CONSTRUCTION MANAGEMENT PROGRAM

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ABSTRACT: The typical limitations of the existing construction management programs are the lack of an integrated approach to managerial decisions in real life construction environment, not enough emphasis on engineering design, construction methods and communication skills, and poor coordination between the undergraduate and the graduate studies. An effective construction management program should integrate teaching on undergraduate and graduate levels and research. On the undergraduate level it should provide the students with a good insight into all managerial tasks in civil engineering projects. On the graduate level it should allow specialization in the various areas of interest both to the practicing engineers and also to students who wish to pursue an academic career. The program should strongly interact with research and engineering practice.

INTRODUCTION

Construction management education has been receiving continuous interest over the last two decades, both in the academy and among the practitioners, more perhaps than any other subject in the civil engineering domain. The sad truth that a graduate of a civil engineering school is usually less prepared to deal with typical construction tasks than with almost any type of design chores may be disappointing and even frustrating to those who choose this career, as well as to their employers. The question how to prepare students for professional performance that requires experience and personal attributes as well as "book knowledge," is therefore of great importance to the industry and conscientious educators.

Several publications on the subject (2,3,4,7,10) present a comprehensive review of the prevailing construction management education programs. Some of these publications describe the attitude of the construction industry towards the various subjects usually included in such programs. This paper will concern itself with some general questions which have been confronting construction management education since it became established as a distinctive academic discipline, and will probably continue to do so in the future. These questions are as follows:

1. Can the skills required for construction management be acquired in school? If experience and personal attributes of managers are as important as theoretical knowledge, and possibly even more so, would it not be wise to carefully select the appropriate candidates for this career and let them train on the job rather than spend extra time in school?
2. Is there a need for a specific construction management education? If a formal education in management is desired, will it not be better to

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acquire it in a general purpose business administration or industrial management program?

3. Towards which tasks should construction management education be directed? Should it prepare solely towards the supervision of construction work on site, or encompass all civil engineering activities which are not associated directly with physical design?

4. Must a construction manager be an engineer? Since it is rather difficult to include both the required engineering basis and the additional managerial knowledge in a regular 4 yr academic program, should the program limit itself to technological essentials and devote most of the time to managerial subjects?

5. Should construction management concern itself with academic research? Or should it just provide a window to the construction practice through which to acquaint future practitioners with the executive aspect of their profession?

6. Who is qualified to teach construction management? "In house" academic faculty, like in other civil engineering disciplines, or experienced practitioners from the field?

Nature of Construction Management

The nature of management can be best explained through its major tasks, as in Refs. 5 and 6:

Planning.—(setting goals and standards, scheduling, budgeting, programming)
Control.—(evaluation of performance, in view of the plan, in terms of progress, resources and quality)
Organizing.—(division of tasks, departmentalization, establishment of communication procedures)
Coordinating.—(with designers, suppliers, authorities, subcontractors)
Directing.—(guiding, instructing, motivating, training)

These universal tasks are the essence of managerial activity in construction as well as in all other fields. However, as explained in Ref. 10, the managerial tasks in construction are executed in an environment which is very different from that encountered in other industries. The differences consist in the following features:

1. Every construction project has a permanent influence on its neighborhood and totally affects the safety and well-being of its users.

2. Unlike a standard production order in most industries, every construction project has distinctive characteristics with respect to its purpose, design, surroundings and resources employed for its realization.

3. The production process is not centralized as in other industries—every project is executed in a different location with a different labor force.

4. There is no unified authority for all phases of design and production; the authority is divided between the sponsor (or his agent), the

designer, the contractor and the local municipality in which the project is erected.

5. The production process employs a large number of highly qualified and independent skills with separate and possibly different employment agreements between them and the owner or the general contractor.

