*A Course in*

# PROJECT EVALUATION IN THE CHEMICAL PROCESS INDUSTRIES

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THERE APPEARS TO BE a difference in perception between teachers of chemical engineering and the industry which employs their students—a perceptual difference as to what constitutes a balanced course of instruction that best prepares the students for their industrial tasks. There is a point of view in some industrial quarters that chemical engineering education is too "theoretical" (whatever that may mean) and that students enter industry unprepared for the realities of the business world. There is an academic point of view that maintains that the task of the university is to *educate* the student in the fundamental sciences (and, at the graduate level, to teach research skills in those sciences), for it is versatility in the fundamentals that allows the chemical engineer in industry to be creative and effective in a gamut of endeavors, to be a *general problem solver*. The latter point of view maintains that it is industry's own responsibility to indoctrinate its employees so they may function well in the world of applied technology and business.

There is a great deal to be said for both points of view. There is no question that chemical engineers, by virtue of their exposure to the unique combination of fundamental sciences which constitutes the chemical engineering curriculum, have gained the reputation of exceptional problem solving ability in all industrial functions. Yet the academic world has not ignored industry's call for educational realism, and university chemical engineering curricula continue to exhibit a growing industrial cant, as evidenced by many articles in this journal. Most corporations in the chemical process industries profess to be moving in the direction of specialized, small-volume, high-priced products; this trend, if true, will demand of the universities, more than ever, an education which blends a strong background in the fundamental sciences with some nurturing of skills that will allow the neophyte engineer to handle the anticipated heavier demands of project management and evaluation.

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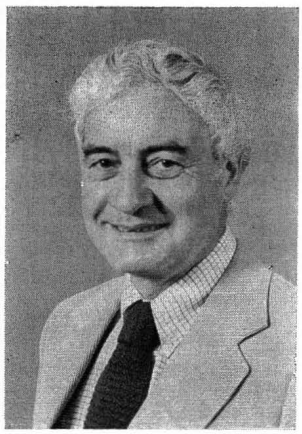
At the University of California, Berkeley, the tradition of an industrial input into the chemical engineering curriculum goes back almost three decades, to the organization of an undergraduate process design course by practicing engineers in industry—Charles F. Oldershaw (Dow Chemical Co.) and later E. Morse ("Bud") Blue (Chevron Research Co.). The participation of part-time instructors from industry has since been extended to the graduate curriculum as well; moreover, an industrial process design and development option is available to students working toward the PhD degree. The department is served by an Industrial Advisory Board whose members are top corporate managers from several companies; many of the industrially-oriented programs were initiated upon their recommendation.

Indeed, some ten years ago the board suggested that an advanced project evaluation course be incorporated into the graduate curriculum. On the strength of my industrial experience, I was asked by Jud King, at that time department chairman, to organize and teach such a course. I confess that I accepted this challenge with a certain degree of reluctance, for I had quite enough to keep myself usefully occupied at The Dow Chemical Co. Nevertheless, I took the plunge, and it seems to me that all concerned—my industrial employer, my departmental colleagues, the students, and certainly myself—have benefitted from the resulting exchange of information, ideas, and points of view.



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## COURSE OBJECTIVES

The purpose of the course is to expose the neophyte chemical engineer to the methodology used in the chemical process industries to evaluate the ultimate commercial feasibility of proposed new projects. It is an attempt to give some insight into the intricacies of industrial project management.

As such, the course goes beyond the subject matter of allied courses previously described in this journal—doctoral level engineering economics (Oran L. Culberson, Fall 1979), or the structure of the chemical process industries (T. W. F. Russell, Fall 1979)—although elements of each are, indeed, to be found. Economic principles which may already be familiar to many students are reviewed, and elements and analytical tools that are new are introduced—the economic, marketing, and managerial techniques commonplace in industry. The principal thrust is to impart skills in the *integration of previously acquired disciplines* to facilitate preliminary process synthesis, to help gain an appreciation for the nature of industrial projects and the industrial viewpoint used in managing them, to become adept at creating a successful business venture. The ultimate objective is to give the neophyte chemical engineer the background for the assumption of project managerial responsibilities at the earliest stages of an industrial career.

