IEEM 101: Industrial Engineering and Modern Logistics

A brief introduction to the course

This course is designed to introduce students with no background in IELM to the basic engineering problems studied by Industrial Engineers (IE). In this preface, we briefly comment on (i) the definition of IE, (ii) the nature of engineering, and (iii) a few important historical events in the history and development of IE. At the end, we list the main topics that will be covered during this course.

Definition (from the *Institute of Industrial Engineers*, or IIE):

Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of people, material, 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.

This definition is fairly broad, but essentially: IE's study *systems and their performance*. A system may be a machine that is cutting metal, or a set of trucks that are transporting goods to and from a factory, or a hospital that has staff looking after the needs of patients, etc. As in any engineering, the objectives are to design systems that work 'better' (e.g. faster, cheaper, improved quality of output, etc.)

Science vs. Engineering

Certainly, IE is a discipline of engineering. *What is engineering* ?

The dictionary definition: The application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems.

What is Science?

In general, science is an enquiry into observable phenomena and objects around us, and the main goals of scientists appear to be making accurate models of the universe and things in it; the accuracy of the models are mostly determined by our ability to use the models to predict the behaviour of the object of interest.

In addition, scientists tend to prefer models that are simpler – out of two models that work equally well, the simpler is considered to be better (this principle is called ***Occam's razor***).

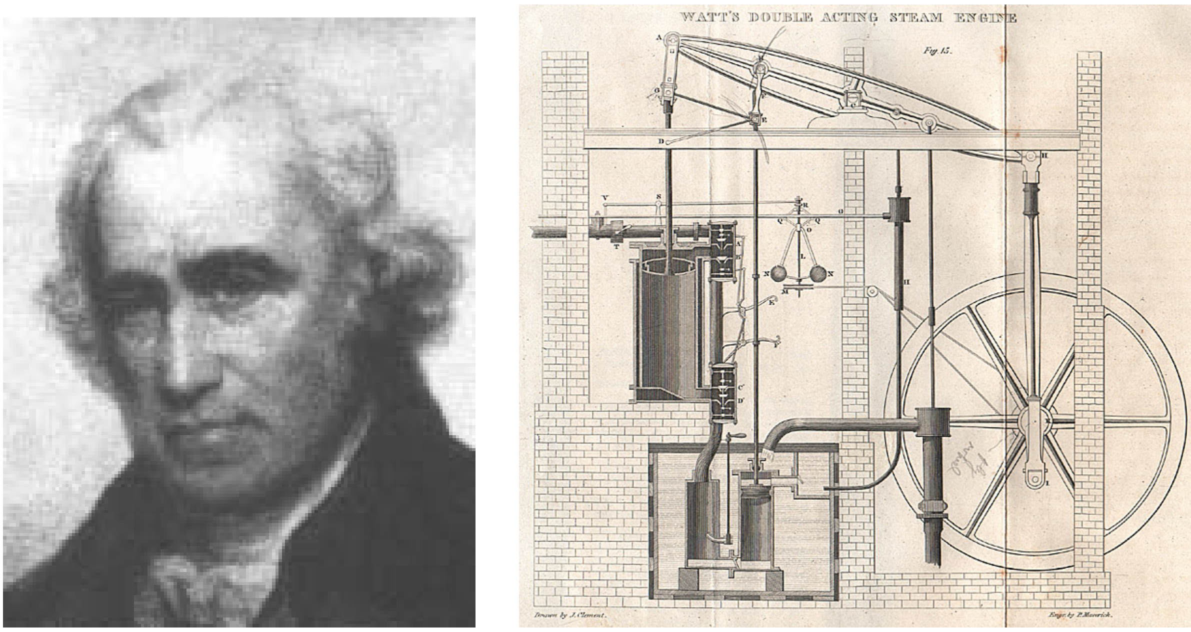
Therefore science is essentially a descriptive quest. On the other hand, I look at engineering as a constructive quest – engineers invent new things.

