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THE PROFESSION AND PRACTICE OF INDUSTRIAL ENGINEERING

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INTRODUCTION

Industrial Engineering is a branch of modern engineering. It has its beginnings only in the early 1800s and is continually evolving. The Institute of Industrial Egnineers defines industrial engineering as the discipline concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment, and energy. It draws upon specialized knowledge and skills 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.

The primary mission of industrial engineering is to create, build, improve, and install industrial systems which are efficient, effective as well as robust. The term "industrial systems" is not confined to a manufacturing facility or a factory but also encompasses service entities such as banks, hospitals, utility firms, transportation and distribution centers, schools, government, and all other productive organizations. Efficient, effective, and robust systems refer to organizations which have well-defined users and goals (effectiveness), requiring the optimal amount of resources to design, operate, and maintain (efficiency) and which are usually insensitive to changes in external factors during their operation (robustness).

HISTORICAL BACKGROUND

Historically, the pioneering work on industrial engineering was started by industrialists and economists in England circa 1800. Adam Smith, the Scottish economist originally observed that economy in the completion of jobs could be achieved by dividing the job into specialized tasks and assigning a single worker to each task. This observation was chronicled in his classic manuscript "The Wealth of Nations" which was published in 1776. Charles Babbage, another applied economist concluded that differential wage rates could be paid based on the skills and extensive experience of the workers. In his work "On the Economy of Machinery and Manufacture" published in 1835, he wrote that jobs which do not require high levels of skills or experience could be organized and paid lower wage rates compared to those tasks requiring higher levels of skills or experience.

The first modern, closely integrated factory to produce steam engines was developed by Matthew Boulton and James Watt in Soho, England in 1795. It was reported that they implemented sophisticated management systems to operate the plant including standards for work. It was mentioned that they used 22 books for detecting waste and production inefficiencies. Methods for forecasting, plant location, plant layout, and wage incentives were employed. It was believed that their factory system was generally recognized to have been 100 to 150 years ahead of its time.

In the United States, industrial engineering started with the work of Frederick W. Taylor. He is often referred to as the "father" of industrial engineering. In the early 1900s, Taylor developed and experimented with the scientific methods of doing work and managing a production facility. Taylor's theories of the science of work were summarized in "The Principles of Scientific Management" which was published in 1947. His theories found easy applications in organizatona systems, production planning and control, wage incentives systems, and metal cutting processes.

The husband and wife team of Frank and Lillian Gilbreth developed the theory and techniques of work measurement. They were responsible for developing principles and guidelines for designing efficient jobs by conducting many time and motion study experiments of various work operations. Henry Gantt, although worked on the theory of work methods contributed more significantly in the area of production planning and control. Gantt developed a systematic scheduling method which bears his name - the Gantt chart.

Prior to 1930, industrial engineering experienced rapid growth. Significant developments took place in wage incentive systems, queuing, organizational concepts, inventory modeling, management planning, facility design, human factors, work methods, and statistical quality control. The most notable development in this period was the theory of variation propounded by Dr. Walter A. Shewhart of the Bell Laboratories in 1924.

Walter Shewhart observed the presence of natural variations and concluded that they can be described statistically. He then perfected the theory of statistical process control which became the foreunner of the modern practice of quality control.

Tippet, an outstanding mathematician and statistician introduced the snap-reading method of measuring operator and machine delays in textile manufacturing in 1934. The method has been formalized into what is known as ratio-delay studies. The current name for this technology is work sampling or occurrence sampling.

From the 1930s to the early 1940s most of the developments in industrial engineering were refinements of the work established by Taylor, Gilbreth, Gantt, Shewhart, and Tippet.

World War II brought about the field of operations research. Operations research applications during World War II was primarily a "team approach" to operational problems. The operations research (OR) originated from "research on military operations." Military problems successfully addressed by OR were location of radar installations, searching of enemy submarines, deployment of aerial mines, optimal sizing of merchant conveyor fleets, and developemnt of manuever strategies for ships under attack. Post-war industrial firms were strongly encouraged by the success of OR during the war.

The "systematic common sense" approaches to problems advocated by Taylor, Gantt, and Gilbreth were now replaced with more quantitative analyses. George Dantzig developed linear programming, one of the most powerful and commonly used OR tools. Following the development of linear programming came the development of dynamic programming, network theory quadratic and nonlinear programming, integer programming, reliability, inventory theory, simulation decision theory, engineering economy, queuing theory, and systems theory. Advances in computer science accelerated the creation of new analytic techniques such as geometric programming, fractional programming, goal programming, simulation, and most recently decision support systems and expert systems.

