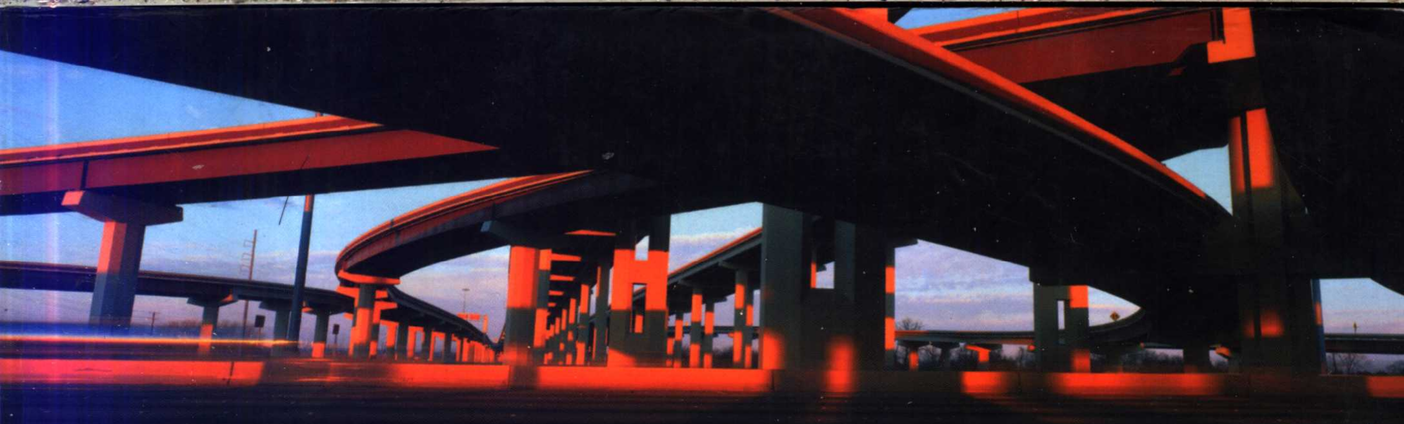

INDUSTRIAL ENGINEERING

工业工程

英文版

马捷 马挺 编

上海交通大学出版社

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（英文版）

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内 容 提 要

《工业工程》是为高等学校工业工程专业编写的专业英语教材。本书内容基本上涵盖了工业工程的知识体系，介绍了欧美国家高校工业工程专业课程的主要内容。本书以培养学生的专业英语阅读能力为目标，同时，也可作为学习用英语写专业论文的教材。

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前　言

大学本科生在学完大学英语课程之后，想要顺利地阅读专业英语图书期刊，尚有一些困难。这主要是因为学生尚未掌握必需的专业英语中所常用的词汇、词组和语法结构知识所致。编注本书的目的，旨在向学生提供专业英语的学习材料，以便学生能在较短的时间内有效地提高阅读工业工程专业英语图书期刊的能力。

本书编选的文章，其内容基本上涵盖了工业工程的知识体系，主要介绍了欧美高校工业工程专业课程的主要内容，对于学生了解和关注欧美高校工业工程专业迅速发展的动向提供了一定的帮助。

本书是为工业工程专业三年级的本科生编写的。《大学英语教学大纲通用词汇表(1～4)》(1999 年 9 月修订版，上海外语教育出版社、高等教育出版社)中的一切词汇、词组，除了极少数有特殊含义的以外，一般不再进行注释。此外，每篇文章的注释是独立的，互不相干。这样，既便于任意选择教学内容，也有利于通过重复学习而加深对词汇、词组的理解和记忆。

《大学英语教学大纲》(1999 年 9 月修订版，上海外语教育出版社、高等教育出版社)规定：专业英语为必修课，可安排在第五至第七学期，教学时数应不少于 100 学时，每周 2 学时。课内外学习时数的比例应不低于 1:2。在第八学期还可继续安排专业英语文献阅读、专业英语资料翻译、英文摘要写作等。本书的选材篇幅和推荐的教学时数就是基于这样的规定。

