnikov in the USSR in the 60s) was produced at the Cugir Mechanical Factory and was a weapon of excellent technical and tactical qualities. Also in 1966, the same plants began manufacturing another remarkable weapon: the 14.5 mm calibre 1966 model machine-gun.

Fig. 14 The 7.62 mm calibre 1974 model semi-automatic sniper rifle (PSL) (Stroea 2017, p. 71)

Fig. 15 The 7.62 mm calibre 1964 model machine-gun (Stroea 2017, p. 71)

Fig. 16 The 1984 model infantry fighting vehicle (MLI-84 M) (Stroea 2017, p. 73)

An important achievement of the national defence industry during this period was the production of *infantry fighting vehicles*. Such a vehicle is the 1984 model infantry fighting vehicle (MLI-84M) (Fig. 16).

It was during this time that the 1971 model armoured amphibious transporter (TAB-71) was introduced into the standard equipment. It was manufactured under licence in Moreni. It is similar, yet not identical to the Soviet BTR-60 model. The successor of the TAB-71 was the 1977 model armoured amphibious transporter (TAB-77).

It was in Moreni that the B 33 Zimbru armoured amphibious automobile (Fig. 17) was produced as well. It is a wheeled vehicle, the Romanian version of the BTR-80 armoured transporter for Soviet troops and it is relatively modern, compatible with NATO standards. The only version of the transporter which was produced and tested was the Zimbru 2000 (Stroea and Băjenaru 2010).

After the Second World War, the *tank corps* registered a powerful development. Its equipping process began with the USSR-designed T-54 and T-55 tanks. Between 1977 and 1981, Romania manufactured 400 TR-580 tanks (Fig. 18), the Romanian version of the T-55.

In 1986, the Romanian industry started to produce the TR-85, which was a version of the TR-580 tank. It was designed at the Mârșa Mechanical Factory, in collaboration with the Tanks and Automobile Directorate (Direcția tancuri și auto) in 1974–1980. The TR-580 tank was manufactured between 1979 and 1985. Of the 400 tanks which were produced, 150 went to export.

The most modern Romanian tank is the 1985 model (TR-85) (Fig. 19). It was designed in Romania in 1978–1986 and produced at the Bucharest Mechanical Factory from 1986 until 1990.

Fig. 17 The B 33 Zimbru armoured amphibious automobile (Stroea 2017, p. 77)

Fig. 18 The TR-580 tank (Stroea 2017, p. 79)

The period between 1975 and 1989 was the most prolific one for the national production of *artillery technology and armament.* New gun mouths were produced and some of the existing ones were modernised.

One accomplishment of the domestic industry is represented by the 100 mm calibre 1975 and 1977 model anti-tank cannons manufactured by the Reșița Factory in its *1975* and *1977* versions. It was the first cannon produced by the national industry after the Second World War. 30 years later, the Reșița Factory resumed their cannon-making tradition.

Fig. 19 The Romanian 1985 TR model tank (TR-85M1 Bizon), (from personal collection)

Another Romanian creation is the 122 mm calibre APR-21 and APRA-40 multiple rocket launchers (Fig. 20). Both were produced in Romania through the national assimilation of the GRAD system. The APR-21 was a multiple rocket launcher mounted on the chassis of the Bucegi SR-114 R four-wheel drive lorry. In 1978, the APRA-40, with 40 guidance tubes, was manufactured. The launcher was placed on the platform of the DAC 665T six-wheel drive lorry.

Thanks to the efforts of Romanian specialists, the Electromecanica Factory of Ploiești began manufacturing missiles for the Malyutka 9K 11 anti-tank guided-missile complex.

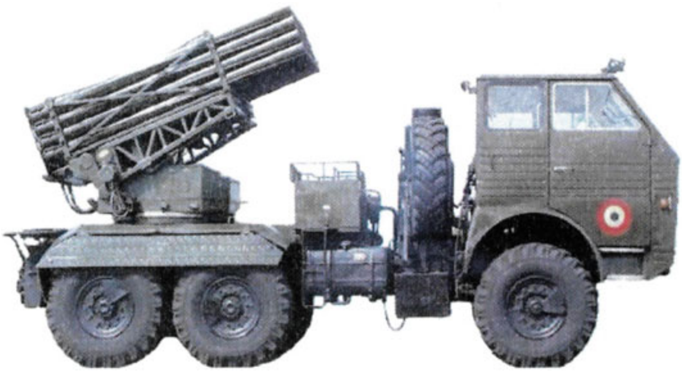

Fig. 20 The APRA-40 multiple rocket launchers (Stroea 2017, p. 94)

Two important accomplishments of the defence industry were the 82 mm calibre 1977 model bomb launcher, as an improved version of the (1937 model) Soviet launcher, and the 120 mm calibre 1982 model bomb launcher.

A notable achievement of Romanian specialists was the 76 mm calibre 1982 model mountain cannon (Jery). It was created by the Sibiu Repair Base of the Artillery Commandment in collaboration with the Yugoslavian defence industry.

This is the period when the Romanian artillery piece with the longest range (30 km) was made, namely the 130 mm calibre 1982 model cannon. It was produced by the Reșița Factory as a version of the Soviet M-46 cannon, made in 1954. The manufacturing was conducted under Chinese licence.

During these years, Romania produced its heaviest piece of artillery, the 152 mm calibre 1985 model cannon-howitzer, using technology imported from China. It became part of the army's standard equipment in 1985. In 1989, the first Romanian 1989 model self-propelled howitzer (Fig. 21) was produced in Mizil, mounted on the chassis of the MLI-84 armoured troops transporter, with a USSR-imported turret.

After the Second World War, there was a swift development of *ground-to-air anti-aircraft defence systems*. Anti-aircraft artillery evolved over a relatively short time from machine-guns and anti-aircraft cannons to missile systems connected to command and control systems.

Such a portable system is the CA-94 missile system. The missile it uses, the A-94, is manufactured in Romania under licence, according to the Russian STRELA 2M model. The functioning of the system is simple, as the shooter identifies the target visually and ensures its acquisition (hitting).

An important place within the equipment of anti-aircraft defence units is held by the *CA-95 self-propelled anti-aircraft complex* (Fig. 22). Its intended purpose is to annihilate airplanes and helicopters flying at low heights through direct aiming. The

Fig. 21 The 2S1 Gvostika 1989 model self-propelled Howitzer (Stroea and Băjenaru 2010, p. 163)

Fig. 22 The CA-95A self-propelled anti-aircraft complex (Stroea 2017, p. 104)

CA-95 is the autochthonous version of the Soviet 9K31 STRELA-1 system. It is mounted on the TAB C-79 vehicle, manufactured by the local armament industry. The modernised version of this anti-aircraft complex is called CA-95A. The complex is manufactured by Electromecanica Ploiești (Stroea et al. 2010).

The national defence industry also produced anti-aircraft machine-guns. One of them is the 14.5 mm calibre anti-aircraft machine-gun (ZPU-2 with two barrels). It is mounted on a two-wheeled chassis, which allows it to be trailed. One version of the Soviet 14.4 mm KPV machine-gun produced in Romania is the 14.5 mm ZU-2 anti-aircraft machine-gun. The latter has been integrated into various anti-aircraft systems and turrets in a variety of configurations.

After the Second World War, an intense process of modernisation of *military engineering technology* took place. Starting with the year 1968, the following internally produced items were introduced into the standard equipment: universal excavators, bulldozers, motor graders, tractors, motor-compressors, compactor rollers, dumpers, breakdown lorries, winches, ordinary and detonating fuses, blasting caps, conductors, etc.

One initial achievement related to *pontoneer technology* during this period is the P.R.-57 pontoon bridge park. The national defence industry produced the P.R.-60 and P.R.-71 pontoon bridges (Fig. 23). The P.R.-60 pontoon bridge park was intended to spread bridges and install gates, having a supporting power of up to 60 tons.

The highlights of the evolution of the army's equipment to include Romanian *automotive technology* during the period under analysis were: the year 1955, when the army was equipped with SR-101 lorries, which had similar specifications to ZIS-150 lorries, and the year 1956, when the first IMS-59 automobiles became part of the standard equipment; there were also the year 1959, when the 3 t Carpați lorry was included, and 1964, when the 9 t Bucegi lorry was made.

Starting with the year 1965, the SR-114 M lorry was included in the army standard equipment. Five years later, the quality of the automotive technology that the army was equipped with rose as a result of the switch to the mass manufacturing of 135

Fig. 23 The P.R.-71 pontoon bridge park (Stroea 2017, p. 114)

HP Diesel-engine products of the Roman and Dac lorry family. Among these, one lorry that stands out is the DAC-665 with 3 powered axles and a 5 t body carrying capacity, used to trail artillery materials weighing up to 5 t and serving a chassis for the installing of corps special-purpose vehicles.

The ARO 24 is a range of Romanian off-road vehicles manufactured from 1972 onwards by the ARO Automobile Company of Câmpulung Muscel. Production ceased in 2006. The models included in this range were the ARO-240 and ARO-266. The most common models found in the military were: ARO-242, ARO-243, and ARO-244.

1.3 The Period After 1990

From 1990 onwards, national defence industry production was initially directed towards ensuring compatibility with similar NATO armament and technology, followed by interoperability with such.

An important achievement in the field of *infantry armament* was the 9 mm calibre 1996 model submachine gun (RATMIL), produced at the Cugir Mechanical Factory.

It is a weapon intended for short-range (50 m) anti-personnel combat. It uses 9 × 19 mm calibre Parabellum cartridges.

In 1995, the decision was made to modernise MLI-84 fighting vehicle to match NATO standards. That is how the MLI-84 M Jderul appeared, with its versions: the MLI-84 M PCMB—intended as a battalion mobile command post, the MLI-84 TEHEVAC—intended for the evacuation of damaged fighting technology, and

Fig. 24 The LAROM multiple launch rocket system (Stroea 2017, p. 102)

the MLI-84 MEDEVAC—intended for the evacuation of the wounded and the administration of first aid.

One notable accomplishment of the defence industry at this time was the production of the "Bizon" TR-85 M1 tank, a version compatible with those in NATO member states. This tank began to be manufactured in 1999. Another version of the TR-85 is the DMT-85 M1 (mine dredger on a TR-85 M1 tank chassis), a specialised engineering vehicle intended for the neutralisation of anti-tank landmines.

The first *artillery-related achievement* of the post-1989 defence industry was the 98 mm calibre 1995 model Bucegi mountain howitzer, the purpose of which was to support the actions of riflemen, infantry, and parachutist units conducted on mountainous terrain.

The most modern artillery system the army was equipped with after 1989 is the LAROM multiple launch rocket system. It was designed and manufactured by the Aerostar Company of Bacău in collaboration with Israeli companies Elbit and IMI. The LAROM launcher (Fig. 24) is the impactor and main component of the system. It is a perfected version of the 1988 model APRA-40 launcher.

In 2007–2009, a specialised armoured engineering vehicle was produced, the DMT-85 M1 mine dredger on a tank chassis, intended for the neutralisation of anti-tank landmines. It was built on the TR-85 M1 tank chassis.

2 History of Operative Technology

Ever since the founding of the modern state in 1859 under ruling prince Alexandru Ioan Cuza and until late in time, when Romania began carving its own path in Eastern European politics, the equipment of intelligence and counter-intelligence structures was put together through punctual and minor acquisitions and through technology adaptation, regardless of the fact that it came from Western countries—predominantly France, Germany, and Austria, or, later on, the Soviet Union. Indigenous technical support in intelligence and operative work appeared in 1948, when the *General Directorate of the People's Security* was created, which comprised the *7th Technological Directorate*, the *Cypher Service* and, subsequently, the *Radio Counter-Intelligence Service*. Beside equipment for the interception of communications, as well as for cryptography and cryptographic machines, requirements began to diversify in specialised fields such as radio bearing direction finding, radio spectrum monitoring, photographic surveillance, and technical and criminological examinations.

In 1967, the first ample project intended to provide security bodies with technological equipment using internal human and scientific resources was initiated. Thus, a switch was made to: securing highly qualified personnel in the fields of both research and execution; providing work spaces; developing laboratories equipped with measuring devices and equipment required for the design process; organising production spaces and furnishing them with electronic and mechanical production devices, with assembly and check lines; ensuring technical documentation resources; providing a horizontal-cooperation system, with the main research institutes and production companies in the fields of electronics, mechanics and optics to ensure additional support in case research on special topics needed to be carried through, commonly used notions needed to be assimilated, or for large serial production. To that end, the *General Directorate for Technological-Operative Activities and for Equipment* was founded, which included one directorate for study, research, construction, and provision of technical devices, led by General Ovidiu Diaconescu.

On 21 November 1968, the *Institute for Research and Design of Specialised Technology* (ICPTS), and, in the following year, the *Military Unit for Special Production* (UMPS) were created, the two bodies subsequently merging into the *7th Directorate (I.C.P.T.S.)* in 1972. This structure, staffed by 400 specialists, most of them recruited from the economic sector, covered research, design, large and medium serial production, or conducted expert examinations and consultancy in fields such as: electronics, mechanics, optics, informatics. The institute was swiftly integrated into the national network of research institutes, as highly topical fields were tackled for the building of equipment: the use of semiconductor lasers, of modern semiconducting components in the field of high and very high frequencies, the use of modern electro-optical devices for observation in difficult conditions; the design of high-performance automatic radio systems; the in-depth studying of voice, and telephone communication; the development of coding and encryption technology for voice and data communication; the development of centralised perimetral protection systems and alarm systems, etc. Chemistry and printing research, as well as part of the pursuits in the field of mechanics, remained the task of the Operative Technology Directorate.

From the very beginning, in order to cover the diverse requirements of operative work and to overcome technological constraints, the Institute established relations of cooperation with certain higher-education institutions, research institutes and avant-garde companies: Microelectronica, IPRS, IFA, IOR, IEMI, Fabrica de calculatoare (the Computer Factory), Electronica, Electromagnetica, etc.

For special-technology production, lines of mechanical and electronic production, respectively, were developed, as well as IT management and design systems. In 1990, the Special P Unit became the *Advanced Technology Institute*, thus proving the excellent professional skills of the specialists working there.

Naturally, a period of transformations followed, as a result of the change in the requirements the institution faced.

In terms of external relations, the Institute maintained and diversified its connections with foreign partners, exchanging knowledge with respect to technical solutions for operative problems. The institute can pride itself on being one of the most important European units of its kind of the time. Today, it carries out projects with European funding, together with other bodies, institutes or companies, in avant-garde fields.

Its research activities have brought it numerous OSIM (Romanian State Office for Inventions and Trademarks) patents and made it possible to participate in national and international exhibitions in the field (Milipol, Expomil, BSDA). Its constant connection to the academic environment has translated into support for a significant number of doctoral theses, many of which were followed by the publishing of works of reference for Romanian technological literature. As a token of recognition for the Advanced Technology Institute's pursuits and accomplishments, ORNISS (National Registry Office for Classified Information) accreditation was awarded to the first *TEMPEST evaluation laboratory* in Romania, the first *laboratory for the evaluation of cryptographic products*, the only evaluator for containers intended for the protection of classified information. Furthermore, it received accreditation as *a supplier of certification services for electronic signatures (timestamps)*, registered with the Ministry of Communication and Information Society Registry.

Researchers' professional training has made it possible to develop new units adapted to requirements: protection against the most diverse forms of cyberattacks, radio spectrum monitoring, the evaluation and processing of open-source data, physical protection, etc., as scientific research and technological development represent a foundation of the institute's many pursuits.

Today, scientific research and technological development hold a key position in intelligence-gathering work. The field of cybersecurity/cyber-intelligence, together with mobile technologies, cryptocurrency, early warning, social networks and the like are some of the most dynamic concepts, while also the most visible. Having initially been developed based on the human and material resources of the Advanced Technology Institute, it became apparent that it was necessary for this field to become a central focus, mainly (but not exclusively) for the protection of information and critical infrastructures, thus safeguarding the protection of individual liberties. Due to the talent of its specialists, Romania has managed to become a leading nation in the NATO Trust Fund, ensuring the transfer of technology towards other states in the region.

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The History of Textile, Clothing, Leather and Footwear Industry

Antonela Curteza

Abstract This chapter briefly presents the main stages of the evolution of the textile, clothing, leather and footwear industry in Romania, being structured in four parts. The first part is concerned with the evolution of specific techniques from their origins. In the fields of weaving and clothing manufacturing, two important inventions are notable in the so-called "Neolithic revolution": the twisting of threads with the help of the spindle, followed by weaving them into the loom. In our traditional crafting, the spinning process has been carried out through three basic tools, authentic relics of a millenary technology: the awl, the rod and the spindle. In the field of weaving, there is a very large typological variety that reflects the entire evolution of tools. The crafts, among which the textile production stands out, marked the first "technical revolution" in the history of mankind, the "Neolithic revolution", which led to the emergence of the social category of craftsmen. In the 14th–16th centuries, in the field of weaving which had become one of the most widespread medieval crafts, a wide use of hydraulic power is recorded. In the second half of the 19th century, during the expansion of capitalist relations in the villages, the textile craft knows a new phase of development—the manufacturing phase, which corresponds to a new historical stage, defined by the concept of "domestic textile industry". At the beginning of the 20th century, with the transition to factory production, new professions emerged in Romania. The second part of the chapter focuses on some particular traits that marked the period between the two world wars. The entire industry develops at a higher rate than the other manufacturing branches in the country, a fact mainly determined by: the existing textile equipment; the increase in domestic consumption; industrial policy based on protectionist tariffs, laws to protect the textile industry, and encouraging the valorisation of indigenous raw materials. After the First World War, textile higher education appeared and developed in Romania. Between the years 1930–1940, the textile industry experienced the greatest development since its emergence. Economic growth ended in 1939 when World War II began and Romania's trade was severely affected. The third part marks the main aspects of textile industry development after the Second World War until the fall of communism. There was a transitional period until 1948, during which the difficult economic situation and

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the uncertain political climate did not lead to special achievements. In the period 1950–1982, the production of textiles increased 21 times, of clothing 26 times, and of fur and footwear 16 times; thus, the clothing and footwear sectors represented, in 1982, 13.1% of the whole Romanian industry. After 1960, special attention was paid to the introduction of modern techniques by equipping with high-productivity machines, reusing and modernizing existing enterprises, introducing new technologies to give textile products superior characteristics and to ensure the processing of new chemical raw materials. The textile industry, until 1989, held an important place in the national economy, both as a branch producing consumer goods and as an activity generating national income and jobs, especially for women. Until 1989, there were numerous state-owned production capacities in Romania, which positioned the country as an important supplier of textile and clothing products, especially in relation to the countries of the former Eastern European bloc. In the fourth part, the main transformations of the industry after 1990, its decline, but also the opportunities and future perspectives are presented.

1 The Weaving Technology—From Its Origins to the First World War

In literature (Cioară 2008) it is mentioned that the origin and the first phases of weaving on Romanian territory are very old; for example, in the 5th century BCE the Greek historian Herodotus recorded the following in his work: “The Thracians grow hemp in their country, from which they make clothes that are very similar to those made of linen; an untrained eye cannot even distinguish between linen and hemp, and people who have never seen hemp think that the clothes are actually made of linen” (Cioară 2008). The Romanian folk costume, which delights us even today, reflects the art of weaving and sewing that has been developed since ancient times.

The textile industry, in its domestic, ancient form, was stimulated by the breeding of sheep which was fostered by a veriety of landforms and the system of transhumance (Caraiman and Vîlcu 2004). Pascu (1982) shows that on the territory of Romania, within the framework of civilization and traditional crafts, the interweaving of vegetables and the weaving of textiles stand out, two “multi-millenary” occupations that allowed the creation of items and clothing for everyday basic needs. In the fields of weaving and clothes-making, at first from vegetable fibers (flax and hemp) and then from animal fibers (wool, goat hair), two important inventions are notable in the so-called “Neolithic revolution”: the twisting of threads with the help of the spindle and their warping into the loom that Childe considered a “brilliant example of applied science” (Pascu 1982). In the traditional folk civilization, spinning has consecrated three basic tools, true relics of a millenary technology: the awl, the rod and the spindle. In the field of weaving, there is a very large typological variety that reflects the entire evolution of tools. The weaving looms, in the order of their appearance, were at first vertical and then horizontal.

Fig. 1 Romanian woman weaving—drawing by Mattias Adolf Charlemont. *Source* www. dragusanul.ro https://dragusanul.ro/wp-content/uploads/D39.jpg

Archaeological evidence and historical writings show that the craft of weaving has been practiced on the territory of our country since ancient times (Romanian Academy, Textile Technical Dictionary–DEX-TEX, http://www.dex-tex.info/). Crafts marked the first "technical revolution" in human history, the "Neolithic revolution", which led to the emergence of the social category of craftsmen with exceptional professional experience (Pascu 1982). Among the first branches of craft production, the textile one stands out (Fig. 1).

The craft of processing textile threads stands out as a household occupation in its own right with the development of the pedal loom in the X–XII centuries (Pascu 1982). The discoveries from the Garvăn-Dinogeția (Dobrogea) settlements in 1954 show that horizontal loom was known in those regions since the first half of the 11th century. In 1958, in the same area, fragments of fabrics and remnants of distaff were discovered, which prove that the craft of weaving had already begun to surpass, from the second half of the 11th century, the level of a household activity (Romanian Academy, Textile Technical Dictionary–DEX-TEX, http://www.dex-tex.info/). According to more recent studies (Caraiman and Vîlcu 2004), the beginnings of textile processing in Romania are linked to the arrival of Saxon emigrants from Flanders who settled, in the 12th century, in the areas around Sibiu and Brașov, where the foundation of textile crafting activity was set. Some of the products made, such as cloths and rugs, also reached the markets of Muntenia and Moldova. In the 14th century, the spinning wheel and the reel wheel appear and spread in our country, first in Transylvania and then in other areas, which led to a real progress in the spinning process (Pascu 1982).

In the 14th–16th centuries, in the field of weaving, one of the most widespread medieval crafts, an extensive use of hydraulic power is noted; there were numerous "industrial" installations that used the force of water to be set in motion, from those for spinning wool to those for finishing (Fig. 2).

Iorga (1927) believes that the history of the textile industry in Romania begins in the 1600s with the establishment of weavers' guilds in Moldova, Muntenia and Transylvania. Weavers, drapers, felt makers and silk weavers opened small workshops

Fig. 2 Sumane loom—drawing by Mattias Adolf Charlemont. *Source* www. dragusanul.ro https://dragusanul.ro/wp-content/uploads/D42.jpg

where they made clothes, carpets, blankets, and towels. The luxury craftsmen of that period, the furriers, had better lives than the rest of the textile manufacturers; tobacconists, tanners, leather craftsmen, and vest-makers were other important workers in the field. Moldova and Wallachia also had local clothiers, who were first called "dressmakers" and then tailors. Tailoring becomes a household activity, being linked to church centers such as the tailor of the Diocese of Huși, in 1623.

The beginnings of the textile manufacturing industry on the territory of our country are traced both in Moldova and in Wallachia. Among the manufactures in Moldova, we can mention the one from Călugăra (Bacău region), which was founded in 1740 (Iorga 1927). The workforce used in manufacturing facilities consisted of free workers, sometimes brought from abroad, and serfs. Craft and manufacturing production had strong competition from household industry. In the mountainous regions, where animal husbandry was the main occupation of the inhabitants, spinning, wool weaving, tanning and leatherwork were predominant crafts. The first manufacturers with feudal-capitalist and, later, capitalist traits were those of textiles: spinners, dyers, etc. They were established by local capitalists (governors, boyars), with great financial efforts, in order to develop their own production and align it with other countries. The first textile manufacturing facilities in Romanian countries were established in the 18th century in (Cioară 2008): Transylvania at Sadu (1721), Timișoara and Gherla (1755)—leather manufactures, Moldova at Chiperești (1764), Wallachia at Pociovaliște near Bucharest (1766), Bucharest (1769), Bălteni and Ilfov (1794), Afumați (1795).

In our country, 1803 was a reference year for the early stages of cotton spinning and, respectively, of specific manufactures. The lack of a mechanical industry for spinning and weaving cotton and the large import of yarn favored the peasant household industry, especially in the monasteries, where they worked on manual looms (Georgescu 1940).

The industrial revolution constituted the stage of transition to new manufacturing processes, beginning approximately in 1760 and evolving until the 1820–1840 period.

This marked the shift from rudimentary manual manufacturing methods to the use of machinery, new chemicals and production processes that used iron devices. Steam power was used more and more, machine tools etc. were created. The Industrial Revolution began in Britain and many of the specific technological innovations were British. The development of trade and the business environment constituted major causes of the industrial revolution. Textiles represented the dominant branch of the industrial revolution in terms of labor absorptive power, value of production capacity and capital invested. The textile industry was also the first sector to use modern production methods. During the industrial revolution, textile manufacturing was a mechanized process where machines were set in motion with the help of water wheels and steam engines. The manufacturing process moved from small-scale production, where the basis was the peasant home, to mass production, based on the organization of assembly lines. Clothing manufacturing, on the other hand, remained manual. Sewing machines appeared, in the context of the modernization of the clothing manufacturing process, only in the 19th century.

In Romania, the mechanized means developed in the countries of western Europe could not be introduced, both due to the restrictions imposed by Turkey and the measures taken by the countries with a strong industry (Belgium, England, etc.) to stop the development of textile techniques in other countries as well. Thus, artisans with tradition and continuity could not reach, in our country, a high technical level and, as a result, a specialized higher education could not be simultaneously implemented (*** 1984). However, the transformations recorded in the textile sector worldwide in the 19th century can be found, in certain forms, also on the territory of Romania. The first textile factories with industrial equipment appear towards the middle of the 19th century, when the textile technique evolves in the Romanian Principalities together with the accentuated national liberation movement and the increase in efforts to create a national industry. Machines were imported in all capitalist textile factories, but some of them relied on equipment built in the country. Thus, in 1806, the first machine for carding wool and spinning cotton and wool yarn was built in Brașov, and in 1815, also in Brașov, fine yarn spinning machines were made. The first factories in the wool industry, about which there is more accurate information, are: 1823—Schei (Brașov), 1868—Dumbrava carpet factory—Sibiu (founded by the Zimermann brothers), 1876—Hat factory (workshop) —Perianu (Timiș) (Caraiman and Vîlcu 2004). In 1840, the first tanneries in Romania appeared: Adam Arndl in Fălticeni and Matei Constantin's factory in Bucharest (Georgescu 1931). In 1842, the cotton spinning mill was established in Zărnești, and the year 1843 marked the establishment of the first mechanical loom in Wallachia, in Tunari near Bucharest, with machines brought from Austria.

The true founder of the textile industry in our country is considered Mihail Kogălniceanu who built a wool factory near Târgu Neamț, in the period 1853–1855, and who thus introduced the "wool industry" in our country, as he called it. The factory was equipped with the most modern machines (of Austrian production) and techniques existing at that time and was an integrated unit because it had departments for sorting and washing wool, spinning, weaving, finishing and embroidery.

In the second half of the 19th century, during the expansion of capitalist connections in the villages, the textile craft enters a new stage of development, the manufacturing phase, which corresponds to a new historical period defined by the concept of “home textile industry” (Pascu 1982). The domestic textile industry is perfected in the dyeing of wool, the weaving of carpets, towels and belts, in the making of sumans—traditional coats, etc. In Banat, where the establishment of guilds was stopped administratively in the year 1872, there were also manufactures of canvas, cloth, blankets, etc., goods which in the principality of Transylvania were manufactured exclusively by the craftsmen. It was only in 1886 that the first mechanical looms for weaving wool and cotton were introduced in the country (Georgescu 1940).

At the end of the 19th century, the first workshops producing knitted goods were organized in Romania as well. In 1880, a workshop in Sibiu equipped with 10 hand-operated knitting machines for making socks and gloves was established. The following workshops were created in Bucharest and Galați (Constanța 1998). In 1885, two large tanneries were founded: *Grigore Alexandrescu* in Bucharest and *Prodanoff Brothers* in Tulcea.

In papers (*** 1984; Preda 1997; Cociu 1999; *** 1994; *** 2012) it is stated that the development of textile, clothing, leather and footwear industries in Romania created demand for qualified personnel, which led to the establishment of specialized schools. Thus, in 1840, the *Arts and Crafts School* was established in Iași, the first of its kind in the Romanian Principalities, where students were also trained for manufacturing textiles and leather. Some graduates of this school were sent to Paris to perfect themselves in the technique of textiles and leather processing. Professional development activities also took place in Bucharest, where the *Weaver Society* and the *Sericulture School* trained female students in the craft of silk weaving.

In Romania, in 1886, the regime of commercial conventions expired and the protectionist customs regime was established, which implemented high tariffs on imported goods. These circumstances favored the development of an industry of its own profile. The law for the encouragement of the national industry passed in 1887 favored an even greater development of the textile industries, through the creation of flax and hemp spinning mills, based on indigenous crops. This year marks the beginning of textile industrialization. The favorable economic situation means that during this period the production of raw wool doubles; for example, in 1897 in Muntenia the sheep farm from Palas came started its activity with merino sheep brought from France.

At the end of the 19th century, there were 69 enterprises in our country: 23 weavers for cotton, linen and hemp, 13 broadcloth factories, 18 knitting factories, 9 embroidery and lace factories and 6 twine and rope factories. Among these, the largest was the *Society for the Textile Industry—Buhuși* (*** 1999). The Buhuși factory had, in 1900, complete installations for manufacturing broadcloth, and the Azuga Broadcloth Factory (founded in 1886) had 280 “perfected” spinning and weaving machines (Iosa 1963). In 1902 there were 25 tanneries with 1042 workers. L. Georgescu (Georgescu 1931) presents a synthesis of the development of the leather industry and mentions that among the shoe workshops spread throughout the country, 7 were larger and functioning around tanneries. From 1902 until the eve of the war, the tanneries increased their production capacity, old installations were transformed or replaced by new ones based on technologies brought from the West and, especially, from America (Georgescu 1931).

At the beginning of the 20th century, with the transition to factory production, new professions began to appear in Romania. In the context of the new economic structures, the organization of production and work, the guilds disappear.

However, the war also left its mark on industry. As early as 1914, the tannery, leather and footwear, broadcloth and clothing factories, etc., were militarized in Transylvania. The production was intended mainly for the army, and the population was left with only the surplus that exceeded military needs. According to the official statistics of the time, the textile industry was ranked first in the overall economy, ahead of the food, metallurgical, chemical and wood industries.

2 The Period Between the Two World Wars

After the First World War and the formation of Greater Romania, the entire textile, clothing, leather and footwear industry experienced a higher rate of development than the other manufacturing branches in the country, a fact mainly determined by (Georgescu 1939): the existing textile equipment in Banat and Transylvania (which had a prosperous industry)—two provinces which joined the old Kingdom and thus brought their contribution to the main national textile industry; the increase in domestic consumption; industrial policy based on protectionist tariffs, laws to protect the textile industry, and encouraging the valorization of indigenous raw materials. According to the statistics of 1919, there were 156 factories in Romania, of which 98 were located in the allied provinces. In the Old Kingdom, only carded wool yarns could be found, and in Banat there was a factory for the production of semi-combed wool yarns, with about 10,000 spindles, and a group of enterprises that produced hat cloches (Șeibulescu 1931).

Between the years 1930–1940, the textile industry experienced the greatest development since its emergence, being stimulated by the introduction of restrictions on the granting of foreign currency for the payment of imports, in June 1931, and by the establishment of Romanian import quotas in December 1932. Strong investments were made in all branches of the textile industry. Cotton, linen, combed wool, jute and sisal spinning mills were established, as well as the first rayon product factories in the country. Viscose began to be produced in Lupeni, from 1930, and at *Vâscofil*—Bucharest, from 1935. Georgescu (1940) states that the factories were equipped with the most advanced technology, with weaving looms and installations for improving fabric quality (bleached, dyed, mercerized, pressed and printed). In terms of fabrics and knitwear, domestic production has grown to cover almost the entire Romanian market (Fig. 3). The cotton industry experienced amazing progress in the period 1930–1940; is the industrial branch which suffered less during the crisis years, continuing its upward trend even in the years 1930–1932 (Georgescu 1940).

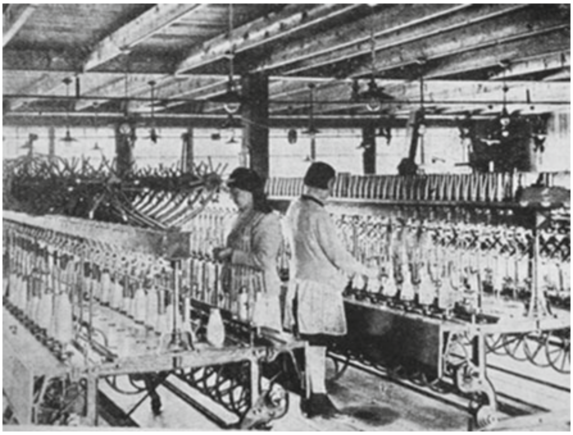

Fig. 3. Romanian weaving mill Pitesti. Room for spinning threads (Georgescu 1939)

Georgescu (1939) presents in detail the situation of the Romanian industry, as follows: in 1935 there were 97 wool spinning and weaving, 145 cotton spinning and weaving, 58 silk spinning and weaving, 98 knitting factories, 10 clothing factories. The greatest benefit came from silk spinning and weaving by tripling the invested capital, while the wool industry was the least profitable. The value of textile production represented approximately 1/5 of the total production value of the industry in Romania, which demonstrates its importance, in general, and of the wool industry in particular, for the entire economy (Georgescu 1939). In the work (Georgescu 1940) it is specified that the year 1935 marks the sudden start of industrialization in the cotton branch, the upward evolution continuing in the years 1936–1938. Of the 195 enterprises in this industry, 18 were cotton spinners, and the remaining 177 were cotton weavers (mostly integrated, producing the full range from raw cotton to highly finished fabrics).

After the First World War, textile higher education was founded and developed. For the leather processing industry, experience was gradually accumulated in the department of applied chemistry that operated within the University of Iași, since 1912. In 1921, a special technological chemistry course focusing on the chemical technology of leather was introduced at this department. Later, the polytechnic schools in Iași and Bucharest introduced their own "tanning" courses, and the leather department was established at the Iași Polytechnic Institute (Cociu 1994). Within the Industrial Faculty of the Polytechnic School in Bucharest, in 1922, a course dedicated to the "Study of the textile industry" was introduced. Here, through his extremely valuable activity, *the engineer Corneliu Casassovici*, who was the first engineer with a diploma in textile specialty, made a name for himself as a graduate of the department with a relevant profile from the *Polytechnic of Dresden*, *Germany*. As a result of the paramount place occupied by the textile industry in the Romanian economy and the evolution of engineering training as a whole, in the autumn of 1934 the *Higher School of Textiles* in *Bucharest* was established, as an independent unit, whose name was later changed to the Special School of Textiles (Cociu 1994; Chiriac et al. 2018).

Engineer Corneliu Casassovici had special merits in the establishment, organization and consolidation of the school. The school operated with two departments: the mechanical one, where the technologies and machines in the fields of spinning, weaving and knitting were studied, and the chemical one, where problems related to the processes of bleaching, dyeing, printing, finishing, mercerization, or special chemical treatments applied to textiles were addressed (Cociu 2012).

Economic growth ended in 1939 when World War II began and Romania's trade was severely affected.

3 The Period After the Second World War Until 1990

After 1945, the textile, clothing, leather and footwear industry evolved in the context generated by the consequences of the Second World War. The stage up to 1948 was one of transition, in which the difficult economic situation and the uncertain political climate did not lead to special achievements.

In 1946, the *School of Higher Textile Studies* was established in Bucharest, numerous vocational and foreman technical schools, specialized high schools and textile school groups and a post-secondary technical education were developed in parallel. In 1947, there was a sufficiently large number of enterprises in the textile and clothing industry (604), but most were small enterprises, which shows an exaggerated fragmentation of the sector. After the application of the nationalization law (from June 11, 1948), the emphasis was placed on industrialization and this fragmentation of the business activity was put an end to by abolishing the unprofitable facilities, by merging and reusing the others and by building large textile factories. Although the number of textile enterprises roughly halved, production increased.

In the period 1950–1982, the manufacturing of textiles increased 21 times, of clothing 26 times, and of fur and footwear 16 times; in 1982, the textile sector represented 13.1% of the total industry in Romania. In 1950, after the merger, there were: 226 enterprises in the textile, knitting and clothing industry and 49 enterprises in the leather, footwear and rubber industry (Malinschi et al. 1964). 640,400 people worked in the textile industry, of which 112,333 were in wool spinning, and the annual production of wool yarn reached 12,800 tons/year (Caraiman and Vîlcu 2004).