Human society has always gained by the use division of labour (more about this concept later). Thus it is not surprising that we created several subsets of engineering activities, and called each subset by its own name (e.g. mechanical, electrical, industrial, chemical, civil). These subsets do not really partition engineering -- each pair of disciplines has lots of overlap. However, the specialization allows practitioners to learn their chosen discipline in a “reasonable” amount time.

Thus the history of IE is linked closely to the history of engineering. However, I will only pick some interesting landmarks.

1. Historical Milestones

1730-1800’s: Industrial Revolution in England. The main thing that happened in this time was that the idea of ***organized factories*** took shape, instead of more traditional, artisan-based techniques of manufacturing.

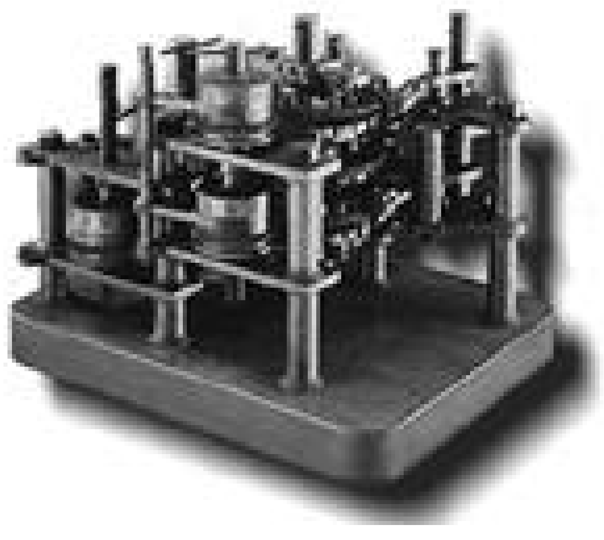


James Watt, and a schematic of one of his steam engines

1776: Adam Smith published *An Inquiry into the Nature and Causes of the Wealth of Nations*. The importance of the idea of ***specialization of labour*** was clearly pointed out. Other important ideas emerging from the book include the importance of free trade, and that prices of commodities are determined ‘fairly’ in competitive markets.

Adam Smith

1832: Charles Babbage published On the Economy of Machines and Manufacture. Crystallised the ideas of ***division of labour***, ***organization of work*** etc. Recall that Babbage also was the inventor of an early mechanical calculator, using techniques that were borrowed in the making of the modern computers – hence many (British) people look to him as a father of the modern computer.



Charles Babbage and a modern reproduction of his difference engine

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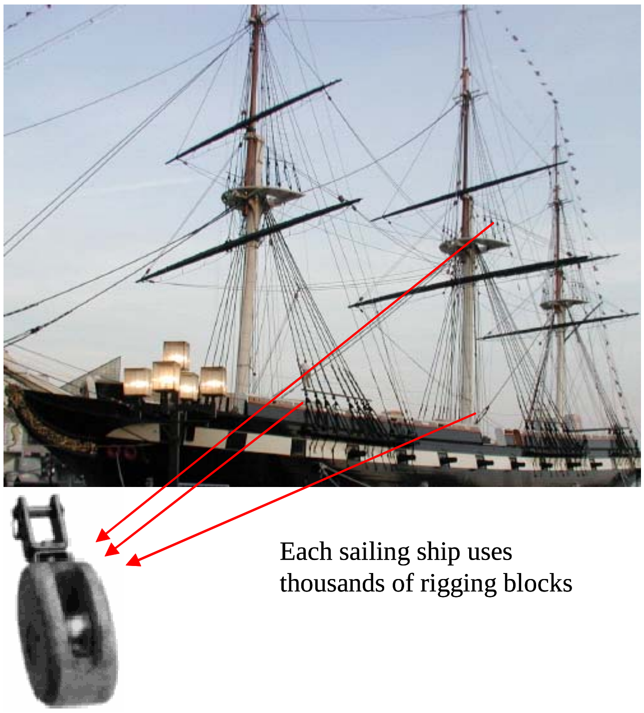
1800s: Henry Maudslay, a toolmaker in England, set up a factory to produce wooden rigging blocks which were used in ships. Each block has several components. His ability to produce thousands of components with very precise dimensions allowed him to assemble the blocks interchangeably -- rather than custom building each block. This was the first industrial example of the idea of ***interchangeability***. Maudslay also designed a screw-cutting lathe, a machine that could produce screw threads of same size repeatably. Thus he was able to standardize screw and nut sizes (before this, each screw and nut pair were ‘made-for-each-other only).



