Vol. XIII & Issue No.10 October - 2020
INDUSTRIAL ENGINEERING JOURNAL

EVOLUTION OF INDUSTRIAL ENGINEERING

Prof. R. P. Mohanty

Definition of Industrial Engineering as adopted by IIIE

Industrial Engineering (IE) 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 system.

1. SCIENCE AND ENGINEERING – EARLY DEVELOPMENTS

To understand the role of industrial engineering in today's complex world, it is helpful to learn the historical developments involved in the progress of IE. Science is concerned with the search for basic knowledge. Engineering is concerned with the application of scientific knowledge. Engineering and science have been developed in a parallel, complementary fashion, although not always at the same pace. Engineering provides feedback to science in areas where new knowledge is needed. In earlier times, although science and engineering each have different characteristics but are different disciplines sometimes. They are the same persons. For example, Leonardo da Vinci (April 15, 1452 – May 2, 1519) was an Italian scientist, mathematician, engineer, inventor, anatomist, painter, sculptor, architect, botanist, musician and writer. The person who discovered the knowledge also put into use for building the Pyramids, the Great Wall of China, the Roman construction Projects with the efforts to provide a better life. Almost all engineering developments prior to 1800 had to do with physical phenomena.

Later developments were concerned with chemical and molecular phenomena:

§ Electricity
§ Combustion
§ Properties of materials
§ Thermal processes
§ Other chemical processes

Fundamental to almost all engineering developments was the advances made in mathematics. Another very important contribution of mathematics was ability to represent reality in abstract terms. The use of abstract models representing complex physical systems is a fundamental tool of engineers.

2. SCIENCE AND ENGINEERING – MODERN ERA

Beginning in 1750s:

§ Engineering schools appeared in France in the eighteenth century.
§ The term civil engineering was first used in 1750.
§ Principles of early engineering were first taught in military academics with road and bridge construction.

Military Engineering

- Same principles were applied to nonmilitary endeavors: Civil engineering.
- Interrelated advancements in the fields of physics and mathematics laid the groundwork for practical applications of mechanical principles.

An important advancement was the development of a practical steam engine.

§ These efforts resulted in the emergence of mechanical engineering.
§ Latter part of the eighteenth century, fundamental work is conducted on electricity and magnetism and static electricity:
§ Samuel Morse, development of telegraph (1840s)
§ Thomas Edison, invention of carbon-filament lamp
§ Generation, transmission and utilization of electrical energy: Electrical engineering

Developments in mechanical and electrical engineering initiated the progress in the understanding of substances and their properties.

§ Fuels, Lubricants, protective coatings, dyes, synthetic materials
§ Chemical engineering

As industrial organizations profit from technological developments, the size and the complexity of manufacturing units increased giving rise to:

§ Mass production
§ Interchangeability of parts
§ Specialization of labor

Science and Engineering – Modern Era

- Within half a century the developing countries changed from largely rural, agricultural economies and societies to urban, industrialized economies and societies (from 1850to 1900).

- The management practices that had worked well for small shops and farms simply were inadequate for large, complex manufacturing organizations.
- The need for better management systems led to the development of what is now called Industrial Engineering.
- Five major engineering disciplines (civil, mechanical, electrical, chemical, and industrial) were the branches of engineering that came out prior to the World War I.

3. THE INDUSTRIAL REVOLUTION

Developments following World War II led to other engineering disciplines, such as nuclear engineering, electronic engineering, aeronautical engineering, computer engineering. Engineers solve problems, but so do mathematicians. Engineers analyze, but so do statisticians and economists. Engineers design systems. Architects design buildings, but they rely on engineers for much of their work. The distinguishing characteristic of engineering is that concerned with the design of systems. Design involves considerable amount of creativity. Creativity is a kind of an art that one learns through experience.

System

- A system may be defined as a set of components which are related by some form of interaction, and which act together to achieve some objective or purpose.
- Components are simply the individual parts, or elements, that collectively make up a system.
- Relationships are the cause-effect dependencies between components.
- Objective which or purpose of a system is the desired state or outcome system is attempting to achieve.
- Air-conditioning system: Components of this system include the heat pump, the thermostat, the air within the system and the electricity that drives the system (even the house (walls, ceiling, floors, furniture, etc.) itself is a component).

The Engineering Process

- Analysis is concerned with resolving something into its basic elements.
- Concerned with existing systems.
- Synthesis is concerned with combining elements into a whole.
- Concerned with a new or improved system.
- Synthesis is a term whose meaning is almost the same as design (in engineering).
- The engineering process, which is used by all engineers, involves both synthesis and analysis

Engineering as a Profession

Professions

- Medicine, teaching, architecture, law and engineering
- Associated with a profession is a significant body of special knowledge.
- Preparation for a profession includes an internship-like training period following the formal education.

Code of Ethics:

- Each member of a profession recognizes his responsibilities to society over his clients or other members of the profession.
- The need for continuous learning and public service are the other features of engineering.