The analysis of the situation of the machines in the enterprises, as it was carried out at the time of nationalization, showed that they were more than 40 years old and had a wear rate of more than 50%, which required investments in modern machines (Pascu 1959). Thus, in 1950, the knitting needle factory was created with machines designed and built in the country, at a high technical level, many of which were automatic. Some small series or one-off machines were also made, such as cotton balers and leather punches. The construction of machinery for: cotton yarns (cards, large-stretch rolling mills, rings, twisting machines, etc.), woolen yarns (triple cards, spinning machines, etc.), hemp yarns (cards of high productivity), weavers (preparation machines, automatic looms, etc.) (Pascu 1959). Numerous machines for the knitwear sector were manufactured at the factories *Encel Mauriciu, Varga Katalin* from Cluj, *Ocsko Terezia* from Timișoara. At the mechanical factory in Cugir, sewing machines were produced classified into two large groups: for industrial use and for domestic use. Between 1946 and 1974, MCI series machines were manufactured for industrial use.

In the paper (Malinschi et al. 1964) it is mentioned that after 1960 special attention was paid to the introduction of modern techniques by equipping factories with high productivity machines, reusing and modernizing existing enterprises, introducing new technologies that would give textile products superior characteristics and ensure the processing of new chemical raw materials. A large number of enterprises were retooled and part of the machinery was modernized, especially in cotton spinning and weaving, in knitting factories, in clothing factories, in the footwear industry (Malinschi et al. 1964). Conditions were thus created for achieving continuous manufacturing flows and increasing production capacity (Ștefănescu and Petrescu 1968). Therefore, in the textile industry, which in 1961 accounted for 8.3% of the country's global industrial production, numerous high-productivity machines were introduced. Automations have been introduced in continuous steaming, bleaching lines, dyeing and washing aggregates, stencil printing machines, continuous steamers and dryers, Multiflex washing machines, etc. Also, as a result of the introduction of modern machines and technologies in the leather and footwear industry, labor productivity increased by approximately 3% in 1962. In the work (Malinschi et al. 1964), the situation of the industry's endowment is presented; in cotton weavers, the ratio of automatic looms reached 36% in 1964 compared to 4% in 1958. In the knitting industry 80–90% of the equipment was replaced in the period 1959–1963, and in garment factories the machines were almost completely replaced. These subbranches were equipped with 550 hosiery machines, 1,100 knitting machines, and nearly 2,000 special garment machines. The tanneries were equipped with a large number of modern machines, such as: leather leveling machines, hydraulic presses for ironing and pressing leather, leather splitting machines, etc. In the footwear factories, 11 new technological lines and modern production systems were installed, which ensured obtaining more flexible, lighter, more pleasant and more comfortable footwear (Fig. 4) (Malinschi et al. 1964).

The machine building industry contributed to raising the technical level of the enterprises. Romania started to design and manufacture, at a high technical level, complex machines for the textile industry, such as: ring spinning machines, automatic cotton weaving looms, twisting machines, winding machines, wool combing machines, etc. The Unirea factories in Cluj specialized in the production of machinery for the textile industry. In the metallurgical enterprises of the Ministry of Light Industry, the production of small series or unique machines has been assimilated. Machine production in the enterprises of the Ministry of the Machine Construction Industry increased approximately 1000 times in 1963, compared to 1955. In the years 1963–1964, in the enterprises throughout the country, Romanians built machines for textile finishing, knitting machines, or tunnels for drying skins on glass plates. Imported machines were also brought in, mostly from the USSR, GDR, France, Italy, and England (Malinschi et al. 1964).

Fig. 4. A section of the tannery and footwear Clujana factory. *Source* Album–Cluj region (1965)

Until 1989, the textile industry held an important place in the national economy, both as a branch producing consumer goods and as an activity generating national income and jobs, especially for women. In 1980, for example, the achievements of the textile and clothing industry represented approximately 5.5% of the social product, respectively 3.6% of the national income (*** 1978). The continuous development and modernization was done in accordance with the evolution of the technical-scientific revolution of that period. The textile industry has undergone radical transformations which also included the original creations of textile researchers from specialized institutes and textile higher education, as well as of experts from other branches of science and national industry (Rusanovschi 1982). In the 80s, for example, almost all of Europe acquired fabrics from Bucegi-Pucioasa.

Until 1989, there were numerous state-owned production capacities in Romania, which positioned our country as an important supplier of textile and clothing products, especially in relation to the countries of the former Eastern European bloc.

4 The Period After 1990

After the political-economic changes of 1989, a series of trading and intermediary companies appeared on the Romanian market in the field of textile products. Their purpose was to facilitate communication with foreign markets on a wider scale, diversify commercial relations, and apply some innovative marketing strategies for that time. Local private companies established since 1990, unrelated to the former state production units, managed to develop and become known worldwide. Technological changes since the beginning of the 90s pushed the existing factories to rechannel their production towards niches that would ensure their survival and connection to the trends of the globalized economy. An example of this is the large-scale use of synthetic fibers that made spinning mills abandon old technologies and reorient their production. If before the 90s Romania was the fifth largest cotton exporter in the world, in 2017 only 2% of the former amount was produced in the country, and only 8 of the 86 cotton spinning mills and weavers were still operating.

Starting with 1990, the demand for textile and clothing products on the domestic market dropped precipitously, the CAER market fell apart, and the competitiveness of Romanian producers was inferior to similar ones from rival countries. In the early 1990s, the evolution of the textile industry was marked by the reduction and closure of several production capacities, which led to a continuous decrease in the economic importance of this subsector. Instead, the clothing industry registered, starting from the mid-1990s, a significant growth that was supported by the development of production in the *lohn* system. The report (*** 2014) states that the main aspects that led to the development of this production system in our country were: the breakdown of traditional export markets; the sharp decline of the textile industry after 1990; the low level of human resource cost; geographical proximity to the EU market; the long tradition in the production of textiles and clothing; well-trained human resource. The *lohn* system has been a beneficial factor, only in the short and medium term, ensuring the transfer of technology, increasing the level of human resource qualification, managerial capacity and competitiveness, connecting to international quality standards.

The main causes of the decline of the textile and clothing industry were (Rusanovski 2014): the total liberalization of imports; the unfavorable exchange rate of the RON in relation to the euro; increase in the price of utilities; rising wage costs compared to those in Asia; the absence of looms, spinning mills and smelters.

Mirciu (2004) shows that the textile, clothing, leather and footwear industry has many strengths that can be a basis for development, such as: it is a viable industry; makes competitive products for the domestic and foreign market; makes better use of raw materials; requires relatively low costs for modernization, re-technology and establishment of small and medium-sized enterprises compared to other industrial branches; shows great flexibility and a high degree of adaptability to changes; has a long tradition as a branch.

The opportunities for the textile and clothing industry are (*** 2016): *relocation of production* to Eastern Europe; the need for a *qualified and experienced human resource*; *rapid demand response production systems*; *new market niches* at European and global level, for products with *high added value*; *developing markets* (*silver economy, functional or intelligent textiles*); the *development of circular value chains* based on sustainable local or regional resources; the possibility of developing *cross-sectoral and transregional partnerships*, at national and European level. Therefore, for the textile, clothing, leather and footwear industry the future offers huge opportunities, but it involves great efforts and risks at the same time.

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History of Mechanics

Dorel Banabic, Costică Atanasiu, Valentin Ceaușu, Sebastian Muntean, Mircea Pascovici, Iulian Popescu, Liviu Vaida, and Ladislau Vekas

Abstract This chapter presents the evolution of research in Romania on the mechanics (the mechanics of rigid solids, deformable solids in elastic, elastoplastic or plastic behavior regimes, the theory of mechanical vibrations, fluid mechanics) but also closely related problems such as the theory of mechanisms, contact mechanics, construction of hydraulic equipment. The important stages in the development of these scientific disciplines are highlighted, the emergence of new disciplines such as tribology, chromoplasticity, the personalities and schools they created. In the same time the theoretical and experimental contributions of Romanian researchers to the progress of mechanics and industry, laboratories, works and published treatises are highlighted.

1 History of the Mechanics of Rigid Bodies

Valentin CEAUȘU, Costică ATANASIU

The mechanics of rigid bodies (rational mechanics, theoretical mechanics) appeared initially as applied mechanics or technical mechanics. The first results can be traced back at least 3000 years. In those early ages, technical knowledge embedded with simple notions of mathematics started to be applied to the design and construction of simple machinery, including means of transportation and devices to reduce hard human labor or to harvest the forces of nature.

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Theoretical mechanics is the first of the physical sciences to have received a theoretical foundation in the 1687 *Philosophiae Naturalis Principia Mathematica* thanks to the genius of Isaac Newton (1642–1727)—mathematician, physicist, astronomer and philosopher. Very few scientific theories have gathered such commanding authority as Newton's works.

On the current territory of Romania, knowledge of practical mechanics has been attested by archaeological discoveries proving the utilization of simple machinery and transportation means from the earliest ages. The first written documents are from the 16th century and were about rocket ballistics. A manuscript describing research of Conrad Haas (1529–1579) on multistage rocket propulsion (Andonie 1965, 1966, 1967, 1971, 1981; Bălan and Mihăileanu 1985; Iancu 2009) is held at the Library of the Bruckenthal Museum in Sibiu. The first published work to contain elements of theoretical and practical mechanics is professor S. Pataky's work dating 1773 (Wolff 1773). Notions of theoretical mechanics have been taught at the highest education institutions of the time: the Academies in Iași and Bucharest beginning with the middle of the 18th century, following the works by Descartes *Principles of Philosophy* (1614) and *An explication of machines by means of which one can lift with a small force a very heavy load* (1637), and mainly the works by Newton. At the Academy in Iași, N. Cercel lectured Experimental Physics and Newtonian Gravity Theory from 1760 to 1773, while N. Theotochis lectured physics with elements of mechanics from 1764 to 1767. The latter published his first modern physics treatise titled *Elements of Physics* in Leipzig, 1765, written in Greek, in two volumes and including mechanics. The earliest nationally published work to contain elements of mechanics (at the end of the 18th century) is Manuscript 1081 from the Romanian Academy Library, also written in Greek. The manuscript contains 225 pages, is not titled and belonged to a certain Dr. M. Gaster. The content related to mechanics includes the motion under the action of gravity, the law of the lever and simple machineries.

The first book to present the fundamental principles of classical mechanics to the Romanian public was written by Gh. Șincai and took after Helmuth's *Physics* (around 1809). The first professor of mechanics was engineer Al. Costinescu who taught in Romanian at the Academia Mihăileană in Iași during 1837–1838. In 1842 the printing house of Sf. Sava College published *Moș Pătru sau Învățătorul din sat. Convorbiri asupra mecanicii* dedicated to teaching notions of mechanics in elementary schools (Marin 1881).

The evolution of theoretical mechanics in our country is directly related to the evolution of higher education. Prior to 1848, technical higher education was in its dawns as its scope had been limited to training agents for various public works (as noted by C. Bușilă in 1918). In Bucharest, a College of Exact Sciences was established in 1850 having three specialties: Topography, Bridges and Roads, and Architecture. In 1852, at the request of the ruling prince of Ţara Românească, the French Government sent L. Lalanne, a graduate of the School of Bridges and Roads, to Bucharest. He organized the system of public works after the French one and founded a post-secondary engineering school in Bucharest. He also introduced the metric system of measurements, organized the Postal and Telegraph Services, as well as the Public Works Corps of Engineers, and coordinated preliminary studies for the construction of railways (Voinea and Voiculescu 2004). In Moldova, Gh. Asachi has established the Applied School of Engineers and Conductors, with a duration of studies of three years.

The real development of higher education in Romania is linked to the period after the Unification of 1859, when major universities were founded. University of Iași was founded on September 26, 1866, and included a Department of Sciences where mechanics has been taught by Melik et al. (1865–1913), Vâlcovici (1913–1921) and S. Sanielevici. From 1938–1945, physicist I. Plăcințeanu, Ph.D. in sciences from the University of Gottingen, taught mechanics at Iași. He published *Relativistic Effects Derived with a Novel Theoretical Mechanics*, where he refers to the *Invariantive Mechanics* developed by O. Onicescu. In 1942, Plăcințeanu published *Mecanică rațională și analitică* (Plăcințeanu 1942), a book of great scientific value. O. Onicescu—the first Romanian to hold a Ph.D. in mathematics from Italy (1920)—made great contributions to the field of theoretical mechanics (Onicescu 1956), relativistic mechanics and statistical mechanics. In his work *Mecanica invariantivă și cosmologie* (Onicescu 1974), he develops a novel mechanics of material systems.

The University of Bucharest was founded in 1864, and included a Department of Physical, Mathematical and Natural Sciences. A dedicated Department of Mechanics has been created in 1880, the discipline of rational mechanics being taught by Haret (1878–1911), Lalescu (1911–1912), Pompeiu (1912–1930) and Vâlcovici (1930–1962). In 1878, Spiru Haret becomes the first Romanian to obtain a Ph.D. in Mathematics from Sorbonne, Paris. Later, acting as the Minister of Public Instruction he introduced reforms of secondary and higher education (1898), and vocational education (1899). His book *Mécanique sociale* (Haret 2010), published in Paris in 1910, has been praised by French sociologist G. Richard.

V. Vâlcovici was the first to use a vector expression in theoretical mechanics. His vast works encompass mathematics, theoretical mechanics, and mostly fluid mechanics. At the Polytechnic School of Timișoara and the University of Bucharest, he introduced modern mechanical laboratories. The treatise *Mecanica teoretică* (Vâlcovici et al. 1958) authored by V. Vâlcovici, Șt. Bălan and R. Voinea with contributions from O. Dragnea, R. Voinaroski, P. Mazilu, Al. Stoenescu, S. Pop and E. Beiu-Paladi represents a work of exceptional scientific importance. In 1938, The Romanian Academy opened a new series of scientific monographs with the works *Ecuațiile mecanicii analitice* by N. Ciorănescu, licensed in Sciences and Ph.D. in Mathematics from Sorbonne in 1924. The preface was written by Gh. Țițeica.

At the National School of Bridges and Roads, later on the Polytechnic School of Bucharest, during 1908–1937 in charge of mechanics was A. Ioachimescu, licensed in mathematics (Paris, 1894). His lectures, rich in engineering content, have been published posthumously in 1947 by his successors Al. Stoenescu and G. Țițeica. I. Ionescu and T. Lalescu, from the same university, made important contributions to the development of theoretical mechanics.

At the University of Cluj, founded in 1911, V. Desmireanu, General Șt. Burileanu, D.V. Ionescu and C. Iacob. taught theoretical mechanics courses. Șt. Burileanu, who earned a Ph.D. in mathematics from Paris, wrote *Curs de mecanică rațională*

(Burileanu 1942, 1944) in 1942, and *Curs de mecanică rațională. Volumul II Dinamica* in 1944. Remarkable works have also been published by D.V. Ionescu, who earned his Ph.D. from Sorbonne, Paris.

The rational mechanics courses at the Polytechnic School of Timișoara, founded in 1920, have been taught by C. C. Teodorescu, V. Vâlcovici, Șt. Drăgănescu and M. Ghermănescu. Mathematician by formation, M. Ghermănescu made important contributions to the field of mechanics. He published *Probleme și propoziții din dinamica punctului* in 1943, and lectures of mechanics. References Ionescu (1932), Mihăiță et al. (2000), *** (1979) give additional information on the historical evolution of teaching and research in the field of classic mechanics.

During 1948–1963, The Romanian Academy had a common Section of Mathematics and Physics that was split in 1963. The regional affiliates in Iași, Cluj and Timișoara had sections dedicated to applied mathematics, and scientific and technical research. Starting with 1948 the applied research activities have been promoted and extended to universities and research institutions leading to some noteworthy results. Mathematician D. Mangeron from the Polytechnic Institute of Iași had contributions in analytical mechanics, in collaboration with N. Irimiciuc. The technical literature retains the equations of Mangeron-Tenov. A. Ripianu, from the Polytechnic Institute of Cluj, studied rotor-dynamics; in collaboration with C. Tudose he studied the central motion of material point. Al. Stoenescu, professor at the Polytechnic Institute of Bucharest, published several works on rocket motion, the motion of Earth artificial satellites, the theory of the gyroscope, and the theory of relativity. R. Voinea, Rector of the Polytechnic Institute of Bucharest and President of The Romanian Academy, has established a veritable school of applied mechanics. He has published books in classic mechanics, strength of materials, theory of elasticity, and theory of mechanisms. R. Voinarovski, from the Oil and Gas Institute of Ploiești has studied the kinematics of rigid systems in a four-dimensional Euclidian space. In collaboration with L. Teodoriu he built an apparatus to determine the acceleration of gravity: the Teodoriu-Voinarovski pendulum. Șt. Bălan, from the Civil Construction Institute of Bucharest, published on new construction materials, as well as textbooks and collections of exercises in solid mechanics. Gh. Silaș, of the Polytechnic Institute of Timișoara has contributions in collisions and percussions, dynamics of machinery and nonlinear dynamics. He has established a research group in vibro-impact dynamics.

Starting with 1990 deep changes affected the entire Romanian society including the fields of education and research. Universities added Master programs in solid mechanics. There was a spike in publications at major printing houses in the country and abroad: *Introducere în teoria sistemelor dinamice* (Voinea and Stroe 2000), *Elemente de mecanică analitică* (Ursu-Fischer 2015), *Mechanical Systems. Classical Models* (Teodorescu 2009a), *Dynamics of the Rigid Solid with General Constraints by a Multibody Approach* (Pandrea and Stănescu 2015), *The Optimal Homotopy Asymptotic Method. Engineering Applications* (Marinca and Herişanu 2015).

Research in the field continues nowadays on fundamental aspects of mechanics, as well as topics of a broader perspective. Problems in dynamic systems control, multibody dynamics, theory of threaded fasteners applied to mechanics have been tackled by research teams led by T. Sireteanu and V. Chiroiu at the Solid Mechanics Institute, by N. Pandrea and N. D. Stănescu at the University of Pitești, and by S. Vlase at the University Transilvania of Brașov. At the Polytechnic University of Timișoara, the research carried out by V. Marinca and N. Herișanu is related to nonlinear mechanics, asymptotical methods and the inverse problem in analytical mechanics. Professors N. Plitea and D. Pâslă from the Technical University of Cluj-Napoca have contributions to the mechanics of parallel mechanisms used in robotics.

2 History of Mechanisms

Iulian POPESCU

Throughout time, people built themselves devices, appliances, machines, in order to process raw materials and products, to build houses, to create weapons, etc. Until the 18th century, mechanisms were built empirically, by people gifted with technical creativity. However, mechanisms were created in *antiquity* that also required some calculations, but they did not survive to our days. During the *Middle Ages* machine builders used the forces of water, wind and animals (Agricola 1994). The bases of calculation methods for mechanisms were set starting with the 18th century (with the research carried out by Euler, Monge and others). The emergence of steam machines was a strong drive for the mathematical and engineering research of mechanisms. The beginnings of the theory of mechanisms were laid by mathematicians (Euler established the law of gearing in 1765, Monge created a theory of mechanical engineering, also establishing a ranging of mechanisms, etc). Throughout this period, researchers did not benefit from the calculation techniques in order to tackle the difficult problems of mechanisms, so they *turned to graphic methods.* These methods, extremely laborious and with a low accuracy, slowed calculation techniques for mechanisms, so that most engineers chose simplified calculations, despite the fact that machines became more and more complicated. Graphic methods were used for many years, becoming more and more complicated, thus reaching a limit in mechanisms' research. The German school and partially the French one, took the lead in mechanisms' engineering between 1914 and 1941. Graphic and graphical-analytical methods expanded, drawing up complicated methods, but more simplified methods were also found, enabling some engineers to carry out partial calculations for certain mechanisms. The experience acquired in machine engineering and building gained force, but the discipline of Mechanisms was still included in Theoretical Mechanics, as application for certain theoretical problems, leading to the emergence of Applied Mechanics.

In 1948, Polytechnic schools of București, Iași and Timișoara became Polytechnic Institutes, such institutes being created in other cities as well. The Theory of mechanisms as a subject emerged from Theoretical Mechanics, which enabled the training of specialized professors and establishing academic and experimental labs.

Among the first Romanian books on mechanisms, it is worth mentioning the ones of Lazaride (1953), N. Manolescu (four volumes lithographed by CFR Publishing House between 1955–1956) (Manolescu 1955–1956; Maros (1953, 1958), and N. Manolescu and D. Maros on kinetostatics and dynamics (1958) (Manolescu and Maros 1958). In 1959, professor V. Manafu published the book 'Structura și cinematica mecanismelor' (Manafu 1959), where he presented the current status of researches in the field of the theory of mechanisms and also original contributions regarding the prevalence of the similarity method to kinematics, the method for binding mechanisms and others. It is interesting to notice that during a 1989 symposium, professor N. Manolescu explained that professor V. Manafu was not mentioned as the author of the book, given the political context of that time. Several collections of problems were very useful in applying the theory of mechanisms: Conţiu 1957, Manolescu and all (1963–vol. I, 1968–vol. II) (Manolescu et al. 1963).

In September 1965, in Varna, Bulgaria, a conference was held on 'Mechanisms and Machines' where the creation of an International Federation for the Theory of Machines and Mechanisms was proposed. With the help of professor N. Manolescu, Romania was a founding member of this federation.

The first meeting of Romanian mechanical specialists was organized in 1972 by professor F. Kovacs from Timișoara, the symposium being held in Reșița, and it was called 'Mechanisms and mechanic transmissions. In 1973 the first International Symposium on Mechanisms was organized—SYROM '73 (held on an ongoing basis every 4 years, and was still organized, in Brașov, for the past few years).

During the 70s, with the emergence and use of computers, technical calculations were developed, enabling researchers to use numeric methods instead of graphic ones for analytical methods, programmed in Fortran (I. Simionescu) or Basic (I. Popescu) or other software (C. Pelecudi). A significant number of books on mechanisms were published by authors like: D. Tutunaru, N. Manolescu, F. Kovacs, A. Orănescu, F. Dudiță, E. Diaconescu, G. Gogu, V. Sandra-Luca, I.A. Stoica, D. Maros, etc. It was in this period that Romania developed the first researches in the field of Industrial Robots, in Timișoara (Prof. F. Kovacs), Bucharest (Prof. C. Pelecudi), Iași (prof. D. Mangeron) and other centers in the country.

Romanian Figures in the Field of Mechanisms

The Polytechnic of Bucharest developed a school of theory of mechanisms where a significant number of researchers was trained: N. Manolescu, C. Pelecudi, R. C. Bogdan, T. Demian, D. Tutunaru, etc. Professor N. Manolescu had an immense contribution to kinetics: the issue of scales in graphic and analytical calculations, the similarity method, synthesizing kinetic chains of different families, speed and acceleration distribution for mechanisms with complex kinematic chains and many others. Professor C. Pelecudi published two fundamental books with Editura Academiei Publishing House, on the basis of mechanism analysis and the theory of spatial mechanisms (Pelecudi 1972, 1975), supporting analytical methods and also being a pioneer of applying calculation techniques in solving problems pertaining to the theory of mechanisms. In 1969, professor D. Tutunaru published a monograph on cam mechanisms (Tutunaru 1959) and another on rectilinear mechanisms and inverters

(Tutunaru 1969), presenting a series of original contributions. Professor R. C. Bogdan analysed mechanisms through experimental mechanical and electric methods using harmonics analysis (Bogdan 1968) and professor T. Demian studied mechanisms of fine mechanics (Demian 1965). Apart from researches in theoretical mechanics, professor D. Mangeron from Iași, also published books on mechanisms, such as the study of reduced acceleration for planar and spatial mechanisms, the similarity method, the tensor method and others (Mangeron and Irimiciuc 1978). He coordinated the publication titled Scientific Bulletin of the Polytechnic Institute, an internationally known journal, and trained important researchers in mechanics and mechanisms. In Timișoara, professor F. Kovacs developed new methods for mechanism analysis and synthesis (Kovacs et al. 1976) and created an important school specialized in industrial robots. At the same time, professor D. Perju left his mark on mechanism analysis and synthesis, especially as regards the mechanisms with top kinematic coupling. In Cluj-Napoca, professor D. Maros established a school specialized in mechanisms, focused on gear kinematics (Maros 1958) and mechanisms with top kinematic coupling. Professor I. Szekelly handled mechanisms of fine mechanics and new calculation methods (spline functions) and others. Professor V. Handra-Luca's researches were published in a treaty on transmission functions (1983) (Handra-Luca 1983), as well as in a two-volume monograph (1983) (in collaboration with I.A. Stoica) (Handra-Luca and Stoica 1983), publishing at the same time a number of papers both nationally and abroad. The school in Brașov was lead by professor F. Dudiță—who contributed to the field of universal joints (Dudiţă 1966a) (translated in French (Dudiţă 1966b) and German (Dudiţă 1973)), mobile homokinetic couplings (Dudiţă, 1974), hinged mechanisms (Dudiţă et al. 1989)—initiated the study of biomechanisms and of the history of mechanisms in Romania. This school trained specialists who handled motor car mechanisms (Alexandru et al. 1977), as well as other various mechanisms (G. Gogu, I. Vișa). Professor A. Orănescu, from the University of Galați, developed methods of kinematic calculations for complex kinematic groups (Orănescu 1963). Professor N. Pandrea, from the University of Pitești had original contributions to kinematics and the synthesis of spatial mechanisms (Pandrea and Popa 2000), machine dynamics, and integration of motion equations, and analysed the dynamics of Gogu Constantinescu's torque converter. Professor I. Popescu (University of Craiova) greatly contributed to the structural synthesis of mechanisms (Popescu 1977), kinematics and computer assisted analytical kinetostatics, biological mechanisms (Popescu et al. 1977), the history of mechanisms (Popescu 2011), aesthetics in mechanisms, etc.

3 History of the Mechanics of Deformable Solids

3.1 Theory of Elasticity

Costică ATANASIU

The mechanics of deformable solids—name under which the strength of materials and the theory of elasticity are known in the scientific literature—is a discipline of engineering. The main goal of the first discipline—strength of materials—is to obtain the stress and strain state in bars and systems of bars subject to external loads, using different hypotheses. The dimensions of a cross section are calculated taking into account the characteristics of the material, in order to ensure that the bar will resist during service. The theory of elasticity studies the stress and strain state in deformable solids considering the material as a continuum displaying a linear elastic behaviour under external loads.

In Romania, the French education system was implemented by Romanian former students who studied in France (Andonie 1965; Atanasiu 2017; Leonăchescu 2011). Written documents on the mechanics of deformable solids published in Romania show that a course of theoretical and applied mechanics was taught (Andonie 1965) in 1851 at the Faculty of Philosophy of Academia Mihăileană of Iași. Also, at the School of Bridges and Roads in Bucharest, elements of mechanics applied to usual machines were taught since 1850. The lecturers of these courses were I. Constantinescu in 1851, C. Zeuceanu during 1869–1870 and 1873–1877, and E. Angelescu during 1870–1873 (Andonie 1965; Atanasiu 2017). During 1875–1879, C. Olănescu, graduate of the School of Art and Manufactures in Paris taught elementary mechanics, kinematics, the strength of materials and hydraulics. During 1881–1902, C. Mănescu—licensed in mathematics at the Faculty of Sciences in Iași, and of the School of Bridges and Roads in Paris—taught a course on mechanics applied to the strength of materials and stability of buildings. This course was printed and lithographed in 1893 and 1894 (Mănescu 1893, 1894) and was subsequently taught during 1902–1915 by H. Schlawe, graduate of the School of Civil Engineering at Ghent University in Belgium. This course (Schlawe 1913) also contained elements of theory of elasticity and new findings of European research in this field during 1893–1913. In 1886, at the National School of Bridges and Roads, professor A. Saligny (Atanasiu 2017) founded the Laboratory of Chemistry as the first technological laboratory in Romania. This laboratory developed during 1886–1940 by acquiring new equipment for chemical analyses, and testing machines. A Werder testing machine with a maximum force of 1000 kN was bought from Germany in 1888. It was, at that time, the state-of-the-art in the field of mechanical testing, and it was used to test steel profiles intended for the structure of Cernavodă Bridge over the Danube River (1890–1895), as well as materials used to build docks in Constanța harbour and other significant national works. In 1923, professor C.C. Teodorescu founded the Laboratory of Strength of Materials at the Polytechnic School in Timișoara. Apart from the testing machines bought from abroad, it is important to note that all of the other machines were designed and manufactured locally.

The mechanics of deformable solids further developed due to G.E. Filipescu, professor at National School of Bridges and Roads in Bucharest, who wrote and published in 1935 a course under the title *Statica construcțiilor și rezistența materialelor* in three volumes, further re-printed in a single volume in 1940 (1940). This work presents the main problems of strength of materials in an original way, using vectors. The high-level scientific content, the mathematical and rigorous level in which the fundamental notions are presented yielded highly appreciative reviews from different European scientific figures, reviews included in the preface of the 1940 edition of the book. G.E. Filipescu carried out research and had new contributions to the theory of elasticity regarding buckling of elastic bars, lateral buckling, bending and torsion of electric car railway tracks, and hypotheses of strength of materials. He proposed an original method to study statically indeterminate bent beams using the principle of virtual displacement. This was the first Romanian contribution to strength of materials, and was called the method of indeterminate coefficients or the Filipescu method. The research carried out by C.C. Teodorescu—professor and Rector of the Polytechnic Schools in Bucharest and Timișoara (Andonie 1965; Popescu 2011; Teodorescu 1945)—focused on two main fields: material testing and calculus, and testing of welded joints. He was the first to apply statistical methods, based on the theory of probability, to the processing of mechanical testing results, and he proposed a method to compare two characteristic limits of materials subject to mechanical tests. The first doctoral theses of Romanian researchers in the theory of elasticity (Andonie 1965) were prepared by R. Müller from Rupea, in 1908, and P. Boroș in 1919, at Technische Hochschule in Berlin. The first thesis defended in Romania in the field of mechanics of deformable solids was titled *La résolution des systemes hypérstatiques par deux méthodes recentes (critique et extension des methodes Filipescu et Cross)*, and it was presented in 1938 by Associate professor C. Mateescu. In 1939, Ș. Nădășan defended his thesis titled *Rezistența dinamică a fontei* at the Polytechnic School in Timișoara. Other contributions to the mechanics of deformable solids were brought by V. Vâlcovici, A. Beleș, M. Hangan, P. Mazilu (Andonie 1965), who proposed new methods for strength calculations in civil and industrial structures. C. Vâlcovici determined the frontier between stability and non-stability in the case of elastic buckling. A. Beleș, together with M. Soare, published the monograph titled *Paraboloidul eliptic și hiperbolic în construcții*, which was the first one on such a subject in the world scientific community. M. Hangan established new methods of strength calculation for beams, plates and tanks made of reinforced concrete. Romanian researchers were present when the International Association for Materials Testing was established in 1928, having N. Vasilescu Karpen—Rector of the Polytechnic School in Bucharest—as vice-president.

After the Second World War, many changes happened in the technical higher education system due to the reform of 1948 and to the new policy of industrialisation in Romania. The number of institutes, faculties, faculty members and students increased, and departments of strength of materials were set up. The activity of the Romanian Academy has been extended and the Research Base in Timișoara has been established. The Institute of Applied Mechanics was established in 1948, and transformed in 1965 in the Institute of Fluid Mechanics, led by E. Carafoli. In addition, the Centre for Solid Mechanics—headed by Ș. Bălan—was established. These institutes have been involved in approaching new directions of research in mechanics, with applications in machine building, hydro-technical and aero-technical constructions, fundamental and applied research. Under the aegis of the institute, the journal titled *Studii și cercetări de mecanică aplicată* started to be printed both in Romanian, and in French. In 1955, the Editura Tehnică published a book of applications in strength of materials, under the coordination of G. Buzdugan, as well as the course on strength of materials by the same author (Buzdugan 1956). This course has been considered a fundamental work in this field for many years, and professor Buzdugan represented a landmark in solid mechanics (Banabic 2013) for over 35 years. After several years, many courses were published, written by different professors from all universities in Romania. In this period, the research in the field of theory of elasticity boosted due to numerous applications proposed in different technical fields. For example, professor A. Șesan from the Polytechnic Institute in Iași demonstrated that the principle of Menabrea can be applied to the elastic-plastic or fully plastic equilibrium of structures (Andonie 1965). Some of the research carried out was based on the planar or three dimensional problem of elasticity to obtain a general solution, while other research approached problems of thermo-elasticity or elasto-dynamics. In this field, several works may be cited, such as *Teoria elasticității* by M. Haimovici, *Teoria elasticității și introducere în mecanica solidelor deformabile* by P.P. Teodorescu, *Statica și dinamica structurilor elastice anizotrope și heterogene* by L. Librescu, *Elasticitate liniară. Introducere matematică în statica solidului elastic* by L. Solomon, *Mecanica mediilor deformabile* by M. Mișicu, *Teoria aeroelasticității* by A. Petre, *Termoelasticitate* by I. Grindei, *Rezistența materialelor și teoria elasticității* by C. Bia, V. Ille, and M. Soare.

W. Kecs and D.Muchinescu worked in the field of applications to the theory of distributions to solve some problems of theory of elasticity. Other important contributions were provided by Teodorescu (2009b). In other works by A. Gheorghiu, D. Mateescu, C. Avram, P. Mazilu, H. Sandi, A. Pârvu, D. Stan, E. Soos, M. Mihăilescu, V. Visarion, (Andonie 1965), technical aspects prevail. During 1950–1965, laboratories from universities and research institutes were provided with equipment for stress analysis in structures, according to the concerns of the international researchers and the needs of the economy. Material testing remained only a part of the experimental work. In 1950 N. Iosipescu initiated the first Romanian experiments in photoelasticity (Iosipescu 1958) for the determination of stress state in loaded structures. He facilitated this course at the Department of Mechanics of the Faculty of Mathematics within the University in Bucharest, where he established a laboratory of research in photoelasticity. Iosipescu can also be considered a pioneer of the moiré method for stress and strain determination in planar plates. He proposed the scientific base of pure shear testing of a double split beam non-symmetrically loaded, for which he obtained patent no. 42082. His method was also patented in USA, Germany, Switzerland, and Austria, and published in the Journal of Materials. Both the Romanian standard STAS 7926-67, and the American standard ASTM D-5379-93 for pure shear testing of composite materials were established based on the Iosipescu's research and his testing method already known all over the world as the Iosipescu method for pure shear testing.

Gradually, strain gauges for static and dynamic testing were introduced in Romania in different laboratories. At the Railway Research Institute, a strain gauge laboratory was established in 1958, consisting of two laboratory wagons for experimental measurements in a dynamic regime. A hydraulic stand for testing locomotives and railway cars was introduced together with an experimental ring for testing rolling stock. Books and papers on strain gauges were published by research groups led by G. Buzdugan and D.R. Mocanu (Theocaris et al. 1966, Atanasiu et al. 1982).

At this time, mostly the laboratories of technical universities used optical methods for the analysis of stress and strain state (photoelasticity, moiré and holography) in machine structures and civil engineering, and in agricultural and industrial structures. Applied research in the mechanics of deformable solids was deeply involved in solving industrial problems, using mainly calculation methodologies experimentally verified using either dynamic or static strain gauge measurements and photoelasticity measurements of the stress state in supporting structures (mechanical equipment of power plants, locomotives, railway cars, elevators, process equipment, precompressed concrete beams, pressurized pipes, tanks, metallurgical or agricultural equipment).

New laboratories for teaching and research were established in technical universities in Bucharest, Timișoara, Cluj, Iași, and Brașov. Modern facilities for scientific investigations in the mechanics of deformable solids were developed in the laboratories of research institutes. During 1970–1989, a rapid development is noticed in research using numerical methods (and especially the finite element method) to obtain the stress and strain states in structures. Several books presenting this method appeared and thousands of papers were published or presented at scientific symposia or conferences. It is worth underlying the contributions of Mangeron (1980), Voinea et al. (1989).

Theoretical and experimental activities in the mechanics of deformable solids have developed due either to the schools established up to 1948 or to new ones created within different universities, and activities of professional associations. The School of mechanics of deformable solids within the Polytechnic University of Bucharest, with deep roots and great tradition, had a very solid base and continuity (Andonie 1965; Atanasiu 2017). The schools established after the Second World War in other various universities drawn their research efforts to solve industrial problems in their area.

The scientific activity in the field of mechanics of deformable solids has been reflected in the organization and participation of Romanian researchers to international conferences. Some of such conferences were organized by the Division of Technical Sciences within the Romanian Academy and by the Romanian Association of Experimental Stress Analysis. The Department of Strength of Materials at the Polytechnic Institute in Bucharest organized several scientific events: the Symposium on Experimental Techniques in Applied Mechanics (1972), the Euromech Colloqium on Dynamics of Machine Foundations (1973, 1985 and 1994).

Great transformations are noticed after 1989 in the technical higher education. New specialisations, faculties and state or private universities appeared; the three-cycle Bologna system was adopted. The fundamental research, especially in the institutes of the Romanian Academy, intensified. The scientific research diversified, including new directions of research such as fracture mechanics, structural integrity, damage modelling and simulation, durability of structures subject to variable loadings. A new direction of research appeared due to the emergence and extensive use of new metallic, plastic or composite materials: mechanical testing for the determination of mechanical characteristics and response under loads. The exceptional development of computers allowed the researchers to extensively use the finite element method for the static and dynamic analysis of the stress state in structures and for stability analyses.