(a) Henry Maudslay [1771-1831] (b) Rigging blocks used in ships

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1900s: Frederick Taylor advanced the notions of ***mass production*** through the extensive use of division of labour via a tool called ***motion and time study***. In 1890’s, Taylor was employed at Bethlehem Steel as a manager. Before him, all labourers were given the same tool to work with. For example, all workers doing shovelling were issues the same sized shovel. Taylor classified the workers by size and strength, and then designed shovels to match each group. This and similar changes increased work efficiency leading to 50% reduction in costs, and later, reduction in labour from 400 to 140. Taylor developed five principles of ***Scientific Management***:

1. Divide each task into parts, and develop the best way of performing each part;
2. Select the best person to do the each part;
3. Train, Teach and develop the worker;
4. Provide financial incentives to follow the methods;
5. Division of labour: managers plan the activities, and workers execute the tasks.

Similar ideas were made more concrete later by the research of Frank and Lillian Gilbreth.

  

Frederick Winslow Taylor Frank Gilbreth Lillian Gilbreth

1905-1920: Henry Ford used Taylor's ideas to for ***mass production*** of cars (Model T).

A Ford Model-T car, the subject of Henry Ford's famous line: "You can have any color you like as long as it's black"

1900-1910: Birth of ***Queueing Theory***. This is the study of system performance when the demand for a service is higher than it can handle. We are familiar with queues at restaurants, department stores like Park-n-Shop, bus stops, bank, etc. In such systems, the demand for a service is usually not known exactly, but can be modelled as a probability distribution; likewise, the amount of time used by each customer is also a random number with some probability distribution (e.g. how long will you take to complete your dinner at a restaurant). **Agner Krarup Erlang**, an engineer working at the Copenhagen Telephone Exchange in Denmark, published the first paper on queueing theory in 1909.

Approximately in the same period, a Russian statistician, **Andrei Markov** studied properties of ***Markov chains*** (a sequence of numbers that are random variables, such that the value of the next variable is determined by the current one, but not a function of how we reached the current number's value). Markov chains later became the basis for the field of ***stochastic systems***. This has many applications in study of ***queues***, ***inventory control*** etc.

Andrei Markov (1856-1922, Russia)

1924: Dr. Walter A. Shewhart (Bell Telephone Labs, USA) introduced important techniques in the quality control of outputs of factories. He used fundamental tools in probability and statistics, and his techniques are still used in some form, under the name of ***Statistical Quality Control***.

1945-1950: The first systematic use of ***Ergonomics*** (or ***Human Factors***) in product design, using tools of statistics and human physiology to reduce risks to humans using mechanical products. Ergonomics is now used for design of products (e.g. to set standards for safety of toys for young children, or for ease of use of mobile-phones), For design of workplace (e.g. to determine if a working environment is safe for the workers).

1945-1955: The systematic use of complex mathematical models for planning of supplies and movements of troops in World War II led to significant developments in the field of ***Logistics***. In 1947, George Dantzig and the *Simplex Method* – the most important mathematical tool for solving large sized linear problems of ***optimization***.

George Dantzig (1914-2005)

1960’s: Ford motor company introduced a new technique for production and marketing of cars, first used in the Ford Mustang model of 1964. Buyers were allowed to select from a set of different engines, suspensions, colours, transmission etc. The first notions of ***mass customization***.

1964 Ford Mustang

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2. Course Plan

Stage	Topics	Methods
I	Facilities planning, Transportation and Logistic	Discrete optimization and Gra techniques
II	Operations planning, Production planning	CPM/PERT, Linear programming
III	Inventories (and perhaps Queueing)	Stochastic, Probabilistic systems
IV	Quality control and management	Statistics
V	Product design, Ergonomics	Statistical methods, Algebra

References:

Turner, Mize, Case, Nazemetz, *Introduction to Industrial and Systems Engineering*, Prentice Hall