本书与大学英语有较好的衔接，文章内容丰富，专业词汇比较全面，行文规范，结构严谨，因而也是学生学习用英语写专业论文的教材。教师在讲授时，可根据教学时数等具体情况适当选用书中的若干篇文章。

由于作者的水平有限，书中如有不妥和谬误之处，恳请广大读者批评指正。

编者

2002 年 2 月

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1. History of Industrial Engineering

Initial work in industrial engineering (IE) is usually credited to applied economists and industrialists in England around 1800. The Scottish economist Adam Smith made pioneering observations as to the economies inherent in the division of labor in manufacturing jobs. He argued that by dividing a production job, such as building a pushcart, into small specialized tasks and assigning a single worker to each task, the overall job could be completed less expensively than if one man were assigned the entire job.[1] Smith claimed that such economics were due to (1) the development of new skills when a single task is performed respectively, (2) the saving of time lost in changing from one task to another, and (3) the invention of new, special-purpose tools and equipment. Smith's theories and observations are summarized in the classic manuscript *The Wealth of the Nations* published in 1776.

Charles Babbage extended the work of Smith. Babbage recognized that by specializing labor task assignments it would not be necessary to pay for skill levels only used during a fraction of the total job. Those portions of the job which do not require high skills or extensive experience can be organized as individual, separate jobs carrying lower wage rates. Thus, the overall cost of production can be reduced. Babbage presented his conclusions in *On the Economy of Machinery and Manufactures* in 1835.

Around 1795, Matthew Boulton and James Watt developed a modern, closely integrated factory to produce steam engines in Soho, England. They implemented sophisticated management systems to aid in operating the plant, including standards for jobs in the factory. They maintained some 22 books of standards for use in detecting waste and inefficiency. They also utilized methods for forecasting, plant location, plant layout, and wage incentives. Their factory system is generally recognized to have been 100 to 150 years ahead of its time.

Developments in industrial engineering in America began with Frederick W. Taylor in the early 1900s. In fact, Taylor is often called the "father of industrial engineering". Whereas Adam Smith and Charles Babbage were primarily observers and writers, Taylor was a "doer", developing principles and concepts through experimentation. He was concerned with developing scientific methods of both performing work and managing a production facility. His theories are summarized in *The Principles of Scientific Management*.

From the beginning of the Industrial Revolution until Taylor's era, work was carried out on a rule-of-thumb basis. There were, generally, no standards as to how a particular job was to be performed or what results should be achieved.[2] Managerial planning and analysis procedures were almost nonexistent. Taylor made a significant contribution toward changing this condition to one in which management is a scientific activity rather than a "happenstance".[3] His efforts were centered around four guidelines for managing an organization:

- Develop a science for each element of a man's work, thereby replacing existing rule-of-thumb methods.
- Select the best worker for each particular task, rather than allowing the worker to select his own task.
- Divide work into almost equal shares between management and labor, each taking over the work for which he is best suited (rather than the former condition in which most of the work and responsibility were thrust on labor).
- Develop a spirit of cooperation between management and labor in order that work be carried out according to the procedures referred to in 1 and 2.

Early applications of Taylor's theories were in such diverse areas as metal-cutting processes, organizational structure, wage incentive systems, work methods, work measurement systems, and production planning and control. However, his major contribution was in the integration of his philosophy as a practical approach to management, leading to what was referred to as scientific management.

Taylor was not alone in his recognition of the need for a scientific approach to management. Frank and Lillian Gilbreth, working as a husband and wife team, were responsible for much of the theory and techniques used today in work methods and in work measurement. They performed many experiments in time and motion studies of various work operations in order to develop principles to aid in designing more efficient job procedures. Henry Gantt was also concerned with the theory of work methods, but made more significant contributions in the area of production planning and control. He developed a systematic method of scheduling production work orders for processing customer jobs on required equipment to account for plant operations as a whole, including interdependencies among work-order processing requirements. The basic tool used in Gantt's approach was a graphical representation of the simultaneous status of all work orders in the plant, called a "Gantt chart".[4] This chart is still used today by many firms as their primary scheduling aid.

