INTRODUCTION: ENGINEERING AND THE ENGINEER

We recognize that we cannot survive on
meditation, poems, and sunsets.
We are restless.
We have an irresistible urge to dip our hands
into the stuff of the earth and do
something with it.
(Samuel C. Florman, engineer and author)

Engineers and other technical professionals interact dynamically among themselves and with clients, owners, customers, constructors, manufacturers, and other implementers.

The interaction process, as illustrated in Figure 1.1, typically begins with a client, owner, or customer retaining a professional (e.g., engineer or architect) to conduct a study, perform preliminary designs, prepare a complete design, and deliver a contract package consisting of plans and specifications or other formal design. The client-owner-customer could be a private or public sector entity, such as a business or a municipality.

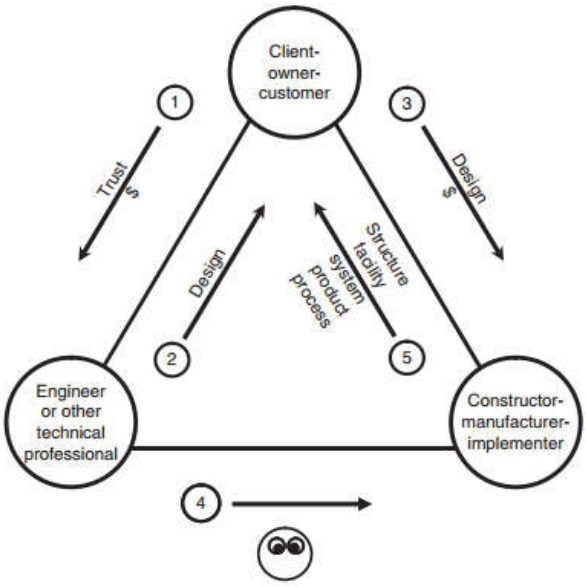

Figure 1.1. The engineer or other technical professional works with the client-owner-customer and the constructor-manufacturer-implementer to produce a useful structure, facility, system, product, or process.

The client, owner, or customer then selects a constructor, manufacturer, or other implementer to produce the structure, facility, system, product, or process. The client, owner, or customer sometimes retains the professional to monitor the construction manufacturing-implementation process so the final structure, facility, system, product, or process conforms to the original plans and specifications.

Design followed by manufacturing or construction can occur within a single organization. For a self-contained manufacturing organization, the bottom two vertices of the triangle shown in Figure 1.1 collapse into one point. Similarly the bottom two vertices become one in a design-build organization, that is, a single firm that both designs and builds structures, facilities, or systems.

For a complete "Typical Building Procedure", go to:

- Typical Traditional Building Procedure: https://www.eeekenya.com/typical-traditional-building-procedure/
- Typical Project Teams: https://www.eeekenya.com/typical-project-teams/

Click the links above for more details. The content of the links forms part of this lecture.

1.2 Definitions of Engineering

"Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind." (ABET 2002)

"Scientists explore what is, engineers create what never has been"~ Aeronautical engineer Theodore Von Karman

"It is a great profession. There is the fascination of watching a figment of the imagination emerge, through the aid of science, to a plan on paper. Then it brings jobs and homes to men. Then it elevates the standards of living and adds to the comforts of life. That is the engineer's high privilege."~ Herbert Hoover, the 31st U.S. President, and a professional mining engineer.

"The great liability of the engineer compared to men of other professions is that his works are out in the open where all can see them. His acts, step by step, are in hard substance. He cannot bury his mistakes in the grave like the doctors. He cannot argue them into thin air or blame the judge

like the lawyers. He cannot, like the architects, cover his failures with trees and vines. He cannot, like the politicians, screen his shortcomings by blaming his opponents and hope the people will forget. The engineer simply cannot deny he did it. If his works do not work, he is damned…

On the other hand, unlike the doctor his is not a life among the weak. Unlike the soldier, destruction is not his purpose. Unlike the lawyer, quarrels are not his daily bread. To the engineer falls the job of clothing the bare bones of science with life, comfort, and hope. No doubt as years go by the people forget which engineer did it, even if they ever knew. Or some politician puts his name on it. Or they credit it to some promoter who used other people's money . . . But the engineer himself looks back at the unending stream of goodness which flows from his successes with satisfactions that few professions may know. And the verdict of his fellow professionals is all the accolade he wants."~ Herbert Hoover, the 31st U.S. President, and a professional mining engineer.

