WHAT IS AN ENGINEERING MANAGER?

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The purpose of this paper is to provide some ideas useful for curricula in engineering management at the master's degree level. These ideas will also be useful to engineering managers in industry and government laboratories.

There are two kinds of engineers in industry: individual contributors and managers. The managers must be competent engineers first on the ground that you can't manage what you don't understand. Ideally these people should be educated in two professions: engineering and management. There are many ways of attaining the knowledge, skills and attributes needed, based as in all professions on some combination of formal instruction and practical experiences.

We start with some definitions. The Engineers' Council for Professional Development say that "Engineering is the profession in which a knowledge of the mathematical, physical, [social and policy] sciences gained by study, experience and practice is applied with judgment to develop ways to utilize, economically [and ecologically], the materials and forces of nature for the benefit of mankind."(1) Words in brackets were added in a proposed revision of the definition.(2) Note that the revision reflects the increasing complexity of engineers' work.

A manager is defined as a person who has more to do than he can do by himself, and who therefore gets things done through other people. This is the classical definition. A more up-to-date version is that a manager is a person who gets the right things done, efficiently and timely, through other people who may or may not report to him.

Managers have devised many ways of organizing work in manufacturing companies. A common way of organizing a medium-sized company or an operating division of a large company is outlined below, in terms of functions:

- Engineering*
  - Current
  - Advance
- Manufacturing*
- Marketing*
- Research*
- Legal*
- Finance
- Information Handling*
- Employee and Public Relations

Engineers are to be found in those functions (departments) marked with asterisks. In this paper we will be discussing engineers and managers in the engineering department. These people may be employed on three kinds of engineering work (as viewed by engineering managers):

- Projects
- Programs (groups of related projects)
- Functions (work that supports the projects, e.g., materials engineering, testing, failure analysis, etc.)

Definitions of these terms are given in Figures 1, 2, and 3. The three kinds of work are often organized into a matrix, illustrated in Figure 4.

Fig. 1 Definition of a Project

A planned undertaking, having--
- Specific goals
- Specific starting and completion dates
- A definite budget

A manager responsible for--
- Achieving or surpassing the goals
- On time
- Within budget

Fig. 2 Definition of a Program

A group of related projects having--
- Specific goals, broader than projects
- A specific starting date
- A specific or an indefinite completion date
- Criteria for completion
- Periodic rebudgeting

A manager responsible for--
- Program success
- Timely results
- Cost-effective results

Fig. 3 Definition of a Function

A planned organizational entity, having--
- Responsibility for some specialized field
- Objectives rather than goals, i.e., no overall starting and completion dates
- A definite budget

A manager responsible for--
- Maintaining a high level of personnel competence in the specialty
- Equipment relevant to the specialty
- Investigating new technology

Fig. 4 Matrix Organization of the Work

	FUNCTIONS 1	2	3	4	5
PROGRAM A					
Project 1	x		x	x	
Project 2	x	x			x
Project 3		x	x		x

<u>PROGRAM B</u> **Project 1**					
| | |					
Project N					

Career progression of engineers and engineering managers is illustrated in Figure 5. Appropriate education for these people starts with a master of engineering for everyone. This is followed by appropriate technical courses for everyone, as needed for specific job assignments. Engineers on the management ladder go on to get a master's degree in engineering management. When they are ready for general management responsibilities, there are six week (or longer) courses that prepare them for such work and may (or may not) lead to an M.B.A. Note the compressed time element here. As with all other professions, they also get knowledge, skills and attributes (the KSAs) from practical experience and mentoring. It is important that these be planned and structured, rather being left to chance.

The general tasks of managers are listed in Figure 6. There are books that expand on these tasks at great length. We can not do that here, but two points are worth emphasizing. One is the feedback nature of the management process, analogous to the engineering design process. Plans are seldom perfect, and are seldom executed perfectly. Organization of the work is often not ideal. Integration of the results of the work with other results can be difficult. It is therefore necessary to measure the results continuously, compare them with the plan and then replan as necessary. Lessons learned should be incorporated in the institutional memory.

