21世纪工业工程专业规划教材

周跃进 任秉银 主编

# 工业工程专业英语

## English for Industrial Engineering 第2版

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# 工业工程专业英语

第2版

主　编　周跃进　任秉银
副主编　马　力　赵丽娟　李　萍
参　编　李　迁　李建辉
主　审　唐任仲



机 械 工 业 出 版 社

本书针对工业工程专业本科生的英文学习要求，结合工业工程专业知识体系而编写，精选了工业工程专业的核心内容，题材广泛，涉及工业工程专业各领域知识。其目的是让工业工程专业学生熟悉并掌握工业工程专业的英文词汇，能够熟练阅读英文专业书籍和论文，提高英文写作能力。全书共13章，涵盖了几乎所有工业工程专业基础和专业主干课程，内容包括：工业工程概述、工作研究（包括方法研究和作业测定）、制造系统、服务系统、生产计划与控制、物流工程、人因工程、质量管理、管理信息系统、人力资源管理、科技文献检索、科技文献翻译和科技文献写作。本书内容均在英文原版教材的基础上做了改编或改写，对其中一些难句做了注释或给出了参考译文。全书收录英文专业词汇和词组500多条，书末还附有大量工业工程专业学习网站、国外著名工业工程学术及研究机构网站和参考文献。

本书可作为高等院校工业工程专业本科生的教材，也可作为工业工程专业人士的参考读物。

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# 21 世纪工业工程专业规划教材

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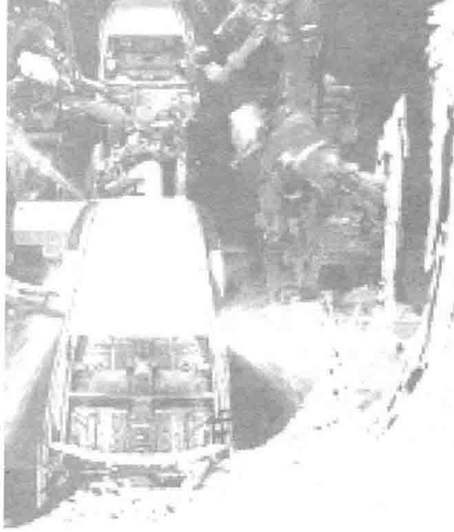


# 序

每一个国家的经济发展都有自己特有的规律，而每一个国家的高等教育也都有自己独特的发展轨迹。

自从工业工程（Industrial Engineering，IE）学科于20世纪初在美国诞生以来，在世界各国得到了较快的发展。工业化强国在第一、二次世界大战中都受益于工业工程。特别是在战后经济恢复期，日本、德国等均在工业企业中大力推广工业工程的应用和培养工业工程人才，获得了良好的效果。美国著名企业家艾柯卡是美国福特和克莱斯勒汽车公司的总裁，他就毕业于美国里海大学工业工程专业。日本丰田生产方式从20世纪80年代创建以来，至今仍风靡世界各国，其创始人大野耐一的接班人——原日本丰田汽车公司生产调查部部长中山清孝说：“所谓丰田生产方式，就是美国的工业工程在日本企业的应用。”韩国、新加坡、中国台湾和中国香港均于20世纪60年代起步工业工程，当时正值亚太地区经济快速发展时期。中国台湾的工业工程发展与教育是相当成功的，经过30年的努力，建立了工业工程的科研、应用和教育系统。20世纪90年代初，台湾省60所大学有48所开设了工业工程专业，至今人才需求仍兴盛不衰。更重要的是于1992年设立了工业工程学门。目前，在中国大陆的台资企业都设有工业工程部和工业工程工程师岗位，在亚太地区的学校都广泛设立工业工程专业。工业工程高水平人才的培养，对国内外经济发展和社会进步起到了重要的推动作用。