The Department of Strength of Materials at the Polytechnic University of Bucharest, the University of Tarbes in France, the University of Patras in Greece, and, further, the University of Porto in Portugal organize every two years an international conference on structural analysis of advanced materials. The Romanian Association of Experimental Stress Analysis and Materials Testing (ARTENS) is currently a member of the Danubia-Adria Society on Experimental Methods, society having as members scientific associations from 11 European countries. Departments of mechanical engineering at the main universities in Romania, professional associations (for experimental stress analysis, fracture mechanics, theoretical and applied mechanics) and research institutes of the Romanian Academy organize every two years international conferences on different aspects and trends of the mechanics of deformable solids.

In 1997, the Technical Sciences Academy of Romania is established, including a Section of Technical Mechanics, which organizes an annual international conference, and is the editor of the *Journal of Engineering Sciences and Innovation.*

3.2 Mechanical Vibrations

Valentin CEAUȘU, Costică ATANASIU

The field of mechanical vibrations studies the oscillations of elastic systems, and is considered a part of mechanics. Oscillatory motion can be otherwise encountered in all chapters of physics. The theoretical and experimental study of vibrations is needed to evaluate their negative effects on human beings, operation of machinery, constructions and foundations. Moreover, vibrations are used in designing devices such as vibrating mills or sieves, vibrating conveyors, vibro-impact machines, etc. The first vibration-related concepts were developed by Thales of Miletus and Pythagoras of the Ionian school of philosophy (Dimarogonas 1990; Dimarogonas and Haddard 1992). The modern study of vibrations begins at the end of the 19th century, and is related to the rapid progress of technology in sea navigation, aviation, and high speed rotating machines (Timoshenko 1928).

In Romania, the first paper in the field was *Oscilarea vagoanelor în timpul mersului,* prepared by Gogu Constantinescu and published in *Buletinul Societății Politehnice* in 1905. During the first half of the 20th century, the study of vibrations could be found (Buzdugan 2011) exclusively in books written by professors at the Polytechnic School in București: *Statica construcțiilor și rezistența materialelor* by Gh. Em. Filipescu (1940), *Probleme de oscilații* by Al Stoenescu (1939), and *Curs de rezistența materialelor* by Teodorescu (1945). In addition, an important contribution is the work titled *Theory of Sonicity. Treatise of Power Transmission by Vibrations* (*Teoria sonicității. Tratat despre transmisiunea puterei prin vibrațiuni)* (vol. I) by Gogu Constantinescu (1922). This book was first printed in English in 1918, then in Romanian in 1922. A second edition was printed in 1985 by Editura Academiei Române. The article *Cutremurul și construcțiile* published by A. A. Beleș in 1941 in *Analele Academiei Române* boosted the theoretical and experimental research in the field of anti-seismic design and analysis.

In technical universities, the study of vibrations was introduced in 1948 as part of two fundamental disciplines: the vibrations of discrete systems with one or multiple degrees of freedom within the discipline of Mechanics, and the concepts of continuum media within the discipline of Strength of Materials. At the recommendation of Romanian Academy members Gh. Buzdugan and R. Voinea, a standalone course on Mechanical Vibrations was introduced in 1976 in the curriculum of all engineering programs having a mechanical profile. Applied courses of vibrations and dynamics were also added to various engineering programs, such as machine tools, automotive, railway, naval systems, construction machinery and technological equipment. Among the textbooks used one can mention those coordinated by Bratu (2002), Ispas (2007), and Chiriacescu (1982). Individually or in collaboration, Gh. Buzdugan, member of the Romanian Academy, published numerous scientific works dedicated to mechanical vibrations in the field of machine manufacturing (Buzdugan et al. 1961, 1975, 1986; Buzdugan 1980, 1968). He also coordinated the translation into Romanian of *Shock and Vibration Handbook* edited by Harris and Crede (1961). A. Petre published remarkable works in the field of fluid-structure interaction, such as *Teoria aeroelasticității* (Petre 1966, 1973). The book titled *Metode dinamice pentru identificarea sistemelor mecanice* (Radeș 1975) by M. Radeș is considered the first monograph on its subject. M. Radeș is also co-author and editor of *Encyclopedia of Vibration* (Encyclopedia of Vibration 2002). Prof. Gh. Silaș at the Polytechnic University of Timișoara covered the area of nonlinear vibrations, especially impact vibrations (Silaș 1968; Silaș and Brîndeu 1968). D. Mangeron, professor at the Polytechnic University of Iași published *Mecanica vibrațiilor sistemelor rigide* (Mangeron and Irimiciuc 1981), and *Fundamentele mecanicii* (Gaboș et al. 1961). A. Ripianu at the Technical University of Cluj published works on crankshaft vibrations such as *Mișcările vibratorii ale arborilor drepți și cotiți* (Ripianu 1973) and *Calculul dinamic și de rezistență al arborilor drepți și cotiți* (Ripianu and Crăciun 1985). Remarkable scientific works in the field of vibrations and acoustics were also authored by other mathematicians, physicists or engineers: Sireteanu et al. (1981), Magheți and Savu (2007), Dinca and Teodosiu (1973).

After 1990 an increase can be seen in the number of research topics, as well as improvements in the equipment available to sound and vibration labs (Silaș 1968). The research in the field of noise and vibrations is currently addressing concerns regarding their negative impact on human beings, machines, equipment and structures.

3.3 Theory of Plasticity

Dorel BANABIC

The theory of plasticity deals with the study of the behaviour of materials submitted to equivalent stress above the yield stress. The application of the plasticity theory in the study of deformation through pressing allows for an analytical approach to technological problems and a scientific examination of the phenomena which occur during these processes. The development of this theory was stimulated by the need for mathematical modelling of certain industrial processes (lamination, forging, extrusion, drawing, etc.).

The first studies on plasticity in Romania were initiated after the First World War by researchers in the field of elasticity and strength of materials (Andonie 1965). The applications of plasticity calculus which occurred during this period were mostly in the field of building and bridge structures. Of those who began their work before 1945, there are several names worth mentioning. C. C. Teodorescu, professor of Material Strength at the Polytechnic school of Timișoara and then at its Bucharest counterpart, contributed significantly to the field of material testing (Teodorescu 1927). He was one of the first researchers worldwide to use statistical methods to process data obtained through mechanical trials (Teodorescu 1934). Furthermore, he helped advance the calculus of the strength of railway tracks placed on elasto-plastic bearings (Teodorescu 1968). Another professor in the field of construction, Mihail Hangan, contributed to determining the order of appearance of plastic articulations in concrete structures, as well as to the calculus of hyperstatic structures in the science of plasticity (Hangan 1959). A special contribution on behalf of the Romanian school of construction came from Romanian Academy Member Ștefan Bălan, who, in collaboration with S. Răutu and V. Petcu, introduced a new method for analysing structures, one which was completely new to the world, called *chromoplasticity* (Bălan et al. 1963).

The founder of the theory of plasticity in Romania is Nicolae Cristescu. He was the one to conduct the first systematic studies in the field of the plasticity theory as part of his doctoral thesis called *Asupra unor probleme dinamice de teoria plasticității* (*On certain Dynamic Issues of the Theory of Plasticity*) (Cristescu 1955), which he defended at the University of Bucharest in 1955 (having Gr. Moisil as a thesis supervisor). In the same year, he introduced the first course in the Theory of Plasticity ever held at a Romanian university. He subsequently went more in depth into the field and published his results in the book titled *Probleme dinamice* *de teoria plasticității* (*Dynamic Issues of the Theory of Plasticity*) (Cristescu 1958). The results of personal and international research were published in 1967 in the book called *Dynamic plasticity* (Cristescu 1967), which was translated into Japanese in 1970, being the first book of exact sciences written by a Romanian ever published in that language. He was invited to hold conferences and courses in the field at numerous universities in Poland, England, France, Germany, and especially the USA. From 1970 onwards, he channeled his research towards the field of rheology and rock mechanics, publishing the results of his work in Romanian (*Vîscoplasticitate* (Cristescu and Suliciu 1976), *Mecanica rocilor* (Cristescu 1990)) and English (*Viscoplasticity* (Cristescu and Suliciu 1982), *Rock Rheology* (Cristescu 1989)), respectively. Furthermore, in 1970-80, he also tackled the technological applications of the plasticity theory, especially those of viscoplasticity, in technological processes such as wire drawing, pipe extrusion and drawing. The results of his research were published in numerous articles and summarised in the book titled *Teoria plasticității cu aplicații la prelucrarea metalelor* (*Theory of Plasticity and Its Applications in the Processing of Metals*), published together with his collaborator, S. Cleja-Țigoiu (Cleja-Ţigoiu and Cristescu 1985). The professional prestige earned due to his many publications (articles in specialised magazines, books) and his role as a pioneer in certain fields of the plasticity theory (the dynamic of plasticity, rock mechanics, viscoplasticity) made it possible for him to found the *International Journal of Plasticity*, as the initiator and first editor-in-chief if this prestigious magazine. In 1990–1992, he was the rector of the University of Bucharest, the first one to be elected democratically after the revolution of 1989. He subsequently worked at the University of Florida until his retirement, after which he returned to Romania. Professor Cristescu created the first school for the theory of plasticity in Romania and one of the most well-known and prestigious schools in Europe. This is the school which trained many mathematician-mechanician researchers, such as: S. Cleja-Țigoiu, I. Suliciu, C. Făciu, O. Cazacu, M. Gologanu and many others scattered all over the world (USA, France, Germany).

Another founder of a school in the field of plasticity in Romania was Professor Cristian Teodosiu, graduate of both the Bucharest Institute of Construction (1958) and of the University of Bucharest (the Faculty of Mathematics) (1960). He defended his doctoral thesis called *Contribuții la teoria macroscopică a dislocațiilor și tensiunilor inițiale* (*Contributions to the Macroscopic Theory of Initial Dislocations and Tensions*) at the Romanian Academy Institute of Mathematics under the supervision of Professor Gr. Moisil. His double specialisation—in mathematics and engineering—allowed him to tackle engineering issues regarding microscopic modelling using advanced mathematical means. Up until his leaving Romania, he worked as a researcher at the Romanian Academy Institute of Solid Mechanics and was the Director of Research of the Bucharest Institute of Physics and Materials Technology. From 1985 to 2002, he worked at the National Polytechnic Institute of Grenoble and the Paris 13 University, where he was the coordinator of the Laboratory for Mechanical and Thermodynamic Properties of Materials (LMTPM). He elaborated a hammer hardening model highly efficient in predicting the behaviour of sheet metal during deformation processes. He supervised numerous doctoral theses and postdoctoral internships during his active time both in Romania and at the universities of Grenoble and Paris. During the last part of his activity (2002–2011), he was coordinator of the *Volume-CAD System Research* laboratory at the Riken Institute in Japan. He was the editor of an excellent book called *Large Plastic Deformation of Crystalline Aggregates* (Teodosiu 1997), which contains the papers presented at a symposium organised under the auspices of the International Centre for Mechanical Sciences of Udine, Italy.

Petrișor Mazilu made significant contributions in the field of constitutive equations and variational principles in plasticity (Mazilu 1982). He worked at various universities in Germany (Bochum and Darmstadt) in the 1980s, where he developed models for the description of the induced anisotropy of pre-deformed materials. He introduced the hypothesis of translating the centre of the isotropic surface (ICT) in order to describe the significant transformation of the shape of the isotropic yield surface of an undeformed material into an anisotropic one after deformation.

Professor Mircea Predeleanu was trained and worked in Romania, then emigrated to France. He defended his doctoral thesis called *Contribuții la studiul matematic al unei clase de corpuri cu proprietăți reologice* (*Contributions to the Mathematical Study of a Class of Bodies with Rheological Properties*) in 1961 under Romanian Academy Member Gr. Moisil. He contributed to the field of rheology and that of creep constitutive equations. Subsequently, after emigrating to France, he directed his research efforts towards the field of fault prediction in manufacturing processes. In 1987, he initiated a series of conferences in the field of numerical methods for fault prediction in the processing of materials (Predeleanu 1987). In 1985–1992, he was the Director of the Laboratory of Mechanics and Technology of the Paris-Saclay Superior School of Cachan.

Sanda Cleja-Țigoiu was a collaborator of Professor Nicolae Cristescu, as she continued the Plasticity Theory course. She specialised in the theory of plasticity at the State University of Moscow, Russia, where she conducted her doctoral studies. Her contributions are related to the irreversible behaviour of elastoplastic materials with structurally non-homogeneous elements such as dislocations and the anisotropic deterioration of elastoplastic materials with structural faults.

Dr. Ioan Suliciu was one of the first collaborators of Professor Nicolae Cristescu, together with whom he published articles and monographs in the field of viscoplasticity (Cristescu and Suliciu 1976, 1982). It was at the school of plasticity of the University of Bucharest that Cristian Făciu was trained as well; he first collaborated with I. Suliciu in research regarding viscoplasticity and subsequently tackled issues regarding the modelling of the Portevin-Le Chatelier effect.

Oana Cazacu, currently a Professor at the University of Florida USA, comes from the same school of plasticity of the University of Bucharest. After her doctoral studies and her habilitation at the University of Lille, France, she continued her research activities at the University of Florida. This is where, together with Nicolae Cristescu, she tackled issues regarding rock mechanics and, in the early 2000s, developed a set of plasticity criteria for original anisotropic media based on the expansion of the Drucker criterion. She edited several books in the field of multiscale modelling of materials, such as: *Multiscale Modeling of Heterogeneous Material* (Cazacu 2008), *Linking scales in computation: from microscale to macroscopic properties* (Cazacu 2012) etc. Mihai Gologanu, graduate of the University of Bucharest, completed his doctoral studies at the Pierre-et-Marie-Curie University of Paris, France. He expanded the plasticity model with gaps by proposing an ellipsoidal shape for them instead of the spherical one and the coupling of this model with non-square models of anisotropic plasticity.

Relative recently (after 1995), a research group was created in the field of the plasticity behaviour of sheet metal at the Technical University of Cluj-Napoca, with Professor Dorel Banabic as its coordinator. In the early 2000s, the group developed a research laboratory for the analysis of mechanical behaviour and of sheet metal deformation. The main results obtained by the group were in the field of modelling and the experimental determination of borderline deformation, anisotropic-behaviour modelling, and multiscale modelling of sheet metal. The model of material developed by the members of the CERTETA group of the Technical University of Cluj-Napoca was implemented in the AutoForm commercial programme with finite elements. A substantial activity within the CERTETA research group was conducted by Dr. Dan Sorin Comșa, Dr. Mihai Gologanu, Dr. Tudor Bălan, Dr. Lucian Lăzărescu. The results obtained by the group were published in several books published by international publishing houses, such as: *Formability of Metallic Materials* (Banabic et al. 2000), *Sheet Metal Forming Processes* (Banabic 2010) (translated into Chinese (Banabic 2015), the first engineering book written by a Romanian to be translated into that language), *Multiscale Modelling of Sheet Metal Forming* (Banabic 2016). Professor Tudor Bălan, graduate of the Technical University of Cluj-Napoca, completed his doctoral thesis at CEMEF, École des Mines de Paris in the field of forging process optimisation and went on to work at the University of Metz, France. This is where he tackled topics regarding anisotropic-behaviour modelling and the simulation of the processes of plastic deformation of sheet metal.

4 History of Contact Mechanics

Mircea PASCOVICI

4.1 The Evolution of the Scientific Analysis of Mobile-Contact Mechanics

The foundations of buildings and machine design were laid along the years mainly through experiments which, at first, were putting under question the problem of "whether or not will it hold", then were intended for phenomenological analyses or for the verification of theories and, more recently, for the validation of models. The components of mechanisms and machines were initially analyzed from a rigidity point of view as more or less rigid (Haton de la Goupilliere 1864). About 200 years ago, starting with Young who, in 1807, defined the elasticity module, and continuing with Navier, Barre de Saint-Venant, Poisson, Cauchy, Maxwell, etc., the foundations of the theory of elasticity and of that of the strength of materials were established. It was still in the first half of the 19th century when the mechanics of viscous fluids was established, due to the equations of Navier-Stokes (Dowson 1998).

These solid grounds provided the prerequisites for the scientific analysis of the friction processes which appear at the interface of the mobile contacts of machines and other such devices. The prime goal has been the drastic reduction of friction and wear, the main solutions being lubricated or rolling contacts. One might say that a triad of pursuits has long been identified in the problematics of mobile contacts, namely *friction-wear-lubrication.* In 1966, the British government introduced the term *tribology* to refer to the set of pursuits comprised by the above-mentioned triad (Wang and Chung 2013), term which then spread worldwide.

The friction processes which occur at the interface of lubricated kinematic couplings could only be tackled thoroughly after the publication of the revolutionary articles authored by Heinrich Hertz (1883) and Osborne Reynolds (1886). In 1881–1883, H. Hertz determined the pressure distribution for non-compliant, punctual (elliptic), stationary, unlubricated contacts in an elastic regime (Hertz 1882). His relation for the calculation of maximum pressure became the calculation basis for bearings, gears, cams, and a plethora of other applications. In 1886, O. Reynolds determined the distribution of pressures in the lubricated gap between conformal contacts with rigid solid surfaces (sliding bearings) by resorting to a brilliant simplification of the Navier-Stokes equations (Reynolds 1886). The differential equation that bears his name, which is extremely flexible/adaptable, is used in its various forms for the determination of the supporting capacity for dozens of types of lubrication problems (Reynolds 1886).

For a detailed account of the personalities who contributed to the development of tribology, one recommends consulting D. Dowson's book *History of Tribology* (Dowson 1998).

4.2 Scientific Research on the Topic of Contact Mechanics In Romania

The first systematic scientific studies in Romania in the field of friction processes on the interface of mobile mechanical contacts appeared in 1949, with the creation of the Institute of Metallurgy and Applied Mechanics of the Academy of the Romanian People's Republic, which later became the "Traian Vuia" Institute of Applied Mechanics (IMA, Institutul de Mecanică Aplicată). Subsequently, the institute was divided into the Institute of Fluid Mechanics (1965) and the Centre for Solid Mechanics (CMS, Centrul de Mecanica Solidelor). After that, names and pursuits changed at an accelerated pace, while the research on contact mechanics in successor institutions, became increasingly scarce and nearly extinct.

The notable figures in the field of the mechanics of lubricated contacts at the IMA were professors Nicolae Tipei (1913–1999) and Virgiliu Niculae Constantinescu (1931–2010). Both of them can be considered giants of the Romanian and the international fields of lubrication. Contact mechanics research at the CMS was led by Professor Dan Pavelescu, then by Ivan Iliuc.

After 1950, significant studies in contact mechanics were conducted at the Bucharest Polytechnic Institute under the leadership of Professor Gheorghe Manea, mainly in the field of sliding radial bearings, and at the "Gh. Asachi" Polytechnic Institute of Iași, ~~led~~ by Professor Niculae Popinceanu, primarily in the field of bearings.

Subsequently, notable studies in contact mechanics were developed at the Ștefan cel Mare University of Suceava, under the leadership of Professor Emanuel Diaconescu, as well as in the field of elasto-hydrodynamic (EHD) lubrication, within Dunărea de Jos University of Galați, led by Professor Ion Crudu, and at the Technical University of Cluj-Napoca, led by Professor Dorina Mătieșan Jichișan.

4.3 The Key Figures of Contact Mechanics in Romania

Chronologically, the key figure of lubrified-contact mechanics was Niculae Tipei, corresponding member of the Romanian Academy since 1963. His activity in Romania is mainly illustrated by the book published by the Publishing House of the Romanian Academy in 1957, with him as the sole author (Tipei 1957), titled *Hidro-aerodinamica lubrificației* (*Hydro-Aerodynamics of Lubrication*), which was translated into English in 1962 by Stanford University as *Theory of Lubrication: with Application to Liquid and Gas Film Lubrication* (Tipei 1962).

The work of professor N. Tipei at General Motors, much more thematically diverse and highly interesting, was the object of many published articles and research works which are yet inaccessible, as they are the property of General Motors. In 1980, he was awarded the Mayo D. Hersey Prize by the American Society of Mechanical Engineers (ASME).

Another particularly important representative of lubricated-contact mechanics was Professor Virgiliu Niculae Constantinescu, member of the Romanian Academy since 1991, and ~~its~~ president from 1994 to 1998. He is the *de facto* father of gas lubrication in Romania. He worked at the IMA and the Bucharest Polytechnic Institute, which he led from the position of rector between 1990 and 1992. In the "Bible" of *hydrodynamic lubrication* written by Pinkus and Sternlicht (1961), published in 1961, he is already cited (at the age of 25!) with an article published in Romanian in 1956 within *Studii și Cercetări de Mecanică Aplicată* (*Studies in Applied Mechanics*). In 1963, the Publishing House of the Romanian Academy issues the monograph titled *Lubrificația cu gaze* (*Gas Lubrication*) (Constantinescu 1963), translated into Russian in 1968 and into English in 1969 (Constantinescu 1969). In

1965, his monograph called *Teoria lubrificației în regim turbulent* (*Theory of Lubrication in a Turbulent Regime*) (Constantinescu 1965) was published, then translated into English in 1968 (Constantinescu 1968). In this monograph, V. N. Constantinescu proposes a new method for solving lubrication problems in a turbulent regime, namely that of the *mixing length*, still in use today. The article *On Turbulent Lubrication*, published in 1959 in the *Proceedings of the Institution of Mechanical Engineers* (Constantinescu 1959), which contains the basic ideas in the above-mentioned monograph, is his most cited work. In 1968, his widely used book *Aplicațiile industriale ale lagărelor cu aer* (*Industrial Applications of Air Bearings*) was published by the Publishing House of the Romanian Academy. In 1980, Editura Tehnică (the Technical Publishing House) published his monograph *Lagăre cu alunecare* (Constantinescu et al. 1980), written in collaboration with others, which was translated into English as *Sliding Bearings* (1985) in 1985 and published by the Allerton Publishing House in the USA. He conducted unparalleled research and training work at international level, especially in collaboration with institutions in the USA and France, tackling almost all the problems of lubricated-contact mechanics.

Professor Gheorghe Manea (1904–1978), corresponding member of the Romanian Academy from 1963, conducted his activity at the Bucharest Polytechnic Institute. Educated at the Polytechnic School of Berlin-Charlottenburg, having doctored in the hydrodynamics of turbine rotors in 1932, under the supervision of famous Professor H. Föttinger, he is the inventor of hydrodynamic couplings.

He introduced and promoted the basis of the design of fluid-friction bearings in Romania. The treatise titled *Organe de mașini* (*Machine Organs*) (Manea 1970), published in 1970 by Editura Tehnică, laid the foundations of modern teaching with regards to this subject worldwide. His training and research work in the field of lubrication and gears was particularly significant due to its rigor and its development of experimental research. Professor Gheorghe Manea supervised four doctoral theses up to their completion, namely those of Teodor Mladinescu, Mustafa Akkurt, Mihai Gafițanu, and Mircea D. Pascovici. The latter three became doctoral supervisors themselves in the same field of machine design and tribology. Professor M. Akkurt worked at the Bucharest Polytechnic Institute until 1969 and then, at the Technical University of Istanbul, Professor M. Gafițanu was active at the "Gh. Asachi" Technical University of Iași, and Professor M. D. Pascovici at the University Politehnica of Bucharest.

The "Gh. Asachi" Polytechnic Institute of Iași hosted the activities of Professor Niculai G. Popinceanu (1913–1999), who founded a school of rolling-contact mechanics with applications for bearings, a school of the highest competence in Romania. He contributed to the training of many specialists in the field, among which Mihai Gafițanu, Emanuel Diaconescu, Spiridon Crețu, and more. Together with the above, he published the monograph *Probleme fundamentale ale contactului cu rostogolire* (*Fundamental Issues of Rolling Contact*) (Popinceanu et al. 1985), issued by Editura Tehnică in 1985.

It was the role of Professor Dan Pavelescu (1922–2013), who worked at the Centre for Solid Mechanics (CMS) and at the University Politehnica of Bucharest (UPB), to coagulate the tribological community in Romania by founding the National

Tribology Committee in 1977 and, in 1990, the Romanian Tribology Association (ART, Asociația Română de Tribologie), affiliated to the International Tribology Council, created in 1973, as well as to the Balkan Tribology Association, founded in 1994, with ART as a founding member.

A comprehensive account of the activities and figures in the field of contact mechanics (called *tribology* in Romania as well after 1977) between 1950-2003 is found in the work of Professor Dan Pavelescu (2003).

5 History of Fluid Mechanics and Hydraulic Equipment

5.1 History of Fluid Mechanics

Sebastian MUNTEAN

Ladislau Vekas

The study of fluid mechanics dates back to the time of Ancient Greece, when Archimedes was pursuing the study of fluid statics (Archimedes' principle). This was continued by the research conducted by Leonardo da Vinci (observations and experiments), Galileo Galilei (who indirectly influenced experimental hydraulics and revised the Aristotelian concept of vacuum), Blaise Pascal (who clarified the principles of the barometer, the hydraulic press, and pressure transmission, as well as certain elements of hydrostatics), Isaac Newton (viscosity), Henri de Pitot (who invented a device to measure water velocity—the Pitot tube). The development of hydraulics was carried forward by Daniel Bernoulli with his mathematical description of fluid dynamics in his work *Hydrodynamica* (1738), where he enunciated, among other things, the famous equation that bears his name. Inviscid fluids were studied by mathematicians such as Leonhard Euler, who explained the role of pressure in fluids, formulated the basic equations of motion, introduced the concept of cavitation and the principles of the centrifugal machine, D'Alembert, Antoine Chézy (1718–1798), Lagrange, Giovanni Baptista Venturi (1746–1822), who performed tests on tapered reducers, Laplace, Claude-Louis Navier (1785–1836), Poisson. On the other hand, viscous fluids were tackled by a plethora of engineers, such as Poiseuille or Gotthilf Heinrich Ludwig Hagen. A more detailed mathematical study on fluids was conducted by Claude-Louis Navier and George Gabriel Stokes, who established the famous Navier–Stokes equations, while borderline conditions were investigated by Ludwig Prandtl. Numerous researchers, such as Osborne Reynolds, Andrey Kolmogorov, Geoffrey Ingram Taylor, etc., facilitated the understanding of the concepts of viscosity and turbulence.

Research in the field of fluid mechanics is closely linked to the development of Romanian higher education. Chronologically, the first paper in this new field for Romanian education was elaborated by **Victor Vâlcovici** in 1913, as it constituted his doctoral thesis called *Mișcări fluide discontinue cu două linii libere* (*Discontinuous Fluid Motions with Two Free Dimensions*), which he defended in Göttingen, Germany. The work was in accordance with the scientific pursuits of the time, so that it was appreciated and frequently quoted in writings about these phenomena. Victor Vâlcovici is considered to be the creator of Romanian theoretical hydrodynamics and aerodynamics.

Professor **Dionisie Germani** pursued specialised education in Belgium, Germany, Great Britain, and France and obtained his engineering degree from the École Supérieure d'*É* électricité of Paris (1919) and his title of Doctor of Science from Sorbonne. In his capacity as director of the Hydraulics and Hydraulic Machines Department (1920–1938) and then dean of the Faculty of Construction of the Polytechnic school (1938–1944), Professor Germani conducted intense teaching and research activities in the field of theoretical and applied hydraulics, hydrotechnical plants, and water supplying in urban settlements; he authored the first treaty on theoretical and applied hydraulics (*Hidraulică teoretică și aplicată*) ever published in Romania (consisting of 4 volumes which appeared in 1937–1938) (Germani 1942). He made remarkable contributions to the theory of similarity and to the development of laboratory procedures for the testing and studying of hydrodynamic equipment and hydraulic plants. Germani supported young Romanian researchers who had returned from studying abroad and contributed in a decisive way to the forming of the school of fluid mechanics of the University Politehnica of Bucharest. Future professors Dorin Pavel, Dumitru Dumitrescu, Elie Carafoli, Nicolae Tipei enjoyed the assistance and guidance of Dionisie Germani. The first Laboratory of Hydraulics of the University Politehnica was created in 1929 by Professor Germani and Dorin Pavel, who at the time was a young teacher, graduate of the famous E.T.H. Zürich university (1923), where he was awarded the title of Doctor under the mentoring of Prof. Franz Prašil, while Prof. Ludwig Stodola was the head of the examining committee (1925).

After obtaining his engineering diploma and degrees in mathematics, letters, and philosophy, **Dumitru Dumitrescu** enhanced his professional training first at the Superior School of Electricity of Paris, as a student of the famous Professor Janet, then at the School of Aeronautics. He carried out his preparation for his doctoral thesis at the University of Göttingen under the supervision of Prof. Ludwig Prandtl. His doctoral thesis called *Curgerea unei bule de aer într-un tub vertical* (*The Flow of an Air Bubble in a Vertical Tube*), defended in 1942, soon became a classic work, quoted in prestigious treatises and manuals in various countries. He returned to Romania after 1940 and worked as an engineer at the Airplane Factory in Brașov, and, in 1943, his long didactic career at the Bucharest Faculty of Construction and then at the Hydraulics Department of the Polytechnic Institute of Bucharest began and lasted until 1974. His concern for equipping the department's laboratories with the didactic and experimental materials required for the adequate training of future engineers was particularly commendable. The research work he performed at the Applied Mechanics Institute of the Romanian Academy materialised into the following contributions: *Studiul privind aplicarea metodelor numerice în domeniul hidraulic* (*Study on the Application of Numerical Methods in Hydraulics*); *Studiul metodei rețelelor aplicate în hidraulică* (*Study of the Method of Applied Networks in Hydraulics*).

Research on scale models conducted in the Academy's laboratories led to the optimisation of the hydrotechnical plants of Bicaz, Sadu, Moroieni, Porțile de Fier. He authored a manual for hydrotechnical engineers (*Manualul inginerului hidrotehnician*) (Dumitrescu and Pop 1969), which is a particularly important instrument for engineers working in the field of hydrotechnical constructions.

One flagship work for the theoretical development of fluid mechanics is *Introducere matematică in mecanica fluidelor* (*Mathematical Introduction into Fluid Mechanics*), written by Romanian Academy Member **Caius Iacob,** published in 1952 by the Publishing House of the Romanian Academy (Iacob 1952) and subsequently translated by the Editions Gauthier-Villars publishing house in 1959. He pursued his higher-education studies at the Bucharest Faculty of Mathematics (1928–1931), obtaining his bachelor's degree at the age of 19. He continued his doctoral studies at the Faculty of Sciences of the University of Paris, where, on 24 June 1935, he defended his thesis titles *Sur la détermination des fonctions harmoniques conjuguées par certaines conditions aux limites. Applications à l'hydrodynamique*, under the supervision of Professor Henri Villat. Once back in Romania, he dedicated his life to higher education and scientific research, climbing the academic ladder from the initial position of assistant professor (from 1935 at the Polytechnic School of Timișoara) all the way to that of professor at the Faculty of Mathematics of the University of Bucharest (where he reached retirement in 1982). Meanwhile, in 1938 and then between 1942 and 1950, he was active at the University of Cluj as well, first as an assistant professor, then a lecturer of general mathematics, only to be appointed professor of mechanics at the age of 31. He moved to Bucharest, but returned to Cluj in 1967–1969 as associate professor at the new Department of Fluid Mechanics created at the Faculty of Mechanical Mathematics.

Another figure at the University of Cluj who stood out due to his remarkable results in fluid mechanics is Prof. **Petre Brădeanu**, whose works focused on the border bed theory, convective heat transfer, the mechanics of a point of variable mass, and the motion of rockets.

Interested in the geometrical aspects of fluid motion, **Gheorghe Gheorghiev**, professor at the University of Iași, studied and described from a geometrical perspective surfaces containing one stream line each and another of vortex lines in the permanent motion of a barotropic liquid, thus determining the conditions for these surfaces to withstand an infinity of such motions. He elaborated studies on the permanent motion of certain ideal fluids and studied the helical motion of fluids (1955–1956), then he established a series of relations between the algebraic invariants of the deformation tensor and those of the fluid's motion (papers of 1962). He studied the motion for which the deformation tensor is null and the deformation tensor of the velocity field.

Fluid mechanics developed as a subject in Romanian universities thanks to pursuits supported by highly trained scientists in the field of mathematics. Holder of a Ph.D. in physics-mathematics, **Elie Carafoli** attended fluid mechanics and aeronautics courses at the Sorbonne, then worked at the Aerotechnical Laboratory of Saint-Cyr, where he constructed an aerodynamic tunnel intended for visualising the motion of fluids. Carafoli tackled the issue of general motion around an outline. He conducted research on monoplane wings and conical motions in a supersonic regime, thus initiating the first course in aeronautics.

The turbulent motion regime is an especially complex phenomenon within fluid dynamics, one which has been studied by many scholars and researchers, physicists, or engineers for over a century. In Romania, **Elie Carafoli** and **V. N. Constantinescu** pursued such research, obtaining remarkable results in the fundamental study of turbulence. Professor V. N. Constantinescu, one of the greatest specialists in the field of fluid lubrication, is the author of the volume *Teoria lubrificației turbulente* (*Theory of Turbulent Lubrication*) (Constantinescu 1965), which was translated into English by the Atomic Energy Commission. Issued by the Publishing House of the Romanian Academy, the volumes titled *Dinamica fluidelor incompresibile* (*Dynamics of Incompressible Fluids*) (1981) (Carafoli and Constantinescu 1981), *Dinamica fluidelor compresibile* (*Dynamics of Compressible Fluids*) (1984) (Carafoli and Constantinescu 1984), written by E. Carafoli and V. N. Constantinescu, are works of reference in the field. *Dinamica fluidelor vâscoase în regim laminar* (*Dynamics of Viscous Fluids in a Laminar Regime*) (1987) (Constantinescu 1987) and *Dinamica fluidelor vâscoase. Stabilitatea mișcărilor laminare* (*Dynamics of Viscous Fluids. Stability of Laminar Motions*) (1993) (Constantinescu 1993) by Romanian Academy Member V. N. Constantinescu continue the presentation of the issues specific to fluid motion. In the volume *Dinamica fluidelor în regim turbulent* (*Dynamics of Fluids in a Turbulent Regime*), published in 2008 (Constantinescu et al. 2008), the topic of turbulent lubrication is extensively discussed by V. N. Constantinescu, S. Dănăilă, and S. Găletușe, with concrete examples as to the calculation and design of various types of sealing.

The development of Romanian higher education often goes hand in hand with the matching development of technology. An example in that sense is that of engineer **Teodor Oroveanu**, who became Doctor of Engineering in 1967 and then Docent Doctor in 1970. He worked as an engineer at the Central Workshops of the former Steaua Română Company in Câmpina, then at the Processing-Metallurgy Industrial Plant (1945–1949). From 1949 to 1968, he worked consistently at the Institute of Fluid Mechanics, while being a lecturer (from 1951) and professor (from 1968) at the Petroleum and Gas Institute of Bucharest. In 1969, as the institute moved, he was transferred to Ploiești and was appointed head of the Hydraulics Department (1971–1984); in 1990, he became consulting professor at the Petroleum-Gas University of Ploiești. He held courses in Baku, Freiburg, Moscow, Paris, Rennes, Toulouse. He conducted an intense scientific activity, mainly oriented towards fluid mechanics, particularly in the fields of the flow of fluids through porous media, convective diffusion in fluids, the motion of viscous fluids, with a special focus on the extraction and transport of petroleum and gas. He followed the manner in which the results of his research were used in technology, as many of them directly served to elaborate calculation and design methods, especially in the oil industry. He conducted studies on the exploitation of oil deposits found in fractured rocks and on the hydraulic fracturing of deposits with reduced permeability. He introduced modern calculation methods for pipes for petroleum, petroleum products, and gas, including optimisation procedures for the latter, using computers for the first time in Romania. The results of his research materialised into numerous written works, the most outstanding of which are *Mecanica fluidelor* (*Fluid Mechanics*), 2 vol., (Carafoli and Oroveanu 1955); *Mecanica fluidelor vâscoase* (*Mechanics of Viscous Fluids*), (Oroveanu 1967), the monographs *Scurgerea fluidelor prin medii poroase neomogene* (*The Flow of Fluids through Non-homogeneous Porous Media*) (Oroveanu 1963); *Scurgerea fluidelor multifazice prin medii poroase* (*The Flow of Multiphase Fluids through Porous Media*) (Oroveanu 1966), *etc.*

The phenomenon of cavitation is present in almost all the fields of modern technology and industry where there are liquids in motion. Cavitation is mainly identified through its effects characterised by the destruction of solid walls, strong oscillations and vibrations, and a decrease in efficiency when present in hydraulic machines. The first book of this type in Romania which distinguishes itself from other similar works due to its unitary character is *Cavitația* (*Cavitation*) (two volumes) by Romanian Academy Member **Ioan Anton**, published in 1984 (Anton 1984). It is based on a vast set of materials from both international technical and scientific literature and the wealth of experience of the school of hydraulic machines of the Polytechnic school of Timișoara.