There was rapid growth of industrial engineering during the two decades prior to 1930. Significant developments took place in the areas of work methods, work measurement, facility design, wage incentives, job evaluation, organization theory, human factors, and production planning and control. However, with these advances came misuse of the techniques and principles developed by Taylor and others, creating a good deal of ill will toward industrial engineering as a discipline. This was especially true in the application of work measurement. Unrealistic time standards were often set for jobs, and standards were frequently set without informing the workers involved. Such practices led workers to resent the "efficiency expert" involved in developing the standard, and to mistrust the use of standards in general in evaluating worker performance.[5] Even today, there is a tendency for a person with a clipboard and a stopwatch on a plant floor to be looked upon with some misgivings.

Until the late 1940s, developments in industrial engineering followed the tradition established by Taylor, Gantt, and the Gilbreths and constituted refinements of their work. However, during the late 1940s and early 1950s the techniques of operations research were introduced to industry in the United States and Britain. Since that time, much of the growth of industrial engineering has been in the development and application of operations research techniques for the solution of problems in both the public and private sectors.

Words and Expressions

inherent *adj.*	固有的,内在的
pushcart *n.*	手推车
assign *vt.*	分配,指派
manuscript *n.*	手稿,原稿
integrated *adj.*	综合的,完整的
incentive *n.*	激励
doer *n.*	行为者,实干家
rule-of-thumb	经验法则
happenstance *n.*	偶然事件,意外事件
thrust *vt.*	强加
interdependency *n.*	互相依赖,相关性
Gantt chart	甘特图
clipboard *n.*	有纸夹的笔记板
stopwatch *n.*	秒表
misgiving *n.*	疑虑
refinement *n.*	改进的地方
operations research	运筹学

Notes

1. He argued that... the entire job.

此句中的 that... entire job 是宾语从句,其中,the overall... entire job 是该宾语从句中的主句,by... each task 是介词短语作状语。全句可译为:

他主张分派生产任务,例如,把制造一辆手推车的任务分成几个小的专门化任务,给每个工人分配一项任务,这样,制造整辆手推车的费用要比一个工人承担整项任务所需的成本要来得低。

2. There were,... be achieved.

句中 as to 后接两个并列的疑问词加动词不定式 how a... performed 和 what... achieved,由 or 连接。全句可译为:

至于如何完成一项特殊工作或应取得什么样的结果,一般是没有标准的。

3. Taylor made a significant... a "happenstance".

主语为 Taylor,谓语为 made,宾语为 a significant contribution,介词短语 toward...

"happenstance"作状语，其中的one指前面的condition，而 in which... "happenstance"为限制性定语从句，说明 one。全句可译为：

泰勒将这一状况改变为一条法则，即管理是一种科学活动，而不是一个"偶然事件"，对此，他做出了重要贡献。

4. The basic tool... "Gantt chart".

主语为 The basic tool，表语为 a graphical representation，介词短语 of... the plant 作 a graphical representation 的定语，called a "Gantt chart"用以说明 a graphical representation。全句可译为：

甘特方法中使用的基本工具是工厂里全部工序同时发生的状况的图解表示法，这种图解表示法被称为"甘特图"。

5. Such practices led workers... worker performance.

主语为 Such practices，谓语为 led，宾语为 workers，两个并列的介词短语 to resent... the standard 和 to mistrust... performance 作 workers 的宾语补足语。全句可译为：

这样的做法引起了工人们对提出该标准的"效率专家"的不满及对评价工人表现而使用的标准普遍不信任。

2. Industrial Engineering Versus Operations Research

There is a diversity of opinion as to whether or not industrial engineering and operations research (IE/OR) is really a single discipline or two separate disciplines. Although they have had somewhat separate histories as we have seen, IE and OR are nevertheless considered by many practitioners to be part of the same overall discipline. This is primarily due to the mission or "reason for being" that they share in common, that of providing effective, efficient answers to questions relating to design, analysis, and evaluation. This common mission is reflected in many of the formal definitions offered for the two areas. For example, consider the definition of industrial engineering as published by the Institute of Industrial Engineers: "Industrial Engineering is concerned with the design improvement, and installation of integrated systems of men, materials, and equipment."[1] 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] The essence of this definition is that of a scientific discipline concerned with the productive use of men and equipment.