Based in part on the preceding definitions, the following six essential features of engineering appear

- Science-based
- Systematic—However, except for trivial problems, judgment and other qualitative considerations always enter in
- Creative and innovative
- Goal-oriented—Satisfy the requirements and get the job done on time and within budget
- Dynamic—Technology, laws, public values, clients, owners, customers, stakeholders, and the physical environment continuously change
- People-oriented—Both in doing and in results in that engineering is essential to the survival of human communities and to the quality of life

Professional Engineer - EUSEC Definition

'A professional engineer is competent by virtue of his fundamental education and training to apply the scientific method and outlook to the analysis and solution of engineering problems. He is able to assume personal responsibility for the development and application of engineering science and knowledge, notably in research design, construction, manufacture, or management, or in the education of the engineer. His work is predominately intellectual and varied and not of a routine mental or physical character. It requires the exercise of original thought and judgement and the

ability to supervise the technical and administrative work of others. His education will have been such as to make him capable of closely and continuously following progress in his branch of engineering science by consulting newly published work on a worldwide basis assimilating such information and applying it independently. He is thus placed in a position to make contributions to the development of engineering science or its applications. His education and training will have been such that he will have acquired a broad and general appreciation of the engineering sciences as well as a thorough insight into the special features of his own branch. In due time he will be able to give authoritative technical advice, and to assume responsibility for the direction of important tasks in his branch.'

1.3 Managing and Leading

The entry-level engineer or other technical person will, by definition, be well-prepared for and will spend a majority of his or her time producing, that is, carrying out the production function of the organization. An undergraduate education is typically a solid preparation for this function.

Another way of understanding what engineers and other technical personnel do, or could do, is examine their leading, managing, and producing roles. One paradigm for an organization, such as an engineering consulting firm, a manufacturing business, a government agency, an academic department, or a volunteer organization is that wholeness, vitality, and resiliency require attention to three different, but inextricably related functions: leading, managing, and producing. In a simplified sense, the leading, managing, and producing functions can also be represented by three Ds: deciding, directing, and doing.

1.3.1 The Traditional Pyramidal, Segregated Organizational Model

The vast majority of employees are the doers or producers, a distinctly different and much smaller group of managers are the directors, and one person, or perhaps a very small group, leads.

An aspiring and successful individual begins in a production mode and then passes serially or linearly maybe into managing and possibly into leading. Rather than being a trait that many can possess, albeit to different degrees, leading is considered the end of the line or ultimate destination for a very few. But is this the optimum way for an organization to meet its leading, managing, and producing possibilities? I don’t think so, although a command and control structure may be appropriate in certain situations.

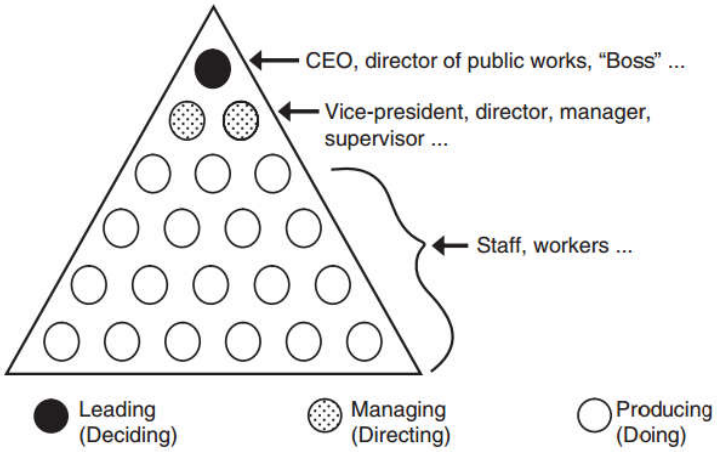

Figure 1.2 The traditional pyramidal and layered organizational model concentrates leading and managing at the top