The unprecedented development of computing technology led to a new approach to the study of issues related to fluid dynamics. Thus, the first pursuits related to numerical fluid mechanics appeared at the Faculty of Aircraft of the University Politehnica of Bucharest. One work in this field, written by professors Sterian Dănăilă and Corneliu Berbente, is the monograph *Metode numerice în mecanica fluidelor (Numerical Methods in Fluid Mechanics*) (Dănăilă and Berbente 2003). Basically, all the important chapters are covered as to obtaining, via numerical calculation methods, the solutions for differential equations with partial derivatives describing fluid flows in various regimes: incompressible, compressible, stationary and non-stationary, non-viscous and viscous, laminar and turbulent.

In 1990, the National Centre for Complex Fluid Systems Engineering (CNISFC, Centrul Național pentru Ingineria Sistemelor cu Fluide Complexe) was created at the Politehnica University of Timișoara, possessing a parallel computing research laboratory equipped with a network of computers and work stations for students. One remarkable monograph which uses the Fluent software is *Mecanica fluidelor cu Fluent* (*Fluid Mechanics with Fluent*), elaborated by a group formed by Diana Broboană, Tiberiu Muntean, and Corneliu Bălan of the University Politehnica of Bucharest (Broboana et al. 2005).

Fluid power drives and hydraulic automations are another chapter which registered spectacular development in the new context determined by new technics, high-performance technologies, and expected quality requirements. A group of teachers and researchers at the Technical University of Cluj-Napoca, coordinated by Professor Liviu Deacu, elaborated an excellent synthesis of the studies and research in the field of adjustable pumps and motors in the work *Tehnica hidraulicii proporționale* (*Technology of Proportional Hydraulics*) *(1989)* (Deacu et al. 1989). It presents, in a coherent manner, both experimental studies and numerical analyses for a wide range of adjustment types, in accordance with the accomplishments of a team of researchers at the Institute for Fluid Power Drives and Control in Aachen, Germany.

Significant theoretical and experimental developments in the systematics of pneumatic and fluid power drives are owed to researchers at the University Politehnica of Bucharest led by Professor Nicolae Vasiliu, who supervised the drafting of the work titled *Transmisii hidraulice și electrohidraulice* (*Hydraulic and Electrohydraulic Transmissions*) (Vasiliu and Vasiliu 2005*)*.

Created in 2005–2007 in order to bring together the research efforts regarding the hydrodynamics of vortexes and applications, the ACCORD-FluiD academic consortium enjoyed the contribution of specialists from the following Romanian higher-education institutions: the Politehnica University of Timișoara, the Romanian Academy—the Timișoara branch, the University Politehnica of Bucharest, the Technical University of Civil Engineering of Bucharest, the Dunărea de Jos University of Galați, the Technical University of Cluj-Napoca, the Eftimie Murgu University of Reșița, the 'Gheorghe Asachi' Technical University of Iași. The research thus performed was summarised in the monograph *Vortex Dominated Flows* (Susan-Resiga et al. 2007).

5.2 Hydraulic Machines and Equipment

The theoretical foundations of fluid mechanics have exerted a strong influence upon industrial development worldwide, along two lanes:

(a) *The appearance and development of hydraulic machines.* These are prime movers inside which a transformation of hydraulic energy into mechanical energy, or vice versa, occurs. Depending on the direction of the transformation, they are called either hydraulic engines (turbines) or hydraulic generators (pumps). Romanian Academy Member Anton (2011) Visuri. Împliniri. Amintiri de la Politehnică (1943–2011) (Dreams. Accomplishments. Memories from the Polytechnic (1943-2011)). Politehnica Publishing House, Timișoara), defines hydraulic turbines or 'hydraulic engines' as those machines which transform hydraulic energy into mechanical energy, and hydraulic pumps or 'generators' as those machines which transform mechanical energy into hydraulic energy. The transformation of hydraulic energy into mechanical energy takes place inside a rotating part equipped with blades or buckets called a rotor. This transformation is carried out with high efficiency and at relatively high rotative speed;

(b) *The appearance and development of hydraulic control and adjustment elements and systems.* Fluid power drive systems are physical drive systems made up of a generator (pump), an engine and adjoining installations. The role of the generator (i.e. hydraulic pump) is to produce hydraulic energy. The engine receives that energy in the form of a mass of liquid set into motion by the generator and transforms it into mechanical energy. The adjoining installations are secondary elements which aid the main process of transformation of hydraulic energy into mechanical energy. Such installations can be: test gauges, connecting pieces, rigid and flexible pipes, faucets, filters, radiators, pressurised tanks, lubrication and outlet orifices, connection valves. The resulting mechanical energy is intended to set an end device into motion.

Hydraulic Machines

Sebastian MUNTEAN

Ladislau Vekas

Towards the end of the 19th century, hydraulic turbines were increasingly used in Europe. This was the result of two main factors, namely: manufacturers specialising in turbines and generators, thus offering adequate equipment proven to be safe to operate and economically efficient; the growing demand for electrical energy due to the ever more powerful development of the industry. These elements, very suggestively summarised by the saying '*technology push and market pull*', were, naturally, noticed by entrepreneurs and local administrations in Romania. The existence of a long-standing tradition of the use of hydraulic energy by means of a great variety of wheels made it impossible to ignore the new technological progress even in its early stages. Hydroelectric plants were built at: the Peleș Castle, with two 60 HP Pelton turbines—1884; Grozăvești, Bucharest, with two 135 kW Girard turbines—1889; Băile Herculane, with two 130 kW Francis turbines—1892; the Topleț Works, Caraș-Severin, with one 110 kW Girard turbine—1893, followed by three 120 kW Francis turbines; Sadu I, Sibiu, with two 270 HP Girard turbines—1897; Sinaia, with four 360 HP Francis turbines—1899; Bocșa, Caraș-Severin, with one 100 kW Francis turbine—1900.

By the year 1900, 19 hydroelectric plants with circa 4,115 kW in installed capacity were built in Romania. Between 1901 and 1918, 35 hydroelectric plants with circa 19,740 kW in installed capacity were completed and 26 with an installed capacity of 35,240 kW (including the expansion and re-equipping of certain extant plants) between 1919 and 1945. The hydroelectric plant with the highest installed capacity was the Dobrești one, from 1930, equipped with four horizontal Pelton turbines made by Voith, of 5,650 HP each. The hydroelectric plants built in Romania before the Second World War added up to an installed capacity of little over 59,000 kW (see Chapter 16 The History of Energy). The equipment used in these plants was imported, primarily from Germany. It is noteworthy that there was intense focus on building hydroelectric plants in Romania during the interwar period. The most representative work in this field belongs to Professor Dorin Pavel from Bucharest, who, in the volume *Plan général d'aménagement des forces hydrauliques en Roumanie* (Pavel 1933), inventoried and established the general plan of 567 hydroelectric plants on the territory of the Greater Romania, comprising a plain view and a longitudinal profile, including the plants' lakes, galleries, canals, and buildings. Before this work, in 1929, the paper *Les forces hydrauliques en Roumanie* (Pavel 1929) was published.

The manufacturing of hydraulic turbines in Romania was a later initiative, which occurred around the time of the Second World War. Although, even before the war, *Fabrica Frații Schiel* (the Schiel Brothers' Factory) of Brașov produced *Francis-system water turbines with a vertical and horizontal shaft, for all water falls* as well (Wollmann 2010), this activity most likely ceased due to the nationalisation.

The data found so far indicate that the first factory to produce hydraulic turbines in Romania was that of the Schiel brothers in Brașov: *Brüder Schiel Maschienen-fabrik AG* (for more details, see Chap. 7 The Machine Building Industry). Thus, as shown in (Wollmann 2010), the factory drew up the documentation and delivered the equipment for the hydrotechnical milling system of Valea Seacă (Sânzeni commune, Covasna County), in 1922 (Fig. 1).

The point of departure for the extended manufacturing based on one's own design, was the Polytechnic school of Timișoara, where the training of future engineers developed simultaneously with the research in the field of hydraulic machines. Thus, in 1928–1929, Professor Pompiliu Nicolau created the first laboratory of hydraulics and hydraulic machines with a test bench for open-circuit hydraulic turbines (Fig. 2).

From 1931 onwards, the subject of hydraulic machines was taken over by young lecturer Aurel Bărglăzan. The name of this eminent professor and engineer is associated with the founding of the Romanian school of hydraulic machines in Timișoara. The remarkable achievements of the members of the Hydraulic Machines Laboratory (Fig. 3) of the Timișoara Polytechnic Institute were acknowledged through the granting of the State Award in 1953: Prof. A. Bărglăzan, Prof. V. Gheorghiu, Eng. I. Anton, Eng. I. Preda, Eng. V. Anton, mechanic I. Drăgălina.

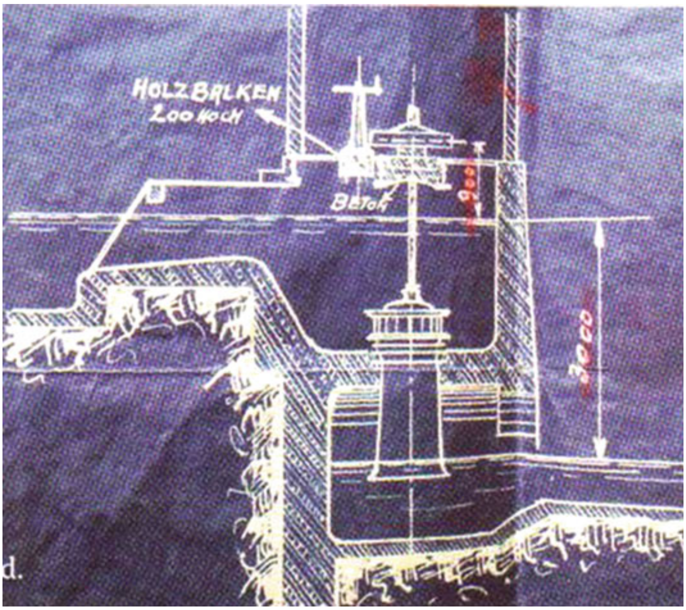

Fig. 1 Detail from the original plan of 1922 as to the manner of positioning the Francis turbine (Wollmann 2010)

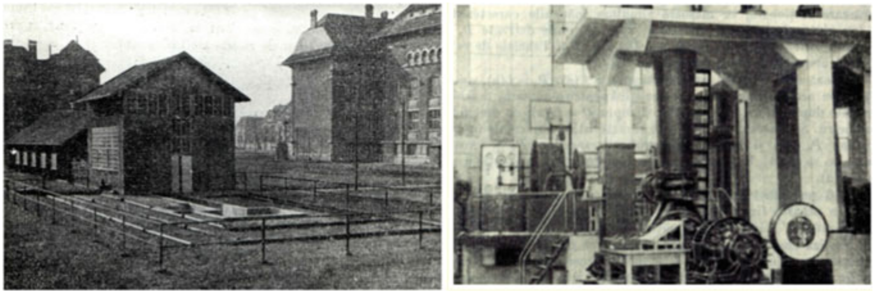

Fig. 2 The Hydraulic Machines Laboratory of Timișoara, 1928

Fig. 3 The Hydraulic Machines Laboratory of Timișoara, 1953

The Timișoara school of hydraulic machines created by Prof. Aurel Bărglăzan, corresponding member of the Romanian Academy, included the members of the Hydraulic Machines Laboratory of the Timișoara Polytechnic Institute and those of the Cavitation Department of the Technical Research Centre (CCT, Centrul de Cercetări Tehnice) of the Timișoara Scientific Research Base of the Academy of the Romanian People's Republic.

The Technical Research Centre of the Academy's Department of Technical Sciences was founded in 1956 through the decision of the Academy Presidium and included four departments: the Welding Department (Romanian Academy Member Cornel Miklosi); the Fatigue and Fragile Fracture in Metals Department (Prof. Ștefan Nădășan, corresponding member of the Academy of the Romanian People's Republic), the Cavitation Department (Prof. Aurel Bărglăzan, corresponding member of the Academy of the Romanian People's Republic) and the Building Materials Department. The leadership of the establishment consisted of Romanian Academy Member Mikloşi (1956–1963), Romanian Academy Member

Ștefan Nădășan (1963—1967), and Prof. Ioan Anton, corresponding member of the Academy of the Romanian People's Republic, as director (1967–1970).

Professor Aurel Bărglăzan's collaboration with the Reșița works materialised in 1939 into a pump for supplying the furnace cooling system. The Bărglăzan pump, as it was called, made to be used by its producer, was subsequently built and delivered in response to orders. After that, a Francis-type hydraulic turbine was produced in Reșița based on documentation drawn up by a team led by Eng. Andrei Berzănescu, to be installed in Moldova Nouă (Caraș-Severin) after the war, in 1946. A 6 HP Pelton group was also made at the mechanical workshops in Anina, which were installed on Mărghitaș lake by Eng. Zeno Jumanca. Furthermore, Prof. Cornel Miklosi, most likely aided by his colleague, Prof. Bărglăzan, built a Pelton-turbine group for the cabin on (Mount) Muntele Mic.

In 1948–1960, even though there were already engineers specialised in hydraulic machines in Reșița and a strong research team was found in Timișoara, there was a lack of trust in the Romanian industry's capacity to produce hydro-equipment. Thus, a series of plants were equipped with imported products. Such was the case of the plants of Moroieni (Ialomița County)—15 MW, Sadu V (Sibiu County)—22.5 MW, Stejaru (Bistrița-Năsăud County)—210 MW, Roznov I—14 MW, and Vidraru (Argeș County)—220 MW. It is important to mention that the technical design for the Argeș plant was done at Reșița, yet the equipment was acquired from abroad.

There were two exceptions during this time. The first was the building at Reșița, in collaboration with Timișoara, of the equipment for the Crăinicel plant, which belonged to the works; it consisted of two aggregates with 1,100 kW Francis turbines and two with 2,900 kW Pelton turbines. The Pelton turbines had two different rotors on the same axle (Fig. 4). The concept of the Crăinicel facility (Fig. 5) and the task of supervising its execution belonged to Prof. Dorin Pavel. The second set to be built was the one for the Târgu Mureș plant, consisting of three 550 kW axial flow turbines, two helical ones, and a Kaplan one. The trials for these models were conducted at the laboratory of the Polytechnic school of Timișoara, while the projects were carried out by the mixed team created and led by Prof. A. Bărglăzan and A. Berzănescu, chief builder of the Reșița facility. It is important to mention that this gave rise to a professional group capable of initiating the future projects in this field.

In 1960, the devising of hydraulic turbines was initiated at Reșița, led by Eng. Flore Coste, who started the designing of the hydraulic turbines (and then generators with related installations as well) ordered by the Ministry of Electrical Energy for the Bistrița-Aval plant: 10 turbines with a power of 8–10 MW for a 20 m water fall and a rotative speed of 250 rpm—Roznov II, Zănești, Costișa, and Bacău II; 8 turbines with a power of 11.5–12.5 MW for a 15 m water fall and a rotative speed of 136.4 rpm—Pângărați, Racova, Gârleni, and Bacău I; 4 turbines of 5.5–6 MW for 15 m water falls and 214.4 rpm—Piatra Neamț and Buhuși; 2 turbines of 23.4 MW for a 26.2 m water fall and 166.7 rpm—Vaduri.

It is necessary to note that Reșița did not possess any test bench at the time, so the testing was carried out in Timișoara, at Prof. Bărglăzan's laboratory, until 1960 (the professor passed away in September), then under the leadership of Lecturer Ioan Anton. The laboratory was expanded to include a cavitation bench with a rotor

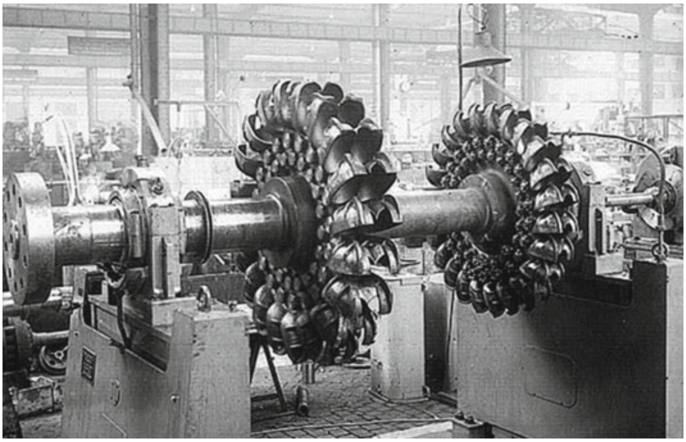

Fig. 4 The Pelton turbines at the Crăinicel plant

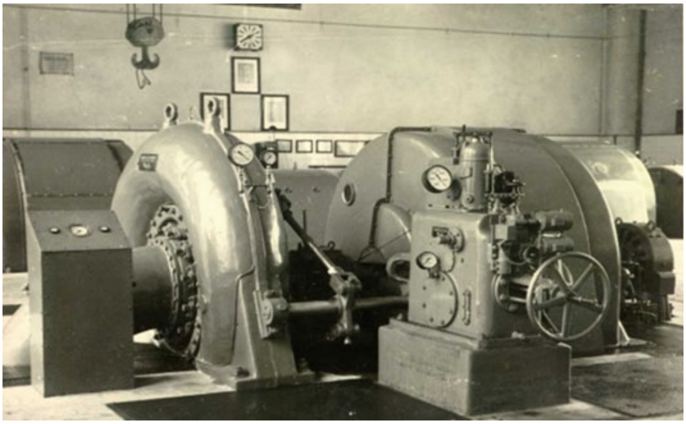

Fig. 5 One of the Francis-turbine groups at Crăinicel

diameter of 200 mm, then 400 mm, which made it possible to conduct tests at IEC international norms (Fig. 6). The energetic and cavitational characteristics of the studied Kaplan rotors with a 400 mm diameter were established in order to mitigate the energy-related and cavitational scale effects for the turbines of the Porțile de Fier I (Fig. 7).

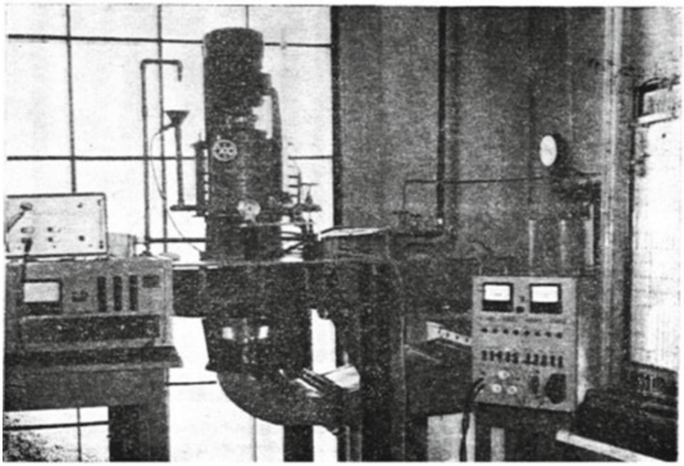

Fig. 6 The cavitation bench for rotors with a 200 mm diameter in Timișoara

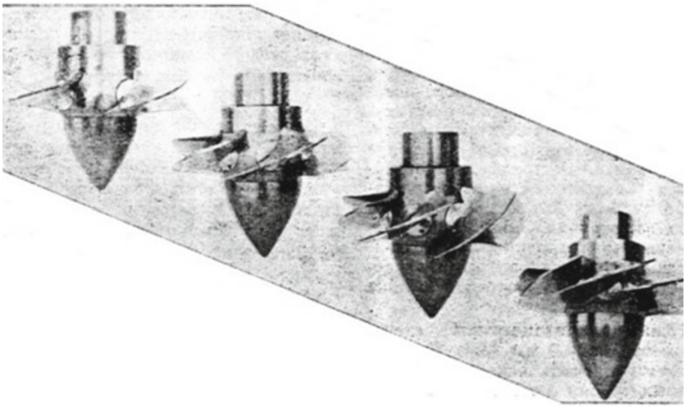

Fig. 7 Models of Kaplan rotors with a 400 mm diameter for the Porțile de Fier I turbines

The activity of the Timișoara school of hydraulic machines focused on basic research, obtaining world-level result in the following fields: turbo-machine hydrodynamics, the hydrodynamics of profile networks, cavitation in hydraulic machines and equipment, and scale effects. Prof. I. Anton, in collaboration with heads of works I. Preda, Viorica Anton, Fr. Gyulai, and Dr. Eng. E. Sisak, conducted in situ measurements regarding cavitation in hydraulic turbines, identifying it at the entry of the aspirating tube due to noises and vibrations far above the ones stipulated by IEC norms. Dr. Eng. V. Câmpian performed the theoretical and experimental studies on bulb and reversible bulb turbines (pump-turbines) by designing and testing reversible rotors. The designing of such rotors was carried out using Prof. O. Popa's method for sizing profile networks based on compliant representation. The results of the research conducted over five decades by the hydraulic machines team of Timișoara in the field of hydraulic turbines were published in the volumes *Turbine hidraulice* (*Hydraulic Turbines*) (1979) (Anton 1979) by I. Anton, *Hidrodinamica turbinelor bulb și a turbinelor-pompe bulb* (*Hydrodynamics of Bulb Turbines and Bulb Turbine-Pumps*) (1988) (Anton et al. 1988) by I. Anton, V. Câmpian, and I. Carte, while those in the field cavitation in hydraulic machines and systems were published in *Cavitația* (Cavitation) vol. II (1985) (Anton 1984) by I. Anton, and those regarding the energy-related and cavitational scale effects in hydraulic turbines applied to the Kaplan turbines of Porțile de Fier I in the volume *Energetic and Cavitational Scale Up Effects in Hydraulic Turbines* (2002) (Anton 2002).

The Timișoara school of hydraulic machines led by Romanian Academy Member Ioan Anton included the members of the Hydraulic Machines Department of the Faculty of Mechanics of the Traian Vuia Polytechnic Institute of Timișoara and those of the Cavitation Department of the Technical Research Centre (CCT) of the Timișoara Scientific Research Base of the Academy of the Romanian People's Republic, which was dissolved in 1970 (Anton and Silaş 1999). The team of the Cavitation Department formed the core of the Centre for Hydrodynamics, Cavitation, and Magnetic Liquids (CCHCLM, Centrul de Hidrodinamică, Cavitație și Lichide Magnetice) founded in 1971 at the Politehnica University of Timișoara. Thanks to the efforts of Romanian Academy Member Ioan Anton, in 1996, the Timișoara branch of the Centre for Basic and Advanced Technical Research (CCTFA, Centrul de Cercetări Tehnice Fundamentale și Avansate) of the Romanian Academy was founded by government decision, thus ensuring the continuity over time of the CCT. The CCTFA comprises three departments coordinated by a full or corresponding member of the Romanian Academy: the Hydrodynamics, Cavitation, and Magnetic Liquids Department (Romanian Academy Member Ioan Anton and currently Dr. Ladislau Vékás), the Metal Construction and Welding Department (Romanian Academy Member Dan Mateescu and currently Romanian Academy Member Dan Dubină), the Electromechanics, Vibration, and Vibro-Percussion Department (Romanian Academy Member Toma Dordea and currently Romanian Academy Member Ion Boldea). The CCTFA was led by Romanian Academy Member Ioan Anton (1996–2008) as its honorary director and subsequently by Dr. Ladislau Vékás, corresponding member of the Romanian Academy and the centre's director (2008).

It constituted the de facto certification of the technological capabilities to build hydroaggregates in Romania, at Reșița. The successful activation of the aggregates of Bistrița-Aval, followed by Argeș-Aval, coincided with the beginning of the preparations for the construction of the Porțile de Fier I facilities. In order to support design in that field, the 1 Ianuarie 1966 Institute for the Design of Energy Equipment of Reșița (for hydroelectricity and thermal energy) was created, only to be turned the following year into the *Reșița Institute for Research and Hydroenergy Equipment Design* with a branch in Timișoara; the part of the institute in charge of thermal equipment was separated and moved to Bucharest once the manufacturing of thermal turbines began. The position of director of the institute was entrusted

Table 1 The turbines built by UCM Reșița up to the year 2000

No.	Turbine type	Amount	Power (MW)
1	Kaplan	209	2,580
2	Pelton	6	374
3	Francis	86	2,762
4	Bulb	13	298
5	Reversible bulb	21	292
Total		335	6,641

to Eng. A. Bitang[1], who used to be the plant's director of technology. The institute continued to support the entire design of hydroelectric equipment. Offices were created in Reșița and Timișoara, and, in 1973, the guarantee bench in Reșița became operational, its equipment being at the level of international technology in the field. This made it possible to conduct intense research, while collaboration with the Polytechnic school of Timișoara reached a high scientific level. An entire string of high-performance achievements followed, including the first exported products, which were two hydroaggregates with 18.2 MW Francis turbines for a 36 m water fall, with a rotative speed of 166.7 rpm and a rotor diameter of 2.8 m, cast in one piece. Up until 1999, Reșița designed and delivered over 330 aggregates, amounting to a total power of over 6,600 MW. Furthermore, a standardised range of turbines was designed, many of which were exported. According to a prospectus of UCM Reșița, the turbines built until 2000 are the ones in Table 1 (Voia 2011).

It is necessary to add two special observations regarding the turbines of Lotru and those of Porțile de Fier. For Porțile de Fier I, UCM Reșița produced 6 Kaplan turbines of 178 MW with a rotor diameter of 9.5 m and a rotative speed of 71.5 rpm; by rotor diameter, they were the largest in the world at the time. Three groups were to be built entirely in Romania. To that purpose, even from the technical project planning stage, the engineers of the Reșița Institute and the plant's technology specialists participated in the making of the design plans at the LMZ plant in Leningrad. It was a particularly useful experience, in terms of both design and technology. The same work method, used for the bulb turbines of Porțile de Fier II, made it possible to build at Reșița 6 of the 8 bulb turbines of 28 MW, 7.5 m in diameter and 62.5 rpm, plus two groups for the Gogoșu plant and two for the plant in Serbia. As there were no prospects of building any similar ones in the future, for the Pelton turbines of Lotru, of 175 MW and 375 rpm, produced in collaboration with the Neyrpic company (France), the builders limited themselves to adapting the design to plant technology.

[1] Eng. Alexandru Bitang held the position of director general of UCMR in 1974-1983 and, in 1983-1986, he was the technical director of the Reșița-Renk Romanian-German reducer factory.

Hydraulic Control and Adjustment Elements and Systems

Liviu VAIDA

In the first stage of the manufacturing of control and fluid power drive elements (the period after the Second World War), production in Romania was channeled towards satisfying the need for such equipment, as it was required in order to produce agricultural machines, equipment for the railway, naval, and oil industry, and military equipment.

Table 2 presents the main enterprises producing hydraulic equipment on Romanian territory and their historical evolution. The first column contains the current name (or last name for those enterprises which have been dissolved).

In 1950-1965, there emerged several research and design units of national interest called 'institutes' in Romania within which departments for fluid power drives called 'design workshops' were created. At present, the development of hydraulic control and adjustment elements and systems is supported by several production and research units in Bucharest, Iași, Râmnicu Vâlcea, Sibiu, as well as by the research teams of the 'Gh. Asachi' Technical University of Iași (D. Călărașu), the Technical University of Cluj-Napoca (L. Deacu), the University Politehnica of Bucharest (N. Vasiliu,), the Politehnica University of Timișoara (V. Bălășoiu). These institutions founded the FLUIDAS National Professional Association of Hydraulics and Pneumatics with the aim of stimulating and creating a favourable environment for research, development, and innovation activities, as well as for production, distribution, and use activities. Under the aegis of this professional association, the HIDRAULICA magazine has been published at national level since 1998.

Table 2 The main producers of hydraulic equipment

Factory	Year of founding, evolution	Main products
AVERSA Bucharest	1882 the foundry and mechanical workshop are founded 1941–1945 occupied by the army 1948 nationalised under the name of the Pump Factory 1965 its name is changed into the Bucharest Pump Plant 1990 privatised 2006 named AVERSA again; becomes insolvent 2012 goes bankrupt 2013 acquired by the Benevo group 2016 ceases its activity	Various small parts Pumps for extinguishing fires Pumps for the industrial, agricultural, and energy sectors From 1985 onwards, it produces hydraulic pumps and installations for the Cernavodă nuclear plant

(continued)

Table 2 (continued)

Factory	Year of founding, evolution	Main products
HESPER Bucharest	1877 Mechanical workshop in Ghencea, Bucharest 1887 the Wolff factory near Carol Park is founded 1948 nationalised and named Steaua Roșie (Red Star) Bucharest 1974 the production of hydraulic equipment and installations begins 1991 turned into a joint-stock company called HESPER	Installations for steam locomotives Central-heating installations for industrial and civil buildings Vacuum pumps and equipment for nuclear plants, and starting from 1991, hydraulic pumps and engines with gears, hydraulic engines and power-assisted steering, simple and complex hydraulic installations upon assignment
ISEH Focșani	1970 tool factory 1973 new department for hydraulic equipment 1980 development, modernisation 1991 closed down following a fire	Tools Distributors A family of throttles and one of check valves Monoblock and proportional batteries (projects of the Hydraulics and Pneumatics Research Institute, IHP) A family of general-use benches (IHP projects) of medium and high complexity
HIDROSIB Sibiu	1975 founded (broke away from BALANTA Sibiu) 2004 incorporated into ADVANCED HANDLING 2006 integrated into METALRAX GROUP PLC 2009 perfecting its activity	Hydraulic equipment and pneumatic pumps Hydraulic and manipulation equipment A modernisation programme followed Unique hydraulic components, solutions in the field of fluid power drives Design and production of hydraulic systems and circuits
HERVIL Râmnicu Vâlcea	1981 created as a hydraulic equipment manufacturer 1987 attains envisaged parameters 2001–2002 modernisation 2013 the WIPRO group takes over HERVIL and turns it into SC WIPRO INFRASTRUCTURE ENGINEERING SA 2013 part of it breaks away and becomes SC HERVIL ASSETS Management SRL	Hydraulic equipment, hydraulic cylinders for agriculture and the metallurgical industry, servo valves, various pumps 80% for export Hydraulic cylinders for excavators

(continued)

Table 2 (continued)

Factory	Year of founding, evolution	Main products
NAPOMAR Cluj-Napoca	1973 becomes the Grinding Machine Factory (FMR, Fabrica de Mașini de Rectificat) with a department for hydraulic equipment 1990 turns into NAPOMAR and stops making hydraulic equipment	Filters, hydraulic master-slave devices, ICENA purifying installations
BADOTHERM Vaslui	1978 the Measuring and Control Device Company is created in Vaslui 1989 restructuring 2000 integration into the BADOTHERM Dutch group	Gauges, thermometer, coupling cocks Modern measuring devices for export (75% of production)
MEFIN Sinaia	1892 metallurgical and mechanical parts factory 1948 nationalised and turned into MEFIN [Mecanică Fină (Precision Mechanics) Sinaia] 2003 incorporated into the WALBRIDGE GROUP of Detroit	Nails, nuts, screws Starting in 1953, it produces its first injection equipment In 1967, it acquires a (BOSCH) licence for injection pumps Standard (DAV) rotary pumps with a licence from LUCAS CAV England Diesel injection systems
HIDROJET Breaza	1974 a branch of MEFIN Sinaia 1990 independent company	Parts and accessories for automobiles and engines Diesel injection components
HIDRAULICA Plopeni	2003 breaks away from the Plopeni Mechanical Works	Hydraulic equipment, pumps for agricultural equipment

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The History of the Construction Works

Dan Dubină, Florea Dinu, and Radu Văcăreanu

Abstract Constructions, starting from the first man-made shelters, continuing with the first organized settlements and the means of transport between them, with fortresses and fairs, monuments and palaces, and ending with the construction works of modern times, they have all supported and marked the human civilization. First, it was the builder master, then the architect appeared, integrating both the knowledge needed for the construction's functionality and esthetics and the safety and durability. Then, when the scale and complexity of the constructions imposed the division of this integrated profession, construction engineering, responsible for safety and durability, but also for the establishment and application of building technologies, separated from architecture. The emergence and development of human settlements have always been influenced, favored, or restricted by the natural conditions and resources of the territory. Soil conditions, climate actions (e.g., wind, snow) and seismicity remained decisive factors in the development of the construction techniques. Constructions in Romania have developed largely in line with the general scheme described above. There was the Stone Age, then the Bronze Age, leaving traces of specific construction, then a Dacian civilization with remarkable achievements, followed by the Roman conquest and integration, with urban development and transport infrastructure at the level of the other provinces of the empire. After the withdrawal of the Roman administration from Dacia, a transition period followed, with numerous migration periods (invasions), during which it collapsed rather than developed. Then followed the early Middle Ages and the consolidation of medieval structures/states (the establishment of Romanian Voivodes), the Late Middle Ages, the Phanariot Rule and Ottoman vassalage in Moldavia and Wallachia, and Hungarian Rule in Transylvania. The modern Romania was marked primarily by the Unification

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of The Romanian Principalities and the introduction of the Austro-Hungarian administration in Transylvania, followed by the independence and the establishment of the Kingdom of Romania. The World War I followed, then the Greater Romania (after the union with Transylvania, Bessarabia, and Bukovina) and the interwar period, the World War II and the period of the communist regime, which started in December 1947. The collapse of the communist regime in December 1989 brought about major changes in all areas of economic and social life, and implicitly in the field of constructions. Constructions followed and characterized these historical periods, each with its particularities (aesthetics, technology, functionality). After the Roman period, starting from the early Middle Ages and ending in the first half of the 19th century, constructions in Romania were made on an empirical and intuitive basis rather than on professional and scientific education. There are two important moments here in the promotion and development of this profession in Romania. The first, on 15 November 1813, when a class of engineering and terrestrial measurements in Romanian language is being established at the Royal Academy in Iasi. It is actually the first high school for construction and geodesy in our country. The second moment is the establishment in Bucharest, in 1864, of the School of Bridges and Roads, Mines and Architecture, according to the French model. Three years later, in 1867, it turns into the School of Bridges, Roads and Mines, which becomes the National School of Bridges and Roads in 1888. This is indeed the first institution of higher education for construction engineers, which in the sense of that time was attributed to civil engineering. Following the Unification of the Romanian Principalities, Romanian cities are undergoing a vast process of modernization. The development and organization of urban infrastructure has also been envisaged through the development and modernization of public lighting, sewage system, and means of transport. The period between WWI and WWII has meant for Romania a period of remarkable economic, cultural, and spiritual progress, with significant achievements in the urban and transport infrastructure. Then, in the period 1948–1989, in Romania was built very much, perhaps not always justified and where it should have been. However, it should be said that, in the field of civil engineering and, in particular, in structural engineering, these structures tested the professional competence of the engineers who designed and executed them. The construction sector experienced a general decline in the early 1990s, then started to grow between the years 2005–2008, being one of the pillars of Romania's economic growth. After significant stagnation between 2009–2012, the construction sector started to grow again, with a very good year 2015, especially due to the residential construction sector. The non-residential construction sector saw lower growth rates. The achievements were however remarkable, as many of these constructions are comparable to similar constructions built in Europe and around the world. The history of construction is ultimately an image of the cultural, social, economic, and technological development of a society. This chapter tried to reflect this complexity and multidisciplinarity of the profession.

1 The Beginning of Construction Works on Romanian Territory

1.1 The Daco-Roman Period and the Early Middle Ages

1.1.1 Dacia Before the Roman Conquest

The culture and civilization of the Dacians have had hundreds of years of development in the Carpathian-Danube area, reaching the highest level between the 1st century BC and the 1st century A.D. In the 1st century BC, the Geto-Dacian society goes through an extensive modernization process that led to the emergence of the centralized Dacian state under the rule of Burebista. The Kingdom of Decebalus (87-106), although it did not have the land area of the kingdom created by Burebista, unified most Dacian tribes from Transylvania, Banat, Oltenia, central and southern Moldova. The Dacians have taken material cultural elements from other peoples, which they have adopted, transformed and often enriched (Fig. 13.1).

Geto-Dacians were organized in tribes and tribal unions led by military leaders who had as their center of residence a fortified settlement called "dava". Geto-Dacians could build cities or bridges, but only occasionally, to prepare a military action. Fortified fortresses and settlements are eloquent evidences of military defense and engineering. In Transylvania and Banat, these fortified settlements have appeared since the 2nd millennium BC and were made with earth walls, ditches and palisades (fence of wooden stakes used as defense structure).

At the beginning of the 1st millennium BC, these reinforcements were also added to stone walls. Probably the greatest such prehistoric fortification is the one of Cornesti, jud. Timis, built around 1500 BC. The Fortification, which spreads on about 1800 hectares, comprised several concentric defense earth walls, palisades and ditches. More than 20 fortifications dating from the 6th to 3rd centuries BC were

Fig. 13.1 Road paved with limestone blocks, Sarmisegetusa Regia

Fig. 13.2 Murus dacicus, stone block assembly system

also discovered in the region of Moldova (e.g., Stanceşti, jud. Botoşani, and Batca Doamnei, near the town of Piatra Neamţ).