All of these features exercise a profound influence on the managerial, economic, legal and sociological aspects of the construction process. Therefore, very few managerial tools and techniques, be it in scheduling, accounting, information systems or robotics, can be applied "as are" to the construction practice. Consequently construction management must be viewed as a distinctive professional discipline with its own particular body of knowledge which requires study, updating, and augmentation through an ongoing and methodological process. As a matter of fact nowadays, with engineering design becoming more and more a mechanical process, aided by codes, manuals and computer programs, the managing of construction ventures may be probably considered the most challenging professional field in civil engineering practice. The knowledge required for this purpose involves the management of all phases of the civil engineering process from the original decision about the project's purpose and scope, through its performance specification, programming, preliminary design, budgeting, design, tendering, construction and its operation and maintenance planning, when completed.

The tasks of construction management pertaining to these activities may be performed within various institutional frameworks, with possibly different interests and responsibilities. The more important of these are owner's project management, contractor's project execution, construction company management, and local or regional construction planning and directing. The major tasks of construction management in each of these categories are enumerated below.

Project Management (on Behalf of the Owner)

1. preparation of functional requirements and performance specifications
2. evaluation of preliminary design
3. preparation of budget and schedule
4. coordination and evaluation of design
5. preparation of contract documents and selection of contractor
6. monitoring and control of the construction process
7. quality control and valuation of contractor's work
8. planning of operation/maintenance of the completed project
9. performing specific tasks of construction management as needed

Construction Management

1. estimating and bidding
2. selection of a construction method
3. site planning
4. organization of construction teams
5. subcontracting

6. scheduling
7. processing of technical information
8. procurement of materials and services
9. contract administration
10. cost and schedule control
11. quality control
12. coordinating and directing of works
13. personnel management

Management of Construction Company

1. organizing
2. forecasting and long range planning
3. estimating
4. bidding
5. marketing
6. organization of projects, their coordination and control
7. operation of information systems
8. personnel management
9. financial management
10. procurement of materials and services
11. inventories management
12. equipment management
13. capital budgeting
14. evaluation and operation of incentive programs
15. evaluation and development of building methods and procedures

Regional/National Building Agency

1. determination of building regulations, standards and procedures
2. needs assessment and long range planning of building development
3. long range planning of building resources development
4. preparation and analysis of development alternatives
5. sponsoring and management of building research
6. initiation, directing and financing of building programs

Naturally, no one person can be employed within the course of his professional career in all the above tasks or even in a large part of them. Consequently, construction management programs in some schools may, and do, choose as their subject only certain aspects of the total managerial activity such as project supervision, business management or quantitative planning, and try to cover those aspects in greater detail. On the other hand, a comprehensive approach while lacking perhaps in depth, may enable a better perception of the interrelationships between the various tasks and promise greater potential for personal development and performance versatility. Both approaches must cope, however, with certain problems inherent in construction management reality, which will be explored henceforth.

The teaching of construction management is a formidable task. The various programs offered in this area usually suffer from several typical limitations which will be now reviewed.

Analytical Orientation of Studies.—Teaching in most engineering schools is traditionally analysis oriented. The courses teach analytical techniques or offer factual data, necessary for exploration of specific attributes of various building (or civil engineering) components. The analysis is an essential part of problem solving, however, it usually examines only a certain aspect of the problem and therefore in engineering systems it should be followed by a synthesis process which emphasizes the interdependence between their various components and various aspects of their behavior. Nevertheless, rarely are students taught how to examine whole self-contained systems even of very simple nature, including their overall performance requirements, technological solutions and execution problems. The analytical approach conforms to the contents of most textbooks, professional publications, and the academic background of most college teachers, who are expected to excel in very narrow and specific fields.

An analytical approach which reflects synthesis may not impair very much the efficiency of a graduate engineer in a design office. For example in structural design, the student may deal with some simple components like beams, slabs, columns, using codes and routine techniques acquired in few basic courses. These will be later assembled into structural systems by more experienced engineers with higher authority. Somebody, on a still higher level, will put this part together with the mechanical systems, finish works into a whole building assembly; and so forth. It will be different, however, with a recent graduate employed in construction management, who is required to do for example scheduling work even for a very simple project, or a part of it. The basic knowledge in scheduling techniques learned in school will not enable him to do it in a useful way without a good insight into the work process, interaction between the various trades, assessment of their productivity, comprehension of work laws, and possibly incentive plans and union practices, all within the particular context of the project under consideration. The student will not find this information in text books or standard documentation, and will not know where to look for it, without being taught it at school in the proper manner.