1990年6月中国机械工程学会工业工程研究会（现已更名为工业工程分会）的正式成立，以及首届全国工业工程学术会议在天津大学的胜利召开，标志着我国工业工程学科步入了一个崭新的发展阶段。人们逐渐认识到工业工程对中国管理现代化和经济现代化的重要性，并在全国范围内自发地掀起了学习、研究和推广工业工程的活动。更重要的是在1993年7月由原国家教委批准，天津大学、西安交通大学首批试办工业工程专业并招收本科生，由此开创了我国工业工程学科的先河。而后重庆大学等一批高校也先后开设了工业工程专业。时至今日，全国开设工业工程专业的院校已经有200多所，其发展速度之快，就像我国经济发展一样，令世界各国瞩目。我于2000年9月应邀赴美讲学，2001年应台湾工业工程学会邀请到台湾清华大学讲学，2003年应韩国工业工程学会邀请赴韩讲学，其题目均为“中国工业工程与高等教育发展概况”。他们均对中国大陆的工业工程学科发展给予了高度的评价，并表达了与我们保持长期交流与往来的意愿。

虽然我国工业工程高等教育自1993年就已开始，但教材建设却发展缓慢。最初，大家都使用由北京机械工程师进修学院组织编写的“自学考试”系列教材。至1998年时，全国设立工业工程专业的高校已达三四十所，但仍没有一套适用的专业教材。在这种情况下，工业工程分会与中国科学技术出版社合作出版了一套工业工程专业教材，并请西安交通大学汪应洛教授任编委会主任。这套教材的出版有效地缓解了当时工业工程专业高等教育教材短缺的压力，对我国工业工程专业高等教育的发展起到了重要的推动作用。

然而，近年来我国工业工程学科发展十分迅猛，开设工业工程专业的高校数量直线上升，同时教育部也不断出台新的政策，对工业工程的学科建设、办学思想、办学水平等进行规范和评估。在

新的形势下，为了适应教学改革的要求，满足全国普通高等院校工业工程专业教学的需要，机械工业出版社推出的这套“21世纪工业工程专业规划教材”是十分及时和必要的。在教材编写启动会上，编审委员会组织国内工业工程专家、学者对本套教材的学术定位、编写思想、特色进行了深入研讨，力求在确保高学术水平的基础上，适应普通高等院校教学的需求，做到适应面广、针对性强、专业内容丰富。同时，本套教材还将配备课件，相应的实验、实习教程，案例教程以及企业现场录像，实现立体化。尽管如此，由于工业工程在我国正处于快速成长期，加上我们的学术水平和知识有限，教材中难免存在各种不足，恳请国内外同仁批评指正。

教育部工业工程类专业教学指导委员会主任
中国机械工程学会工业工程分会主任

于天津

# 前　言

本书是为工业工程专业学生学习专业英语而编写的。其目的是加强工业工程专业学生的英语训练，使其能掌握工业工程专业的英语词汇，顺利阅读工业工程专业英语文献，提高与国外同行的学术交流和交往水平。

本书共13章，涵盖了几乎所有工业工程专业基础和专业主干课程，内容包括：工业工程概述、工作研究（含方法研究和作业测定）、制造系统、服务系统、生产计划与控制、物流工程、人因工程、质量管理、管理信息系统、人力资源管理、科技文献检索、科技文献翻译和科技文献写作。此外，还附有工业工程领域著名的学术机构及协会组织的名称、网站以及工业工程方面的常见词汇等。

本书内容丰富，在教学安排上各学校（各任课教师）可根据学生的英语水平和学校对该课程的课时要求灵活安排，其中有些内容可作为学生课外阅读材料。

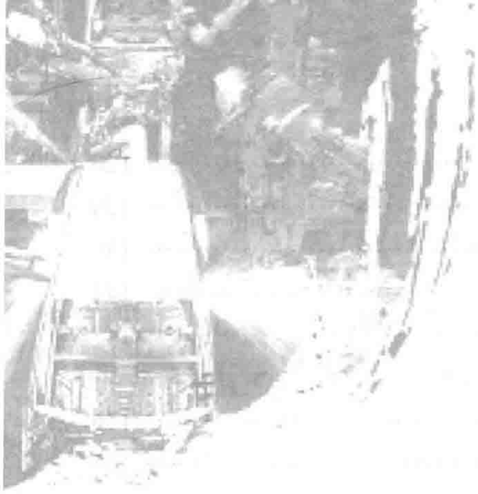
本书的特色是：① 针对性强。本书针对工业工程专业学生介绍与该专业基础课程和专业课程有关的英语基础知识和专业知识。② 方便学生阅读。本书附有大量注释和词汇以帮助学生自己阅读。③ 包含思考题和习题。它们方便读者练习和复习，考查其掌握本书基本理论和方法的程度。