The full development of information theory and the maturity of computer technology expanded the horizons of industrial engineering. With contributions from control theory, cybernetics, social systems, and "systems" engineering, industrial engineering has assumed a much broader, more analytic, holistic systems perspective in the design of products and processes.

The contemporary industrial engineering is involved in designing systems using an understanding of all aspects of all systems components, structure, relationships and their processes. It is likewise concerned with integrating technologies and emerging philosophies in achieving productivity, quality and systems goals. Among the popular technologies and current philosophies are just-in-time (JIT), computer integrated manufacturing (CIM), quality engineering kaizen (continous improvement), total quality management (TQM), quality function development (QFD), concurrent engineering, expert systems, information technology (IT), and systems integration (SI).

KNOWLEDGE AND SKILL BASE OF INDUSTRIAL ENGINEERING

The knowledge base of industrial engineering has become standard and includes industrial processes, methods engineering, work measurement, production systems, production planning and control, organizational productivity, materials handling, human performance and ergonomics, information systems, project development and management, probability and statistical analysis, optimization, simulation, queuing analysis, decision theory, engineering economy and systems analysis and design. Shown in Figure 1 depects areas of specialization in Industrial Engineering. Additionally, industrial engineers are expected to have working knowledge of materials engineering and analysis, psychology and social dynamics. He is also expected to possess professional skills in interpersonal relationships and human communications.

INDUSTRIAL ENGINEERING PRACTICE

The industrial engineer is employed in a wide range of positions and functional responsibilities in various manufacturing industries as well as service industries. Common position titles include industrial engineer, industrial engineering manager, planning engineer, methods analyst, systems analyst, industrial engineering superivosr, management analyst, quality engineer, production planner, project analyst, productivity engineer, materials planning engineer, information analyst, industrial engineering consultant and specialist. The most predominant functional applications of industrial engineering are management service groups providing staff support to corporate management, corporate planning, production cost control, production planning and materials control, quality assurance, process engineering, industrial engineering and operations research departments.

Below is a listing of the typical activities performed by industrial engineers.

Activity	*Some Specific Area of Interest*
1. Design of products or characteristics services	• specify product/service • determine best design • determine optimal mix • determine best material • improve product/service • design user-friendly products
2. Design of processes	• determine best process and methods of manufacture • select equipment • determine best sequence of operations • balance assembly process • determine best facility layout • determine best material flow and material handling system • determine materials procurement system • design work place and work environment • design standard operating procedures • design measurement system
3. Improve production or operations	• forecast level of activity • determine optimal production plan • determine optimal inventory levels • determine optimal schedules • smooth production • design quality control systems • standardize methods • simplify and value engineer work
4. Design work standards and methods	• design human tasks • specify "best" methods

		• develop work standards • design effective measures of performance • design systems of auditing performance • simplify, value engineer, and error-proof work
5.	Design of human resource systems	• design procedures for employee selection, testing, and training • design and install job evaluation & wage incentive systems • design safety procedures • design ergonomic work environment
6.	Design of energy productivity systems	• determine "best" energy sources • optimize allocation of energy • specify energy monitoring systems
7.	Design of information	• specify information systems systems • design reports • analyze data • design feedback systems
8.	Design of finance and	• design budgeting system cost system • design and install flow procedures • design effective cost control procedures
9.	Design of facilities	• determine the best location • determine the best flow configuration • determine the best layout • evaluate layout performance
10.	Forecasting and planning	• long-range planning • expansion decisions • new product lines • define systems

11.	System optimization evaluation	• specify system of measures of performance • build systems models • solve systems models • evaluate models • statistically analyze data
12.	Systems analysis and evaluation	• build models • analyze dynamic system behavior • determine cost/benefit of system
13.	Productivity and quality improvement	• specify quality and productivity • specify quality improvement methods • evaluate improvement
14.	Design and installation of maintenance systems	• specify maintenance requirements • measure equipment effectiveness • predict equipment life • establish replacement policies • evaluate maintenance systems
15.	Design of complex	• define systems structures and largescale systems • define relationships • simulate system behavior • obtain optimal policies

In terms of activity intensity, industrial engineers are usually involved in facilities planning and design, methods engineering, work system design, production engineering, work measurement, project development and management, organizational analysis and design, operations research, job evaluation and wage administration, production planning and control, productivity improvement studies, cost control and standards, materials control, and economic evaluation. Frequently, industrial engineers are called upon to perform management and operations audit, safety programs and installation, set up of process controls, tool and equipment selection, set up of preventive maintenance systems, product packaging, handling and testing, product design, energy audit and improvement, and training effectiveness evaluation.