Leading	Managing	Producing
Deciding where we want to go	Determining the best way to get there	Getting there
Deciding what ought to be done	Directing how things will be done, by whom, and when	Doing it
Moving forward to create something new	Taking care of what already exists	–
Selecting a jungle to conquer	Writing procedure manuals, setting up work schedules, sharpening machetes	Cutting through the jungle
Deciding if the ladder is leaning against the right wall	Determining how to efficiently climb the ladder	Climbing the ladder and getting over the wall
Dreaming during the day	Dreaming at night	–
Creating change	Reacting to change	–
Using the right brain	Using the left brain	–
Working through people and culture. Soft and messy	Working through hierarchy and systems. Hard and neat	–
Influencing by permission	Influencing by position	–
Stressing people work over paper work	Stressing paperwork over people work	–
Causing people to want to do things	Causing people to have to do things	–
Molding consensus	Searching for consensus	–
Creating teams	Directing groups	–
Inspiring	Informing	–
Having followers	Having employees	–
Concentrating on what is right	Concentrating on who is right	–
Having very little formal education and training in this function	Having some formal education and training in this function	Having lots of formal education and training in this function
Very few personal models	Some personal models	Many personal models
Interruptions are the work	Work gets interrupted	–

1.3.2 The Shared Responsibility Organizational Model

An organization will be stronger if the three organizational responsibilities (mentioned above) now also become individual responsibilities.

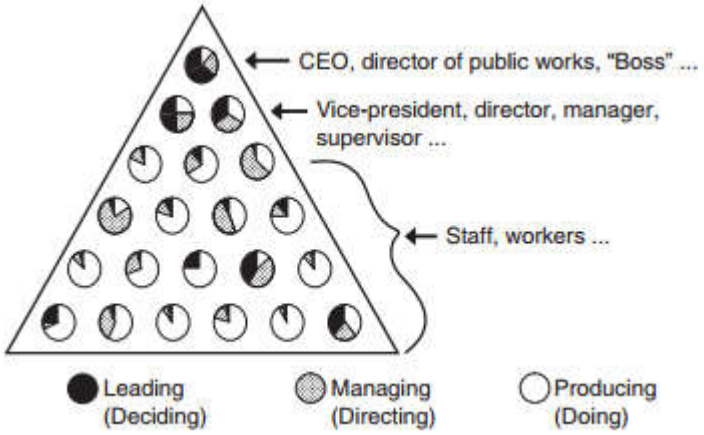

Figure 1.3 The shared organizational model enables dispersed leading, managing, and producing.

The goal should be to enable each member of the organization to be a decider, a director, and a doer.

While the relative "amounts" of leading, managing, and producing will vary markedly among individuals in the organization, everyone should be enabled and expected to do all three in accordance with their individual characteristics. This shared responsibility organizational model, in contrast with the traditional segregated model, is much more likely to mine the organization's gold, that is, extract and benefit from the diverse aspirations, talents, and KSAs (knowledge, skills, and attitudes) that are typically present within an organization.

Because essentially all members are fully involved, the shared responsibility organization is more likely to synergistically build on internal strengths, cooperatively diminish internal weaknesses, and learn about and be prepared to respond to external threats and opportunities. Striving to enable everyone creates confidence, results, and pride. As noted by Chinese philosopher Lao Tzu, "But of a good leader, who talks little, when his work is done, his aim fulfilled, they will say, we did this ourselves."

1.4 Qualities of Effective Leaders (Engineers)

Becoming a leader is something you can do without anyone's "permission." It is developed conscientiously through self-improvement.

1.4.1 Honesty and Integrity

The leader in each of us practices honesty and exhibits integrity, that is, tells the truth and keeps his/her word.