Teaching a comprehensive approach to construction problems is a demanding and expensive task. It requires faculty with appropriate background, extensive preparation of material and much individual guidance. Courses oriented towards this purpose will be discussed later in this paper.

Difficulty to Recapture Real Life Construction Environment.—Successful construction management involves not only performance of specific tasks such as scheduling, cost estimating, organizing etc., but also a multitude of routine activities such as negotiating and coordinating subcontractors and suppliers, quality control, processing of design information, contract details administration, interaction with local authorities, introduction of changes, and so forth. Such activities, although less

conspicuous in the various texts and publications, form the backbone of construction routine and require a fair amount of knowledge, usually obtained with time and experience. It is difficult to teach them as separate subjects in the program, however, their importance may be illustrated and emphasized while teaching other more amenable aspects of construction management, and discussing case studies.

Lack of Emphasis on Communication Skills.—Engineers are conditioned to communicate with symbols—mostly through drawings and formulas. This way of communication is quite sufficient (and very efficient) for people employed in a purely technical capacity, processing routine information in a standardized way and transmitting it to other people with a similar technical background. It is not sufficient in construction management where there is a continuous need to communicate with people of different background, mentality and status. The success of every construction venture depends on the quality of communication by management, of the orders, instructions, requests, reports and other types of information, to all the participating parties.

Although communication, both oral and written, can be taught as a special subject within the academic curriculum, such a course most often does not attain the desired purpose since it is considered by students as "non-engineering" and therefore not important material. It seems that the only efficient way to improve written and oral presentation in engineering schools is to require them, and emphasize their importance, in regular assignments given in the various engineering subjects. The regular faculty, well experienced as it is, in teaching, lecturing, research reporting and publications is certainly very well qualified to supervise this task.

Not Enough Teaching of Technical Solutions.—The emphasis in most construction management programs is usually on general managerial techniques and their application and adaptation to the construction practice. Not enough effort is expended on acquaintance with technical construction alternatives (selection of appropriate construction method, equipment type, and site organization) for various types of works like high rise construction, excavation, use of prefabricated elements, underground construction and others, under various types of constraints—space, weather, etc. Ultimately the capacity to solve efficiently such problems distinguishes the real construction expert and leader, from a mere "administrator." Teaching of this knowledge can be done most effectively through analysis of case studies, and requires a considerable effort for identification of meaningful cases, compilation of the necessary material, and safeguarding participation of professionals involved in actual execution of those or similar works.

Not Enough Emphasis on Design.—It was mentioned before that teaching even the basics of construction management within the regular framework of undergraduate civil engineering education may prove difficult. For this reason there has been a trend in various circles to view construction management as a distinctive profession, divorced from engineering design. Thereby the analysis and design courses forming the core of the regular engineering education could be substituted to a large degree by additional management and construction oriented courses in special programs designated for this purpose. This approach is quite ap-

propriate when preparing professionals for specific tasks in construction supervision on site or in processing of managerial information in the construction companies. In fact it may produce more satisfactory immediate results as evidenced by the surveys conducted on this subject among contractors (2). However, if the purpose of the construction management program is to prepare individuals for eventual leadership of the technical effort in construction ventures, the design oriented engineering basis seems to be essential for the following reasons.

1. No complete understanding of construction alternatives of a civil engineering subject is possible without an insight into its design considerations (and of course vice versa).
2. The major part of decisions concerning the technological solution and its eventual cost is made in the design stage. A technical team leader who cannot participate (at least in advisory capability) in this process, for lack of adequate background, forfeits his ability to affect the efficiency of the project at its most influential stage.