本书第1章和第2章第2、3、4单元由周跃进编写，第2章第1单元和第5章由马力编写，第3章和第4章由李萍编写，第6章和第13章由赵丽娟编写，第7章、第8章和第10章由任秉银编写，第11章由李迁编写，第9章和第12章由李建辉编写。全书由周跃进统稿，唐任仲教授主审。

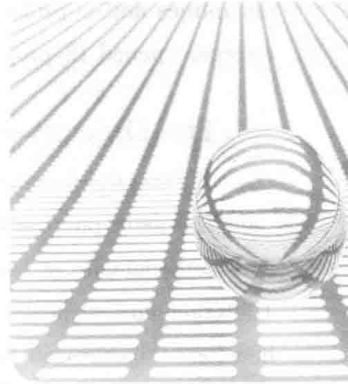
在本书的编写过程中，陈卉、翁元、刘聆哲、时楠、王佳、胡冬伟、王天博等研究生做了大量工作，在此表示衷心感谢！

本书涉及工业工程领域相当广泛的内容，由于编写时间较紧，加之作者英语水平所限，书中难免出现疏漏或不当之处，敬请广大读者和同仁提出宝贵意见，以便今后再版时加以改进。

周跃进
于南京大学南园



# Contents



# Chapter 1
# Introduction to Industrial Engineering

## Unit 1 What is Industrial Engineering?

### The Roles of IE

Industrial engineering (IE) is emerging as one of the classic and novel professions that will be counted for solving complex and systematic problems in the highly technological world of today.[1] In particular, with the transformation and promotion of China's economy and China's reform and opening deep-going, the demand for IE will increase and widen continuously and urgently.

A production system or service system includes inputs, transformation, and outputs. Through transformation, the added values are increased and the system efficiency and effectiveness are improved. Transformation processes rely on the technologies used and management sciences as well as their combination.

Managing a production system or service system is a challenging and complex task—one that requires the knowledge of fundamental sciences, engineering sciences, behavioral sciences, computer and information sciences, economics, and a great number of topics concerning the basic principles and techniques of production and service systems.

### The Demand for IE Graduates

Industrial engineering curricula are designed to prepare the students to meet the challenges of the future for the construction of Chinese economic and harmonious society. Many IE graduates (IEs) will, indeed, design and run modern manufacturing systems and facilities. Others will select to engage in service activities such as health-care delivery, finance, logistics, transportation, education, public administration, or consulting and so on.

The demand for IEs is strong and growing each year. In fact, the demand for IEs greatly exceeds the supply. This demand/supply imbalance is greater for IE than for any other engineering or science disciplines and is projected to exist for many years in the future. Therefore, over 250 universities or colleges opened IE program in China in 2015.

## The Objectives of the Textbook

The main purpose of this textbook is to introduce systematical theories and advanced techniques and methodologies of the relevant subjects of industrial engineering as well as their English expression. The other aim of the textbook is to strengthen and improve student's the ability of reading and comprehension of specialized English literatures related to industrial engineering.

## Engineering and Science

How did the two words "industrial" and "engineering" get combined to form the term "industrial engineering"? What is the relationship between industrial engineering and other engineering disciplines, to business management, or the social sciences?

To understand the role of industrial engineering in today's economic and knowledge-based era, it is beneficial to learn the historical developments that were hopeful in the evolution of IE. There are many ways to write a historical development of engineering. The treatment in this unit is brief because our interest is in reviewing the significances of engineering development, particularly those leading to industrial engineering as a specialty. More complete histories are available in the reference [2]—[4].

Engineering and science have developed in a parallel, complementary fashion, although they are not always at the same pace. Whereas science is concerned with the quest for basic knowledge, engineering is concerned with the application of scientific knowledge to the solution of problems and to the quest for a "better life". Obviously, knowledge cannot be applied until it is discovered, and once discovered, it will soon be put to use. In its efforts to solve problems, engineering provides feedback to science in areas where new knowledge is needed. Thus, science and engineering work hand in hand.