Covey (1990) says "Honesty is telling the truth—in other words, conforming our words to reality. Integrity is informing reality to our words—in other words, keeping promises and fulfilling expectations." Stated differently, honesty is retrospective and integrity is prospective; honesty is what you say about what you've done and integrity is what you do about what you've said.

1.4.2 Vision: Reach and Teach

Leaders know where their organization is going; they believe in it and much of what they say and do reflects and supports the vision. Each organization should have a multi-year strategic plan and an annual business or operating plan. The strategic plan should contain and be based on brief, widely-understood mission and vision statements.

The mission statement explains the purpose of the organization—why it exists, what service or product it provides and to whom (Tompkins 1998). Tompkins offers this example of a mission statement for a consulting firm: "To provide our clients with total confidence in our solutions and to treat all employees with fairness and dignity."

In contrast with an organization's mission statement, its vision statement looks boldly into the future. "Vision...is mental, cognitive—not reality, or even close to reality, as we know it today. It is influenced, at least in part, by imagination, reflective of actual or desired values, and focused on "what," not "how." Finally, a vision is stimulating, energizing, engaging, and inclusive" (ASCE 2007). Consider the advice of city planner and architect Daniel Burnham: "Make no little plans, they have no magic to stir men's blood. Make big plans, aim high in hope and work and let your watchword be order and your beacon beauty."

The vision statement declares, as specifically as possible, what the organization intends to become. Like the mission statement, the vision statement must be clearly and widely understood throughout the organization. Tompkins (1998) provides these two examples of vision statements:

- For a consulting firm: "To be the best engineering-based consulting firm in the world while providing all employees a rewarding and satisfying work experience."
- For an appliance manufacturer: "To be the world's leading manufacturer of diversified laundry equipment by continuously improving customer satisfaction, employee motivation, and company profitability."

If the organization does not have a vision, a mission, and a plan, the leader takes action to get such statements articulated and a plan developed. But what if an individual's values and goals are in serious conflict with an organization's mission and vision? ***The answer is obvious—try to effect change and, if not successful, move on.*** Life is too short to dissipate yourself in a hostile environment or prostitute yourself by feigning allegiance to alien values.

1.4.3 Strategies and Tactics to Achieve the Vision

Visions, as engaging as they may be, are just dreams until they are converted to strategies and tactics that will help to achieve them. Engineers, architects, planners, and other technical professionals know how to create plans that bring their projects to fruition. Plans, that is, strategies and tactics, are also needed to bring visions to fruition. The leader in you does not wait for someone to tell you what to do, when to do it, and how to do it. You act because you view the future as something you and others can make happen, not something that happens to you.

Drawing again on the example of Abraham Lincoln, Phillips (1992) says that Lincoln had "an almost uncontrollable obsession" to achieve. Phillips sets forth these action principles, all quoted, at the conclusion of a chapter titled, "Set Goals and Be Results-Oriented":

- Set specific short-term goals that can be focused on with intent and immediacy by subordinates
- Sometimes it is better to plow around obstacles rather than to waste time going through them
- Your war will not be won by strategy alone, but more by hard, desperate fighting

- Your task will neither be done nor attempted unless you watch it every day and hour, and force it.
- Remember that half-finished work generally proves to be labor lost

1.4.4 Always a Student

Leaders develop and maintain, through formal study, self-study, and experience, their unique set of knowledge and skills. Maintaining one's expertise is a leadership element that is particularly important in a technical organization because rapid changes in science and technology drive the services and products the organization offers and produces.

Competency in knowledge and skills is crucial to an organization for three reasons. First, it contributes to what the organization can do or offer in serving its clients, owners, customers, and constituents. Second, maintaining currency at the individual level sets a positive example for others in the organization, earns respect from them, and encourages them to develop and maintain their expertise. Third, and finally, by being an expert, a person is much more likely to value expertise, people who possess it, and the wisdom of drawing on the proper mix of expertise in meeting needs of internal and external clients, owners, and customers.