Coordination of Undergraduate and Graduate Studies.—Following the reasoning offered previously in favor of a sound engineering basis for future construction managers, it may be concluded (and it often is) that a specific education in this direction should be given only within the framework of graduate studies. However a survey (2) shows that only 10% of persons actively engaged in construction management participated in graduate studies. It follows, therefore that students who were not offered these subjects in their undergraduate courses will probably not have a chance to ever study them in formal fashion. It will be shown later how basics of construction management can be acquired in undergraduate studies without infringing on the conventional engineering core. That will not obviate continuation of the studies on the graduate level for the same reasons as in other academic disciplines. Obviously, both levels have to be integrated with defined objectives into one comprehensive program, so as to prevent repetition of the basic material on the graduate level on one hand, and ensure sufficient basic knowledge of all entering graduate students, on the other.

Difficult to Teach Leadership.—It is accepted that one of the most important qualifications of any manager is his ability to lead and motivate people. The capacity to lead is only in very few cases a result of natural charisma. It can be developed, if the person is motivated to act and succeed as leader, and has some basic attributes which are necessary for almost any kind of success. Individuals can be schooled towards leadership (as they are e.g., in the military schools) however the academic environment is not very conducive to this purpose. The least that can be done in this respect is a review of leadership case studies, possibly within the framework of a "Human Resource Management" subject, and improvement of presentation skills and confidence as was already suggested in a different context.

Structure of Construction Management Program

As noted previously, the structure of a construction management program will depend upon its objectives. Accordingly, it may focus on spe-

cific areas of construction management activity, or alternatively it may provide a basic knowledge of a more general and comprehensive nature on an undergraduate level, later augmented by graduate studies, continuing education courses or informal learning on the job. As was also noted, the graduate studies should in any case offer an orderly continuation of the undergraduate basis within the framework of an integrated education program. We shall proceed now to review in more detailed terms the desired contents of a construction management program, following the comprehensive approach, in order to offer some more specific solutions to the various problems presented in the former section.

Undergraduate Level.—The objectives of a construction management program on the undergraduate level may be formally defined as follows:

1. To prepare the graduate for execution of basic managerial tasks like scheduling, estimating, cost control, etc., first under supervision and then independently.
2. To acquaint the student with construction procedures and environment so that he will be able to develop with additional experience to higher and more responsible tasks with an owner, a contractor or a public agency.

The studies will consist of three parts:

1. General base.—common to all engineering studies and including subjects from mathematics, physics, chemistry, mechanics, materials science, computer science, and possibly also from economics and social studies.
2. Engineering base.—providing insight into the practices of analysis and design in major areas of civil engineering. It will include subjects in the areas of structural design, building materials, environmental studies, water resources, geotechnics, transportation systems etc. Considering the wide scope of civil engineering activities it may be preferred to confine the study of the design subjects (within the construction management program) to a more limited area of applications such as buildings, transportation systems or water resources or environmental projects, according to the student's selection.
3. Construction management subjects, which may be divided into two groups.

The first group will include basic managerial subjects such as engineering economics, statistics, accounting and operations research, and also introductory subjects in construction management like construction planning, construction equipment and construction methods and processes. If possible, the general managerial subjects should be also taught by civil engineering faculty and emphasize adaptations and applications to civil engineering practice. These applications are amply described in various textbooks available for each one of the aforementioned subjects. All the subjects in this first group although naturally of primary importance to students who want to specialize in construction management, should be also of interest to others who wish to engage in design.

The second group may include more advanced subjects which focus on the application of basic knowledge acquired heretofore to the solution of real life problems of managerial planning. Presented are several examples of such subjects taken from this author's teaching experience.

Project construction planning, includes a comprehensive assignment in which the students are required to prepare a detailed construction program of a given project with quantity surveying, choice of construction method, selection of equipment, site planning, determining the composition of construction teams, progress scheduling, and cost estimating. The project may be building, highway, dam, etc., and the students are provided with all the design drawings necessary for their work.

Economic analysis of a construction project includes a comprehensive guided assignment in which the students perform a feasibility study of a given project—private or public. The study consists of demand forecasting, preparation of alternative solutions (in terms of scope, location, preliminary design), evaluation of costs and benefits, comparison of alternatives, and sensitivity analysis for varying market and financing conditions.

Planning of an industrialized building system includes a comprehensive guided assignment in which the students select a prefabrication method for a given building, design the precast elements and plan the production system (plant, equipment) for their manufacturing.