## Engineering Applications—Tools

Although "science" and "engineering" each have distinguishing features and are regarded as different disciplines, in some cases a "scientist" and an "engineer" might be the same person. This was especially true in earlier times when there were very few means of communicating basic knowledge. The person who discovered the knowledge also put it to use.

We naturally think of such outstanding accomplishments as the pyramids in Egypt, the Great Wall of China, the Roman construction projects, and so on, when we recall early engineering accomplishments. Each of these involved an impressive application of fundamental knowledge.

Just as fundamental, however, were accomplishments that are not as well known. The inclined plane, the bow, the wheel, the corkscrew, the waterwheel, the sail, the simple lever, the many, many other developments were very hopeful in the engineer' s efforts to provide a better life.

## Engineering Basis

Almost all engineering developments prior to 1800 had to do with physical phenomena: such as overcoming friction, lifting, storing, hauling, constructing, and fastening. Later developments were concerned with chemical and molecular phenomena: such as electricity, properties of materials, thermal processes, combustion, and other chemical processes.

Fundamental to almost all engineering developments were the advances made in mathematics. Procedures for accurately measuring distances, angles, weights, and time were necessary for almost all early engineering accomplishments. As these procedures were refined, greater accomplishments were realized.

Another very important contribution of mathematics was the ability to represent reality in abstract terms. A mathematical model of a complex system can be manipulated such that relationships between variables in the system can be understood. The simple relationship commonly called the Pythagorean theorem is such an example. This theorem says that the hypothenuse of a right triangle is equaled as the square root of the sum of the squares of the adjacent sides. The use of abstract models representing complex physical systems is a fundamental tool of engineers.

As a final comment on early development, let us take care of an early development that did not come. The missing early development is related to the behavioral sciences. The understanding of human behavior has lagged greatly behind developments in the mathematical, physical, and chemical sciences. This is important to industrial engineers because the systems designed by IEs involve people as one of the basic components. The lack of progress in behavioral science has impeded the industrial engineer in his efforts to design optimal systems involving people.

## The Modern Era of Engineering

Based on the book *Introduction to Industrial and Systems Engineering*, it defines the *modern era* of engineering as beginning in 1750, even though there were many important developments between 1400 and 1750. There are two reasons to choose 1750 as the beginning of modern engineering:

(1) Engineering schools appeared in France in the eighteenth century.

(2) The term *civil engineer* was first used in 1750.

## Civil Engineering

Principles of early engineering were first learned in military colleges and were concerned primarily with road, bridge and fortifications construction. This kind of academic training was referred to as military engineering. When some of the same principles were applied to nonmilitary attempts, it was natural to call them as civilian engineering, or simply civil engineering.

## Mechanical Engineering

With the development of civil engineering, the relevant disciplines had also developed. Interrelated advancements in the fields of physics and mathematics set up the groundwork for practical applications of mechanical principles. A significant advancement was the development of a practical steam engine that could accomplish useful work. Once such an engine was available (approximately 1700), many mechanical devices were developed that could be driven by the engine. These efforts culminated in the emergence of mechanical engineering as a distinct branch in the early nineteenth century.

## Electrical Engineering

The discovery and applications of electricity and magnetism are another example of such advancement, which were the fundamental work done in the later part of the eighteenth century. Although early scientists had known about magnetism and static electricity, an understanding of these phenomena did not start until Benjamin Franklin's famous kite-flying experiment in 1752. In the next 50 years the foundation of electrical science was built up primarily by German and French scientists.

The first distinguishing application of electrical science was the development of the telegraph by Samuel Morse. Morse telegraph is a kind of telegraph that sends messages using dots and dashes or short and long sounds or flashes of light to represent letters of the alphabet and numbers. Thomas Edison's invention of the carbon-filament lamp (which is still used today) led to widespread use of electricity for lighting purposes. This, in turn, spurred very rapid developments in the generation, transmission, and utilization of electrical energy for a variety of labor-saving purposes. Engineers who chose to specialize in this field were naturally called electrical engineers.

## Chemical Engineering

Along with the developments in mechanical and electrical technologies were accompanying developments in the understanding of substances and their properties. The science of chemistry came up, which is concerned with understanding the nature of matter and in learning how to produce desirable changes in materials. Fuels were required for the new internal combustion engines being developed. Lubricants were needed for the rapidly growing array of mechanical devices. Protective coatings were required for houses, metal products, ships, and so forth. Dyes were needed in the manufacture of a wide variety of consumer products. Somewhat later, artificial materials were required to carry out certain functions that could not be performed as well or at all by natural materials. This field of engineering effort naturally became known as chemical engineering.