The center of the Dacian defense system, located around the political and administrative center, was made up of the system of fortified fortresses and strongholds (strong fortresses, fortified places, towers of defense or surveillance) of the Orăştie Mountains: "*A system of fortifications that has no equal, not only to us, but also to another part of Europe*" (Crişan 1969).

Greek architects and craftsmen also worked in constructions, as is shown by the Hellenistic technique used. The large number of cities in this system, but also in other areas inside the Carpathian Mountains, especially those in Blidaru, Costeşti and Grădiştea Muncel, are sufficient to explain the design and technique of their manufacturers. Built in the style of Murus Dacicus (latin for the Dacian Wall), the six Dacian fortresses in the Orăştie Mountains (Sarmisegetusa Regia, Luncani-Piatra Roşie, Costeşti-Blidaru, Costeşti-Cetăţuie, Căpâlna and Baniţa), were erected between the 1st century BC and the 1st century AD (Fig. 13.2).

1.1.2 Dacia in the Roman Period (106-271 AD)

The conquest of Dacia by Romans in 106, during the reign of Emperor Trajan, led to the emergence of the Roman province of Dacia, with its capital at Ulpia Traiana Sarmizegetusa. Important economic changes are taking place during Roman rule, such as the construction of numerous cities, fortresses, fortifications (castra) and monuments, and the development of an extensive road network. Infrastructure development was both military and commercial.

Related to *roads*, one of the most important documents on the relationship between Roman Dacia and rural settlements is Tabula Peutingeriana (Fig. 13.3). The document, made up of twelve sections (the twelfth section has been lost), shows the road network of the Roman Empire, including Roman Dacia (sections VII and VIII). The most important roads in Dacia were connecting the Danube River to Northern Transylvania, crossing the Banat and the corridor from the Iron Gate of Transylvania, then passing through Ulpia Traiana, Apulum, Potaissa, Napoca and reaching Porolissum (Fig. 13.4).

Another road started from the Mures Valley and reached the Augustiae, going out through the Oituz pass and heading through Moldova to Tyras, at the mouths of the Nistru River (near Cetatea Albă, today Ukraine). There were also roads from Drobeta, passing through Vilcan and then to the Olt Valley. In the Dobrogea area (or the Pontic Dacia), the first road spread along the Danube, continuing the route from Moesia, and passing through all the settlements from Transmarisca (in the place of Turtucaia, Bulgaria) to Salsovia (Mahmudia, jud. Tulcea); the second run parallel to the Black Sea coast and connected Greek cities from Histria to Dionyopolis (Balcic, Bulgaria); the third crossed Dobrogea through the middle, passed through the Tropaeum Traiani and Ibida (current Slava Rusă, jud. Tulcea), where it forked,

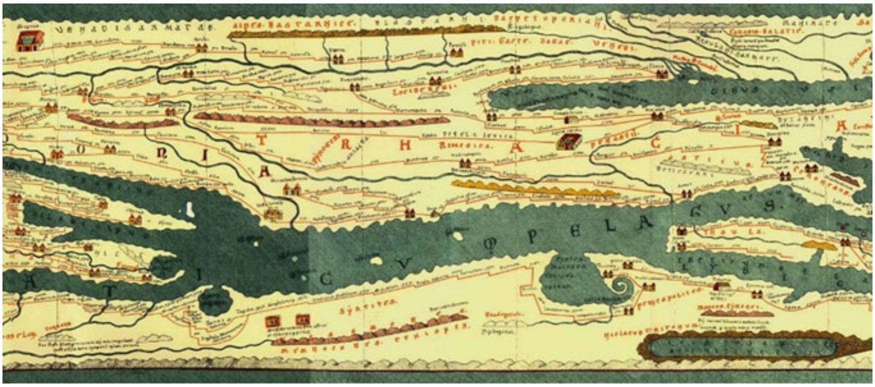
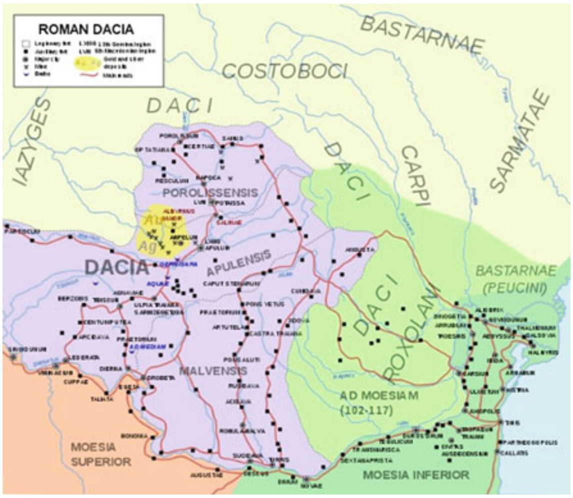


Fig. 13.3 Tabula Peutingeriana (sections VI to VIII) with the roads from Roman Dacia

Fig. 13.4 Map of settlements and roads in Dacia



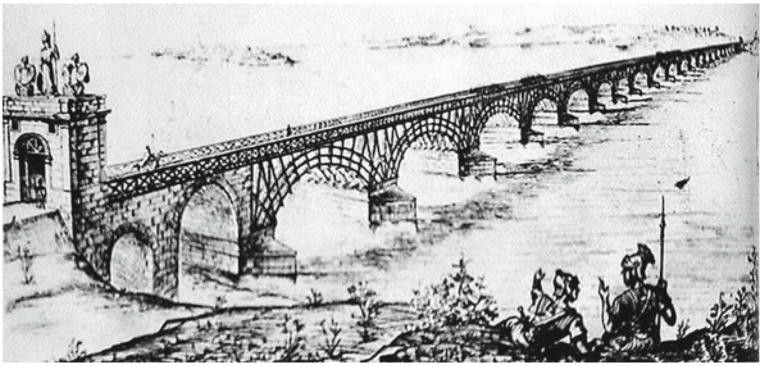


Fig. 13.5 Traian's bridge over the Danube, artistic reconstruction (Giurescu 1981)

forming a branch to Aegyssus (fortress in the eastern side of Tulcea town) and one to Noviodonum (Roman fort on the Danube bank, near Isaccea, jud. Tulcea). Technically, three categories of road could be distinguished: *viae terrenae*, which were simply laid on the surface with only a layer of ground that was packed and leveled; *viae glarea stratae*, having as main characteristic the gravel pavement; *viae silice stratae*, paved with stone slabs, sometimes with a thickness of up to 70 cm.

One of the outstanding achievements of this period in the field of *bridges* remains the construction of Trajan's bridge (Fig. 13.5). Built between 103-105 AD, on the lower Danube, near Drobeta Turnu Severin, the bridge was the work of Apollodorus of Damascus. The bridge was constructed before the Second Dacian War to allow Roman troops to cross the river. The bridge was made of stone and wood, 1.135 m long and 12 m wide. The construction has been very resilient, with its 20 piers remaining intact over eighteen centuries. Today, only the remainings of the first and last piers, one on each bank of the Danube, still exist.

Roman conquest has brought about radical changes in the way of life, mainly through the founding of numerous *settlements*. The first such newly built settlements were fortified military camps, or castra. The castra had 1-2 defense ditches and a wall of earth or rock. Ahead of the line of castra, was a line of towers, such as the one on Meses Mountain, near the north-western border of the province. The Roman castra were built inside the province: Apulum (Alba Iulia), Potaissa (Turda), Praetorium (near Mehadia, jud. Caraş-Severin), Pelendava (Craiova), Buridava (Stolniceni, near Râmnicu Valcea), Germisara (Geoagiu, jud. Hunedoara). Other castra were used by the auxiliary troops who were watching the internal order: Castranova (jud. Dolj), Romula (near Caracal, jud. Olt).

In Roman Dacia, most of the population lived in villages, which were organized either by the Roman pagus system (on the colonies-dependant territories) or the vicus (civilian or military) or in their traditional communal organization. The status of the Roman province has also led to the founding of numerous urban centers. Depending on their importance, urban settlements were established as a colony or as a municipality (lower ranked than a colony). In Trajan's era, the only new founded

Fig. 13.6 Ulpia Traiana Sarmizegetusa, the arena

city was Ulpia Traiana Sarmizegetusa (Fig. 13.6), who has been awarded the colony title since its establishment. A little later, starting with the reign of the emperor Hadrian (117-138 AD), many cities were built, such as the municipality of Napoca (Aelium Napocensium) or Drobeta (Aelium Drobetense). The urbanization process is intensifying during the reign of Marc Aurelius, 161-180 AD, when a new municipality, Apulum, is being built, and reaches the peak during the reign of Septimius Severus, 193-211 AD, when several settlements are rised to the rank of municipality, an example being Potaissa, which then becomes a colony.

The first information on the existence of *hydro-technical works* (dams) on the territory of the Dacia dates back to the Romanian occupation (106-271 AD). They were built on the Rosia Montana River in the Apuseni Mountains, where there were rich gold deposits. The water accumulated by these dams was used to break down ore and separate gold. The dams had heights of up to 10 m and were made from earth, with the upstream and downstream faces protected by stone walls.

1.2 The Middle Ages and the Period before the Unification of the Romanian Principalities

After the political disintegration and the economic and social downturn that characterized Europe between the IVth and the XVth century, the dawn of a new period of development began. The first signs began to appear in the XI–XIII centuries and have meant the demographic increase, the revival of transport and trade, the revival and development of urban communities. Cities have attracted a larger number of inhabitants, located in places favorable to trade, around castles, on the crossing of roads or near waterways. Without strong state relations, local centers of power have emerged in which military fortifications continued to develop. Ancient fortifications were replaced by the fortresses, which had as their elements of defense walls, towers, and ramparts. They had access to water and food supplies. There were also living spaces and reserves of building materials. Inside many cities, chapels or churches were built. Alongside fortified cities and fortified towns, fortified churches have emerged since the 11–13th centuries.

1.2.1 The Middle Ages

Representative constructions. One of the most representative medieval constructions on Romania's territory is the Hunedoara Castle, also called the Corvin Castle (Floca 1957) (Fig. 13.7). The castle, built in the 15th century by Ioan de Hunedoara, is one of the most important monuments of Gothic architecture in Romania. Another impressive medieval construction is the Neamţ Fortress (Fig. 13.8). The fortress, built at the end of the 14th century by Petru I and fortified in the 15th century by Stephen the Great, guarded the valley of Moldova and Siret rivers and the road crossing the mountain in Transylvania. The Neamţ fortress was part of the system of fortifications built in Moldova at the end of the 14th century.

Fig. 13.7 Hunedoara Castle, an impressive medieval construction in Romania

Fig. 13.8 Neamţ Fortress, with an important role in the Moldavian defense system

Braşov Fortifications (Fig. 13.9) are military constructions with defensive character, built starting with the 13th century. The fortifications were made up of walls of 12 m high and 1.70 to 2.20 m thick, 8 bastions and 28 square-shaped towers.

The city of Sighişoara, whose historic center is included in the UNESCO world heritage, is a special area, a depository of centuries-old culture and history (Fig. 13.10). The city was first documented in 1280, under the name of Saxoburgum. In 1241, during the great Mongol invasion, the city was not yet fortified. The wall, constructed later, was 950 m long and 4 m in height, then rised by 4 m in the 15th century. It had 14 towers, one for each guild, and four bastions. Today there are 9 towers and 3 bastions left, the most famous of which is the Clock Tower.

Fig. 13.9 View of the Braşov fortifications

Fig. 13.10 Sighişoara, one of the Europe's best-preserved medieval cities

The wooden houses of the Middle Ages were often dismantled and could be moved from one place to another. In the past, there were whole villages specialized in the construction of houses made of pre-built elements. These houses were raised either on a wooden base, full beams, placed directly on the ground or on large stone boulders. There were also specific foundation procedures, such as in “forks”.

With the development of constructions also grew the production of construction materials. Instead of the oak or fir splinter, in the 16th century the tiles were more and more used in Transylvania and Moldova, while in Walachia were preferred roofing tiles (glazed or simple). They were produced in manufactories already during the rule of Alexandru Lăpuşneanu, in Baia, in 1555. For stoves there were used tiles of glazed terracotta that sometimes were used for floors (Dimitrie Cantemir mentioned their use at the Royal Palace in Iaşi). Glass was used in all Romanian countries; glass workshops were mentioned in 1629 at Făgăraş, in 1644 near Targovişte and around 1700 in Moldova.

In this period, lime production has steadily increased, whole villages being specialized in the production. Toward the end of the 17th century, particularly since the 18th century, numerous stone buildings are being built in the area and by the royal courts. To note that, in 1813, the Moldavian Scholar Gheorghe Asachi has open within the *Princely Academy* of Iaşi a Course in Romanian Language in Topography and Engineering. This is considered the first Civil Engineering school in Romania. 5 years later, in 1818, the Engineer Gheorghe Lazăr has founded within the St. Sava Covent, in Bucharest, the Academic School for Philosophy, Mathematical Sciences and Surveying Engineers”. This school, after a series of subsequent changes, will become in 1864, the School of Bridges and Roads, Mines and Architecture.

Infrastructure and urban development. From the 12th century to the mid-19th century, a new phase has been noted in the development and construction of roads in Romania, most of them following the route of old Roman roads. Some of them crossed Valachia from east to west or crossed the Carpathians and connected the Danube ports and Wallachian cities with Transylvania. The wooden “bridges” (mentioned since 1574) were used to pave the streets in the cities of Walachia and Moldova. They were made up of 25–30 cm thick oak wood floors, resting on two thick oak blocks, placed along the streets, one on each side, with a deep gutter to drain the pluvial and wastewater. The first street paved with stone dates from in 1661, starting with a part of the road “Tărgul din Afară”.

The permanent (fixed) bridges in brick masonry were rare. It was only during Stephen the Great that the first stone bridges were built (e.g., Borzeşti, Cotnari). Fixed wooden bridges have been built often on wooden trestles in the riverbed, or on wooden boxes weighted down by stones, after a Roman technique. It is worth mentioning the covered wooden bridges, from the Tarnave, Somes and the north of Moldova as bridges from the 18th century, with pillars beaten in riverbeds.

The lad surveying has been practiced since the ancient times in Romanian countries and has developed in the early Middle Ages, serving delimitations and measurements. Topography and geodesy began to be used in the land surveying in the second half of the 18th century. It was kept to us the first plan of Iaşi (1769) and the first plan of Bucharest (1781). Apart from the physical, economic, political, and archaeological map of Walachia, drawn up by the Constantin Cantacuzino, remained from Dimitrie Cantemir the particularly detailed map of Moldova in Descripthio Moldaviae. In 1797, a map of the Balkan Peninsula, with Moldova, Muntenia and the western coast of Asia Minor, and two more detailed maps, one of Moldova and another of Muntenia, appeared in Vienna; also, in Vienna appeared in 1800 the atlas of Gh. Golescu.

It can be noticed significant hydro-technical works for deviation of water courses, through numerous ponds and lakes with earth dams across. Also, prestigious works were carried out across the Danube and on the backwaters connecting the Danube meadow with the river. In Moldova there are marks and traces of some ponds, built in the 15th century, in order to mitigate large waters and ensure local use. River dams and diversions have also been carried out for military purposes by Radu Negru and Stephen The Great.

In Muntenia (Vallachia), works are known in connection with the defense of Bucharest against the floods. They started in the time of Alexandru Ipsilanti (1775) and consisted in directing the floods of the Dambovita River in Argeş through channels, connected in turn with the tributaries of the river, i.e., Răstoaca, Sabarul, and Ciorogârla (1805). In Banat, in the 18th century, works were carried out to drain the marsh around the city of Timişoara. Thus, a 70 km long canal was built between Timişoara and Klek, the Bega River was regulated upstream of Timisoara, and a unique work in its way was carried out: the double connection between the Timis-Bega rivers through the canals of the Costei-Chizatau and the Topolovăţ-Hitias. Work also began in the 18th century to drain and regularize the rivers in the Criş and Someş plains. Dams or locks have been built for the construction of ponds, in some cases impoundments being necessary. Documents from the 18th century testify the rehabilitation or repair of some dams from previous periods. In the same period, the name "tau" appears for dams of 5–6 m height, constructed for the storage of water on mountain rivers. In the Western Carpathians, was built the reservoir "Tăul Brazilor", a dam made from compacted earth with puddle clay core, and vertically stabilized with carved stone walls; this type of dam can be considered as a precursor of earth dams with a modern-day clay core.

1.2.2 The Period Preceding the Unification of the Romanian Principalities

This period has been marked by a more sustained effort in the development of transport and communications. Thus, in 1845, in Walachia is voted the Road Law, and in 1847 a direction of public works was formed, in which operated a bridge and road section. Between 1835 and 1853, in Moldavia and Walachia were built roads in the length of 775 km.

In the case of water transport, log rafts were used on large rivers. Water transport has a certain development after 1834, when Walachia obtains free navigation on the Danube, and in 1837, together with Moldova, it achieves the same right on the sea. Also, during this period, Braila and Galati are declared as free ports, leading to a significant increase in traffic. Efforts are also being made in Transylvania to modernize the transport network. After the province of Banat entered under Habsburg rule (1716), a priority of the new administration was the drain of the marshes and the canalization of the Bega River.

Also in the field of infrastructure, numerous reference works, such as the first works for water abstraction and filtration for water supply (Bucharest, 1845), the first road on Romania’s territory, between Turnu Severin and Vârciorova (built from river stone boulders, 1845), or construction of a road system linking Bucharest to Sibiu, Braşov, Focşani, Orşova and Brăila (1846) appear in the years before the unification of the Principalities. New architectural complexes, specific to contemporary urban planning, are being built in large cities (Figs. 13.11, 13.12, 13.13, 13.14).

In 1704, the country’s first hospital, Colţea, is being built in Bucharest. In parallel, more specific structures such as port constructions are also being developed. Given the strategic location of Brăila and its importance for navigation on the Danube, the most important port in the Romanian countries was developed in that time.

Fig. 13.11 Bucharest, period 1800–1849

Fig. 13.12 Iasi, Trei Ierarhi Monastery

Fig. 13.13 Timişoara, "Union Square"

Fig. 13.14 Cluj-Napoca, "Big Square"

2 The Period Between the Unification of the Romanian Principalities and the First World War

2.1 Urban and Infrastructure Development

In the period following the unification of Romanian Principalities under the leadership of Ruler Alexandru Ioan Cuza, a comprehensive reform package shaped the framework that allowed and stimulated the evolution of Romanian society, from a late feudal society to a modern society (Florian et al. 1997). The message of the Ruler to the Parliament on 6 December 1859 states: "*We have everything to build; we have to... open roads, make bridges, decorate cities, broaden ports, increase trade, encourage industry, strengthen the army and dig channels, extend iron road lines on the surface of our land...*". The development and management of the cities was supported by cadastral, municipal, urbanistic, and architectural regulations. Within this period, called *the Modern Age*, several priority infrastructure development lines have been followed, such as the construction of railways and the development of river transport, especially on the Danube.

After coming to the throne in 1866, King Carol I supported the constructions that are necessary for the functioning of the state, i.e., offices of the state institutions, universities, administrative palaces, libraries, train stations, schools, churches, and hospitals.

In 6 of June 1906, was inaugurated the Romanian National Exhibition in Bucharest, dedicated to the jubilee of the 40 years of the rule of King Carol I and 25 years from international recognition of Kingdom of Romania (1881). All important constructions, building and infrastructure have been presented in that Exibition.

2.1.1 Construction Materials and Technologies

The building materials used up to the second half of the 19th century were mainly wood, stone, bricks, and mortar. In Romania, the interest in the use of "new" construction materials (concrete/reinforced concrete, metal) came shortly after they entered the market. For example, engineer Anghel Saligny *is using for the first time in the world the reinforced concrete precast elements* for the construction of the silos in Brăila, in 1888 (Fig. 13.15), Galaţi (1889) and Constanţa, construction that still exist today. Among the pioneers of the reinforced concrete can be named the engineer George (Gogu) Constantinescu, a graduate of the School of Bridges and Roads in Bucharest in 1904, who will elaborate a design theory for concrete structures that will be successfully applied to the construction of bridges and buildings in Romania. The road bridges that have been built since the beginning of the 20th century have been mostly of reinforced concrete, including the engineer Elie Radu among the pioneers of these solutions.

In the Romanian Principalities, in Transylvania and Banat, the industrial production of construction materials began in the mid-19th century, but it has rapidly evolved, particularly the production of bricks, tiles, and cement.

Fig. 13.15 Reinforced concrete silos, port of Brăila

Fig. 13.16 First cast iron bridge (Florian et al. 2023a)

Forged iron bars (cast iron and then wrought iron) were produced in Reşiţa and Bocşa as early as the second half of the 17th century. In 1851, the Reşiţa plant started to deliver the tracks for the construction of the Oraviţa–Baziaş railway. Iron and steel bars have also been produced in Hunedoara since 1884, when the Iron Plant came into operation. In the railway sector, Reşiţa plants are the first in Austria-Hungary and Southeast Europe. In 1909, the rolling mills for hot rolled steel profiles were producing plates and profiles. The oldest cast iron bridge, in fact a footbridge, called "the Lies Bridge", was erected in Sibiu, in 1860 (Fig. 13.16), while the first bridges of wrought iron are the ones over the Siret, at the Bucecea, in 1871, with the 72.5 m span and the multi-span bridge over the Olt river, at Slatina (45.5 + 5 × 57.3 + 45.5 m), in 1875.

The building solutions currently used in the second half of the 19th and early 20th centuries had a resistant structure in brick masonry or in combination with stone masonry. Generally, lime-based mortars were used; cement mortars, although known, only started to be used at the end of the 19th century. The foundations were continuous, mainly of stone, but also of brick masonry. Wooden piles were used in soft soil conditions. After concrete has appeared, it was increasingly used for building infrastructures. The floor over the basement was made with masonry vaults, and after the appearance of cast iron beam, from masonry vaults supported by metal profiles. The floor over the ground floor was made of wooden beams of different thickness upon which a layer of sandy earth layed. The ceiling was made of plaster applied to the cane. The roof framework was made of solid softwood elements. Toward the end of the 19th century, metal trusses will also be used, while and at the beginning of the 20th century there are roof structures with reinforced concrete vaults or domes; in some cases, metal elements have been used in the dome structure. Stairs—before the arrival of reinforced concrete, they were made either of stone or wood, less often with metal elements.

2.1.2 Urban Infrastructure

In the last decades of the 19th and early 20th centuries, Romanian cities are undergoing a vast process of modernization. We are witnessing the planned expansion of urban centers, by modifying the street formation, by avenues, by creating public spaces and placing the buildings against the vicinities. The development and organization of urban infrastructure has also been envisaged through the development and modernization of public lighting, sewage system, and means of transport (Florian et al. 2023b; Buiumaci 1906).

In Bucharest, in 1879, the water supply was provided through the exploitation of 10.5 km of pipelines, 41 public fountains, 188 private installations, and 200 water wells. In 1891, the 42 m-high compensatory reservoir for fire intervention at the Iancului (Foişorul de Foc), built according to the plans of architect George Mandrea, chief architect of Bucharest, is completed. To achieve a better-quality water, the city hall decides to collect the groundwater from the southwestern town, in the Bragadiru area. Engineer Elie Radu, who had studied the groundwater sources in this area, is appointed director of the work in Bragadiru (Radu 1903).

In connection with the water supply and the sewage system of Bucharest, must be also mentioned the work to systematize and regulate the Damboviţa river (Fig. 13.17), started in 1879–1880. The works, led by French engineer Alexandre Boisguerin, were completed in 1885 (Fig. 13.18).

In 1857, Bucharest already had street lighting based on lamp oil (Fig. 13.19), system that then extends to the country: Craiova 1858, Bacău 1867, and Ploieşti 1881. Only 6 years after the installation of the world's first power plant in New York, the electrical light also appeared in Bucharest, being introduced by engineer Henry Slade (1882). Electric current lighting has also been introduced in the other cities of the Kingdom of Romania: Craiova (1896), Iaşi (1897), Brăila (1901), Bacău (1902), Piteşti (1913).

In Romania, the first public carriages appear in the first half of the 19th century. In 1871, Henry Slade obtained a concession for horse-pulled trams and in 1872 the first

Fig. 13.17 The Damboviţa at the Radu Vodă Bridge, before regularisation, 1874

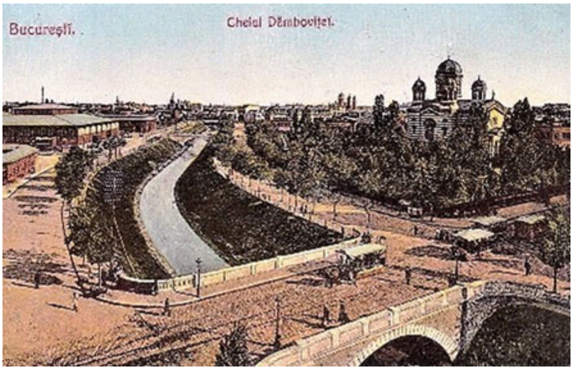


Fig. 13.18 Damboviţei Quay, after regularisation, 1905

Fig. 13.19 Bucharest, street lighting with oil lamp

line was completed, starting at Mogoşoaiei Barrier, and ending on Calea Moşilor. In 1890, Bucharest city hall decided to lease to Fr. Thalasse and comte E. Graziadei an electric trams company. The first electrical line was made in 1894 along the Colţea Street—Obor. Omnibus lines are being established alongside trams (Fig. 13.20).

Fig. 13.20 Bucharest, Sf. Gheorghe square, horse-pulled tram

At 1900, Bucharest had about 300.000 inhabitants, spread only on a quarter of today's surface and had about 800 streets or alleys, some paved. At 1890, there were 12 bridges across Dambovişa, 7 stone and 5 iron bridges; The Grant Bridge was mounted in 1910. In 1909, another tram company (S.T.B.) was established, which had the main task to electrify routes on the main roads of the city. According to the statistics, there were 14 km of electricity lines in 1913 and 21 km of horse-pulled tram lines. Electric trams were introduced into other Romanian cities: Iaşi (1897), Brăila (1901).

In Transylvania and Banat, a pioneer in the modernization of urban infrastructure was the city of Timisoara, which marked a series of premieres. On 1st of November 1857, Timişoara is the first city of Romania and the Habsburg Empire with the gas street lighting, then, 7 years later, in 1864, for the first time in Europe, 731 electric lighting lamps will come into operation on the city's streets. On 12 July 1889, the electric trams are introduced. Timişoara was the country's first horse-pulled tram city, in 1869. Traffic increased continuously—in 1898, the banner year of the horse-pulled tram, more than 850.000 passengers were transported. Under these conditions, the municipality decided to replace the horse-traction with the electric traction, the first electric lines being inaugurated on 27 July 1899.

As regards Timişoara's sewage and water supply networks, in 1909 work started on the two North and South collectors and a treatment plant, which opened in 1912. In 1914, the water plant no. 1, the fountain groups, the distribution network, and two balancing tanks are put into operation. In 1916, The Industrial Water Plant and its own distribution network were put into operation. It is obvious that the great cities in Transylvania (Arad, Cluj, Oradea, Sibiu) soon followed the model of Timişoara.

Public buildings. In Bucharest, construction of new boulevards and buildings (following the urban renewal plans of Baron Haussmann in Paris) began in the years 1870. The architectural heritage of the end of the 19th century and the beginning of the 20th century is still dominated by many buildings of great value, including buildings that hosted or host public institutions today. The creators of these buildings were both foreign and domestic architects, working with Romanian construction engineers trained in European universities, but also in the School of Bridges, Roads and Mines in Bucharest. The Banat and Transylvania, Romanian provinces integrated into the Austrian-Hungarian Empire, have also seen an accelerated development of urban areas and infrastructure in the light of the economic momentum of that period. In the following, the urban development and progress of construction technologies will be illustrated through selected public buildings in the *capitals* of Romanian provinces.

Bucharest

- *The Old Palace of the National Bank* building was designed by French architects Cassien Bernard and Albert Galleron. Execution of the work, led by ing. arh. Nicolae Cerkez, started in 1884 and ended in 1890 (Fig. 13.21).
- *The Palace of Post and Telegraph* was designed according to the project of architect Alexandru Săvulescu in a neoclassical style (Fig. 13.22). Construction

Fig. 13.21 Palace of the national bank (Radu 2023)

Fig. 13.22 Palace of post and telegraph (Radu 2023)

works, which were carried out by the "Romanian Construction and Public Works Company", started in 1894 and ended in 1900.

– *The Palace of Justice* (Fig. 13.23) was constructed between 1890–1895 according to the plans of architect Albert Ballu.

Fig. 13.23 Palace of justice (Radu 2023)

Fig. 13.24 CEC palace (Radu 2023)

- *The Palace of the Savings Bank* (CEC) (Fig. 13.24) was constructed according to the plans of architect Paul Gottereau, and was executed under the guidance of Romanian architect Ion Socolescu from 1887 to 1900.

- *The Palace of the Chamber of Deputies* (Fig. 13.25), located on Dealul Mitropoliei, it was erected in several phases, between 1906–1908, 1911–1913, and 1914–1916, according to the plans of architect Dimitrie Maimarolu in the neoclassical style. The structure of walls made of masonry has the floors made of masonry or concrete filled steel profiles. The Hall is closed at the top with a ring and reinforced concrete cantilevers, which supports the metal roof dome. Gogu Constantinescu has achieved here, for the first time in the world, the construction of a reinforced concrete shell to strengthen the dome.
- *Romanian Athenaeum.* In 1886, French architect Albert Galleron and Romanian architect Constantin Băicoianu draw up plans after which the Athenaeum will be built, helped by renowned architects of the time: Grigore Cerchez, Constantin Olănescu, Ion Mincu, Ion Gr. Cantacuzino. The Athenaeum was inaugurated

Fig. 13.25 The palace of the chamber of deputies

Fig. 13.26 Romanian Athenaeum, photo from 1910

on 14 February 1888 (Fig. 13.26). On 29 December 1919, in the Great Hall of Athenaeum, the Chamber voted to ratify the unification of Transylvania, Bessarabia, and Bukovina with Romania.

Iaşi

- The most important urban community of the new Romanian state, after Bucharest, has undergone a development characterized by innovation and modernization in the field of public-service buildings. The innovative spirit and the tendency toward modernity from that time are also given by the employment of the French engineer Gustave Eiffel for the construction of three major buildings for the urban development of Iasi. These are *Grand Hotel Traian*, inaugurated in 1882 (still in use), (Fig. 13.27), the *Great Hall* of the city in 1883 (collapsed in 1960 due to heavy snow), and the mausoleum of the Petre P. Carp from Tibăneşti (estimated 1885). The "*Vasile Alecsandri*" *National Theatre* (Fig. 13.28) was built between 1894 and 1896.

- The construction of the *Palace of Administration and Justice* (the *Palace of Culture* since 1955) began in 1906, following the plans of architect I. D. Berindey, and was completed after the war, in 1925 (Fig. 13.29).

Fig. 13.27 Grand hotel Traian

Fig. 13.28 “Vasile Alecsandri” national theatre

Fig. 13.29 The palace of the Chamber of Deputies

– *The Palace of the University Ioan Cuza* was built between 1893 and 1897, according to the plans of architect Louis Blanc (Fig. 13.30). The cornerstone was laid in the presence of the Prince Ferdinand on 28 April 1892.

– We remain in the Kingdom to illustrate (through some exceptional achievements) the reference works of Romanian architects. Two main cities will be focused, i.e. Galaţi, the most important Danubian Port-City, and Constanţa, port at Black See and the Capital of Dobrogea Province. At Galaţi, the architect Ion Mincu, the

Fig. 13.30 University Ioan Cuza

creator of the *neo-romanian style*, realized between 1905–1906 his first construction with administrative function, the Prefecture building (Fig. 13.31). Another reference work is the Palace of Navigation (Fig. 13.32), built between 1911–1913 after the project of architect Petre Antonescu, a brilliant disciple of Ion Mincu. After the Romanian War of Independence (1877), in Dobrogea, returned to Romania, and especially in its capital Constanţa, the same effervescence of urban development is felt as in the Kingdom of Romania. The Communal Palace (Fig. 13.33), today the Museum of History and Archeology, built in phases between 1911–1913, 1914, then continued after the war between 1919–1921, the Royal Palace, opened in 1906, now the Constanţa Court, and the Casino, which opened in 1910, are good examples of this flourishing period. The Headquarters of The City Hall at the time dominated The Ovidiu Square in Constanţa.

Timişoara

– With a legacy of over 14000 historic buildings, Timişoara, the Capital of Banat Province is the richest city in Romania in buildings constructed before 1940. Representative of the local cultural heritage are over 900 buildings, mostly found

Fig. 13.31 Prefecture building, Galaţi

Fig. 13.32 Palace of navigation, Galaţi

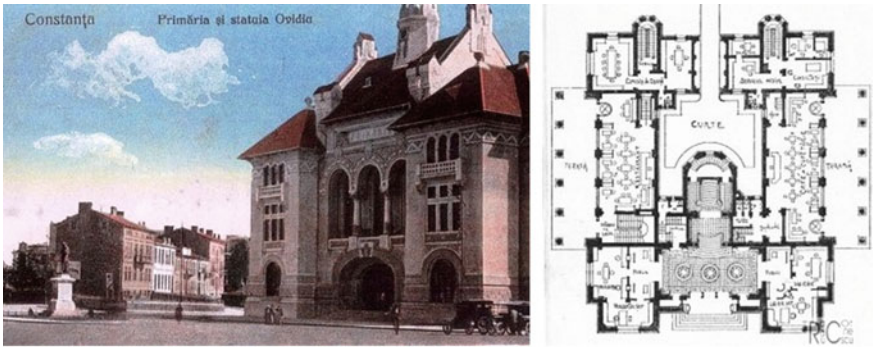


Fig. 13.33 Constanţa communal palace (left) and ground floor plan (right)

in the neighborhoods of Cetate, Josephin, and Fabric districts, in an union of truly unique architectural styles: baroque, eclectic, secession, neo-romantic, neo-gotic, or neo-classical. Two examples are presented here:

– *Lloyd Palace* (the building houses today the Rectory of the Politehnica University), built between 1910–1912 in eclectic style with the influence of Secession, architect Leopold Bauhorn (Fig. 13.34).

– *The historic Opera House in Timişoara*, built according to the plans of the Viennese architects Helmer and Fellner, opened in 1875 (Fig. 13.35). After the fire in 1920, the reconstruction is carried out according to the plans of architect Duiliu Marcu.

Cluj-Napoca

– **In Cluj-Napoca, the capital of Transilvania, some 21 monumental buildings were built during this period. Most of these buildings are located around the "Big Square" area,** as it was named until the mid-19th century. In the first part of

Fig. 12 34 Lloyd palace, Timişoara

Fig. 13.35 Opera house, Timişoara, 1875

Fig. 13.36 "Big Square" and "New York" hotel, at the end of the 19th century (http://gurmika.blogspot.com/)

the 20th century, the square was named "King Matia" (Mátyas Király tér), then, after the unification in 1918 it became the "Union Square", which it still holds today. Fig. 13.36 shows the square at the end of the 19th century, with the *New York* hotel, built between 1893–1894 by the chief architect of Cluj, Lajos Pákei (center, back).

2.2 Transport Infrastructure

2.2.1 Railways and Roads

The Paris Peace Congress (1856) regulations have led to an increase in navigation on the Danube (with the ports Brăila and Galaţi) and on some inland rivers, such as Olt and Siret. At the mouth of the Danube, in 1858–1861, the European Danube Commission carried out hydro-technical work to increase depth on the Sulina Channel from

2.75 m to 5.33 m. The construction of the first railways and the development of the railways network were determined by the critical transport situation. In Romania, the first railway lines were built by the concession holders (1856 Baziaş–Oraviţa, 1860 Cernavoda Port–Constanţa, 1869 Bucharest Filaret–Giurgiu and Burdujeni–Roman). Started in 1865, the construction of the Bucharest–Giurgiu railway line was finalized in 1869; on this occasion, the first Bucharest railway station, Filaret, opens. The first railway line on the current Romanian territory, which is also the oldest on the CFR network, was opened for freight transport on August 20, 1854 between the Danube port of Baziaş and Oraviţa.

In 1847, a "Public Works Directorate" with four "partitions" (engineering, bridges and roads, architecture, and hydraulic works) was established in Moldova. In 1851, it was established in Muntenia the "Central Directorate of Public Works" at the Ministry of the Interior. In 1867, there were approx. 1.100 km of paved roads and in 1900 approx. 24.000 km. In 1862, the Romanian "Corp of civil engineers" was organized, transformed in 1866 into the Romanian "Technical Corp". The first law on roads and bridges was passed only in 1868 (Buiumaci 1906), law that was in force until 1906. Based on these regulations, over 25.000 km of roads (1.900 km of national roads and 23.400 km of county, communal roads) were completed between 1868–1906. The second law on roads and bridges was passed in 1906.

As regards the railway, the development of which King Carol I was concerned with assiduity, it is to be noted that in 1877 it reached 1.300 km in the Kingdom of Romania (Walachia and Moldavia), and over 500 km in Transylvania and Banat. At the beginning of the 20th century, it exceeded 3.000 km in the Kingdom of Romania, of which 1.800 km were designed and executed by Romanians.