4. CHRONOLOGICAL DEVELOPMENT OF INDUSTRIAL ENGINEERING

Although there is considerable commonality among the different branches of engineering, each branch has distinguishing characteristics that are important to recognize.

- 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 work systems.
- The need to increase efficiency and effectiveness of operations was also an original stimulus for the emergence of IE.
- Charles Babbage (1791–1871) visited factories in England and the United States in the early 1800's and began a systematic recording of the details involved in many factory operations. He carefully measured the cost of performing each operation as well as the time per operation required to manufacture a pound of pins. 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.
- Division of labor: right person for the right job.
- Interchangeable parts manufacture is 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.
- Eli Whitney(1765 –1825)received a government contract to manufacture muskets using this method.
- Laborers were having only a minimal amount of training.
- Whitney created the first mass production system.

- Frederick W. Taylor (1856-1915) recognized potential improvements to be gained through analyzing the work content (minimum amount of work required to accomplish the task) of a job and designing the job for maximum efficiency. Improving efficiency is a three-phase method that involves:
  - § Analyze and improve the method of performing work,
  - § Reduce the times required,
  - § Set standards for what the times should be.
- Frank B. Gilbreth (1868-1924) extended Taylor 's work considerably. His primary contribution was the:
  - § Identification
  - § Analysis
  - § Measurement

Measurement of fundamental motions involved in performing work. Gilbreth was able to measure the average time to perform each basic motion. This permitted, for the first time, jobs to be designed and the time required to perform the jobs known before the fact (art to science)

- Lillian Gilbreth (1878 –1972) – the first industrial psychologist.
- Henry L. Gantt (1861 –1919) developed the Gantt chart. The Gantt is a systematic graphical procedure for pre-planning and scheduling work activities, reviewing progress, and updating the schedule.

During the 1920s and 1930s much of fundamental work was done on:

- economic aspects of managerial decisions,
- inventory problems,
- incentive plans,
- factory layout problems,
- material handling problems,
- principles of organization.

Idea of scientific management (systematic work study) became very successful. It has increased the productivity, while reducing physical efforts and hours of work of labours, and increased the productivity by a factor of one hundred. The period from 1900 through the mid- 1930s is generally referred as scientific management. Industrial engineering begins in the late 1920s and extends to the present time. Operations researches had a great influence on IE practice starting in the mid-1940s and extend past mid-1970s.The fourth period known as industrial engineering and system engineering is shown beginning around 1970 and extend indefinitely into the future.

5. DEFINITION OF INDUSTRIAL ENGINEERING

- Formal definition of Industrial Engineering adopted by the Institute of Industrial Engineers (IIE) USA:
- The definition implies industrial and systems engineering.
- The term industrial is often associated with manufacturing organizations; here it is intended to apply to any organization.
- The basic principles of IE are being applied widely in agriculture, hospitals, banks, government organizations, and so forth.

6. INDUSTRIAL ENGINEERING EDUCATION

- Industrial Engineering subjects were initially taught as special courses in mechanical engineering departments (elective in ME).
- The first separate department of Industrial Engineering was established in 1908 (Pennsylvania State University, USA).
- But it was only after the World War II, separate IE departments became wide spread in USA Universities.

7. IMPACT OF RELATED DEVELOPMENTS – IMPACT OF OPERATIONS RESEARCH

- The development of industrial engineering has been greatly influenced by the impact of an analysis approach called operations research.
- This approach originated in England and the United States during World War II and was aimed at solving difficult war-related problems through the use of science, mathematics, behavioural science, probability theory, and statistics.
- Following World War II, OR were extended to problems in industry and commerce.
- This resulted in considerable number of mathematicians and scientists who contributed to OR (and also IE).

Some IE departments have changed their names to IEOR:

- University of California, Berkeley
- Colombia University
- Cornell University

A specific problem was identified. Specialists from appropriate fields formed an interdisciplinary task force to develop a solution. One person cannot have expertise in all the scientific areas. Currently, OR represents a set of quantitative methods that are applicable to a wide range of managerial and operational problems. Many industrial engineers do consider operations research as being their primary interest.

8. IMPACT OF RELATED DEVELOPMENTS – IMPACT OF DIGITAL COMPUTERS

Another development that had a significant impact on the IE profession is the digital computer. Digital computers permit the rapid and accurate handling of huge quantities of data, so permitting the IE to design systems for effectively managing and controlling large, complex operations. The digital computer also permits the IE to construct computer SIMULATION models of manufacturing facilities in order to evaluate the effectiveness of alternative facility configurations.

9. COMPUTER-AIDED DESIGN (CAD) AND COMPUTER-AIDED MANUFACTURING (CAM)

Generate process plans, bills of material, tool release orders, work schedules, operator instructions (ERP). IEs are good at computers, since they use PCs extensively to:

- perform various analyses,
- execute mathematical models,
- plan and manage complex projects,
- create data bases,
- implement a wide range of decision support tools.