1.4.5 Courageous

Leading requires courage to hold people accountable for carrying out their responsibilities and keeping their promises, to confront individuals exhibiting unacceptable behavior, to walk away from a project-client-owner-customer on ethical grounds, to speak up when someone is being treated unjustly, to aim high and risk apparent great failure, to apologize and ask for a second chance, and to persist when all others have given up. But, what constitutes courage and courageous people?

1.4.6 Calm in a Crisis and Chaos

Whenever competent and committed people are involved in group efforts, often in competition with other organizations, difficult interpersonal and other serious conflicts and situations are inevitable. Confronted, usually unexpectedly, with such crises, the leader instills calm, seeks understanding, and does not make premature judgments.

The leader should "Seek first to understand, then to be understood" (Covey 1990).

We've all heard the expression, "this is not a problem, this is an opportunity." The leader in us actually believes this—at least most of the time. When faced with a crisis or chaos, we look for that opportunity. Alexander Graham Bell, the inventor, offered this observation: "When one door closes another door opens; but we often look so long and regretfully upon the closed door that we do not see the ones which open for us."

Personal competency skills such as time management, listening, writing, speaking, delegating, and meeting facilitation enable you to effectively and efficiently carry out your day-to-day work. Of particular relevance here is that these skills are invaluable when faced with crises and chaos. The next way to prepare for handling crisis and chaos is to proactively seek a variety of personal and professional experiences.

1.4.7 Creative, Innovative, Collaborative, and Synergistic

Leaders seek ways to utilize the right hemisphere of the brain to complement the left hemisphere. Stephen Covey (1990) notes that decades of research have resulted in brain dominance theory. Covey explains: Essentially, the left hemisphere is the more logical, verbal one and the right hemisphere the more intuitive, creative one. The left deals with words, the right with pictures; the left with parts and specifics, the right with wholes and the relationship between the parts. The left deals with analysis, which means to break apart; the right with synthesis, which means to put together. The left deals with sequential thinking; the right with simultaneous and holistic thinking. The left is time bound; the right is time free.

Clearly, leadership qualities of creativity, innovation, collaboration, and synergism are products of the whole brain. Because of the nature of their college education, engineers and some other technical personnel are likely to be dominated by the left hemisphere of the brain. Cultivation and development of the right hemisphere is, therefore, especially important for engineers and other similar professionals who want to be creative, innovative, collaborative, and synergistic.

1.5 The Engineer as Builder

Engineering is an old profession; its roots can be traced back to the beginning of recorded history when nomads first came together and formed communities along what are now the Nile River in Egypt, the Tigris and Euphrates Rivers in Iraq, the Indus River in India, and the Yellow River in China. With the creation of communities came the need to provide basic infrastructure such as

housing, transportation, defense, irrigation, water supply, and wastewater disposal. The work of the engineer had begun.

Besides being one of the oldest professions, engineering is one of the broadest. Within any of the engineering types, engineers carry out a broad spectrum of functions such as research and development; planning; design; construction and manufacturing; operations; teaching; marketing; and management.

Throughout engineering's long history and within its great diversity, however, there is at least one widely-shared interest and function: building in the broadest sense. In the final analysis, whenever everything else is stripped away, the engineer is, at the core, a builder. Building is the glue that binds engineers together.

When civil engineers "build," they usually call the process construction. When mechanical engineers "build," they routinely refer to it as manufacturing. Whatever term you use, the ultimate end of the engineering process is to "build" something to meet human needs, usually something that never before existed. Examples include the water supply system "built" by the civil engineer, the energy-efficient and safe automobile "built" by the mechanical engineer, and the electrical power distribution system "built" by the electrical engineer. Some engineers "build" less concrete but nevertheless important things such as computer programs, better tools for performing engineering functions, and improved ways to organize engineering organizations.

"Builders" accrue great responsibility and liability as well as great satisfaction. President Herbert Hoover quote at beginning of this lecture (Page 2) illustrates this.