Organization of a construction company includes a comprehensive guided assignment in which the students are required to design an organization structure, operating procedures, and information system for a construct company of a given size and objectives.

Seminar work, which requires from each participating student to study a selected topic in the area of construction management from bibliographical sources, field trips, interviews etc., and present the findings in a lecture and a written report.

Construction case studies, which includes analysis and review of the technological and managerial solutions to several interesting large scale building projects as executed in practice.

This advanced group of subjects may be offered jointly to the undergraduate and the graduate students. It seems that devoting the last year of civil engineering studies to construction management subjects as described here should suffice to acquire the minimum necessary background in this area.

Graduate Studies.—The purpose of an integrated construction management program on the graduate level is to augment the students general knowledge, mainly in areas which require for their better understanding some practical exposure, and also to allow for a specialization in the various subjects of their particular interest. Such a program with an usual duration of 1.5–2 yr must consider three different types of applicants: (1) Practitioners without prior formal education in construction management; (2) practitioners who want to attain additional knowledge in specific areas of construction management in which they may engage, like contract administration, financial management, use of computers, etc.; and (3) graduates who want to pursue a career in teaching or research.

Students without prior formal schooling in construction management should be required to study first the basic managerial subjects described

before (as the first group) either as prerequisites or in a specially structured intensive graduate courses awarding partial credit. The more advanced courses (of the second group) may be studied, as suggested before, also on a graduate level, provided of course that they meet the accepted standards for this purpose. Students with formal undergraduate background in construction management will be able to study specifically oriented subjects such as the following:

1. Information systems in construction
2. Cost estimating methods
3. Financial management in construction
4. Legal aspects of contracting
5. Work improvement methods
6. Personnel management
7. Advanced construction methods
8. Specifically oriented building systems (residential, power plants, etc.)
9. Electrical/mechanical systems in construction
10. Computer methods in construction
11. Management of industrialized building systems
12. Labor relations in construction
13. Construction economics
14. Decision models in civil engineering

Students should be also encouraged to take courses within the area of their interest in other fields of civil engineering, in business, industrial management, computer science or architecture. They may be also required (as customary in most graduate schools) to prepare a limited thesis work involving an extensive survey of a selected topic or a solution to a practical problem of a particular interest.

Students who wish to pursue careers in teaching or research may be advised to select more subjects of a general theoretical nature (e.g. in the areas of economics, operations research, business, statistics, computer science, etc.) and prepare a thesis work with some application of a research methodology as explained later.

Research

An academic educational program in construction management should engage not only in teaching but also in research. Research activity is essential for faculty who want not merely to transfer textbook information to students, but also advance the frontiers of knowledge in their field. It is particularly important in an area like construction management which abounds with problems of long range nature, and has almost no other place outside the academy where these problems can be explored in a thorough and methodical way.

To qualify as research, a problem study must fulfill some basic conditions (11). Its aim must be to advance knowledge in a specific area of interest. It must also follow an established procedure which includes these elements:

1. A clear definition of the problem and of the specific research objectives.
2. A thorough survey of the "state-of-the-art" in the problem area.
3. An accepted and reliable method which promises, under existing constraints, attainment of the best possible solution to the problem.
4. Objective examination of the various factors associated with the system under consideration, of the possible changes in these factors, and their effect on the results.
5. An orderly and objective presentation of the results.

An identification of research subjects may be done systematically with one of the methods described in Ref. 11. Various studies conducted for this purpose were described in Refs. 1, 8 and 9 and other papers. It seems that the following groups of problems deserve special attention.

Rationalization of construction works, i.e., increase of productivity through technological-managerial improvements. The three most promising thrusts in this direction involve:

1. Industrialization of work through use of prefabricated off site components and assemblies.
2. Standardization of construction components and activities.
3. Robotization of construction activities on and off site.

Preparation of a common data base for construction information which involves the following activities:

1. Classification of the construction items on several hierarchical levels—that of basic inputs, of works, of assemblies, of systems, and of project types.
2. Compilation and arrangement of standard information—productivity figures, costs, specifications, technical details for each of these classes.
3. Design of a data structure and maintenance procedures of data base management system for the aforementioned data.