10. IMPACT OF RELATED DEVELOPMENTS – SERVICE INDUSTRIES

- In the early days of the industrial engineering profession, IE practice was applied almost fully in manufacturing organizations.
- After World War II there was a growing awareness that the principles and techniques of IE were also applicable in non-manufacturing environments.
- Health-care industries applied IE to improve their operations, eliminate waste, control inventories, schedule activities.

11. GOVERNMENT AGENCIES

Thousands of Industrial Engineers are employed by government organizations to increase efficiency, reduce paperwork, design computerized management control systems, implement project management techniques, monitor the quality and reliability of vendor-supplied purchases, and for many other functions.

12. CHALLENGES OF THE FUTURE

Major challenges are:

- Learn to accomplish the engineer's mission in recognition of constraints on natural resources.
- Design systems and processes that are compatible with our natural environment.
- Design and production of safe and reliable products.

13. DIVERSITY OF IE

- Industrial engineering is a diverse (various) discipline concerned with the design, improvement, installation, and management of integrated systems of people, materials, and equipment for all kinds of manufacturing and service operations.
- Industrial engineering is concerned with performance measures and standards, development of new products and processes and product applications, ways to improve use of scarce (limited) resources and many other problem solving endeavors.
- An Industrial Engineer may be employed in almost any type of industry, business or institution, from retail establishments to manufacturing plants to government offices to hospitals.
- Because their skills can be used in almost any type of organization, and also industrial engineers are usually distributed among industries than other engineers.
- Industrial engineers work in insurance companies, banks, hospitals, retail organizations, airlines, government agencies, consulting firms, transportation, construction, public utilities, social service, electronics, personnel, sales, facilities design, manufacturing, processing, and warehousing.

14. DUTIES OF IE

- Industrial engineers determine the most effective ways for an organization to use the basic factors of production - people, machines, materials, and energy. They are more concerned with people and methods of business organization than engineers in other specialties.
- To solve organizational, production, and related problems most efficiently, industrial engineers design data processing systems and apply mathematical analysis such as operations research.
- They also develop management control systems to help in financial planning and cost analysis, design production planning and control systems to coordinate activities and control product quality, and design or improve systems for the physical distribution of goods and services.
- Industrial engineers conduct surveys to find plant locations with the best combination of raw materials, and transportation.
- They also develop wage and salary administration systems and job evaluation programs.
- Install data processing, management information, wage incentive systems,
- Develop performance standards, job evaluation, and wage and salary programs,
- Research new products and product applications, Improve productivity through application of technology and human factors,

- Select operating processes and methods to do a task with proper tools and equipment, Design facilities, management systems, operating procedures, improve planning and allocation of limited resources, enhance plant environment and quality of people's working life, Evaluate reliability and quality performance,
- Implement office systems, procedures, and policies,
- Analyze complex business problems by operations research,
- Conduct organization studies, plant location surveys, and system effectiveness studies,
- Study potential markets for goods and services, raw material sources, labor supply, energy resources, financing, and taxes.

16. NEW ROLE OF IE

- The diffusion of digital technologies in Industry 4.0 – e.g., internet of things, cloud computing, block chain, big data, artificial intelligence etc. – has facilitated a remarkable transformation in work system's boundaries, processes, structures, roles, and interactions. To be sure, this is not just a traditional process since it affects the work systems in totality, thereby mandating to redefine strategies, management processes, and innovation mechanisms. This permeation will in turn lead to the emergence of new ways of organizing value chains and inter relationships, which now will increasingly occur not in isolation but in digital ecosystems. Firms and organizations will use digital transformation in different ways. Some will be compelled to use it to improve the internal organizing process of innovation and run it more efficiently and effectively. Others will use it to sharpen the way they connect to and collaborate with stakeholders. Others instead will leverage digital transformation to build two-sided platforms and remodel their role and impact within entire industries by changing the rules of competition. Industrial engineers will be engaged in studies that clarify how digital transformation affects:
- the boundaries, processes, structures and roles of extended enterprise's value chain in the industries where they operate, and/or collateral ones,
- the way organizations create and capture value,
- the way organizations cooperate and compete simultaneously,
- the way organizations form and operate partnerships in the digital ecosystems,
- the way organizations manage the risks arising from interconnected products and increasing interdependence.

Although Industry 4.0 is driven by new production and information technologies, people centered organizational concepts will continue to be important. Even with highly automated production techniques, smart factory, blue ocean techniques, lean practices, team building and the emotional engagement of employees in particular will remain important critical success factors. Education and the willingness of employees to engage in lifelong learning are major success factors. The aim of I4.0 is not a factory devoid of people; rather more it is the synthesis of the use of information technology and classical people centered forms of work systems.

Ultimately, the professional ethics will remain the same **(MAXIMUM WELFARE FOR THE MAXIMUM PEOPLE).**

AUTHOR

Prof. R. P. Mohanty, Former Professor, NITIE, Mumbai, Former Chairman, National Council, Indian Institution of Industrial Engineering, IIIE, President IIIE Odisha Chapter, Former Vice Chancellor, Siksha O Anusandhan University Bhubaneswar Odisha, President, Indian Institution of Industrial Engineering, IIIE NHQ.