Railway Architecture: Construction of Stations in Romania until 1916

The Romanian stations had an own monumental character generated by the operating conditions and less by esthetic considerations. For the period between the end of the 19th century and the beginning of the 20th century, stations were the main gateway to cities. From an urban point of view, the location of the stations was treated either as a head of perspective, at the end of a boulevard leading to the center usually, or by including station in the sides of a square (Popescu 2014, 2023a). Between 1869–1879, the design and construction of the railway infrastructure in Romania, including stations, was done exclusively through concession companies, such as H.B Soussberg. However, with the entry into force of the first government railway construction program (Decree 137/5 May 1882), a new typology will be promoted for the construction of stations, i.e. "CFR-style train stations". Based on the size of the settlement, four main typologies (series or families) have been established. It can be said that the CFR style was a national response of the community of architects and civil engineers to the patterns promoted by foreign concession companies, in railway architecture. Bucharest's first stations, Filaret Station (Fig. 13.37) and Târgoviştei Station (Gare du Nord) (Fig. 13.38), were terminal stations, different from those previously illustrated. *Filaret Station.* On 31 October 1869, Carol I officially inaugurated the Bucharest-Giurgiu railway line and the first railway station of Bucharest,

Fig. 13.37 Filaret Station with the platforms, 1873 (Popescu 2014)

Fig. 13.38 Târgoviştei station (North Railway Station) with the platforms, 1873 (Popescu 2014)

Filaret Station, while the North Railway Station, initially named Târgoviştei Station, was completed in 1872.

2.2.2 Works of Art: Bridges, Viaducts, Tunnels

Bridges and Viaducts on Railways
The first bridge on the CFR network was built from masonry in 1854 at Iam. On 28 December 1863, on the occasion of the construction of the Oraviţa–Anina railway line, several works of art were built: 14 tunnels (2.084 m in length), 10 viaducts (Fig. 13.39) (of an overall length of 834 m), hills breaks of a length of 21.171 m, and 102 bridges.

In general, the first bridges built on the CFR network were temporary wood bridges, such as those designed by Scarlat Ottulescu for the Buzău-Mărăşeşti line. As bridges allowed reduced traffic speeds and axle loads, they had to be replaced by stronger ones of iron structures. An example of this was the bridge over the Prut River

Fig. 13.39 Two viaducts on the Oraviţa–Anina line: Jitin (left) and entrance to Oraviţa (right)

Fig. 13.40 The bridge over Prut River at Ungheni, under construction (left) and today (right) (Popescu 2014)

at Ungheni, between Moldova and Bessarabia (Fig. 13.40), originally established as a temporary wood bridge in 1876. In 1877, the bridge was replaced by an iron one, designed and built under the coordination of Gustave Eiffel. In general, after 1882, the General Directorate of CFR begins replacing the provisional wooden bridges, action continued and intensified in the period between WW I and WW II.

In 1883, Anghel Saligny, as director of the construction sites, headed the metal bridges construction department for the replacement of wooden bridges, rebuilding, among others, the bridge over Siret, bridges over the Onesti and Urechesti and the bridges on the Buzau-Marasesti line.

Other important bridges with metal structure during this period are: the Micalaca bridge (over the Mures River), built in 1912, 350 m long, the bridge at Slatina (over the Olt River), the Bridge at Goleşti (over Argeş), and the bridge at Bărboşi (over the Siret). The Grădiştea Bridge (over the Argeş river), which collapsed during the 2005 floods, was also inaugurated in 1891.

However, the most important achievement of Anghel Saligny and the Romanian technicians and construction industry at the time is the railway bridge over the Danube, named Carol I, that linked Romania to the Black Sea, a bridge designed between 1887 and 1889 and built between 1890 and 1895. In December 1887, the government officially commissioned Saligny to develop the Feteşti-Cernavodă line project. The bridge consists, in fact, of an assembly of three bridges with a cumulated

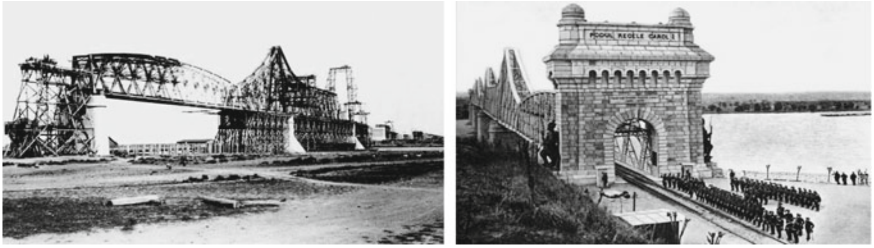


Fig. 13.41 Carol I bridge, under construction (left) and bridge entrance (right)

length of 4.088 m. At the time of the opening, this bridge *was the longest in Europe and the third in the world* (Fig. 13.41).

Road Bridges and Viaducts

Reinforced concrete bridges were first built on the main roads at the end of 19th century, and more and more from the beginning of 20th century. Innovative design solutions and advanced construction technologies have been applied. The two examples presented hereafter, among many others, demonstrate that. First, the bridge over the river Vedea at Văleni (jud. Olt), built between 1906–1911 (116 m long) (Fig. 13.42) and the bridge at Lainici, over he river Jiu (Fig. 13.43).

Tunnels

The first railway tunnels on the current territory of Romania were carried out between 1856 and 1863, on the Oraviţa–Anina line (34 km), by the Austrian firm St. E.G (Popescu 2023b). 14 tunnels were built along the route of this line in a total length of 2.092 m (Fig. 13.44). In the 60-year period from 1856 to 1916, 70 tunnels were built on the current territory of Romania, with a total length of 23.142 m, of which 53 tunnels in length of 14.937 m executed on the Austrian-Hungarian network and 17 tunnels in length of 8.205 m on the network in the Romanian principalities.

Fig. 13.42 The bridge at Văleni

Fig. 13.43 The bridge at Lainici

Fig. 13.44 Tunnels without waterproofing on the lines Oraviţa–Anina (left) and entrance portal in the tunnel Gârliştea (right) (Popescu 2023b)

2.3 Hydrotechnical Constructions

2.3.1 River Regularization and Flood Protection Works

The works started in Banat in the 18th century on the Timiş-Bega hydrotechnical system were continued, including maintenance operations and development. In the first two decades of the 20th century, a new canal development project was promoted, with the six navigation locks (kept until today) built between 1912 and 1915. Also then was built the dam at Topolovăţu Mic, the connecting channel between Timiş and Bega, the hydroelectric plant and the first turbines on Romania's current territory.

In Muntenia, works are known in connection with the defense of Bucharest against the high river discharges on Dambovita river. Extensive works for the regularisation of the Dambovita river started in 1879–1880, when the riverbed was deepened by 6 meters, with two waterfalls, one in Grozăveşti (where an electric plant was located) and another in Vitan. The systematization of the banks of Dambovişa was subsequently extended outside the city, upstream of Grozăveşti. Apart from the regularization of the Dambovişa course, in the capital city it had been put into operation in 1885 the hydrotechnical node in Brezoaiele, which was deriving the Dambovişa river flashfloods into the Ciorogârla river, while the small and medium-sized flows were allowed to flow through a canal to Arcuda, where they were treated then used as a source of drinking water for Bucharest.

Hydrotechnical works on the Danube have begun relatively late in 1875 with the construction of the first quay walls required for navigation. One of the important works, carried out between 1897 and 1902, was the planning of the Sulina branch. Another important work is the stripping of the Danube in 1895 in the Mahmudia flooded area on the left side of Sf. Gheorghe branch.

2.3.2 Hydroelectrical Works, Dams, and Reservoir Lakes

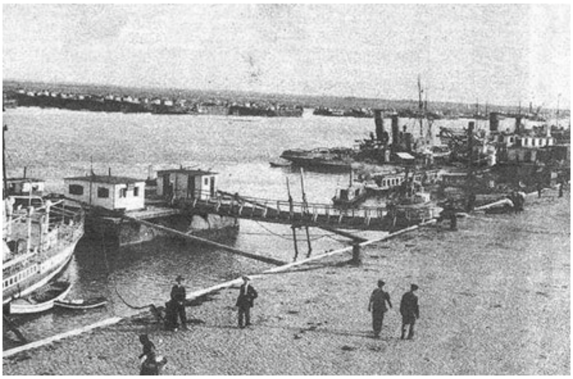
The first developments that used hydraulic power for power generation were made between 1888 and 1900, shortly after the first hydro power plants in the world. The Grozăveşti hydroelectric plant on the Dambovişa River was the first industrial hydroelectric plant in Romania (inaugurated in 1889). The first dams with significant dimensions for the river course regularization (hydroelectric, water supply) were Valiug, Sadu II, and Râşca Mică. The Valiug dam was an arc-shaped mass dam with a radius of 120 m, a height of 27 m, a base thickness of 18 m, the crown width of 3 m, and a length of 90.46 m. The dam was built from raw stone with cement and lime mortar (Cornescu 2015). The Râşca Mică dam (concrete gravity dam and stone masonry, arc shaped, 20 m high) and the Sadu II dam (stone gravity dam, arc shaped, 13 m high) were made between 1907 and 1909. It is worth mentioning the complex hydrotechnical system built on the upper Bârzava between 1902 and 1904, including several canals, 10 tunnels with a total length of 5.341 m, five metal aqueducts, with a length of 704 m, and 11 masonry aqueducts with a total length of 216 m.

2.3.3 Water Communication Routes and Port Facilities

The only interior river in which regulated navigation was practiced was Bega, in Banat, after the 18th century regularisation of this river. The Bega canal was 114 km long and spread between Timişoara and the Serbian town of Titel. The port of Timişoara has been documented since 1860 with a Port Authority and a Custom; the length of the arranged quay for barge mooring was 450 m and was subsequently extended at the beginning of the 20th century (Fig. 13.45). In 1869, the first passenger service opened and Timişoara became the first city in the current territory of Romania to use this type of public transportation. In 1912, 415.000 tons of cargo are loaded in the Port of Timişoara and are unloaded about 200.000 tons (Cornescu 2023).

Fig. 13.45 Port of Timisoara on the Bega Canal

Fig. 13.46 The quays at Brăila, end of the 19th century



The river-sea port of Brăila was Romania's largest river port at the end of the 19th century. The period between 1881 and WW I is a truly flourishing period. In this period, the port of Brăila was extended and equipped with port facilities (Fig. 13.46).

The sea port of Constanţa. Work at the Black Sea ports started in 1888 when the plans of the Port of Constanţa were drawn up. On 16 October 1896, construction works are being opened following the project of Gh. Duca and A. Saligny. The final plan foreseen a total port area of 157 ha, 7.010 m long quays, and 3.000 m long piers. A series of modern warehouses for storing grain (silos) with a total capacity of 140.000 tons (Fig. 13.47), an Electric Plant, th Port Administrative Building, and a complex containing the Maritime Railway Station and Railway Station have been built (Cornescu 2015). With these developments, the port of Constanta became the largest port at the Black Sea, with impressive values of cargo traffic at that time: Oil—797,9 thousand tons/year in 1912; cereals—556,9 thousand tons/year in 1911; wood—70 thousand tons/year in 1910 (Cornescu 2003).

Fig. 13.47 Silos in Constanţa port: drawing for one unit (left) and overview (right)

2.4 Industrial Constructions

According to the 1863 census, there were 12.867 industrial units in Romania, 7.849 of which were established between 1850 and 1863. The vast majority were workshops with small craft production, and only 51 of the large industry. The number increased to 136 in 1878 and belonged to the textile, food, timber, and soap branches. Broader development is known by the extractive and oil processing industries. The economic legislation adopted aimed to expand the process of industrial development. In this respect, the Patent Law (1863) and the Law for the establishment of Chambers of Commerce and Industry (1864) were adopted. In Transylvania, mining continues to develop, where in 1854 is established the Company of the STEG (the State Railway Company), then in 1855 the Economic Society of the Iron Plants of Transylvania and Banat and the Society for the Exploitation of the Mines and Smelting Plants in Braşov. In Transylvania and Banat, the iron and coal mining industry has developed significantly, boosting the steel industry, in Reşiţa, Bocşa, Hunedoara, and Călan.

2.4.1 Power Plants

The hydropower plant Grebla. The country's oldest hydropower plant was built between 1903 and 1904 on the Bârzava river (Fig. 13.48). The plant supplied electricity to the metallurgical plants in Reşiţa. After a 1.2 million cubic meter capacity dam was built in Breazova in 1907–1909, a hydropower group was installed here.

Filaret Power Plant, Bucharest. Bucharest's first power plant was built in 1907–1908 in collaboration with Societé du Gaz pour la France et L'Étrangère, according to French engineer Alin Lonay (Fig. 13.49).

"*Turbines*" *Power Plant in Timişoara.* Between 1907–1910 it is built at the entrance to the Fabric neighborhood the hydropower plant "Turbines". Being still in operation, the construction is one of the most beautiful *Secession* building of Timişoara's industrial heritage (Fig. 13.50).

Fig. 13.48 The hydropower plant Grebla

Fig. 13.49 Filaret power plant, Bucharest

Fig. 13.50 The hydropower plant "Turbinele", Timişoara (Cornescu and Both 2013)

2.4.2 Manufacturing Plants for Construction Materials

The first modern brick factory in Romania was the one built one in 1891 at Ciurea, near Iaşi, being equipped with German machinery (Fig. 13.51).

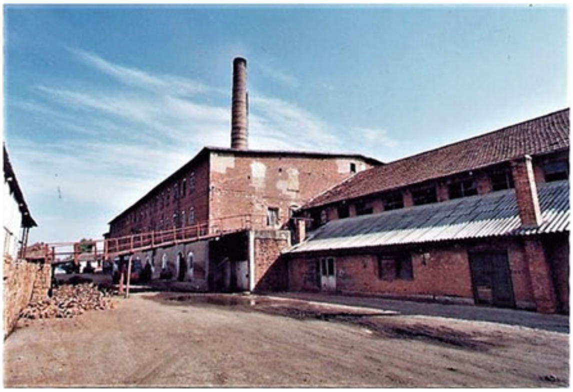


Fig. 13.51 The brick factory in Ciurea (Muzeul Ştiinţei şi Tehnicii)

Fig. 13.52 Romania's first Portland cement plant in Brăila (Stanciu 2014)

Romania's first Portland cement plant was erected in 1988 in Brăila, taking benefit from the access to Danube port (Fig. 13.52). Other cement plants, planned to cover all Romanian territory, were built in the coming decades. The construction of a *cement plant in Fieni* had been under discussion since 1912, as there were resources of raw materials in the area (limestone, clay, shale, gypsum) and fuel (coal, wood) (Stanciu 2014) (Fig. 13.53).

The first metalurgical plants on Romania's territory that produced metallic materials (cast iron, wrought iron, steel) were the ones in Reşiţa. From the second half of the 19th century, the structure of the plants halls starts to be made from iron and, in time, from steel (Fig. 13.54). In 1882, the construction of the iron Plant Hunedoara started, with the first two blast furnaces being built.

2.4.3 Production and Processing Units for the Food Industry

Located on the Danube bank, close to the port, the *Violattos steam mill* from Brăila was built in 1898, and was among the largest in Europe (Fig. 13.55). Built by Anghel Saligny, the mill was an exceptional achievement—it was the largest steam-based

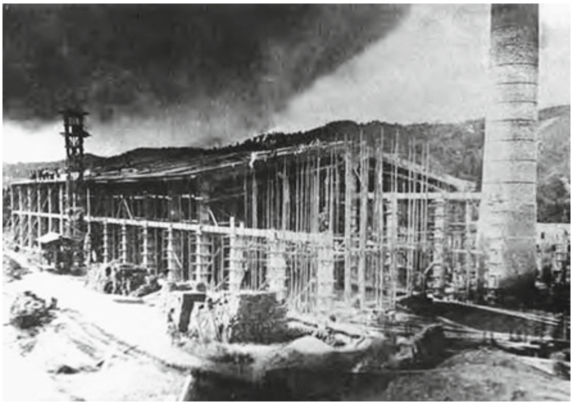


Fig. 13.53 Portland cement factory from Fieni during construction (Stanciu 2014)

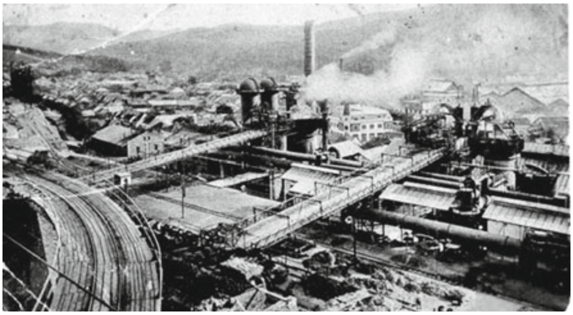


Fig. 13.54 The metalurgical plants in Reşiţa, 1893

mill in Eastern Europe. The Violattos mill was built on wooden piers, set up in clay soil and connected with concrete elements. The superstructure was made of bricks, and floors above the ground floor and the 5 levels above of metal profiles with reinforced concrete slabs.

3 The interwar Period

3.1 Urban Development in the Interwar Period

3.1.1 Bucharest—the Capital of the Kingdom of Romania

Urban Development (Pârvulescu 2003; Teică 2023; Marcu 2023a)
The capital city of Bucharest, Romania's main political, administrative, economic and cultural center, is a special place in the process of urbanization. Between 1918 and 1939, the capital's population rose from 382.000 to 872.000 inhabitants. The main

Fig. 13.55 Violattos steam mill from Brăila, 1898

explanation for this phenomenon is economic. In 1938, the city's industrial output accounted for 17% of the total production in the country (Marcu 2023b). Such an urban agglomeration required transportation systems to link the residential districts with factories. The Bucharest public transport company became the largest employer in the city and the second in Romania, after the Reşiţa Iron Works and Domains. In 1938 there were 689 tram wagons and 589 bus wagons. From 5.614 hectares in 1919, the city of Bucharest extends to 7.800 hectares in 1939. Between 1920–1934, *29.518 buildings were built in the capital, with a maximum of 3.484 buildings reached in 1928*.

By the Law for the organization of the Bucharest administration of 7 February 1926, the capital was divided into a central area, with four sectors retaining the name of the old colors (The Yellow Sector I, The Black Sector II, The Blue Sector III and the Green Sector IV) and a peripheral zone made up of the 12 suburban municipalities. Industrial areas are being consolidated and delimited: *The industrial area Gara Filaret-Rahova-September 13.* The initial core was Filaret railway station, then it expanded in all directions: East (Marasti), west (Rahova/Ferentari), north (Razoare/Military Academy) and south. *The second oldest industrial area in Bucharest is the North Railway Station—Grozavesti-Polytechnic School. The industrial area in the eastern city (Stefan cel Mare- Obor Railway Station-Pantelimon-Titan)* has developed since 1860, when several mills and bakeries have emerged, but also several construction factories. In the 1930s, the area expanded greatly by the construction of Malaxa Plants. *The Damboviţa Industrial Zone (Timpuri Noi-Văcăreşti)* is also one of the oldest industrial areas in Bucharest.

In Bucharest, it demolishes, drains, stands high buildings—the Telephone Palace (1933)—and new parks are being developed. The Baneasa Airport (1921) and the Romanian Airlines (1933) are being established. According to the plans of architect George Matei Cantacuzino, the Bank of Investments Palace (1923–1928) is raised. Between 1929 and 1934, the Telephone Palace, a 52.5 m high building, in the Art

Deco style, is built on Calea Victoriei. It was the first building with a metal skeleton in Romania and the highest construction in Bucharest until the 1960s.

After the plans of architect Horia Creangă, more than 70 major buildings are being built, including Giulesti Theater, Malaxa Factories, Mihai Bravu School Group, Burileanu-Malaxa Bloc, the famous ARO building, built in 1929, or Hala Obor, built in 1936 with concrete encased welded steel structure and concrete foundations. The monumental building of the Faculty of Law of the University of Bucharest was built between 1933 and 1935 according to the plans of another great architect, Petre Antonescu, the architect of the Arch of Triumph memorial. The memorial, originally built of wood and stucco in 1922, is being rebuilt and inaugurated on 1 December 1936. Athénée Palace, the most elegant Bucharest hotel, built according to the plans of architect Teophile Bradeau in 1912, *the first multi-story building in Bucharest to use the reinforced concrete*, was transformed and upgraded in 1937 by architect Duiliu Marcu. It was built intensively, especially in the city center: The Carlton block at the end of the Royal Street (collapsed at the 1940 earthquake), the Wilson Block, the Union Hotel or the *Adriatica Building* on the bank of Damboviţa. In 1936, Carol II National Park (today Herăstrău Park) is being arranged on a land of 187 hectares. On 8 June 1938 the Pavilion of Television was opened. The construction of the *Royal Palace* (today, the National Art Museum) is completed in 1937. Already in 1923, the central area was illuminated using electricity on more than 20 streets, dozens of others with gas or oil. In 1925, the first bus line was opened between the Calaraşi Barrier and the Sfântu Gheorghe square. The last trams with horses are put out of use in 1929.

Bucharest North railway station has been undergoing a process of enlargement and reorganization. The Locomotive and Wagons Repair Workshops were established within the station. The project for enlargement and modernization was carried out between 1930 and 1932 by architect Victor Ştefănescu. The new building, as it looks today, has a monumental facade, designed in a modern neoclassical style (Fig. 13.56). The systematization of train arrival/departure lines has been carried out, increasing their number from 10 lines to 16 lines (two of them will be later disbanded). The entire area of the North Station has been systematized starting with the site of the old repair workshops.

Below are presented some of Bucharest's iconic boulevards and squares, to illustrate the extent of urban development:

– *The Royal Palace Square in 1941* (Marcu 2023c. https://www.facebook.com/BucurestiRealist/photos/. Accesed May 2023). Fig. 13.57 shows the Royal Palace with a wing still under construction (the one currently hosting the Art Museum), on the right is the Athenee Palace Hotel.
– *Calea Victoriei* (Fig. 13.58). Numerous public and private buildings with architectural and historical value were spanned along the Calea Victoriei. Among them: Royal Palace, National Theatre, Adriatica Building, Telephone Palace, Stirbei Palace, Grand Hotel Continental, CEC Palace.
– *Telephone Palace* (Fig. 13.59), located on Calea Victoriei, 52.5 m high, was built between 1929–1933, with features representative of the Art Deco style. The

Fig. 13.56 Bucharest North railway station, main entrance with the monumental portico

Fig. 13.57 Royal palace square (aerial view, 1941)

Fig. 13.58 Calea Victoriei, 1930, with the national theater and adriatica building

building project was entrusted to a team of three foreign architects: Louis Weeks, Edmond van Saanen Algi and Walter Froy. The steel structure was provided by the Iron Works and the Domains Reşiţa (UDR). The official opening took place on 24

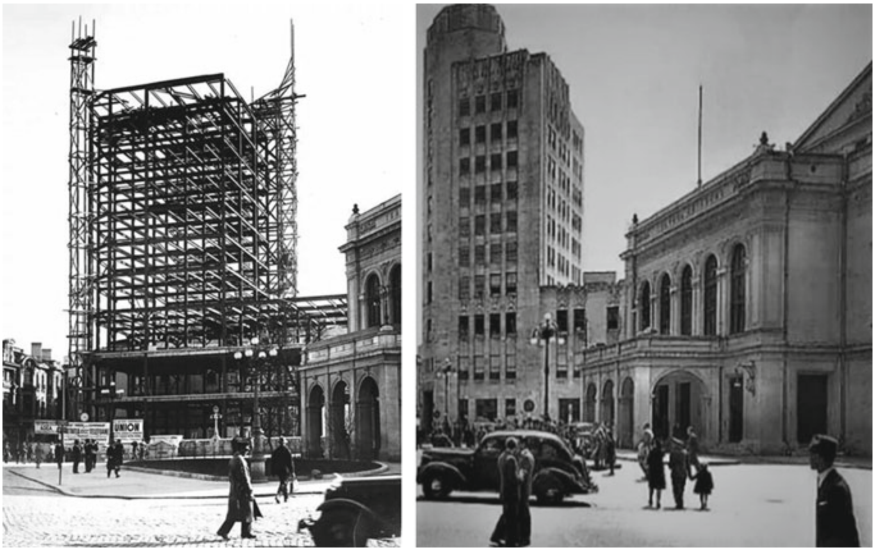


Fig. 13.59 Telephone palace, 1935: steel structure (left) and after completion (right) (Marcu 2023a)

April 1933. The building was extended in 1940 and 1946 and resisted earthquakes in 1940, 1977, 1986 and 1990.

- *Magheru Boulevard.* Designed around 1900, the avenue was to be a part of the North-South bus between Piaţa Romana and the Şerban Vodă street. Between 1923–1930, 10 to 12 story buildings are built in Masonry infilled reinforced concrete frames, with Mining Credit and Carlton building blocks being illustrative examples (Fig. 13.60). But the latter, which opened in 1936, collapsed at the earthquake in November 1940. Between 1930 and 1938, the ARO block and cinema, Scala building and the two famous hotels, the Ambassador and Lido were built.

3.1.2 Buildings with Innovative Constructive Solutions in Interwar Romania

- *Victoria Palace.* Built between 1937 and 1944 according to the plans of architect Duiliu Marcu, the building, with an area of 26.000 square meters, was originally intended to host the Ministry of Foreign Affairs (Fig. 13.61). A Neo-Romanian architecture style promoter, Duiliu Marcu joined the modern current in 1930. The building facade was made with Carrara marble, and at the interior with Ruşchiţa, Botticino, Carrara, Issorie and Verona marble. The building was damaged by the 1944 bombing and the works were completed in 1952.
- *CFR (State Railways) Palace* (Fig. 13.62). The CFR Palace is in the south of the North Station square. The project was carried out under the leadership of architect Duiliu Marcu, who also included architects Ştefan Călugăreanu, Paul Emil

Fig. 13.60 Magheru Boulevard in the 1930s with mining credit (left) and carlton building (right)

Fig. 13.61 Victoria palace, main facade (Marcu 2023d)

Miclescu and Theonic Săvulescu. The structural system, made from concrete encased welded steel frames, was an innovative technology at the time. The design and execution of the structure was carried out by the UFD Reşiţa, the coordinator of the work being the young engineer Dan Mateescu, a graduate of the Royal Technical Higher School of Charlottenburg in 1935. Dan Mateescu will later become an academician and founder of the well-known Steel Constructions School in Timişoara. The completion of the work, with the interruption caused by the war, lasted from 1937 to 1948.

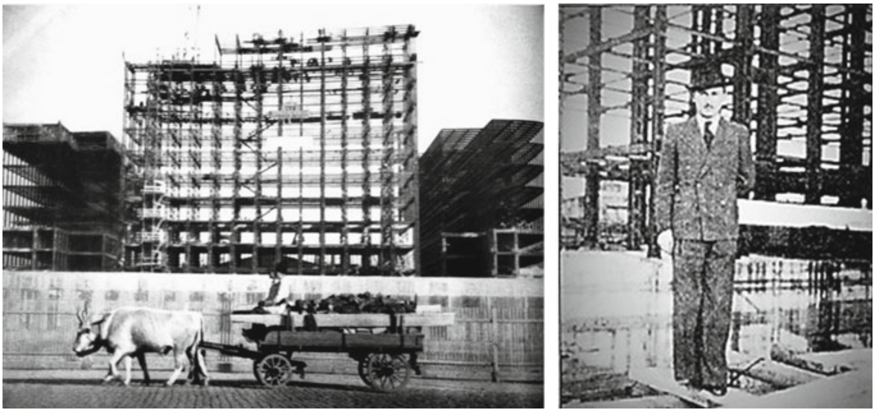


Fig. 13.62 The steel structure of the CFR palace under construction (left), and engineer Dan Mateescu on the construction site (right)

3.1.3 The Capitals of Historical Regions

Chişinău

Urban Development and Infrastructure

Chişinău, the capital of the historical province of Bessarabia prior to the unification with the Kingdom of Romania (1918), was the residence of the Lapuşna county. Through this place, the trade road was passing to Tighina and in Târgu Lăpuşna customs was being given. The population of the county was 421.857, of which urban 121.752, Chişinău with 117.016 inhabitants (Ivănoiu and Gheorghiu-Bradley 2023a).

Industry and transport infrastructure. In the county there were 55 companies, mostly concentrated in Chişinău, in the industries: food, textile, chemical, metallurgy, paper, leather, wood, construction materials, glassware.

Roads. The county was crossed by a total road network of 751.85 km, distributed as follows: national roads 251.7 km; county roads 490.4 km; municipal roads 9.6 km.

Railways. The county of Lăpuşna was crossed by a total 119 km railway network, of which 61 km simple main lines and 58 km simple secondary lines. Main itineraries: Express trains Bucharest–Iaşi–Chişinău (Kiev, Moscow).

Air navigation. In 1927, the first air route was made on the Chişinău–Bucharest route and in the coming years in Chişinău the passenger airport was built. Here was the L.A.R.E.S. air navigation line with departure and arrival from/to the Chisinau aerodrome. Itineraries: Bucharest–Galaţi–Chişinău and Cernăuți–Iaşi–Chişinău–Cetatea Albă.

In 1930 in Chişinău there were electric plants, water works, water pipes, sewage, public transport, electric trams, and paved streets (in the central area).

Public Buildings and Outstanding Construction Work

The City Hall of Chişinău (Fig. 13.63) is a monument of architecture and history, built in an eclectic style inspired by the Italian Renaissance architecture. *The railway station Chişinău* was built in 1871 according to the plans of the architect Heinrich Lonsky (Fig. 13.64).

Cernăuţi

Urban Development and Infrastructure
The capital of Bucovina, Cernăuţi, was also the capital of the county with the same name. According to the 1930 census, the county population was 305.097 inhabitants, of which in 130.205 in urban areas, the majority of 111.147 living in Cernăuţi (Ivănoiu and Gheorghiu-Bradley 2023a).

Industry and Transport Infrastructure
The industrial enterprises of the county were in the following industries: food, textile, chemical, metallurgy and construction materials.

Roads and Rails. The county of Cernăuţi was crossed by a road network of 833 km with bridges of 3330 m cumulative length. The total length of rail lines crossing

Fig. 13.63 The city hall of Chişinău in 1930

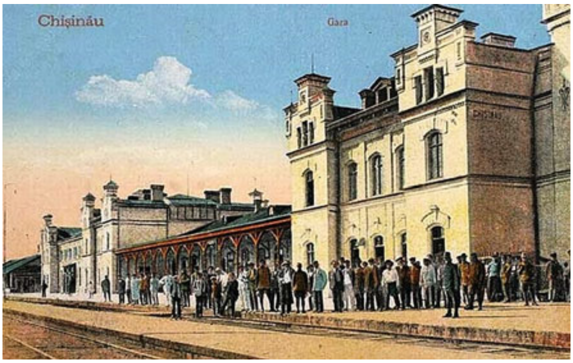


Fig. 13.64 The railway station

the Cernăuţi county ammounted 253 km, with links to Bucharest, Warsaw, Berlin, and Moskow.

The Bucovina capital was one of Romania's most interesting cities. The city's urban infrastructure included a power plant, 3 water plants, 70 km water network, 70 km sewage network, paved streets, and electric tram public transport (Ivănoiu and Gheorghiu-Bradley 2023a).

Public Buildings and Outstanding Construction Work

Among the many beautiful buildings of the city, the Metropolitan Cathedral, hallowed in 1882 and built in mauro-Byzantine style by the Czech architect Iosif Hlavka (Fig. 13.65) must be remembered. The list can be continued with the Central Square and City Hall (Fig. 13.66), the Orthodox Cathedral, the Dramatic Theater, the Chamber of Commerce and Trades, the State Philharmonic, etc. In the interwar period, in Cernăuţi both public and residential buildings have been built. These include: the Romanian Cultural Palace; the Airport, 1937; the new headquarters of the Social Security House, inaugurated on 18 June 1937; the telephone Palace, 1937. *The National Romanian Cultural Palace* is the work of architect Horia Creangă (Ivănoiu and Gheorghiu-Bradley 2023b). The construction started in 1937 and ended in 1939. The reinforced concrete structure, very modern for that age, with columns, diaphragms and coffered ceiling, with a large glazed facade, was the first in Romanian space.

Iaşi

According to the 1930 census, the Iaşi population was 102.872, in a region with 276.200 inhabitants. Between 6 December 1916 and November 1918, Iasi was *de facto* capital of Romania, the war capital, following the occupation of the German armies of Bucharest. Iaşi has played a key role in the formation of Romania, which shows the quality of the social environment, of political and intellectual elites in particular (Ivănoiu and Gheorghiu-Bradley 2023a). In the interwar period, the dynamics of urban development and infrastructure was lower than the one that was seen after the Unification of the Principalities.

However, it is worth noting the completion of the Justice and Administration Palace in 1925 and other public institutions such as the "Gh. Asachi" Polytechnic,

Fig. 13.65 Cernăuţi, metropolitan cathedral

Fig. 13.66 The "union square" and city hall

the Palace of the University Foundation "King Ferdinand I", currently known as the Central University Library "Mihai Eminescu", built between 1930 and 1934, being designed by architect Constantin Iotzu and built by engineer Emil Prager, a Romanian promoter of reinforced concrete. Below are some images of the interwar Iaşi (Figs. 13.67, 13.68).

Fig. 13.67 Lăpuşneanu street

Fig. 13.68 Cuza Vodă square

Fig. 13.69 Union square (Central), 1939

Cluj

According to the 1930 census, the Cluj population (today Cluj-Napoca) was 104.019, out of a population of the county of 333.545. The interwar period was an important moment for the city in its urban and architectural development. The installation of the new Romanian administration in 1919 and the opening of the city to the Romanian population in Transylvania and the old Kingdom have led to an increasing demographic evolution. In addition, the role of the important academic and university center that the Cluj city has won during this period (Gusti 1938) is also added.

Representative Public Spaces (Antonescu 1963)

At the beginning of the interwar period, the main public spaces in Cluj were those existing prior to the war: Carolina Square (now the Museum Square), The Union Square (Central) (Fig. 13.69), Cuza Voda Square (renamed Avram Iancu), Mihai Viteazu Square and Lucian Blaga Square.

The Metropolitan (Orthodox) Cathedral in Cluj, situated in Avram Iancu Square, was erected between 1920 and 1930. It is one of the main religious buildings in Cluj and is dedicated to the Assumption of the Virgin Mary (Fig. 13.70). On October 7th, 1923, the cornerstone of the cathedral was laid, attended by the Romanian crown prince Carol II and Prime Minister Ion I. C. Bratianu. The cathedral construction lasted ten years.

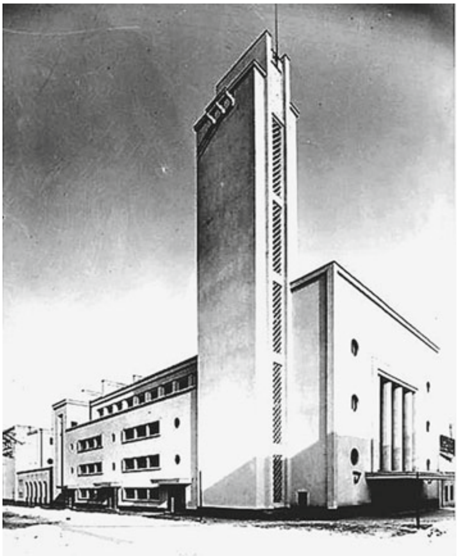
In the case of multi-story buildings, concrete began to gain ground from brick masonry walls and metal structures had not yet gained momentum. Two representative examples are presented below:

The Academic college "Carol II" building, designed by arh. George Cristinel. The work started in 1934 and was completed in 1936 (Fig. 13.71).

P+3 collective housing, Avram Iancu Street number 3, Cluj (Fig. 13.72). The work was carried out in 1932 according to the plans of architect Tiberiu Niga (Antonescu

Fig. 13.70 The Metropolitan Cathedral in Cluj, completed (left) and during construction (right) (Antonescu 2023a)

Fig. 13.71 Academic college "Carol II" (Antonescu 1963)



1963). The floor plans include two apartments on a level, arranged around an inner courtyard to which secondary functions are directed.

Fig. 13.72 Collective housing (Antonescu 1963)

Timişoara

The interwar period has meant for Timişoara a period of remarkable economic, cultural, and spiritual progress. Integrated in *Greater Romania*, Timisoara has become a modern urban center with a complex and dynamic public life. In the social-economic landscape, dozens of industrial enterprises, commercial establishments, banks, offices, dozens of educational establishments in Romanian, Hungarian, German, Serbian, Hebrew language have been built. In 1930, after the provisional census data of that year, the municipality of Timisoara had 91.866 inhabitants. On 15 November 1920, Timisoara became the university center by decree signed by King Ferdinand I, setting up the University of "Polytechnic School".

Public buildings new or rehabilitated in the central area of Timisoara in the interwar period.