Improvement of communication in construction ventures with a focus on the following attributes:

1. Desired organization structures for various types and sizes of construction ventures.
2. Desired information systems for these construction ventures.
3. Desired operational procedures for these construction ventures.

Automation of decision making in construction, which will devise rules, algorithms and expert systems for computerized processing of technical project information (with the aid of the database aforementioned) into cost estimates, budgets, resources allocations, schedules, cash flows, employment plans, inventory programs and other tools of managerial decision making.

Increasing labor productivity in construction through development and evaluation of procedures for workers participation in decision making, training programs, and safety plans and procedures.

Formalization of valuation methods of construction systems, project designs and development plans through identification of pertinent attributes for each of these cases and preparation of objective procedures for evaluation of costs and benefits associated with the attributes in the various types of civil engineering works.

Standardization and improvement of legal relationships between the various parties in the construction process with special emphasis on innovative contracting techniques (design-build, target contracting, serial contracting, etc.), union practices, and government regulations.

Teaching Staff

The success of educational progress will ultimately depend upon the qualifications of individuals who are to put it into effect. What are, therefore, the defined qualifications of the teaching staff in a construction management program in terms of academic achievements and practical experience?

The usual time for a qualified student on an "academic career" track to attain the doctoral degree is about 10 yr from the beginning of his undergraduate studies. It takes an additional 8–10 yr of intensive academic effort to establish himself as a senior faculty member in a reputable academic institution. His qualifications at the end of this period include theoretical expertise in his specialization area, teaching experience, and possibly a reasonable acquaintance with research methodology. Rarely does he have at this stage the practical experience necessary to convey to students the "construction environment" knowhow so important for success in real life circumstances. Neither is he likely at the age of forty to abandon even temporarily, his academic career to gain that practical field experience.

A comparably talented practicing engineer at the same age has probably already acquired sufficient experience to share with others. He will have gained a good first hand knowledge of techniques, solutions and procedures necessary to survive and even prosper in the customary construction environment. He will, however, be lacking in theoretical background and teaching skills. He is obviously very well qualified to offer "working" solutions based on his personal experience, however, not always willing to search for "optimal" alternatives as reflected (often too idealistically) in the managerial or professional literature. Such a person, even if definitely qualified, is not likely to start at this age his studies towards a doctoral degree which will bring him up to date in the theoretical domain and is mandatory today for most types of academic careers.

There are indeed some lucky cases of people in managerial positions who had an opportunity to complete within the frame of their regular work (in the army, government or private companies) a doctoral degree or engage in an extended academic research activity. There are also cases of faculty engaged in practical field work without neglecting their parallel academic activity. Obviously such people are very well qualified for educational activity in construction management, however, their profile can be hardly used as a required stereotype of a faculty in this field. It seems therefore that the practical solution to the staffing problem of a

construction management program would be to attract the two types of educators; people on an academic track with required scholastic achievements on par with their peers in other academic disciplines, and seasoned practitioners with ability and motivation to teach, and possibly some prior experience in postgraduate academic activity. The first type will teach subjects of more general or theoretical nature. The second, will teach application oriented courses including guided assignments, which simulate real life conditions. Both types will interact in research projects with the first offering the methodological framework and the other the practical insight.

Conclusions

An effective construction management program in engineering should integrate teaching on undergraduate and graduate levels and research. On the undergraduate level it should provide the students with a good insight into all managerial tasks in civil engineering projects, starting with the general definition of their objectives, through the various stages of design and execution and up to their operation and maintenance upon completion. The program should emanate from a solid base of general and civil engineering subjects and contain two types of courses: those which deal with general management techniques (adapted to the special needs of construction), and those which stress comprehensive solutions to construction problems involving real life conditions. The program on the graduate level should allow specialization in the various areas of interest both to practicing engineers and also to students who wish to pursue an academic career.

A construction management faculty should engage in research to solve the long range problems of the industry through objective and methodological effort. The faculty may include two types of teachers—those with a strong academic background and those with a thorough practical experience.

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