Industrial engineers differ from other engineers both in orientation and application. One of the strengths of industrial engineers is their versatility. They can be employed wherever and whenever there are wastes, inefficiencies, dysfunctionalities, and opportunities for improvement.

Industrial engineers emphasize usability, operational effectiveness, economic attractiveness, enviromental benignness over and above technical feasibility. The systems perspective in design is a unique characteristic of professional industrial engineers. Problems re viewed as systems. With their well-defined knowledge and skills base coupled with their systems perspective and orientation, industrial engineers are professionally prepared to create systems which are expected to benefit humankind on a sustained basis.

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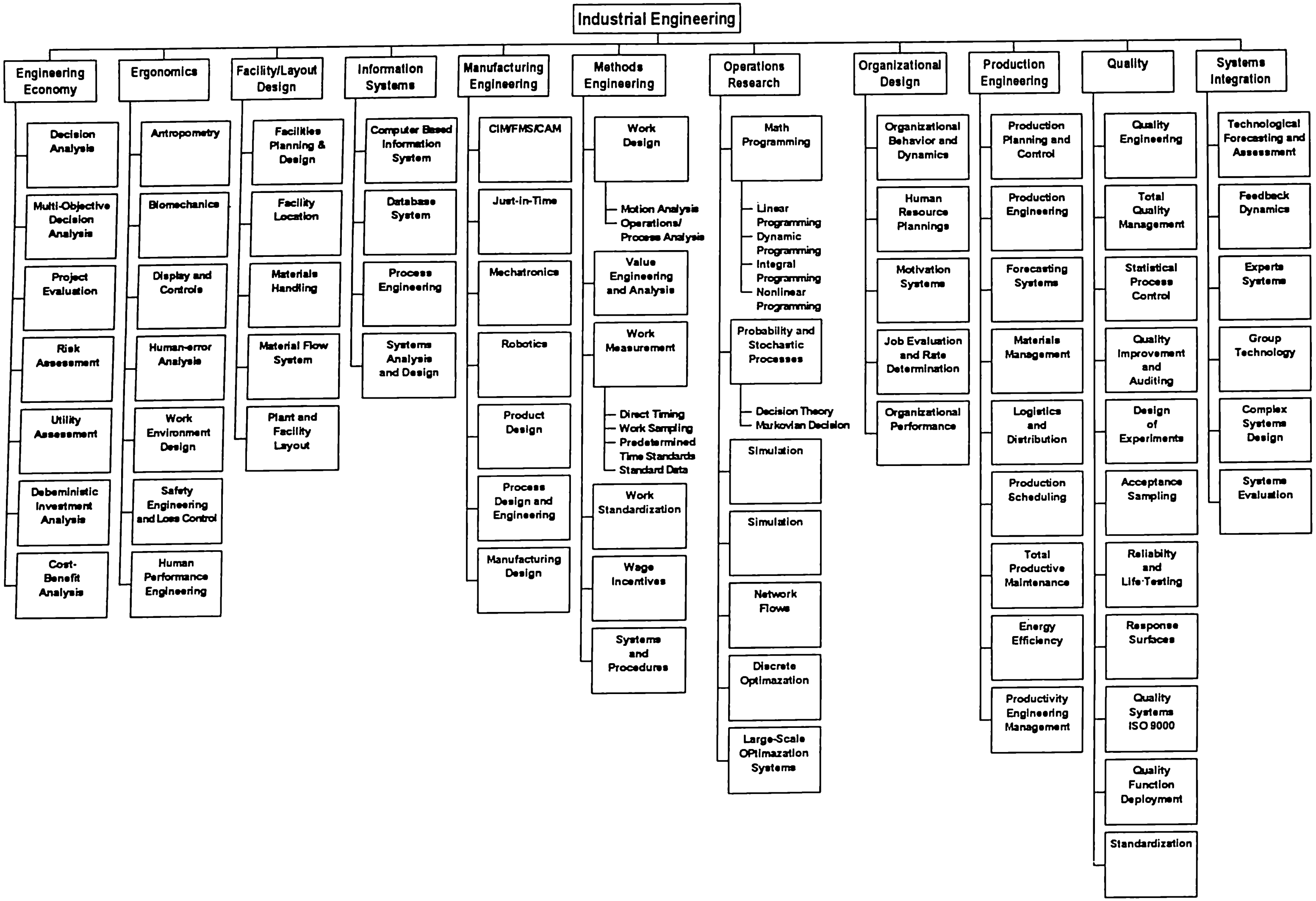

Figure 1. Areas of Specialization Industrial Engineering