The architecture of the new buildings built in the interwar period has kept some decorative elements spread at the beginning of the century, but the Neo-Romanian style, then the modernist and the cubist, became dominant. More and more projects have been entrusted to Romanian architects from Timisoara or Bucharest (the most known being Duiliu Marcu).

The Palace of Culture: Opera and Theater House in Timisoara. The original construction, in a Renaissance style, carried out in accordance with the plans of the Vienese Helmer and Fellner architects, was put into use in 1875. Two major fires devastated the building, first in 1880, and the second in 1920. The reconstruction was carried out under the coordination of architect Duiliu Marcu and lasted until 1928. Fig. 13.73 shows the actual façade, in the form of a triumphal arch.

The Polytechnic School Buildings. Timişoara Polytechnic School was established by Decree of 11 November 1920, signed by King Ferdinand I. On 11 November

Fig. 13.73 Final facade of the the palace of culture, 1936 (Antonescu 2023b)

1923, the complex of the Polytechnic School was inaugurated in the presence of King Ferdinand I and Queen Maria. The main building (Fig. 13.74), the residence hall, the canteen and the laboratories, designed by Duiliu Marcu, are distinguished by their proportion and architectural harmony.

Metropolitan Cathedral. The Metropolitan Cathedral of Timişoara is the largest religious building in Timisoara, dedicated to the Three Saint Hierarchs (Fig. 13.75). It was built between 1936 and 1941 and has a height at the top of the cross of 90.5. The cathedral project has been entrusted since 1934 to architect Ioan Traianescu. The construction began in 1936 and was completed in 1941. The Cathedral was consecrated on October 6th, 1946, in the presence of King Michael I of Romania, who is also one of the founders of this church.

Constanţa

Urban development and infrastructure. After Dobrogea became part of Romania (1878), Constanţa experienced a period of extensive urban development (Fig. 13.76). According to the 1930 census, the population of Constanţa was 58.258 inhabitants,

Fig. 13.74 First building of the polytechnic school

Fig. 13.75 Ferdinand square after the construction of the metropolitan cathedral

and of the county with the same name of 249.914 (of which in urban 79.663). The city, named by King Carol I "the Romanian lung", became the country's main port after Anghel Saligny built the Cernavodă Bridge (1895). In the interwar period, the port has a continuing development. In 1937, freight traffic through the Port of Constanţa (Fig. 13.77) placed the city among the first in Europe. Roads and railways linking Constanţa to Bucharest and the rest of the country were built. During this period, maritime traffic has exceeded 6 million tons of goods per year. In this period was also built the shipyard, which was the region's strongest company till the World War II.

The Maritime Station, connecting Constanţa with 17 other Black Sea and Mediteranian ports, is one of the representative interwar buildings of Constanta, performed in the style *Art Deco*. The initial project was carried out in 1930 by architects Gheorghe Brătescu and Crizantema Stamatescu, and the building wass completed in 1935. The station had a dual role: it was both the maritime station and the railway station, being the European end for the famous Orient Express train.

The Ovidiu Square, together with Port and Casino, is part of the urbanistic emblem of Constanţa. In 1921, in the Ovidiu Square was erected the new City Hall, in an exceptional neo-romanian style.

Fig. 13.76 The peninsular area with Carol I mosque and the Archbishop's palace (Roman 2023a)

Fig. 13.77 The passengers port of Constanta, 1930

3.2 The Transport Infrastructure

3.2.1 Railway Network

Repair of Borcea Bridge. The World War I resulted in large destruction of the railway network and the locomotive and wagon fleet. The number of locomotives decreased by 71% and the number of freight wagons decreased by 85%. Under these circumstances, the General Directorate of CFR had to solve the restoration of destroyed infrastructure, the restoration of circulation, and administrative unification.

The first measures to re-establish circulation were for the connection with Moldova through Feteşti-Făurei-Bărboşi-Galaţi-Bârlad. At the same time with the re-establishment of the railway link with Moldova, work has also started to re-establish the railway traffic between Bucharest and Constanţa. Rail traffic has resumed rapidly, but with transshipment at Feteşti where the bridge over the Borcea branch (Danube) had been destroyed (Fig. 13.78) (Roman 2023b). To restore the traffic on the Bucharest-Constanţa railway, it was necessary to execute a new superstructure for the 3 spans of the bridge (each with a length of 140 m) (Fig. 13.79). The bridge circulation was resumed in December 1921. This work is considered the most important in the field of bridges in Romania between WW I and WW II.

3.2.2 Road Network

After World War I, due to lack of maintenance, almost all the roads were severely damaged. *The Road Act* of 2 August 1929 will come up with a series of provisions aimed at improving the organization of road maintenance and execution, specifying the duties and responsibilities of the factors involved. In 1930, the national road network comprised 12 roads of approximately 12.785 km in length, of which 466 modernized and 11.818 km paved (Kaliani 2018). *The Road Act* of 22 April 1932

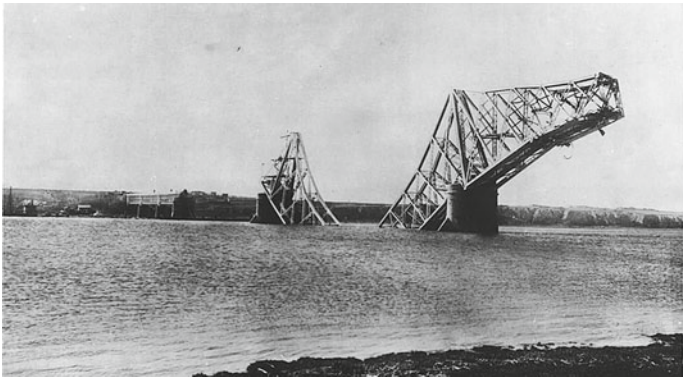


Fig. 13.78 The main structure of the Borcea Bridge with 3 × 140 m spans over the riverbed, destroyed by the Romanian army in its retreat (Iordănescu and Georgescu 1986)

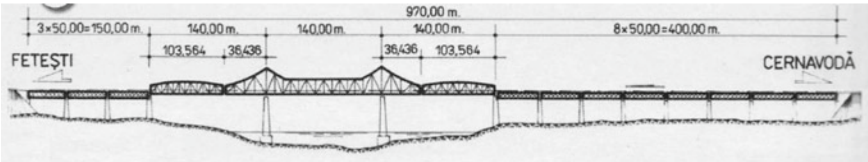


Fig. 13.79 The bridge over the Borcea branch with the new structure over the riverbed (3 × 140 m) (Florea and Ionescu 2012)

abolishes the Autonomous House of State Roads and establishes the General Directorate of Roads under the Ministry of Public Works and Communications. According to the new law, public roads are classified as *national, county, and municipal roads*. The width of the road area according to the provisions of the Law of 1906, respectivelly 20 m for national roads, 15 m for counties, and 10 m minimum for municipal roads is maintained. 77 roads are classified as national roads, amounting to about 13.850 km. Table 13.1 summarizes the state of public roads in the inter-war period, taking as reference the year 1915, before Romania's entry into the war.

Table 13.1 The situation of public roads in Romania (without local street network) between 1915 and 1939 (Iordănescu and Georgescu 1986)

Nr. Crt.	Year	Total	From which							
			National roads				County/municipal roads			
			Total km	Types of road surface			Total km	Types of road surface		
				Modern	Paved	Earth		Modern	Paved	Earth
1	1915	44.222	4.162	–	3.873	289	40.060	–	34.138	15.121
2	1930	103.360	12.785	446	11.818	521	90.575	–	46.939	44.520
3	1939	108.281	13.850	1.791	11.904	155	94.441	–	54.300	40.141

3.3 *Industrial Constructions*

3.3.1 Benchmarks of Romania's Industrial Development in the Interwar Period

After World War I, the industry was supported by the State by increasing the role of the Reform Directorate from the Ministry of Industry and Trade, created in 1919 and the establishment of the Industrial Credit Company in 1923. The results of this industrial policy were the establishment of metalworking companies: Câmpia Turzii wire factory in 1922, Titan-Nădrag-Călan Plants in 1924, Copşa Mică-Cugir in 1925, and machine makers Malaxa and I.A.R. Braşov in 1926. The growth rate of the industry was 5.4% per year, considered one of the highest in the world at that time. Romania was among the world's advanced states in the oil industry, the production of locomotives, wagons, and airplanes (Kaliani 2023a). In addition to the Malaxa Plants, the welded tube manufacturers also benefited from state aid through loans and orders. In Bucurestii Noi, a rolling mill plant, Laromet Ford-Romania, based in Floreasca, is being established.

The development of the industry was accompanied by the construction of new buildings, industrial installations and facilities, plants, and factories. The most important examples are the heavy and energy industry—machinery, metallurgy and oil. For these industries, steel structures are characteristic. For a country whose *construction culture* was mainly based on masonry, the metal construction, validated by the construction of spectacular bridges but applied also at the construction of civil and industrial buildings, was a new technology, being itself part of technological progress and implicitly of Romania's development. Then, it has increasingly begun to make room in industrial constructions for reinforced concrete, not only through frame structures but also through shell and arch structures.

Apparently, the industrial construction sector is less spectacular for the architectural creation, but in general it benefits from a significant creative impetus at the time. Among the notable works that allowed the registration of industrial buildings among the real architecture creations are those carried out by Horia Creangă, for Malaxa company, in Bucharest. This is the Main Entry 1931–1932 (Fig. 13.80), the Pipe Factory 1935–1936, or the Administrative Pavilion, 1936.

The contribution of other architects to the transformation and development of industrial buildings to works that give them the status of modern industrial architecture should also be noted.

The functional trend and esthetic innovation are found in a large range of industrial-thematic works such as (Kaliani 2023b): Workshops and Annexes of the Griviţa (Fig. 13.81), Bucharest 1930–1940, architect Maria Cotescu; IAR factory (Fig. 13.82), 1937, architect G.M. Cantacuzino; Export Slaughterhouse from Constanta, 1933–1934 (Fig. 13.83), architect Nicolae Nenciulescu.

Fig. 13.80 Malaxa complex in Bucharest, 1940

Fig. 13.81 Griviţa workshops in Bucharest, 1930–1940

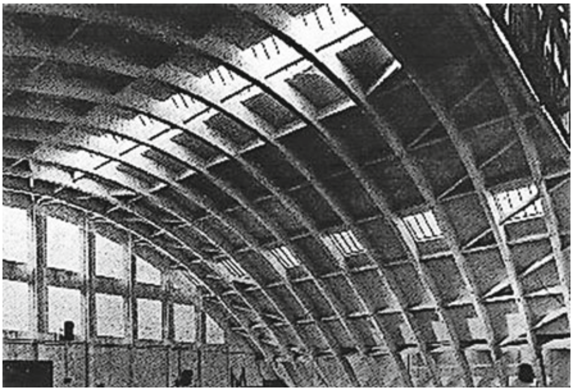


Fig. 13.82 Hangar at IAR Braşov

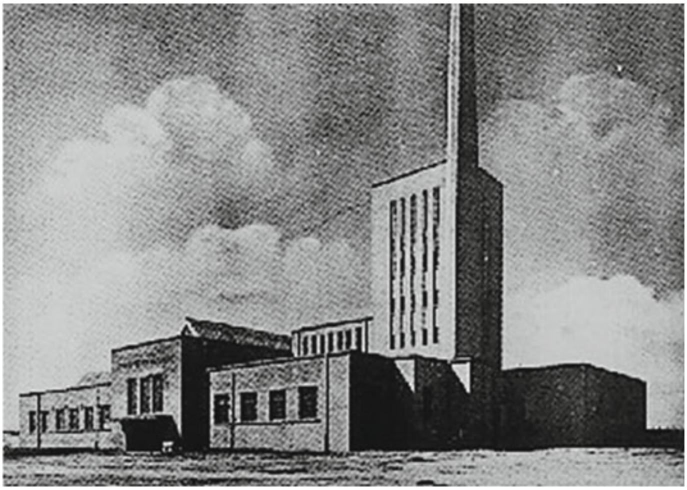


Fig. 13.83 Export slaughter house, Constanţa

4 Period 1948–1989

4.1 Higher Education and Civil Engineering Schools

Institute of Civil Engineering of Bucharest
In the autumn of 1948, following the reform of education, the Construction Faculty came out of the Polytechnic School forming a self-standing institute—the Institute of Civil Engineering Bucharest ICB. A year later, the Institute of Architecture and Civil Engineering is established with four faculties: Civil and Industrial Buildings, with specializations Civil and Industrial Buildings and Installations; Bridges and Massive Construction with specializations Bridges and Hydrotechnical Constructions; Roads and Public Works; Architecture and Urban Planning. In 1955 the Geodesy Department is established, to which a Machineries for Constructions/Technologic Equipment for Constructions specialization will be added. Ultimately, these specializations will work in the ICB until 1990.

Faculty of Civil Engineering from the Polytechnic Institute of Timişoara
In 1948, the faculty operated with two specialized departments, Civil and Industrial Buildings, and Hydro-Technical Constructions. In the academic year 1953–1954, the Water Supply Department is established, then in 1957 the Civil and Industrial Buildings becomes Civil, Industrial and Agricultural Buildings, and Hydro-Technical Constructions and Water Supply specializations are merged into Constructions and Hydro-Technical Installations.

In 1962 a section in Agricultural Hydrotechnics is established and in 1963 the Road and Bridges section is established. In 1970, the section of Conductor Architects with a 3-year duration is established, which runs until 1982. Starting with the academic year 1977–1978, the specialization of Installations in Constructions is set up within the faculty.

Faculty of Civil Engineering from the Polytechnic Institute of Iaşi
In 1949, the specializations at the Faculty of Civil Engineering in Iasi were Civil and Industrial Buildings and Roads and Public Works. The Civil and Hydro-Technical Installations section was established in 1961, which was transferred to the Faculty of Hydrotechnics, newly established within the Polytechnic Institute of Iasi on 1 October 1963. In 1977, an engineering department with the specialization of Installations in Constructions is established.

Faculty of Civil Engineering from the Polytechnic Institute of Cluj-Napoca
In 1953, the Polytechnic Institute of Cluj-Napoca was established, of which the Faculty of Civil Engineering and Installations with specialization Civil, Industrial and Agricultural Buildings is also part. In 1970, the section of Conductor Architects is established within the faculty. In 1971, the Railways, Roads and Bridges department—full-time engineers and Installations in Constructions for sub-engineers are established.

Since 1977, two Civil Engineering specialities have been operating at the Constanta Higher Education Institute: Hydro-Technical Constructions and Land Reclamations in short-term education. The institute, which became the Institute of Sub-Engineers Constanta, operated until 1990. In this context, one can see a good coverage of schools for civil engineering and related specialities.

4.2 R&D Activity in Civil Engineering

4.2.1 Civil Engineering and Research Schools

When we talk about "*Research and Engineering Schools*" in the context of this section, we refer to personalities and academic groups who have created science and methods of application in specific professional-scientific fields, formed leading specialists, who have gained, through the results achieved, recognition as "*schools*" by national and international scientific and professional communities. Some of such Romanian S*chools* are selectively presented below.

Earthquake Engineering and Structural Safety School (Şerbănescu and Sandi 1972; Vlad 2007)
The starting point for seismic engineering in Romania was the 1940 Vrancea earthquake (10 November 1940). This was the strongest intermediate-depth earthquake in Europe in the 20th century. The earthquake has had devastating effects in epicentral areas, has seriously damaged many buildings in Bucharest and caused the collapse of

one of the capital's largest and most modern concrete buildings, known as the "Carlton Building". Following the earthquake, for the first time in Romania the problem of "*building safety under seismic actions and defense against their effects*" was raised. *Founder of the School of Seismic Engineering in Romania*, professor Aurel Beleş has drawn up the *first manual of seismic design of buildings*, published in the "Polytechnic Society Bulletin" in 1941 in the form of a brochure titled "*Earthquake and constructions*". The second book, "*Elements of engineering seismology*", published in 1962 at the Technical Publishing House (together with Mihail Ifrim), will strengthen its founding position of this *School*. At the time of the publication was the first print-out paper in Europe and among the few published worldwide.

Since the academic year 1977/1978, the "*Seismic Engineering*" course has been introduced for the first time in higher education as a compulsory discipline, thought by Professor Mihail Ifrim, who in in 1973 published the volume "*Dynamic analysis of structures and seismic engineering*".

The research teams in the field of seismic engineering within the ICB's "*Department of Mechanics*" were leaded between 1960–1990 by professor Ştefan Bălan, a Member of the Romanian Academy, professor Sanda Hangan, and professor Mihail Ifrim.

As part of the work to regulate the design of the construction works at the seismic action, it is worth mentioning the name of professor Alexandru Cişmigiu and engineer Emilian Ţiţaru, who played a decisive role in the beginning of the Earthquake Engineering in Romania. In 1953, the State Committee on Architecture and Building (CSAC) was established (after 1959 the CSCAS State Committee on Construction, Architecture and Systematization), which was responsible for "*ensuring the development of standards in the field of architecture, construction and construction materials*".

In 1954, Alexandru Cişmigiu and Emilian Ţiţaru drafted the "*Regulatory document for the design of industrial, civil and rural constructions, located in the seismic regions of Romania*", which was not published officially; they elaborated between 1958–1960 "*the background theory for building design under seismic action*", which which was presented in 1960 at the second World Conference on Earthquake Engineering held in Japan (2WCEE).

The first anti-seismic design code entitled "*Conditional code for the design of civil and industrial buildings in seismic zones P13-63*" will be published by the CSCAS in 1963 and the next edition P13-70 in 1970. In both cases, the design spectra were totally unsuitable with the specific seismicity of Romania, and this will be seen at the earthquake on 4 March 1977. A new Code, P100-78, followed by an improved version P100-81, which substantially changes the design spectrum, will be developed in 1978. However, this will change after 1990, as the lower PGA value for the P100-78/81 spectrum was not justified.

A new generation of specialists has started to assert themselves and take the lead since 1980. Here are professors Liviu Crainic and Dan Lungu from ICB, dr.ing. Horia Sandi from INCERC Bucharest and, of course, Professor Victor Gioncu from INCERC Timişoara. It can also be mentioned here that the Center for Earth Physics (CFP) was set up in February 1977 by merging the Seismology Department at the

Romanian Institute of Geology and Geophysical with the Geodynamic Laboratory at the Romanian Academy.

School of Reinforced Concrete Constructions in Bucharest

The founder of the school for Reinforced Concrete Constructions in Romania is Professor Mihail Hangan (1897–1964), a graduate of the National School of Bridges and Roads in Bucharest in 1922. Hir career in higher education began in 1926 at the Polytechnic School of Bucharest. In 1938, he defended the doctoral thesis entitled "Concrete shrinkage and its influence on the adhesive strength", then became the first head of the Reinforced Concrete Department. From 1929 to 1964 he taught the course of Reinforced Concrete at the Polytechnic School and then at ICB, the Faculty of Civil and Industrial Buildings. It is also worth mentioning the participation of professor Hangan in the elaboration of the first prescriptions for the design and execution of reinforced concrete constructions (in cooperation with Professor Ion Ionescu Bizeţ, ing. Anton Chiricuţă, acad. prof. Cristea Mateescu). The outstanding reputation of the Bucharest reinforced concrete school continued by contributions from professors George Călin (1909–1980), Dan Dumitrescu (1925–2004), and Radu Agent (1925–2000).

Speaking about a *Romanian School of Concrete Construction,* particularly with reference to scientific research, the contributions of the team from the Faculty of Civil Engineering in Timisoara, coordinated by professor Constantin Avram, corresponding member of the Romanian Academy, must be highlighted: professor Ioan Filimon, in *low reinforcement ratio concrete*; professor Ovidiu Marsu in *special reinforced concrete structures,* and Decebal Anastasescu in *framed structures*. From Cluj-Napoca, the contribution of Professor Mircea Mihăilescu (1920–2006) in reinforced concrete shells needs to be highlighted, too.

Finally, in the context of the phrase *Romanian School of Concrete Constructions*, we must mention *engineer Emil Prager* (1888–1985), graduate of the School of Bridges and Roads in Bucharest in 1912, promoter of the use of reinforced concrete in construction with complex structures, contractor, designer and expert, representative of the *school* through his expertise and creativity.

School of Steel Constructions and Structural Stability in Timişoara (Dubină 2013; Mateescu et al. 2000; Dubina and Ungureanu 2014)

The emergence and development of metallic constructions in the western part of Romania, and in particular in the historical territory of the province of Banat, was stimulated and influenced by the emergence and development of the metal industry in this area at the beginning of the 17th century. The first plant set up here in 1771 by the Austrian authorities was the metal plant in Resita. In 1884, the Iron and Steel Plants in Hunedoara were established. A steel work and bridge workshop, which included a design office at the time, was operating at the Resita-based plant. This is where the professional career of young Dan Mateescu began in 1935, after graduating at the Berlin Polytechnic School, Charlottenburg. After 13 years of industrial career in design and execution, Dan Mateescu has been appointed in 1948 as full professor at the Faculty of Civil Engineering from the Polytechnic School of Timişoara.

Synergies between design, research, and education was the paradigm of the Timişoara school. Among the works that have made the fame of the team led by professor Mateescu are the dome of the Bucharest Rom-Expo pavilion (Fig. 13.84), in 1963, structures of the machinery room at CHE Porţile de Fier I (Fig. 13.85) and II, structure of the Prague North Power Plant, sports hall and covered velodrome in Tripoli, Libya. Professor Dan Mateescu was to become the first head of the Department of Steel Structures at Timişoara, established in 1952. Under his guidance and initiative, the Laboratory of Steel Structure, the first of its kind in Romania, was built in 1959. From the team of collaborators coordinated by professor Dan Mateescu, we mention those who acted, during the period we refer to, as responsible for research topics and/or large projects: professor Iosif Appeltauer, Ionel and Eugen Fleşeriu, Marin Ivan, Eugen Cuteanu, Gheorghe Mercea, Ioan Caraba, Liviu Gădeanu. To these is added the team from INCERC Timisoara of Victor Gioncu and Nicolae Balut.

Since 1973, the National Conference of Metal Constructions, a scientific event with international participation, was organized in Timişoara, as a forum between *education, research, design, and execution*. In October 1982, the first session of the 3rd International Stability Colloquium, organized by the Structural Stability Research Council (SSRC) of the United States in collaboration with the European Convention for Constructional Steelwork (ECCS), was held in Timişoara. Shortly after this event,

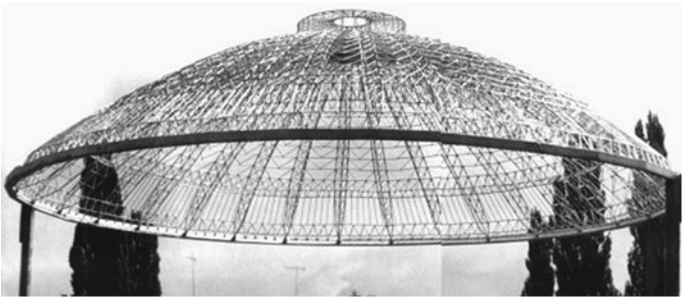


Fig. 13.84 The small-scale model of the Rom-Expo dome, tested in the Steel Structure laboratory

Fig. 13.85 Steel reticulated structure at CHE "Portile de Fier I", the first application of such a solution in the country

in 1984, the Stability Commission of the Romanian Academy was set up in Timişoara, under the chairmanship of academician Dan Mateescu.

The Main Scientific Contributions of Timisoara School of Steel Structures in the Field of Structural Stability (Mateescu et al. 2000; Dubina and Ungureanu 2014)
Stability of Bar Structures, Particuraly in Thin-Walled Members.

Some of the contributions made in this area were published in a treatise, published at the Academy Publishing House in 1980 by Mateescu, Appeltauer, and Cuteanu and entitled "Stability of the compressed bars of metallic structures". Special attention has been given to structures made from U- and T-section profiles where the flexural buckling is coupled with lateral-torsional buckling (D. Mateescu, V. Gioncu, M. Ivan, N. Balut, D. Dubina).

Stability of plated and shell structures
Stability of shell structures. This topic was initiated and developed by Dan Mateescu, the results being included in the two editions of the book "*Special metal structures*", the Technical Publishing House, 1956 and 1962 and the "*Buckling of shell structures*" (authors Victor Gioncu and Marin Ivan), the book received the Romanian Academy Award as the world's first work in which all types of shells are analyzed in terms of stability.

Stability of curved reticulated steel structures. Research on the stability of *curved reticulated steel structures* was stimulated by the collapse (in 1963) and the reconstruction, following the project of Dan Mateescu, of the steel roof of the Bucharest Exhibition center. In recognition of this work, Professor Victor Gioncu has become co-chair of the IASS (*International Association of Spatial Structures*) Working Group 8 on space metal structures.

Cold-Formed Thin-Walled Steel Members.
The research activity has been and continues to be focused on three areas: (1) assessment of effective geometrical characteristics of thin-walled sections; (2) interaction between local and global buckling; (3) experimental evaluation of the load-bearing capacity of bars subjected to compression (centric or eccentric). The first Romanian Design Code for these structures was drafted by Timisoara team (1983).

Fundamental Concepts in Stability and Instability of Steel Structures.
The Timisoara School has made important contributions in the stability of steel structures. The main results were published by Gioncu and Ivan in two books published in Romanian: *The theory of post-critical behavior of elastic structures* (Facla Publishing House, Timişoara, 1983) and Th*eory of critical and post-critical behavior of elastic structures* (Academy Publishing House, 1984).

Hydro-Technical Engineering School in Bucharest
By 1942, the education in the field of waterworks and hydro-technical constructions is carried out in Bucharest as part of the unique construction specialization at the Polytechnic School. Leading figures from this school have made significant contributions, both through extensive engineering works of importance to Romania and

through studies and training of engineers in the field; we have named here professors and engineers Elie Radu (1853–1931) and Dionisie Germani (1877–1948), but also later Cristea Mateescu (1894–1979) and Dorin Pavel (1900–1979), who were active within the Bucharest Institute of Constructions (ICB) after 1948. Among the university's outstanding professors, academician Cristea Mateescu, professor Dumitru Cioc, the brilliant hydro-technical construction professor Radu Prişcu has created and developed a *school of large dams recognized worldwide.*

4.2.2 Research Institutes in Constructions

The research activity in constructions was initiated in Romania in 1950 through the establishment of the *Institute for Research and Testing* (ICI) and then, shortly, of the *Institute for Scientific Research in Construction* (ICSC). Both were merged in 1957 into the *Institute for Construction, Construction Materials and Wood Industry* (ICML). A new research institution called the *Institute for Design and Research in Construction and Construction Materials* (IPCMC) was set up in 1959 and the *National Institute for Research and Development in Construction and Building Economics* (INCERC) was set up toward the end of the same year and operated under this logo till 2009. In 1955, branches were established in Timişoara and Iaşi, and in 1962 in Cluj-Napoca. Specialized research institutes have been set up for transport infrastructure, and for hydro-technical and hydro-energy buildings respectively.

The Design Institute for Hydrotechnics and Roads (IPHD) was established in 1953 and became the *Auto, Naval and Air Transport Design Institute* (IPTANA) in 1966, which is still operational.

The Institute of Hydroelectric Studies and Design (ISPH) has designed all hydro facilities and construction in Romania. ISPH emerged in 1963 through the merger between the hydro-energy department that existed since 1949 under the Institute for Studies and Power Engineering (ISPE) and Institute for Power Research and Studies (ICSE). The areas of activity were hydroelectric dams and power plants, water transfer systems, river regularisation, riverbank protection, and navigation structures.

The Design Institute for Hydraulic Structures (IPCH), established in 1953, was the second largest design company in the field of hydro-technical construction. In 1959, the institute was subordinated to the Water State Committee (CSA) and was also involved in the drafting of the river basin planning and management. Since then, the institute has been named IPACH (Institute for Water Development Plans and Hydraulic Structures). In 1976, the institute changed its name to Research and Design Institute for Water Management (ICPGA), which is subordinated to the National Water Council (CNA).

The Design Institute for Standardised Constructions (IPCT), established in 1956. The institute's main activity was the development of technical solutions and standard projects based on which thousands of industrial, housing, and social-cultural constructions were carried out, both in the country and abroad. The Institute had also a department responsible with the application of IT in constructions (software development, handbooks, etc).

Institute for Research and Development in Construction and Building Economics (INCERC). Since 1950, INCERC gradually became a leader in the evolution of new structural safety concepts. In the context of the high seismic risk, following the experience of the earthquake of 10 November 1940 and especially of 4 March 1977, special attention will be given to seismic safety; in 1980, the largest department in the institute was the one which dealt with the seismic safety (under the leadership of dr.ing. Horea Sandi). INCERC has branches at Timişoara, Cluj-Napoca, and Iaşi.

4.3 Remarkable Constructions Built during the Period 1948–1989

4.3.1 Economic Context and Urbanization

Industrialization was the main driver of the economic policy of the communist Romania. The aim was to transform Romania from an agrarian society into an industrial one, to close the regional discrepancies and to develop the society (at least in terms of social and economic indicators). The achievement of this plan was primarily to be done by developing the extractive, complex mechanization, heavy industry (steel, machinery, and equipment) and automating production. Since 1965, the country's industrialization plan has been amplified. In 1989, the number of industrial enterprises is 2.102 units, 444 more than in 1965 and almost twice as compared to 1945. Over the period 1948–1989, the urban share of the population increases from 23.4% to 54.3% of the total population.

The urban planning process, which started in 1972, aimed at configuring rural and urban areas into well-defined hierarchies, where each city or village fulfilled clear functions to ensure an integrated territorial development. Between 1951 and 1955, more than 14.000 apartaments were built per year, while between 1956 and 1960 an average of 26.000 new apartaments were put into service. At the beginning of the 1960s, their number reached about 45.000, so that at the end of the decade they went up to 80.000 units built annually. The maximum number was reached in the 1970s with over 100.000 new apartaments built each year (Chirot 1978).

The high rate of housing construction and development of social and commercial services for the population, including the necessary urban infrastructure, has called for the adoption of efficient technical solutions such as standardization and prefabrication. In this context, for residential buildings (since 1970 mainly for 4 story buildings) large-scale projects with large precast concrete panels were implemented, and for higher multi-story buildings (higher than 8 story) (Fig. 13.86) reinforced concrete frames and diaphragms, site-poured concrete at the beginning of the period, then precast concrete frames and diaphragms.

The residential development of the capital city during the communist regime is closely linked to the large industrial platforms—Republica in the east, IMGB in the south, and the light industry in the western part of the city. Were constructed the first

Fig. 13.86 Obor, 1970–1980, ground floor + 10 story buildings

buildings of Bucharest–Titan neighborhoods to the east, which in 20 years became the largest "residential assembly" in the capital city, with about 200.000 inhabitants, and in parallel, also begun the works for the Drumul Taberei and Militari districts in the west, designed at that time as a whole, and Berceni district in the south. 2.938 apartment buildings were put into use between 1971–1980, 65% more than in the previous decade; 2.653 buildings were completed in 1980.

4.3.2 Public and Residential Buildings

In the period 1948–1989, in Romania was built very much, perhaps not always justified and where it should have been. However, it should be said that, in the field of civil engineering and, in particular, in structural engineering, these structures tested the professional competence of the engineers who designed and executed them. In the following, a selective overview of several buildings that could not have been carried out without engineering science, especially in a seismic country, is made.

Examples of Remarkable Buildings
The Palace Hall (Sala Palatului). The Palace Hall is one of the iconic buildings of the period 1948–1989, which marks a new stage in the communist-era architecture (Fig. 13.87). It was built between 1959 and 1960 by architects Horia Maicu-project head, Tiberiu Ricci, Ignace Şerban, and engineers Alexandru Anton Necşulea and Nicolae A. Băilescu.

National Theatre "Ion Luca Caragiale". The National Theater in Bucharest (TNB) was designed and built between 1963–1977 by a team from I.P. Proiect Bucuresti led by prof. arch. Horia Maicu, prof. arh. Romeo Belea and prof. Nicolae Cucu. The structural design was done by engineer Alexandru Cişmigiu (Fig. 13.88, left). After the fire from the night of 16/17 August 1978, an overall rehabilitation work has lasted almost three years (1983–1985) (Chirot 2023a) (Fig. 13.88, right).

Fig. 13.87 Palace hall square

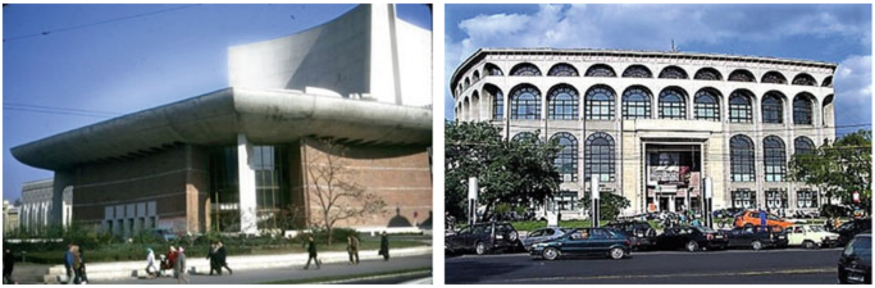


Fig. 13.88 National theatre, 1973 (left) and 1986 (right)

InterContinental Hotel. Construction of the InterContinental Hotel began in 1967, after a project of Romanian architects Dinu Hariton, Gheorghe Nădrag, Ion Moscu, and Romeo Belea (Fig. 13.89). The construction, done entirely by Romanian construction companies, was completed in three years, and the hotel was opened on 23 May 1971. Almost 90 meters high, InterContinental was one of the highest buildings in the city.

The Romanian National Economy Exhibition Pavilion EREN. The central pavilion of EREN is 42 m high, has an area of 10.000 m^2, is built on a circular plane of 180 m in diameter, has a 93 m diameter dome, and was built between 1960–1963 (Fig. 13.90). The pavilion was opened on 27 April 1962. In January 1963, due to a heavy snow, the central dome collapsed, reversed its curvature, and became a "notorious" example of the instability due to *snap-through buckling* (Chirot 2023b). The dome was rebuilt in 1964 in a new, safer but "less spectacular" version. The design, detailing, and experimental validation were carried out by a team from the Department of Steel Structures and Structural Mechanics of Polytechnic Institute of Timisoara, coordinated by Professor Dan Mateescu (Fig. 13.91).

Fig. 13.89 InterContinental during construction (left) and after completion (right) (Chirot 2023c)

Fig. 13.90 Central Pavilion of EREN complex

Fig. 13.91 Dome structure

Parliament Palace. The construction, which started in 1983 and ended in 1997, extends on an area of 350.000 m^2, with about 1.000 rooms, including 440 offices, over 30 lounges, 4 restaurants, 3 libraries, 2 underground parking spaces and a concert hall. The building is 276 m long and 227 m wide. The height of the building is 86 m, it has 12 above grade stories and 8 below grade levels. In 1989, the cost of the building was estimated at 1.75 billion USD. It is the world's largest civilian administrative building in terms of area, the most expensive administrative building in the world and the heaviest building in the world. The "Parliament Palace", initially called "People's House", then "House of the Republic", was designed by the Carpaţi Design Institute, and the chief architect was Anca Petrescu. Between 1983 and 1988, most of the structural engineers in Bucharest worked at this gigantic project. The coordination of the structural engineering team was done by Professor Alexandru Cişmigiu, dr.eng. Traian Popp, and eng. Mircea Mironescu. Major contributions have also made professor Ion Stănculescu for foundations, professor Andrei Caracostea for the steel part of the structure and, in the last period of the project, professor Panaite Mazilu for analytical verifications of the design project. The construction is divided by joints, has 20 main sections and 3 secondary annexes, with different number of levels and different heights (Figs. 13.92, 13.93).

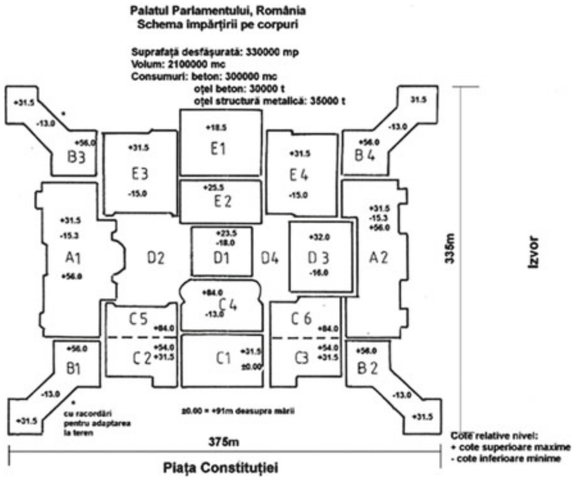


Fig. 13.92 Plan view of the palace

Fig. 13.93 Parliament palace under construction

4.4 *Transport Infrastructure*

4.4.1 Railway Network

In the development of the railway network during the period 1944–1990, it can be distinguishing three stages:

1. The restoration of circulation on lines destroyed during the war and the repair of the railway network (1944–1947);
2. Network strengthening by lifting the traffic restrictions and increasing the load capacity (1948–1959);
3. The upgrading/development of the railway network (1960–1990), which was mainly achieved through electrification, the introduction of diesel and electric propulsion, the doubling of the main lines, the construction of new lines, the introduction of the welded rail. In 1990, the railway network in Romania was 11.376 km long, of which 26% was double-track and 34% was equipped with electric propulsion.