Fig. 5 Career Progressions

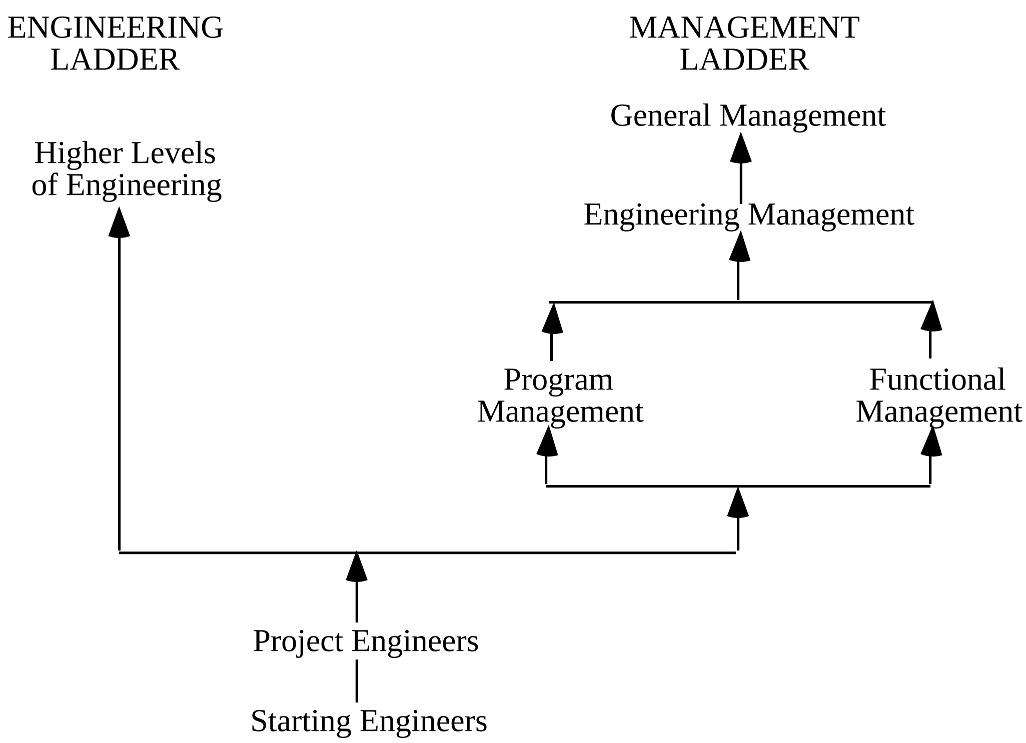

Fig. 6 General Tasks of Managers

Planning the work
- What is to be done (goals)
- Why (benefits)
- When (schedule)
- Where (location)
- How (work statement, resources needed)
- How much (costs)

Organizing it
- Who is to do it

Integrating the work and the results into the organization's operation

Measuring results against the plans

Providing leadership

The second point to be emphasized is the difficulty of establishing and getting agreement on the goals of projects and programs, and the objectives of functions. It is reported that Japanese technical managers lay great stress on setting goals and spend much time on getting them right before starting work. American technical managers tend to plunge right into the work, planning as they go. There is something to be said for both methods, but a real problem arises when clear goals or objectives never get established. For example, "product quality" is sometimes defined as "satisfying the customer", i.e., giving him what he wants. It is considered to be a worthy objective. Experienced managers in this field, however, will say that usually the customer doesn't know what he wants. Some other way of setting the objectives for quality must therefore be devised. Peter Drucker has said that managing by objectives is fine if you know what the objectives are, but that ninety percent of the time you don't know.[3]

Figure 7 lists some of the complexities, internal to the organization that engineering managers have to deal with today. Figure 8 lists some of the complexities, external to the organization.

Fig. 7 Some Internal Complexities

- Selecting the right projects
- Writing clear project goals
- Identifying the kinds and depths of technical knowledge needed
- Building tiger teams
    - Recruiting the best people
    - Training them
        - Planning and providing engineering experience
        - Continuing their formal education
    - Providing facilities and tools
    - Demanding performance
- Downsizing

    - Improving time management
- Dealing with coarseness
- Disruptive reorganization
- Knowing when to stop a project

Fig. 8 Some External Complexities

- Local civic responsibilities
- Complying with regulations: OSHA, EPA, product safety
- Regulation divestitures, mergers
- Outsourcing: quality and delivery problems
- Legal problems: patent protection, liability lawsuits
- Benchmarking
- Dealing with educational institutions
- Computer hardware and software problems
- Exponentially increasing technical knowledge
- Proliferation of management gurus
- Globalizing: foreign assignments; language and culture problems
- Rates of change and increased business risk

Authors who write about managers like to provide lists of traits or key characteristics that distinguish competent managers from incompetent ones. There are many such lists, which are usually quite long. A short list, of considerable value, is provided by Bennis: (4)

Technical competence
People skills
Conceptual skills
Judgment
Character

In this paper, instead of trait lists, I present eleven modes of thinking that are applicable in many walks of life, but that are especially applicable in the practices of engineering and engineering management. These are listed in Figure 9. Very few curricula in either engineering or engineering management provide for adequate instruction in the use of these modes. Several more papers would be required to discuss them in any depth. What I propose to do here is to discuss one of them -- time-related thinking -- and show how it relates to the duties of engineering managers, especially as it is required in the innovation process. This mode of thinking may be defined as continuous awareness of the time factor in all business activities, and acting on that awareness.