## COURSE STRUCTURE AND CONTENT

The course is listed in the catalog as "Chemical Engineering Economics and Project Evaluation"; it is a three-unit course given once a year. (It will be maintained as a three-unit course following conversion this year from the quarter to the semester system at Berkeley.) A senior process design course is prerequisite; most participating students have been graduates, but undergraduates taking process design concurrently have performed quite well.

The subject matter is presented as six sequential concepts:

1. **The Industrial Environment.** The nature of the industrial workplace wherein project evaluation is practiced is described, and the job functions of the professional chemical engineer are placed in context.
2. **The Mathematics of Finance.** The mathematical tools of project evaluation are presented, but concepts rather than manipulative skills are emphasized. The concept of the time value of money, which permeates the subsequent course material, is introduced.
3. **The Evaluation Process.** This is the core material of the course and includes project definition, investment analysis, net revenue analysis, project economic analysis, and evaluation of criteria of economic performance—the various subjects tied together as shown in Fig. 1.

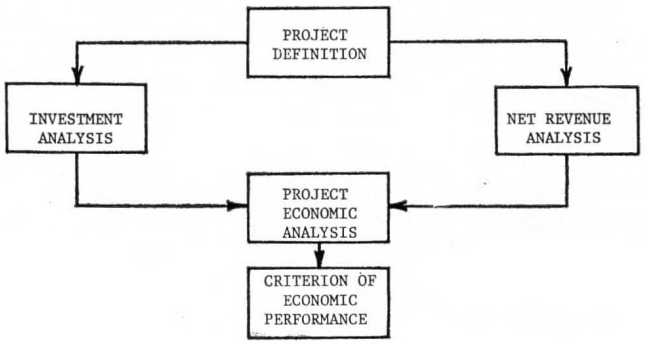


**FIGURE 1**

4. **The Analysis of Alternatives.** The core material is generalized for the case of "multicomponent" systems.
5. **Management of the Developing Project.** Management techniques for the advancement of projects from the laboratory to operating commercial units are introduced; these include techniques of construction time and cost control.
6. **Performance Analysis of the Corporation.** The corporation is evaluated as an ensemble of individual projects, and the performance is gauged in terms of criteria prescribed for the separate projects.

Within the context of this sequence a variety of special topics is introduced, all of which impact

peripherally upon the core material and are intended to stimulate the interest of the student. The discussion of the industrial environment incorporates an overview of many aspects of the chemical engineer's work—the gamut of human relations problems; challenges of professional development; the technical-managerial dichotomy; a realistic approach to the problems of ethics. The engineer's responsibilities for environmental protection and product stewardship are repeatedly emphasized, from the point of view of ethics and good citizenship as well as the point of view of assuring the continued productive functioning of the chemical industry in a distrustful society. Project definition, the first step in the evaluation sequence, includes an introduction to marketing research and the methods of projecting demand and an acceptable pricing structure—subjects frequently entirely novel to students.

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Chemical engineers are fond of systematization and mathematical analysis, and these preferences are recognized by introducing aspects of risk analysis—decision trees, Monte Carlo methods for projecting the probability distribution of criteria of economic performance, life cycle theory, construction of sensitivity diagrams, and others. Both strengths and weaknesses of risk analysis are emphasized. Several aspects of network analysis are presented, in particular CPM and PERT techniques used in project planning. Methods of linear programming are applied to the problem of the allocation of resources. A unique approach is outlined for the calculation of the inflation-adjusted, after-tax rate of return upon the average corporate project investment from data in annual reports.

## TEACHING STRATEGY

Problem solving receives heavy emphasis in the course. Assigned problems not only illustrate but also expand and supplement lecture material and reading assignments. The problems are often open-ended and unstructured; students are given a wide-ranging indoctrination into methods of attacking such problems and are taught the techniques of problem *synthesis*, in contrast to the analytical approach common to most of their previous courses. Most of the problems require the application of knowledge acquired in the course of a typical undergraduate chemical engineering curriculum. The purpose is to force students to utilize the sum total of their acquired engineering know-how, to reach back and to apply facts and techniques not necessarily contained in lecture material. This is a source of irritation and unhappiness to some students, but it is typical of the problems that actually confront the engineer in industry.