The concerns and methods of operations research are similar to those of industrial engineering. Wagner defines operations research as "a scientific approach to problem-solving for executive management". He goes on to state that:

An application of operations research involves:

- Constructing mathematical, economic, and statistical descriptions or models of decision and control problems to treat situations of complexity and uncertainty.
- Analyzing the relationships that determine the probable future consequences of decision choices, and devising appropriate measures of effectiveness in order to evaluate the relative merit of alternative actions.

Churchman characterizes OR as "the application of scientific methods, techniques, and tools to problems involving the operations of systems so as to provide those in control of the operations with optimum solutions to the problem."[3] From these definitions, we can conclude that both IE and OR are concerned with the application of scientific techniques to operational problems. The underlying systems are often the same, as are the study objectives. The primary differences are usually in the scope of the analysis and the type of models and methodology used in the study.

For instance, the early developments in industrial engineering were associated with manufacturing plants, and were heavily based on systematic common-sense approaches to problems rather than on a predominate use of mathematics. This included activities such as process planning, methods improvement, setting job time standards, and job evaluation, which were collectively recognized as industrial engineering.[4] Although these activities are just as important and commonly applied today as in the past, they have been labeled "traditional" or "classical" industrial engineering activities.

However, in the last 30 or so years, the majority of the developments in industrial engineering have arisen through the derivation and application of analytical techniques based on applied mathematical concepts.[5] These are operations research techniques and have been developed by industrial engineering specialists as well as by economists, mathematicians, physicists, chemical engineers, and civil engineers, to mention but a few.

Because of the contrast in the mathematical orientation between traditional industrial engineering and operations research, it may be used to think of these two areas as a spectrum or continuum of activities with traditional IE at one end and OR at the other. Traditional IE tends to be more applicable to problems in a manufacturing environment on the other end of the spectrum, OR has a broader scope, being oriented toward more macro level problems in a wide variety of application areas of which manufacturing is only one. Operations research also places heavier reliance on mathematical concepts, especially mathematical models, than does traditional IE.

Under this continuum view of industrial engineering and operations research, activities such as work methods and job evaluation are at one end of the spectrum and linear programming and queueing analysis are at the other. However, there is a great deal of overlap in the middle of the spectrum of activities where problems that have been an integral part of traditional industrial engineering have recently been analyzed using the mathematical methods of operations research.[6]

An example of this type of activity is facility design. Industrial engineers have traditionally been concerned with facility design issues such as determining the best layout for a plant or the best location of a distribution warehouse. Traditional analytical tools have been used, such as flow diagrams, templates, and guidelines checklists. However, more recently OR techniques such as queueing analysis and mathematical programming have been successfully applied in resolving these same facility design problems. In addition, the scope of facility design has been broadened beyond the industrial context to include layout and location problems for post offices, airports, sports organizations, and other service industries. Other activities and problem areas in the middle of this IE/OR spectrum include inventory control, forecasting, production scheduling, and quality control.

An additional area in the IE/OR spectrum is human factors. This area also is a traditional industrial engineering activity, but one in which mathematical and statistical methodologies recently have assumed a more important role. However, these methodologies are not operations research techniques such as mathematical programming. Rather, they include experimental design and analysis techniques, and digital and analog computer process control and analysis.

The distinction between IE and OR is treated in a somewhat different fashion by Barish. He suggests that OR is the *applied science* for managerial systems, whereas IE is the *engineering* of managerial systems. This distinction is analogous to the relation between medicine and medical science, or chemical engineering and the science of chemistry. Barish believes that "while the industrial engineer should be primarily concerned with the application and modification of existing techniques to the problems as they occur, the operations researcher should be endeavoring to discover fundamental relations and to develop new approaches, models, and techniques.[7] Obviously, the two fields overlap in many areas." Barish is essentially defining a continuum or spectrum similar to the one discussed earlier. However, the spectrum is defined by Barish to have at one end the pure application of existing IE/OR concepts and tools, and at the other end research activity directed at the development of new concepts and techniques. IE activities are at the application end of the spectrum, while OR activities are at the research end.