Fig. 9 Eleven Modes of Thinking

LOGICAL	STRATEGIC/TACTICAL
CRITICAL	LONG-RANGE/SHORT-RANGE
LARGE-SCALE	SYSTEM
ECONOMIC	STATISTICAL
CREATIVE	TIME-RELATED
ETHICAL	

There are many examples of important applications. Among these are turn-arounds; enlargement of existing businesses; restructuring enterprises by reorganizations; mergers; acquisitions and divestitures; and establishing new businesses or product lines (the subject of the following discussion).

Competitiveness of an enterprise is thought of as having three components: productivity (the number of salable product items produced in n hours by n employees); product quality (satisfying or even delighting customers); and innovation (establishing in the market of all products, processes, or services that are new to customers). (Figure 10)

Fig. 10 Factors Contributing to Competitiveness in the Manufacture of Discrete Products

COMPETITIVENESS

PRODUCTIVITY
- To reduce costs of production
- To increase margins

QUALITY
- To attract and retain customers
- To eliminate costs of low quality

INNOVATION
- To provide new and better products and processes, and thus generate jobs

In order to innovate, four tasks must be performed:

IDENTIFY: What product?
CREATE: Product engineering
MAKE: Process engineering
MARKET: How will we get the product to the customers?

The goal is to get the new product to the market, in a dominant position, before the competitors. In planning the project, it is necessary to consider the time element for each task.

ENGINEERING

It has long been an axiom that one of the keys to successful engineering is to pick the right project. In an innovation project this means picking the right product. This is done in cooperation with marketing, especially with market research. At least sixteen ways of identifying what customers will buy have been identified. Engineers aid in this by performing technical forecasting -- what new products will be made possible by technology advances? They also have a role by performing s-curve analysis. This is applying the life cycle curve to forecast replacement of a product by another, e.g., fountain pens by ball point pens. Various market research techniques are applied to gauge the likelihood of market acceptance, and cost estimates of product engineering are made. Key questions at this point are: "What if the engineering project is successful?" and "If so, are we prepared to push the product all the way from the laboratory, to production, to a dominant position in the marketplace?" If so, then we must reduce the time from concept to customers, reaching the break-even point. This gives us a legal, temporary monopoly. Ways of doing this include use of creative engineers, concurrent engineering, group technology, appropriate use of computers, accelerated testing, and in some cases, simulation instead of testing. Serious warranty problems sometimes come up during early production. The engineers must therefore know how to do fast failure analyses, with prompt corrective action. Finally, it is necessary to practice kaizen, i.e., to continuously reengineer the engineering process so as to improve productivity and quality without disrupting operations.

MANUFACTURING

The manufacturing engineers can also help to reduce the time from concept to customer, reaching the break-even point. Ways of doing this include creative process engineering, concurrent engineering (design for fabricability, design for assembly, design for quality), appropriate use of computers, such as for process controls, and in some cases, using simulation instead of pilot production. Also included are methods engineering such as just-in-time delivery of materials and parts, optimum machine layout, and no idle machines or people. Emphasis on product quality is essential -- no rework, and minimal warranty costs or returns from customers. Practice of kaizen is essential.

By the time the product is beginning to reach maturity, the company can exploit the experience curve and thus capture a larger share of the market.

MARKETING

The task of the marketing people is to reduce the time from introduction of the product to market dominance. Robertson has proposed a four-step process for doing this: (5)

1. Raise awareness of the new product by potential customers.
2. Generate a favorable attitude toward the product.
3. Persuade potential customers to try the product.
4. Close the sales.

Robertson has shown how to use conventional market tools to hasten each of these steps. Delays such as market testing can be eliminated (a judgment matter). The market can be blanketed with multiple brands and by going after more segments. The market penetration rate is to be monitored and corrective actions taken as needed: more advertising, product enhancements, refreshments, a continuous stream of innovations, and building marketing alliances. Here again, the practice of kaizen is necessary.

Product refreshers postpone the onset of decline. This permits the reaping of additional profits over what they would have been if no refresher action is taken.

MANAGEMENT

Of all the roles, that of management is the most important in speeding the innovation process. Several tasks can be identified to this end. One is to exercise leadership to induce a sense of urgency in employees. A second task is to perfect all technical, production, marketing and business processes, reengineering as needed, and practicing kaizen. A third task is to ensure that organizational time is expended wisely, with no time spent on non-essentials. Fourth is to understand and use the learning curve. Finally, what managers are doing is to reshape the product life cycle curve (Figures 11 & 12) and keep a stream of new products coming, to guard against obsolescence. or replacement of existing products and to ensure growth of revenues and profits.

A final point is that the failure rate of innovative ideas is far too high. Many never reach the market at all, or reach it too late, or fail in the market. A key responsibility of management, therefore, is to raise the success rates dramatically. It follows that they must understand the innovation process completely, and manage it.

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