## Industry

After making clear of science and engineering, it is time to talk about the term "industry". A clear indication of the way in which human effort has been harnessed as a force for the commercial production of goods and services is the change in meaning of the word industry. Coming from the Latin word *industria*, meaning "diligent activity directed to some purpose" and its descendant, old French industrie, with the senses "activity" "ability" and "a trade or occupation", our word (first recorded in 1475) originally meant "skill" "a device" and "diligence" as well as "a trade". As more and more human effort over the course of the Industrial Revolution became involved in producing goods and services for sale, the last sense of industry as well as the slightly newer sense "systematic work or habitual employment" grew in importance, to a large extent taking over the word. We can even speak now of the Shakespeare industry, rather like the garment industry. The sense "diligence, assiduity", lives on, however, perhaps even to survive industry itself. From the origin of this word, we can find that it means a variety of economic or social activities.

## Large Scale Production

As industrial organizations emerged to make use of the rapidly developing array of technological innovations, the size and complexity of manufacturing units increased dramatically. Large scale production was made possible through three important concepts:

(1) Interchangeability of parts.

(2) Specialization of labor.

(3) Standardization.

Through large scale production the unit cost of consumer products was reduced dramatically and productivity was increased substantially.

## The Origination of IE

The base was now laid for a dramatic shift in the lifestyles and cultures of industrialized countries. Within nearly twenty years the People's Republic of China and other developing countries changed largely rural, agricultural economies and societies to urban, industrialized economies and societies. The suddenness of this change is probably the cause of many of today's urgent problems, for example, air pollution, enviromental change, resources shortage, diseases increase, traffic crowding and population aging, and so on.

During the early part of this movement it was recognized that business and management practices that had worked well for small shops and farms simply were inadequate for large, complex manufacturing organization. The need for better management systems led to the development of what is now called-industrial engineering.

## The Definition of Industrial Engineering

The following formal definition of industrial engineering has been adopted by the Institute of Industrial Engineers (IIE):

Industrial engineering is concerned with the design, improvement, and installation of integrated systems of people, materials, information, equipment, and energy. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate, the results to be obtained from such systems. [2]

As used in this context, the term *industrial* is intended to be interpreted in the most general way as mentioned above. Although the term *industrial* is often associated with manufacturing organization, here it is intended to apply to any organization. The basic principles of industrial engineering are being applied widely in agriculture, education, hospitals, banks, government organizations, and so on.

Read this definition again. Imagine any large factory that you have seen in which thousands of workers, hundreds of machines, a large variety of materials and thousands and millions of yuans must be combined in the most productive, cost-effective manner. Think about a large city that also requires millions of workers, millions of vehicles and other machinery, materials, and thousands and millions of yuans in order to deliver services required by public. Imagine how much more effectively the city could be run if the principles of industrial engineering were applied.

## Notes

1. Industrial engineering (IE) is emerging as one of the classic and novel professions that will be counted for solving complex and systematic problems in the highly technological world of today.

句意：作为一种古老而又新颖的专业，工业工程的出现将用来解决当今高度技术发展的世界所遇到的复杂的系统问题。

classic 意味着工业工程是一个古老的专业，有100多年的历史；novel 意味着工业工程一直致力于改革和创新，紧跟时代步伐并致力于解决当今社会现实问题。

2. Industrial engineering is concerned with the design, improvement, and installation of integrated systems of people, materials, information, equipment, and energy. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate, the results to be obtained from such systems.

句意：工业工程是对由人员、物料、信息、设备和能源所组成的集成系统进行设计、改善和设置的一门学科。它综合运用数学、物理学和社会科学方面的专门知识和技术以及工程分析和设计的原理与方法，对该系统所取得的成果进行鉴定、预测和评价。

## Exercises

1. What is science? What is engineering? What is industry? What is industrial engineering?
2. Simply describe the formulation of industrial engineering.
3. Explain the definition of industrial engineering.
4. Explain the origination of industrial engineering.
5. What are the focus topics of the five big disciplines?
6. What is the base of engineering and why?