The fact of the matter is that students *like* to solve problems, and the review of solutions and the accompanying commentary take up a considerable portion of class time. Students also enjoy group participation in the solution of experiential exercises and other enrichment activities to supplement lecture material. My lecture notes have been expanded into a book, "Project Evaluation in the Chemical Process Industries", published this year by McGraw-Hill Book Company. I anticipate that use of the text, with supplemental reading assignments, will leave more class time for enrichment activities and anecdotal accounts of industrial experiences.

## TERM PROJECT

Short (one-hour) examinations constitute a standard evaluation technique of acquired skills in specific course areas. However, a massive final examination has not appeared to me to fill a useful course overview role. In order to demonstrate skills in project evaluation, one ought to evaluate a project, and this, in fact, constitutes the substance of a term project assignment. Four-person teams are asked to investigate the commercial feasibility of building a new production facility in a specific geographical area to manufacture a specific product. The team starts with a common scenario describing an existing integrated corporate complex, and an additional scenario is given which outlines an assigned business proposal in general terms. The team is asked to write a report to the corporation's management summing up and documenting its recommendations. Team members are asked, on a prearranged basis, to visit industrial libraries to consult business publications not normally available in university libraries.

A typical proposal might involve the construction of a hydrogen peroxide plant in the San Francisco Bay area to serve the West Coast pulp and paper industry, or the investigation of prospects for gasohol, obtained from cottonseed hulls, in the Gulf Coast area. The scenario given

to each team must be carefully designed to keep the investigation within reasonable limits. The final report gives students much-needed writing practice and serves as a vehicle for teaching content and style that corporate management likes to see in a business overview report. Students invariably approach the project with a great deal of enthusiasm, for they quickly recognize the challenge of a "real world" situation. I must say that the results have been a joy to me—topnotch professional-grade business analyses.

Occasionally student teams have chosen to concentrate on term projects of their own choosing, not necessarily involved with production planning —perhaps a study of the feasibility of aeolian power, or research into novel economic analyses such as process step scoring. Individual projects have been assigned to those who, for some reason, cannot participate in a team effort. Assignments have spanned such widely diverse subjects as life cycle theory, optimum surge tank policy, and the economics of reclamation of paper from garbage.

## ENRICHMENT TECHNIQUES

Term projects and other enrichment activities do require effective instructor-student contacts outside of classroom hours. A few of the more important classroom enrichment techniques have included the following:

**Oral Presentations.** Students are asked to do library research on specially assigned subjects and to give a ten-minute presentation in class. The purpose is to give students some badly needed practice in technical speaking and to give them some feel for the nature of time-restricted, industrial oral presentations. Typical assigned subjects have included:

**The Delphi method.**
**Status of engineering registration in state.**
**ASPEN, use in economic evaluation.**
**Geothermal power: status and costs.**

The presentations have not proved to be very popular with students, most of whom just do not like to speak in front of their colleagues. Nevertheless, I consider the speaking experience to be beneficial.

**Rèsumés.** A first assignment in the course has been the assembly (or update) of the student's rèsumé. The instructor writes out an individual critique on each rèsumé submitted; this is followed by office consultation when requested. After-class seminars on job interview techniques have been well attended.

**Term Project Reviews.** A worthy review technique involves a small group of volunteer engineers from industry who interact directly with the project team by offering a report critique and exploring alternative project aspects. Such interaction has been warmly received by both groups of participants.

**Visiting Lecturers.** A welcome break in class routine is to have visiting lecturers talk about special subjects such as the evaluation of securities.

**Special Projects.** Projects involving participation by all members of a class have been tried. One such project involves contacting of equipment vendors by individual students to get recommendations and quotations on purchase inquiries for specially formulated "pretend" applications. The exercise gives students the experience of such vendor contacts and a great deal of useful technical information. Most vendors have been eminently cooperative in this venture.

## EVALUATION

Students are fascinated and excited by the opportunities the course offers—a glimpse into the "industrial real world", an opportunity to sharpen the skills which that world demands. Even students with some industrial background welcome the chance to integrate their haphazard experiences into a systematized project-evaluation discipline. End-of-the-course written evaluations have been gratifyingly favorable.

The adoption of a course of this kind into the graduate curriculum is an important step in preparing students of chemical engineering for the assumption of project-management duties which form such a paramount part of their industrial careers. □