Chapter

Introductory Chapter: Background and Current Trends in Industrial Engineering

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1. Introduction

The Institute of Industrial and Systems Engineers' Body of Knowledge [1] formally defines industrial engineering as being "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 with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems."

While some authors trace the roots of industrial engineering (IE) to much earlier periods, industrial engineering began to define itself during the Industrial Revolution of the 1800s, and particularly the early 1900s. Dr. Batson's chapter, later in this book, includes a fine summary of these historical roots. Frederick Taylor (1911) developed efforts in standardization and specialization, and particularly a focus on workers, their work, and how to effectively manage them [2]. This led to the formalization of such IE sub-disciplines as production planning, scheduling, and inventory control. Nadler [3] further notes that industrial engineering has gone through three broad phases of purpose. The first, building on Taylor's initial work, focused on achieving productivity improvements (mainly efficiency0 in manufacturing plant operations. This early work established the IE profession, and lasted until the late 1920s or early 1930s. The second phase, which lasted until the mid-1980s, extended the efficiency concept with mathematical, statistical and computer-based tools [3]. These included the mathematics of engineering economics, statistics of work measurement and quality control, the modeling and optimization of operations research. As the economy transitioned to an emphasis on the service industry during the 1970s and 1980s, the same techniques and tools of manufacturing-based IE were adapted. These service workers and the systems that they work in require industrial engineering techniques to improve their productivity, just as manufacturing does.

The third phase, according to Nadler [3], shifted from "efficiency to effectiveness and quality, from relatively small systems to large or macro systems". The 20th Century saw the effective application of techniques that progressively subdivide activities to improve operations. More recently, there has been a sharp emphasis on the study of "total systems" in order to optimize operations through the integration of subsystems or parallel systems. For example, the traditional factory-centric perspective in manufacturing application shifted outward to the analysis and improvement of the entire supply chain [4]. Continued expansion and adaptation of IE principles occurred. Whereas, the supply chain once addressed the flow of parts and materials from outside sources to internal company use, supply chain analysis has now been extended to encompass materials, services and information from raw material suppliers, through distribution centers and factories, to the final customer [5]. This establishes a value chain of activities that a firm performs in order to deliver a valuable product for the market.

2. Current status and trends

As implied in a series of articles published by the Institute of Industrial and Systems Engineers (IISE), with the beginning of this third decade of the 21st Century, the field of industrial engineering is experiencing a series of further changes, opportunities and innovations [6]. These emerging trends are built on historical precedent, are not mutually exclusive, and overlap/interweave to a varying degree:

- Continued evolution of applications in the manufacturing and service industries.
- The total systems approach to operational decision-making.
- The use of enhanced data analytics.
- Resulting in the emergence of Industry 4.0.

3. Continued evolution of manufacturing and service applications

As service-centric and factory-centric gains were progressively made, associated improvements in efficiency and effectiveness were obtained. As global markets have emerged, the productivity and competitiveness of companies and nations continue to be a priority. The challenge for IEs is to streamline and better integrate the product or service cycle [5]. The techniques of continuous improvement, six sigma and lean manufacturing, as described in later chapters, support this goal. For example, the concept of lean manufacturing addresses process flow and lead-time then identifies and reduces waste from the process. Six sigma creates value through consistent process output and reducing variation. At the same time, the scope of industrial engineering has expanded to also consider the consequences for safety and sustainability due to increasing public interest, regulatory pressures and corporate social responsibilities [7]. Occupational safety engineering “addresses the origins of workplace accidents, regulations and management practices towards mitigating hazard exposures, preventing harm and reducing liability” [1]. Sustainability refers to practices and efforts that balance the environmental, social and economic needs of current and future generations [7].

4. Total systems approach to operational decision-making

Classical industrial engineering studied the way that people worked in the factories, and the relationship of those workers to their tools and machinery. The focus was on the individual and how to improve the effectiveness of their work. Industrial engineers continue to study how the individual works, but much greater emphasis is being placed upon studying the systems within which the work is performed in order to optimize the performance of the total system by studying the application of knowledge [3]. The need for organizations to develop and implement effective integrated systems has enhanced the profession of industrial engineering. The social sciences provide a source toward which IE looks for information about the behavior of human elements within a system. This is particularly true regarding decision theory and operational analysis [8]. Capturing the desires and judgments of users, stakeholders and customers requires the ability to incorporate such values and model the likelihoods and uncertainties of the alternatives. This role will increase in importance as the decision-making systems of the world continue to grow more complex.

5. Enhanced data analytics

Operations research has long been a specialty area within industrial engineering. It involves the development and application of mathematical models that aim to describe and/or improve real or theoretical systems [1]. This generally involves mathematical optimization to support the decision-making process. For example, the case study provided by Drs. Berhan and Kitaw presents a classic application of linear programming. Subsequent chapters in this section note the development and usage of more sophisticated mathematical models and logic, and their leveraging via computer-based platforms. As data volume, variety and speed of updating increases to support increasingly more complex problems, this linkage of these sophisticated models and computer platforms has evolved into the field of data analytics [9]. Data analytics encompasses such enhanced areas as machine learning concepts, and predictive and prescriptive models.

6. Emergence of industry 4.0

The nexus of these three trends leads to the emergence of what has been termed "Industry 4.0". As noted by Amaba et al. [10], "the terms "Industry 4.0" and "Manufacturing 4.0″ describe the fourth wave of the Industrial Revolution." Each phase was driven by unique technological advances. Industry 1.0 was based on steam power to drive production machines. Industry 2.0 harnessed electricity, mass production and labor division. Industry 3.0 was driven by "computer automation and the use of electronics and IT to further automate production with robotic machines that augmented or replaced operators" [10].

The rise of Industry 4.0 is achieved by integrating digital systems with physical systems (i.e. a cyber physical integration) across the value chain to achieve intelligent manufacturing operations, otherwise known as "the smart factory." Technologies supporting Industry 4.0 include [11]:

- Artificial intelligence and machine learning
- Internet of Things
- Additive manufacturing
- Cloud computing
- Big data analytics

An internet-of-things (IoT) enabled device, broadly defined, is a device connected to the internet, allowing users to access its data and to control its functions remotely [10]. For example, in manufacturing systems, data can be collected from all of the factory workstations to make system operations transparent and enable smart operation decisions to improve various key performance measures [11]. With IoT, a large amount of data from multiple similar subjects/devices/machines are available in real time. The dimension and volume of the data collected is often very large and contains data of different and diverse types. These features set forth the need to rethink many traditional predictive and prescriptive methods to adapt to the unique data features collected, and real-time predictions and decisions often at very high frequencies [12].

7. Summary

For over a century, industrial engineering has arguably been responsible for much of the economic progress in the manufacturing and service industries. Industrial engineering serves people and can lead all workers to improved productivity and to a higher standard of living. The needs for change and continuous improvement are too important, and there is no other profession with the breadth of industrial engineering available to meet them. Of particular importance is the range of directions which the profession can follow. Many threads about the future have been woven into this chapter. Subsequent chapters in this book will illustrate the full range of industrial engineering possibilities.

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