Each student of industrial engineering and operations research will undoubtedly develop his own philosophy of the relationship between these two areas. The important factor in this philosophy is not so much the exact distinction between the two areas as it is the recognition of their complementary nature. Both areas share in common productivity-oriented goals and provide the analyst with powerful tools useful in their appropriate setting.

Words and Expressions

versus *prep.* 与……相对
discipline *n.* 领域
practitioner *n.* 专业人员
mission *n.* 使命,任务
essence *n.* 本质
executive *a.* 行政的
characterize *vt.* 具备……的特征
optimum *a.* 最适合的,最佳的
underlying *a.* 根本的
methodology *n.* 方法论,方法学
predominate *vt.* 主导,起主要作用
collectively *adv.* 全体地,共同地
label *vt.* 把……分为
derivation *n.* 推导
spectrum *n.* 范围,领域
continuum *n.* 连续区,连续流
macro *a.* 巨大的,大量使用的
reliance *n.* 信任,依靠
mathematical model 数学模型
linear programming 线性规划
layout *n.* 规划,设计,(工厂等的)布局图
warehouse *n.* 仓库

flow diagram *n.* 工艺流程图
template *n.* (=*templet*) 模板
inventory control 库存控制
assume *vt.* 承担,担任
analog *n.* 模拟
analogous *a.* 模拟的
overlap *v.* 交叠

Notes

1. Industrial Engineering is concerned with... of men, materials, and equipment.

此句中,主语为 Industrial Engineering,谓语为 is concerned with,宾语为 the design... and equipment。全句可译为:

工业工程是研究将人、物料和设备组合成综合系统进行设计改进和组合配置的科学。

2. It draws upon specialized knowledge... to be obtained from such systems.

此句中的主语为 It,指上句中的 Industrial Engineering,谓语为 draws upon,宾语为 specialized knowledge... and design,介词短语 to specify, predict, and evaluate the results to be obtained from such systems 为宾语补足语,其中的 to be obtained from such systems 为动词不定式作 the results 的定语。全句可译为:

它运用数学、物理学和社会科学等方面的专门知识和技能,并使用工程分析和设计的原理和方法来说明、预测和评价从上述综合系统得到的功效。

3. Churchman characterizes OR as... to the problems.

此句中,宾语为 OR,由引导词 as 引导的宾语补足语为"the application of scientific methods, techniques, and tools to problems involving the operations of systems so as to provide those in control of the operations with optimum solutions to the problems."分词短语 involving the operations of systems 说明前面的 problems,而 so as to provide... optimum solutions to the problems 为表示目的的状语。全句可译为:

Churchman 将工业工程称为解决涉及系统操作问题的科学方法、技术和工具的应用,目的是向控制着操作的人们提供解决问题的最佳方法。

4. This included activities... industrial engineering.

此句中的 which were... as industrial engineering 为非限制性定语从句,说明 activities。全句可译为:

工业工程的早期发展包括许多内容,诸如工艺规程设计、方法改进、制定工作时间标准和工作评价等等,这些内容都被公认为工业工程。

5. However, in the last 30 or so years,... applied mathematical concepts.

此句中的主语为 the majority of the developments in industrial engineering,谓语为 have arisen,介词短语 through the derivation and application of analytical techniques based on applied mathematical concepts 作状语,其中的 based on applied mathematical concepts 用来说明 analytical techniques。全句可译为:

然而,在过去的 30 多年里,工业工程大多数的发展是通过基于应用数学概念的分析技术

的产生和运用而实现的。

6. However，there is a great of... operations research.

此句中的 where problems that have been... of operations research. 为限制性定语从句，说明 overlap，而其中的 that have been an integral part of traditional industrial engineering 为 problems 的同位语从句。全句可译为：

然而，在工业工程体系的“光谱”中有许多交叠点，近来，人们运用运筹学的数学方法来分析属于传统工业工程一个整体部分的交叠点的一些问题。

7. Barish believes that... to develop new approaches，models，and techniques.

此句中，主语为 Barish，谓语为 believes，宾语为 that while the industrial engineer... to develop new approaches，models，and techniques。全句可译为：

当问题发生时，虽然工业工程师应该主要研究解决问题的现有技术的应用和修改，但是，运筹学家应该致力于找出基本关系并提出新方法、新模型和新技术。

3. Characteristics of Industrial Engineering

Two factors, in combination, characterize industrial engineering and serve to differentiate it from other occupations: (1) the kind of work performed; and (2) the qualifications required for the work.