4.4.2 Road Network

In order to understand the state and evolution of the road network after the World War II, it should be recalled that in 1938 rail transport accounted for 97.7% of the total volume, inland waterway and maritime transport accounted for 2.1%, and that of road and air transport for only 0.2% (Iordănescu and Georgescu 1986). After the war, by 1947, the existing road network was brought to a satisfactory technical condition. Important steps have been taken through modernization and construction of new roads. Thus, between 1953 and 1965, 4.575 km of roads were upgraded to reach 6.867 km of upgraded national roads, which represents 57% of all national roads. In 1953 the first bridge with precast concrete superstructure was done on the DN64 Slatina-Drăgăşani with two spans of 18.40 m. By 1955, road transport has increased 100 times compared to 1938. By 1968, 10.942 km of roads have been upgraded, which represents 75% of the road network. The first highway, Bucharest-Piteşti, was built in 1972. The "Transfăgăraşan" road was built between 1970–1974, crossing the Făgăraş Mountains between the Argeş hydropower plant and the Carţişoara village. During the same period, the upgrading works started on national road DN67 Novaci–Sebeş (Fig. 13.94). One outstanding road work is the reconstruction of DN6 national road in the Iron Gates Hydropower and Navigation Complex area (Fig. 13.95) and the deviation of the national road 7 on the sector Turnu–Călimăneşti.

4.4.3 Infrastructure Works

Some important works realized after WW II can characterize the evolution and performance achieved in the field of railway, road and bridge construction. A selection of these works is presented below.

Fig. 13.94 Sector DN67C, Novaci-Sebeş “Transalpina”, opened in 2013 (Chirot 2023d)

Fig. 13.95 The new viaducts Bahna for railway and road (DN6) on Turnu Severin-Orşova sector (Chirot 2023e)

Construction of the bridge over Danube between Giurgiu and Ruse for simple track and two-way road, and two decks (1951–1954). The bridge has 38 foundation blocks, of which 18 were caisson foundations and the others on reinforced concrete pilots. The superstructure has 37 spans and is symmetrical to the central span of 86.0 m made with a movable structure: 12 × 33.4 m+4 × 80.0 m+2 × 160.0 m+86.0 m+2 × 160.0 m+4 × 80.0 m+12 × 33.4 m. The 80.0 m and 160.0 m span structures are continuous on two spans.

Strengthening of the Danube bridges (1963–1967). The strengthening of the Danube bridges (1963–1967) was a highly complex work carried out under difficult conditions. The strengthening was necessary due to the fast evolution of road and rail loading. If the original design of the Danube bridges was done for convoys with 13 t concentrated loads and uniformly distributed loading of 3.5 t/m, the strengthening

Fig. 13.96 Cernavodă bridge after strengthening, the detailed view with 3 chords for top chord (left) and overall view after strengthening (right) (Florea and Ionescu 2012)

Fig. 13.97 Giurgeni-Vadul Oii bridge, views during construction (left) and in use, 1970 (right) (Buzuloiu 2006)

was done considering the convoys from the new codes, with concentrated loads of 22.0 t and 25.0 t and uniformly distributed loads of 8.5 t/m (Fig. 13.96).

The design and execution of the Giurgieni-Vadu Oii bridge over the Danube (1965–1970), a 4-lane road bridge, two on each way. The bridge used a modern, box girder and orthotropic deck structure, continuous on 5 spans and with variable height and viaducts with precast concrete beams (Fig. 13.97). The sequence of the bridge spans is 8×46.0 m + 120.0 m + 3×160.0 m + 120.0 m + 8×46.0 m.

The 4 large bridges crossing the Danube-Black Sea Canal: (a) at the Cernavodă lock, the combined double rail and road double deck bridge; (b) the bridge with Langer arches at Medgidia (Fig. 13.98, left); (c) bridge at Basarabi with arches joined at the crown using the Nielssen system; (d) bridge at Agigea, cable-stayed (Fig. 13.98, right).

4.5 Hydrotechnical Constructions

The field of hydrotechnical construction is broad: water retention (dams, locks), complex hydro-energy works, river regulation and flood control, water communication routes, water port, water-supply, aqueducts, tanks and retention basins, irrigation

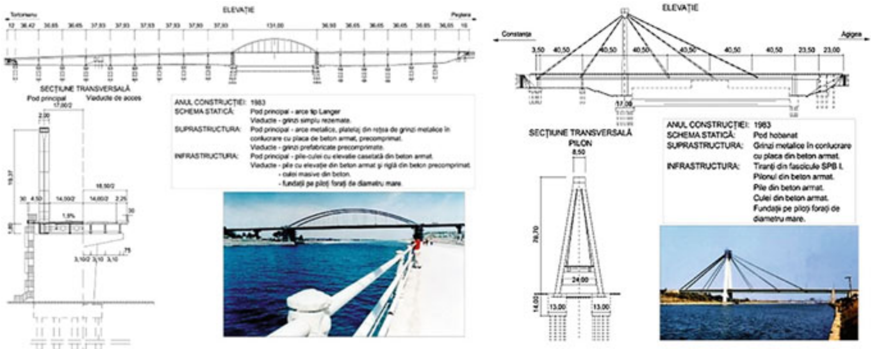


Fig. 13.98 Langer arch bridge at Medgidia (left) and cable-stayed bridge at Agigea (right) (Buzuloiu 2003)

systems, etc. However, in the following only some dams and the Danube-Black Sea Canal will be further introduced.

4.5.1 Dams

A comprehensive plan for the development of the country's hydropower resources was launched after 1948. The coordinators of this program were the outstanding professors Dorin Pavel and Cristea Mateescu, who were the founders of the Romanian hydrotechnical school (Buzuloiu 1990). In most cases, the accumulation of water by means of retention works had complex uses, in addition to the hydro-dynamic force required to produce electricity, ensuring that water is supplied for urban and industrial needs, for irrigation, for flood control, etc. The *Romanian registry of Large Dams*, with dams at least 10 m high or reservoirs up to at least 1 million cubic meters, records 246 dams. Fig. 13.99 shows different typologies of representative dams in Romania [92].

First important dam, built in the second half of the 20th century and entered in service in 1953, was the *Gozna* dam on the Bârzava River in Caraş-Severin county. The dam, made with rockfill (embankment) and steel-coper upstream face of 8 to 10 mm thickness, is 47 m high and provides the retention of a volume of 11.5 million cubic meters of water. But the real school of Romanian dams' engineers was the construction of the *Izvorul Muntelui* dam in Bicaz, completed in 1961 (Fig. 13.100). The dam, made of concrete, was 127 m high and 1.230 million cubic meters of water.

The period 1961–1963 was the time when record-breaking dams were constructed in Romania. These dams are Vidraru, on the Argeş river and the Iron Gates I on the Danube.

The period 1970 to 1990 can be considered the most flourishing period in the history of the construction of dams in Romania. Over 75% of all dams in service today in Romania have been designed and executed during this period.

Heavy dams				
Poiana Uzului	Somesul Cald	Scropoasa	*Valiug*	
Arch dams				
Vidraru	Dragan	Paltinu	Tarnita	Tau
Buttress Dam				
Poiana Uzului	Gura Raului	Stramtori	Secu	
Dams with spillways				
Portile de Fier I	Stanca Costesti	Tileagd	Portile de Fier II	Golesti
Earth dams / rock				
Măneciu	Motru	Zetea	Săcele	Frumoasa
Rockfill dams				
Siriu	Vidra	Râuşor	Cerna	Pecineagu

Fig. 13.99 Representative dams for different typologies applied in Romania and their location

Fig. 13.100 Izvorul Muntelui dam—Bicaz

The Vidraru dam—arch dam. With a height of 166.60 m, the Vidraru dam was at the time of its completion, in 1966, the 6th such dam in Europe and the 7th in the world. The length of the arch is 305 meters, and the volume of the reservoir is 465 million cubic meters of water. In 2003, it was still the 15th in Europe and 27th in the world in terms of height (Fig. 13.101).

Iron Gates I dam—spillway dam. Considering the huge hydro-energy potential but also the navigation difficulties of the Danube River, the Governments of Romania and Yugoslavia agreed to jointly build a hydropower plant. The general plan of the hydro-energy and navigation system Iron Gates I is symmetrical (Fig. 13.102), with a spillway dam located in the middle of the riverbed and one powerplant and lock on each side of the river. The Iron Gates dam is a gravity dam with 14 spillways of 24.0 m span, equipped with double flat hook type locks of 25 × 14.85 m. The height of the dam is 60 m and the length at the crown is 441 m. The dam entered in service on 16 May 1972.

Gura Raului dam—buttress dam. The dam, which entered in operation in 1979, is located on the Cibin river upstream of the city of Sibiu. The reservoir has a volume

Fig. 13.101 Vidraru dam

Fig. 13.102 Iron gates I dam and hydropower plant

of 15.5 million cubic meters. The dam is a concrete buttress and multiple-arch dam, with a height of 73.5 m (Fig. 13.103). The length at the crown is 328 m and the volume of concrete in the dam is 360.000 mc.

4.5.2 Danube-Black Sea Canal

The Danube-Black Sea Canal, which entered in service in 1984, is a navigable canal linking the ports of Cernavoda and the Danube with the ports of Constanta, Midia Navodari from the Black Sea, shortening the route to the port of Constanta by about

Fig. 13.103 Gura Râului dam

400 km. The Danube-Black Sea Canal is part of the major European waterway between the Black Sea and the North Sea (via the Rhine-Main-Danube Canal). The construction of the canal started in 1949, but the work stopped in 1955, and resumed after a new project in 1976. 294 million cubic meters were excavated on the main canal and another 87 million cubic meters on the northern branch Poarta Alba—Midia Navodari (which exceeds the Suez and Panama canals in terms of volume excavated by 25 million cubic meters and 140 million, respectively) and 5 million cubic meters of concrete have been poured. The canal, with a total length of 95.6 km, consists of the main branch of 64.4 km and the north branch (known as the Poarta Albă—Midia Năvodari canal) with a length of 31.2 km. The canal has a base width of 60 m and 90–120 m at surface with a water depth of 7 m (Fig. 13.104). The draft is limited to 5.50 m, allowing access for river and small sea ships).

Fig. 13.104 The Danube-Black Sea canal (left) and Agigea hydrotechnical node (right)

4.6 Special Constructions

At the beginning of this section, it was pointed out that the central point of economic development in the communist regime was industrialization. Huge investments have been made and large masses of population from rural areas have been dislocated in an accelerated process of urbanization, with many negative consequences for the quality of life. Constructions of all kinds have been built, for various industrial purposes, aimed at supporting all economic sectors, from the metalworking and heavy-duty machinery industries to the chemical, electrical engineering, textiles, food industries, etc. Precast concrete blocks of flats, steel structure industrial buildings, refineries, thermo and hydro plants, pipeline networks, storage tanks, multistory buildings, oil platforms, communication routes to serve them, and so on. Three objectives will be further presented, to illustrate *special constructions*, which, by their nature, demonstrate the ability and level of competence achieved by Romanian construction engineering. These are *Bucharest Underground (Metro), the Offshore Oil Platforms, and the Cernavodă Nuclear Power Plant.*

The construction of the metro (Tănăsache 2009a, b). The decision approving the development of technical documents for the construction of the underground was taken in October 1974. On 3 February 1975, the Metro Bucharest (today Metro S.A.) was set up, which was to be a general designer, general contractor, and beneficiary of the investment. The construction work started on 20th of September 1975 (Fig. 13.105). On 16th of November 1979, after four years of unprecedented complexity of construction works, the first metro line (M1) was put into service. By the end of 1989, 56.8 km of double track and 39 stations were built and put into service. Currently, the length of the underground network extends for over 71 km of double track, distributed over four main lines and 53 stations (Fig. 13.106).

Offshore oil platforms. The decision to extend exploration of oil and gas reserves on the Romanian continental Black Sea shelf was taken at the beginning of the 8th decade of the 20th century. In 1972, IRCHC (Romanian Institute for Marine Research Constanta) began the exploration in sites located on the Romanian Black

Fig. 13.105 Connecting works at tunnels, 1981

Fig. 13.106 Piaţa Victoriei station

Sea continental shelf. A specialized institution, Petromar, has been established, which has decided, considering the conditions in the Black Sea, that the most appropriate platforms are the four-column self- elevating platforms with hydraulic lifting and lowering facilities. In 1974, Galati shipyard started the construction at the first platform, "Gloria" (Fig. 13.107). The platform had a metallic structure in the shape of a rectangular parallelepiped of a length of 52.46 m, a width of 40.82 m and a height of approximately 6.4 m. At the rear, on the deck, there is a derrick with a height of 44 m which allows drillings to a depth of 6.000 m. The oil platform started drilling on 16 September 1976 at 72 km from the coast at a maximum water depth of 90 m. Later, at Galati shipyard were built other six offshore platforms: "Orizont" (1981), "Prometeu" (1984), "Fortuna" (1985), "Atlas" (1985), "Jupiter" (1987) and "Saturn" (1988).

Cernavodă nuclear power plant (CNE Cernavodă). In 1974, Romania purchased a license and a project for a 700 MW power plant with PHWR (pressurized heavy-water

Fig. 13.107 Gloria offshore platform

reactor) CANDU (Canada Deuterium Uranium) nuclear reactors from the Canadian company AECL. The CANDU reactor design avoids the use of enriched uranium and guaranties effective nuclear safety by a protective envelope around the reactor. Initially, it was planned to build 4 independent units of 700 MW each (the decision for the fifth unit was taken later). At present (2018), only Unit 1 (since 1996) and Unit 2 (since 2000) are in operation and deliver together 20% of the total national electricity production.

5 Period after 1990

The construction sector experienced a general decline in the early 1990s, then started to grow, reaching a rate of about 30% between the years 2005–2008, being one of the pillars of Romania's economic growth. However, the economic and financial crisis has again affected the sector, which in 2009 decreased by 12%, and this trend has continued in the coming years (2010–2012), when approximative 25% of Romanian construction companies went bankrupt (Chirilă 2013) (Fig. 13.108).

After 2012 the construction sector started to grow again, with a very good year 2015. Growth continued in 2016 (but weaker), when a mixed development was recorded in 2017, i.e., if the residential construction sector was growing, the development was overall negatively influenced by the lack of large projects in the infrastructure. Regarding the other construction categories, i.e non-residential ones—large commercial buildings, logistics buildings, warehouses and industrial buildings, office buildings, etc., with lower growth rates, the achievements are considered remarkable, demonstrating the capacity and competence of architects and civil engineers that designed and executed them. Through the design concept, the professionalism of designers and the technologies applied in the execution, many of these constructions are comparable to similar constructions built in other more developed European or world countries.

Negative growth indices % compared to 2008, 100%				
Year	2009	2010	2011	2012
Total construction	81,7	72,7	71,0	72,0
New construction	74,4	76,4	75,3	81,3
Capital repairs	88,9	70,8	64,7	58,7
Maintenance	92,2	74,3	77,0	69,0

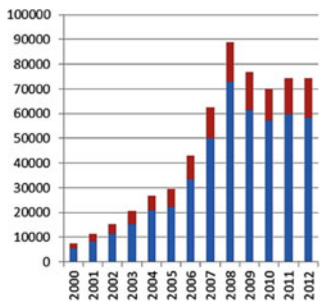


Fig. 13.108 The dynamics of the construction sector over the period 2000–2012 (Iacoboaea et al. 2023a)

A selection of some outstanding non-residential buildings and other public works will be presented in the following section.

5.1 *Urban Development*

5.1.1 Outstanding Buildings in Urban Environments

Tall buildings: Office and Collective Housing
Vertical development is inevitable in dense urban areas, especially in the context of an emerging real estate market as a result of accelerated urbanization, in which land prices are constantly rising. Secondly, the construction of tall buildings demonstrates the financial strength and technological capacity, supporting confidence in the creditworthiness and stability of the beneficiaries. Finally, these buildings can be seen as a sign of urban modernity and emancipation. Fig. 13.109 (Iacoboaea et al. 2023b) shows the profile of the representative tall buildings in Bucharest, 85 m or high, completed or under coonstruction.

Tower Center International, is an office building located in Bucharest. With a height of 106 m and 26 levels (22 above grade and 4 below grade), it also held between 2006–2013 the height record for this kind of buildings in Romania. The general designer of the structure was the architecture company SC Westfourth Architecture (project head arch. Vladimir Arsene) and the client of the building was SC Tower Center International (Fig. 13.110). The technical project of the steel structure was carried out by SC Britt SRL and the concrete work (above grade) by SC Popp&Asociatii SRL. In the design were also involved Emanuel E. Necula PC for the technical project of the infrastructure, SC Topo-Cad Project SRL for topographic survey, and UTCB—The Hydraulic and Environmental Protection Department, The Aerodynamics Laboratory and Wind Engineering for the wind tunnel tests. The execution and erection of the steel structure was done by Unger Steel Austria. The building has a composite steel—concrete frame system and bolted joints. The steel structure employs a *dual-steel* concept (hybrid), i.e., lower steel grade in dissipative braces and higher steel grade in the rest of the elements (Dubina et al. 2009a). The work was distinguished by the European Convention for Constructional Steelwork with the *Steel Design Award* in September 2007 in Luxembourg.

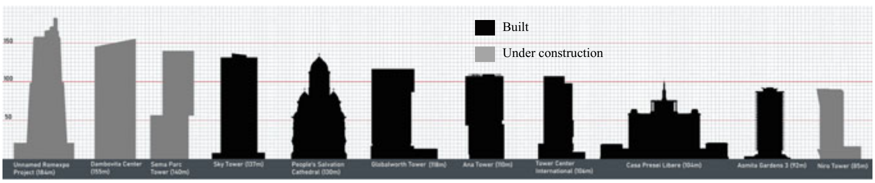


Fig. 13.109 Profile of the tallest buildings in Bucharest (85 m or high)

Fig. 13.110 Tower center international (Dubina et al. 2009b)

Bucharest One Tower, built by the Globalworth Investment Fund, was completed in 2016. It consists of two buildings (A and B) with different functions (Fig. 13.111). Building A is a 118.0 m high office building with 26 above grade stories and 3 below grade stories; building B has two below grade levels and a ground floor. The two buildings have a seismic separation joint on the full height. The building structure was designed by SC Allied Engineers Group SRL using the architecture project developed by SC Architect Service SRL. The general contractor of the work was SC Bog'Art SRL. The main structure consists of two cores and perimeter reinforced concrete frames. The perimeter frames have concrete beams and circular shape concrete or composite concrete-steel columns, spaced at 8.0 m distance across the building perimeter. To resist gravity loads, at the lower levels, composite columns made of king cross steel sections encased in concrete were used. The foundation system is a reinforced concrete raft foundation supported by reinforced concrete piers and perimeter walls.

Cathedral of National Redemption is a monumental building, with three underground levels that required excavations of 20 m depth protected by slurry walls, above grade height of about 120 m, and an in-plane surface of about 7.165 m^2. The construction works started in 2010. Above the ground, the first partial floors (side naves) of the construction have 9.00 m high up to level +45.00 m, above which are several independent structures with different functions: six secondary towers up to level +70.00 m, Bell Tower, where the six bells will be placed, up to level +80,00, respectively the main tower Pantokrator, up to level +120,00. The Cathedral's foundation is a massive slab of reinforced concrete and reinforced concrete beams placed on two orthogonal directions. The main structural system of the building is made of high strength reinforced concrete elements and steel-concrete encased elements. The

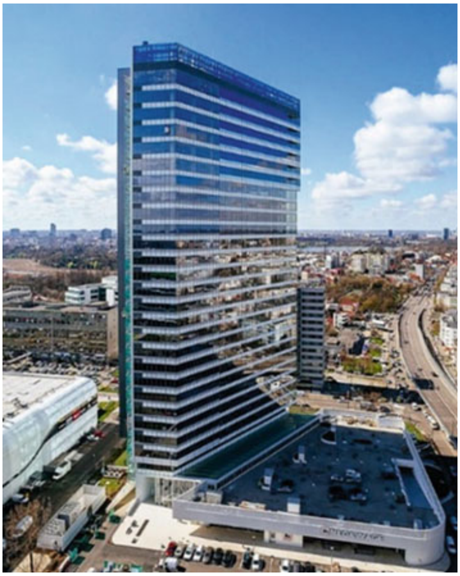


Fig. 13.111 Bucharest One tower

special features of the construction required large and complex structural elements: massive arch type elements, cylindrical or spherical surfaces, intersections of curved spatial surfaces, etc. (Fig. 13.112). The roof is made of steel framework over which are placed wood elements (arches, roof battens, decorative elements) and steel sheeting. The construction was classified as of vital importance against earthquakes, thus aiming to ensure structural integrity and functionality during and immediately after the occurrence of a major seismic event.

Fig. 13.112 Cathedral during construction

Fig. 13.113 Naţional Arena stadium (Dubina et al. 2023a)

5.1.2 Stadiums and Sport Halls

In the period after 1990, seven new stadiums were built in Romania. Three of the newly built stadiums (the Naţional Arena in Bucharest, Cluj Arena in Cluj-Napoca, and Ion Oblemenco in Craiova) have capacities of more than 30.000 seats.

National Arena
The National Arena stadium, with a capacity of 55.000 seats, has a roof which covers the stands and a retractable roof for the field (Fig. 13.113). The beneficiary is the Bucharest City Hall, and the construction was carried out by the association of JV Max Boegl Bauunternehmung GmbH & Co. KG and Astaldi SPA Italy. The structural designers are Krebs und Kiefer (Germany) and Consild (Romania). The structural system is made of reinforced concrete in a hybrid monolithic—precast system. The construction is separated into sections by four radially oriented joints. The main stand has 3 undergrounds and 3 above grade levels. The secondary stands have 3 above grade levels and partially one level below ground for technical services.

Cluj Arena
Cluj Arena complex opened on October 11, 2011. The construction was carried out between 2009 and 2011. The architecture was developed by SC Dico and Tigănaş S.R.L. Cluj-Napoca, the engineering by Technical University Cluj-Napoca, SC Bogart Construct Cluj-Napoca and DAS Engineering Group, and the construction by ACI Cluj. The owner of the complex is the Cluj County Council. The stadium has a capacity of 30.200 seats and is one of the symbols of the city. The external finishing is a titanium-like surface covered with a transparent surface layer (Fig. 13.114).

5.1.3 Large Commercial Areas

The first *shopping center (mall)* in Romania, Bucharest Mall, was opened in September 1999. The International Council of Shopping Centers has estimated that

Fig. 13.114 Cluj Arena stadium

around 100 malls will be built by the end of 2018. With complex structural architecture and configuration, malls combine various structural and material systems (reinforced concrete, steel, wood), their design and execution must ensure a coherent structural response, providing strength and robustness under the effects of natural, service or accidental actions and ensuring the safety of occupants and goods. Here are two illustrative examples.

AFI Palace Cotroceni
It is currently the largest shopping mall in Bucharest, located in the western part of the city, in sector 6; it was opened on 29 October 2009. Initially, the mall had a lease area of about 76.000 square meters, 300 shops, 2.500 parking spaces, a hypermarket, 20 cinema halls, the first Imax cinema in Romania (3D), restaurants, two casinos, an approximative 1.000 m^2 ice-skating rink, a climbing wall, an artificial lake, a roller-skating track, bowling and snooker. At the end of 2017, after successive extensions, AFI Cotroceni reached a lease area of 90.000 square meters.

Iulius Mall Timisoara and Open Ville Complex
This large shopping center in Timisoara was built in two stages, starting in 2005 and 2009, respectively. The total built area reaches 178.500 square meters, and the lease area has been extended to 71.000 square meters, becoming the largest mall outside Bucharest. The shopping center has 350 brands, a food court with a capacity of over 1.700 seats, underground and above grade parking spaces with 3.000 spaces, multiplex cinema with 7 halls, fitness room, playgrounds for children, climbing wall, casino, restaurants, and terraces. In 2015, Iulius Group started expanding the center through the OpenVille complex, a multifunctional urban regeneration project, the investment being one of the largest private investments in the Romania's real estate sector (Fig. 13.115). The complex will include the highest multistory building in Romania (155 m).

Fig. 13.115 Openville complex Timişoara

5.2 Transport Infrastructure

5.2.1 Construction of New Airports

Romania has 16 international airports located in 15 of the largest cities. Those with traffic above 1 million passengers/year (in 2017) are: *Bucharest-"Henri Coandă"* with 12.840.000*; Cluj-Napoca-"Avram Iancu"* 2.690.000; *Timişoara-"Traian Vuia"* 1.621.529 and the Iaşi Airport 1.126.218. A new terminal was built at Cluj-Napoca Airport in 2008. In Iaşi, one of the oldest airports in the country, operational since 1905, two new terminals were built successively, T2 in 2012 and T3 in 2015 and the runway was expanded in 2014.

Bucharest "Henri Coandă" Airport Extension

The airport knew extensive modernization works after 1990. In 1993, the airport became a full Member of ACI (Airport Council International). The terminal of international departures, with a capacity of 1.200 passengers per peak hour, opened its doors in 1997. In 2000, the international arrivals flow is opened as a result of a restructuring process of the old terminal. In the following year, the public parking for the arrivals' terminal is opened (three stories with 900 parking spaces). In 2003, the internal/domestic flights terminal was opened with a capacity of 200 passengers per peak hour for each of the two flows (departures and arrivals).

The opening of the new Departures Terminal of Henri Coandă Bucharest International Airport took place on 6 November 2012 (Figs. 13.116, 13.117). The work was awarded with the Steel Design Award by the European Convention for Constructional Steelwork in Berlin in September 2011. By 2022, Terminal 2 for passengers will be completed, which will consist of four modules, each with a capacity of 5 million passengers/year. Another extension of the airport consists of a new terminal construction, to be linked to the A3 Bucharest-Ploiesti highway (Dubina et al. 2023b).

Fig. 13.116 New Departures Terminal

Fig. 13.117 "Henri Coandă" airport after extension

5.2.2 Land Transport System

After 1990, the main works on the railway network, apart from routine maintenance and regular repairs, were and continue to be those for the rehabilitation of the lines which are part of the European corridors, where the main objective is to increase the traffic speed to 160 km/h for passenger trains and to 120 km/h for freight trains. Rail traffic in Romania occupies an important place in Europe. On the Pan-European Corridor IV, which accounts for 13% of the length of the railway network in Romania, takes place 35% of the total traffic. The link to Constanţa port, the largest port at the Black Sea, provides a good link between Western Europe and the Black Sea transport area, Central Asia, and the Middle East. Given the importance of this rail transport corridor, the first sections of the rehabilitated railway line include: Bucharest-Câmpina-Predeal (Fig. 13.118) and Bucharest-Constanţa. Work is being done on the Sighişoara-Mediaş-Coşlariu sector, and in 2018 work will start on the Braşov—Sighişoara section.

In 1990, the public road network in Romania had a total length of 153.014 km, of which 14.683 km national roads, 26.967 km county roads, 31.166 km municipal roads and 80.198 km streets in municipalities (Dubina et al. 2017). At the end of 1993, the technical condition of the national road network was characterized by:

Fig. 13.118 Rehabilitated sector on the railway Bucharest—Predeal between Comarnic and Valea Largă

87% of the network had modern pavement, 11% light pavement, 2% were gravel roads; 74% of the network had the time of operation exceeded, of which almost half had a critical technical condition with major degradations. Of the total number of bridges (3.131) with a total length of 128.617 m located on national roads, only 58.8% fulfilled the conditions for loading class E. The other 55.600 m of bridges did not meet the requirements of international traffic. Therefore, the strategic objectives set by National Company for Road Infrastructure Administration were:

- Improve the technical condition of the public road network through maintenance and reinforcement measures to stop the degradation process;
- Creating conditions for bringing the road network to the level of European requirements through rehabilitation and modernization programs. As an example, a rehabilitation program for 1.053 km of national roads was carried out between 1993–1996;
- Step-by-step development of a highway network.

On the basis of the proposals made by the IPTANA (Transport, Auto, Naval, Air Design Institute) in 1990, the Romanian Government adopted a program for the implementation of a highway network of a total length of 3.616 km (Dubina et al. 1995) (Figs. 13.119, 13.120). The phases of the program were:

Fig. 13.119 A1 Highway sector on the Turda–Sebeş section, Pan EU Corridor 4

Fig. 13.120 A3 Highway sector on the Bucuresti–Ploieşti

- Phase I (till 2006), 280 km;
- Phase II (2006–2015), 636 km;
- Phase III (after 2015), 2.600 km.

However, the political debates and changes in priorities of left-leaning parties after 2014 greatly slowed down motorway projects. Thus, in 1990, at the start of the program, there were 113 km of highway; at the end of 2019, the total length of operational highways was no more than 850 km (Table 13.2).

In this stage, several *infrastructure works*, *tunnels,* and *bridges* have been constructed or are under construction. Among the, the cable stayed bridge over Danube—Black Sea Canal at Agigea (Fig. 13.121).

5.3 "Romanian Schools" of Civil Engineering and the International Scientific Cooperation

In 1990, in Romania were four main schools of Civil Engineering, i.e., the University of Civil Engineering in Bucharest, UTCB, which continued the *National School of Bridges and Roads*, and 3 Civil Engineering Faculties integrated in the Technical Universities of Timisoara, Iasi and Cluj-Napoca. In Constanta, within the Higher Education Institute of Constanta, two specializations for civil engineer assistants were operating since 1977. The "Institute" will become "University" and will include a Civil Engineering Faculty. Since 1999, this faculty will open study programs for Hydrotechnical Engineering and Land Improvements and Rural Development Engineering. On 12 June 2003, the Civil Engineering Faculty, with Civil, Industrial and Agricultural Buildings, Building Services, Railways, Roads and Bridges, and Construction Technology programs, was established at the "Transylvania" University

Table 13.2 The construction of motorways in Romania (*source* https://en.wikipedia.org/wiki/Highways_in_Romania)

Year	2004	2006	2007	2009	2010	2011	2012	2013	2014	2015	2017	2018	2019	2020
Opened km	97	37	14	42	27	71	128	119	51	48	15	59	43	-
Total km	210	247	261	303	330	402	529	638	688	735	748	807	850	1090 (est.)

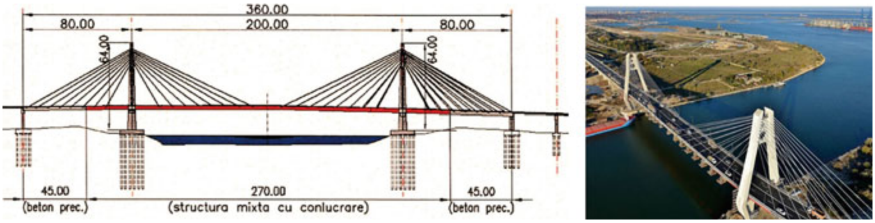


Fig. 13.121 Cable stayed structure for the new bridge over Danube—Black Sea Canal at Agigea

of Brasov. In this period, specializations on "Urban Engineering and Regional Development" will start in Constanta, Bucharest, Cluj-Napoca, and the new university in Alba Iulia, at the Faculty of Exact and Engineering Sciences.

In different forms and associations, at some faculties, bachelor programs were offered for *Economic Engineering* or *Construction Management*, and *Environmental Engineering,* respectively. It is worth also mentioning the development of Civil Engineering programs in foreign languages in early 1990: at UTCB in French and English, at Timişoara in German and English, at Iaşi and Cluj-Napoca in English. Since 1994, Advanced Studies of one-year programs start, which will then become a 2-year Master Courses, when the application of the "*Bologna*" learning structure changes the engineering programs in four years bachelor program. At this point, the three programs in Civil Engineering study scheme (bachelor, master, and Ph. D) are 4 + 2 + 3 years.

An important step in the development of the higher education in civil engineering was the introduction of the Eurocodes and Euronorms in the educational program, which allowed later the Ministry of Public Works and Land Planning (MLPAT) to start the harmonization of the Romanian design codes with the European ones.

5.3.1 Participation of Main Romanian Schools in Civil Engineering in EU Academic and Research Programs and World Exchange of Knowledge in the Field

In Sect. 12.4.2, the *Romanian Schools of advanced engineering and construction research* were presented. In the context associated with the title of this paragraph, for the period to which we refer, only two of the previously mentioned schools shall be pointed out, namely:

- School of earthquake engineering and structural safety
- School of steel structures and structural stability

This selection does not mean that there are no research groups or researchers with outstanding achievements and international recognition in specific research areas in Romanian universities or research institutes; with no doubt there are many, but not in the *school* concept, defined in 12.4.2.

5.3.2 School of Earthquake Engineering and Structural Safety

During the period 1990–2018, the activity of theoretical and experimental research in seismic engineering at the *Technical University of Civil Engineering Bucharest* experienced a remarkable development.

The outstanding public contributions of the Structural Safety School at UTCB (Dan Lungu, Tiberiu Cornea, Sorin Demetriu, Alexandru Aldea, Cristian Arion, Cristian Neagu, Florin Pavel, Radu Văcăreanu, et al.) can be summarized as follows:

- Drafting the natural hazard chapters of design codes (seismic action, wind action and snow action);
- Comparison of previous earthquakes recordings from Vrancea source (1986 and 1990) made in Bucharest and in the country using deterministic, probabilistic and stochastic models;
- Classification of the spectral composition of earthquakes in Bucharest and Moldova, based on the values of the stochastic indicators of the frequency band width of the recorded accelerations;
- Stochastic response spectra with different probabilities of exceedance compared to the deterministic response spectra;
- Correlation of the frequency composition of recorded earthquakes with the superficial geology of the terrain in the location of the records (V. Ciugudean);
- Defining the response deterministic spectra of the earthquakes recorded in 1977, 1986 and 1990 in terms of (i) probability of exceedance and (ii) control/corner periods, for macrozonation of Bucharest and Romanian territory;
- Development of attenuation models for Vrancea earthquakes based on all earthquakes recorded in Romania, the Republic of Moldova and Bulgaria during earthquakes generated by the Vrancea intermediate depth source from 1977, 1986, 1990 and 2004.

Finally, the series of national conferences with international participation *National Conference on Earthquake Engineering*, initiated 1997, should be highlighted.

The 2022 Edition of European Conference on Earthquake Engineering and Seismology will be held in Romania, with the support of UTCB.

5.3.3 School of Steel Structures and Structural Stability from Timişoara

Current research themes continue, generically, those of the *School* created by academician Dan Mateescu in the second half of the 20th century but complemented and adapted to the current knowledge and trends (Dinu and Ungureanu 2016). They can be integrated into the following three thematic programs:

- **Stability of cold formed thin-walled steel elements**, with main contribution in interactive buckling and innovative technical solutions for cold-formed steel applications (Victor Gioncu, Dan Dubină, and Viorel Ungureanu);

– **Global performance (strength, stability and ductility) of multi-story steel frame structures under extreme actions**, with main contributions in evaluation of structural robustness; seismic protection of existing and new buildings with innovative fuse dissipative components; application of high strength steel in seismic resistant building structures; fire engineering of steel structures (Victor Gioncu, Dan Dubina, Florea Dinu, Aurel Stratan, and Raul Zaharia);
– ***Sustainable development and environment protection,*** with contribution in development of *sustainable steel building solutions* and *reuse of steel structures* (V. Ungureanu, Adrian Ciutină)

Participation in the Development of National and European Design Codes
CMMC/CEMSIG team members participated intensively during the reference period at the development of technical regulations and supporting background documents in the field of steel structures. Then, they took part in the implementation of structural Eurocodes and Euronorms in Romania, especially in the field of steel structures, between 2000 and 2010. The team is currently involved in the development of new versions of structural Eurocodes (started in 2015), with its members present in several CEN/TC 250/SCe committees (SC4, SC8 working groups and 3 drafting committees for Eurocodes 3, 4 and 8, i.e., steel structures, composite steel-concrete structures, and earthquake-resistant structures).

Organization of National and International Scientific Events
In addition to the research activity, the team from CMMC participated, and in some cases coordinated, the organization of many national and international scientific events. These include two series of outstanding international conferences, i.e.:

– *Conference series CIMS* (Coupled Instabilities in Metal Structures) initiated at Timişoara by J. Rondal, V. Gioncu and D. Dubină in 1992, followed by Liege (1996), Lisboa (2000), Rome (2004), Sydney (2008), Glasgow (2012), Baltimore (2016); the following is Lodz, Poland, in 2020.
– *Conference series STESSA* (Behavior of Steel Structures in Seismic Areas), which was initiated in 1994, Timişoara, by V. Gioncu and F. Mazzolani, followed by the editions in Tokyo (1997), Montreal (2000), Napoli (2003), Yokohama (2006), Philadelphia (2009), Santiago de Chile (2012), Shanghai (2015) and Christchurch (2018). The 10th edition will return to Timisoara in 2021.

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