# Unit 2 History of Industrial Engineering

## The Formulation of Industrial Engineering

Industrial engineering emerged as a profession as a result of the industrial revolution and the accompanying need for technically trained people who could plan, organize, and direct the operations of large complex systems. The need to increase efficiency and effectiveness of operations was also an original stimulus for the emergence of industrial engineering. Some early developments are explored, in order to understand the general setting in which industrial engineering was born. For more details, see the excellent work of Emerson and Naehring—*Origins of Industrial Engineering: the Early Years of a Profession*.

Now let us recall some famous people who contributed their efforts for IE.

## Charles Babbage's Division of Labor

Charles Babbage (1792 - 1871)[1] visited factories in England and the United States in the early 1800's and began a systematical record of the details involved in many factory operations. For example, he observed that the manufacture of straight pins involved seven distinct operations. He carefully measured the cost of performing each operation as well as the time per operation required to manufacture a pound of pins. Babbage presented this information in a table, and thus demonstrated that money could be saved by using women and children to perform the lower-skilled operations. The higher-skilled, higher-paid men need only perform those operations requiring the higher skill levels. Babbage published a book containing his findings, entitled *On the Economy of Machinery and Manufactures* (1832). In addition to Babbage's concept of division of labor, the book contained new ideas on organizing and very advanced (at that) concepts of harmonious labor relations. Significantly, Babbage restricted his work to that of observing and did not attempt to improve the work methods or to reduce the operation times.

## Eli Whitney's Interchangeable Concept

The concept of interchangeable manufacture was a key development leading to the modern system of mass production. This concept was to produce parts so accurately that a specific part of a particular unit of a product could be interchanged with the same part from another unit of the product, with no degradation of performance in either unit of the product. Eli Whitney (1765 - 1825)[2] received a government contract to manufacture muskets using this method. His another contribution was the design and construction of new machines that could be operated by laborers with a minimal amount of training. Through the successful application of these two concepts, Whitney created the first mass production system.

In the period of around 1880 industrial operations were conducted in a much different manner from today. There was very little planning and organizing, as such. A first line supervisor was given verbal instructions on the work to be done and a crew of (usually) poorly trained workers. The supervisor was expected to his men make as hard as he could. Any improved efficiency in work methods usually came from the worker himself in his effort to find an easier way to get his work done. There was virtually no attention given to overall coordination of a factory or process.

## Frederick Winslow Taylor's Efficiency Improvement

Frederick Winslow Taylor (1856 – 1915)[3] is credited by recognizing the potential improvements to be gained from analyzing the work content of a job and designing the job for maximum efficiency. Taylor's original contribution, constituting the beginning of industrial engineering, was his three-phase method of improving efficiency: Analyze and improve the method of performing work, reduce the times required, and set standards for what the times should be. Taylor's method brought about significant and rapid increases in productivity. Later developments stemming from Taylor's work led to improvement in the overall planning and scheduling of an entire production process.

## Frank B. Gilbreth's Motion Study

Frank B. Gilbreth (1868 – 1924) extended Taylor's work considerably. Gilbreth's primary contribution was the identification, analysis, and measurement of fundamental motions involved in performing work. By classifying motions as "reach" "grasp" "transport" and so on, and by using motion pictures of workers performing their tasks, Gilbreth was able to measure the average time to perform each basic motion under varying conditions. This permitted, for the first time, jobs to be designed and the time required to perform the job known before the fact. This was a fundamental step in the development of industrial engineering as profession based on "science" rather than "art".

## Lillian Gilbreth's Human Relations Study

Dr. Lillian Gilbreth (1878 – 1972), wife of Frank, is credited by bringing to the engineering profession a concern for human welfare and human relations. Having received a doctoral degree in psychology from Brown University, Dr. Gilbreth became a full partner with her husband in developing the foundational concepts of industrial engineering. During Dr. Gilbreth's long life, she witnessed and contributed to the birth, growth, and maturation of the IE profession. She became known as the "first lady of engineering" and the "first ambassador of management". She received many, many honors and awards from professional organizations, universities, and governments around the world. She was the first woman to be elected to the National Academy of Engineering[4].