Industrial engineering positions are characterized by the application of scientific and mathematical methods to evaluate or predict the resources needed to produce a product or render a service. This concern with scientific methods forms the basis for the classification of positions in industrial engineering. It should be noted, however, that many industrial engineering positions involve related functions and responsibilities.

For the purposes of this definition, integrated systems of men, materials, and equipment may be found in almost all commercial and government installations engaged in fabrication, assembly, repair, overhaul, or storage: in warehousing or operations involving mechanized materials-handling equipment and related processes required in receipt, packing, storing, and shipping; in managerial, clerical, data processing, or other types of office activities; or in other service functions.

The nature of the function performed is such that the industrial engineer must have broad and intensive knowledge—theoretical and practical—of the characteristics, potentials, and limitations of: (1)the components of the system (men, materials, and equipment); and (2) the processes, methods, techniques, and procedures applied in the planning, design, analysis, improvement, and installation of such systems.

The basic means of preparing an individual for professional work in industrial engineering is through completion of a full four- or five-year accredited curriculum in industrial engineering. The curricula vary to some extent, depending upon the fields of industrial engineering that a college or university emphasizes. However, industrial engineering curricula accredited by the Accreditation Board for Engineering and Technology require:(1) courses common to all branches of engineering, including physics, chemistry, mathematics through differential equations, and engineering sciences such as statics, dynamics, strength of materials, thermodynamics, and fluid mechanics; (2) social studies; and (3) specialized subjects characteristic of industrial engineering, such as organization planning, safety engineering, work measurement, facilities planning and layout, materials handling, production planning and control, principles of administration, human engineering, cost accounting, engineering economy, systems and procedures analysis, computer sciences, quality control, operations research, and applied statistics.

While industrial engineering emphasizes the social sciences and industrial management, it shares a large core of knowledge with all branches of engineering. The work of the industrial engineer typically differs from that of other engineers in the relative intensity of application of basic knowledge of those physical and engineering sciences that are common to all branches of engineering; it does not differ in terms of required basic knowledge and understanding of such sciences.

For example, industrial engineering may involve the utilization of professional engineering knowledge in establishing performance requirements, and in reviewing and analyzing the designs of engineers in specialized fields of engineering, with a view toward the successful incorporation of these designs into an integrated system. The industrial engineer, in establishing requirements and analyzing the designs of engineers in other specialized fields of engineering, applies professional knowledge of engineering fundamentals and practice.

Some examples of industrial engineering objectives, and the use of various mathematical disciplines and engineering techniques in the solution of problems are:

- Developing programs for the optimum utilization of resources by evaluating, specifying, and integrating the processes and the adjuncts to the processes through the use of human engineering systems analyses, mathematical interpretations, statistical analyses, and other specialized techniques.
- Providing management with the information required to make decisions by designing, evaluating, and improving management information systems and by conducting engineering economy and value analysis studies of alternative courses of action.
- Improving the efficiency and effectiveness of the organization by various approaches, such as developing organizational, administrative, operating, and production procedures; designing tools, equipment work processes and methods; developing performance standards, work measurement systems, and other management controls; and designing long-range planning programs, as may be appropriate to the organization served.

Industrial Engineering Functions

Management and Operations

This broad group of functions covers work performed by industrial engineers in planning and advising management and production officials on the most effective type and form of organization, and on basic standards, methods, and systems and procedures to be used within these organizations. Generally, industrial engineers propose improvements in the form of alternatives and predictions of the results that can be expected from different courses of action. Economy and effectiveness of operations are prime considerations.

Since industrial engineers work with the total system, they are necessarily responsible for the integration of the worker into that system. Industrial engineers are concerned with factors that govern work performance to a greater extent than are most other engineers.[1] Typically, they are required to be familiar with and to apply modern analytical methods in industrial management and industrial psychology.