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PROJECT-BASED COURSE FOR PRACTICING CONSTRUCTION PROJECT MANAGEMENT

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ABSTRACT

The Construction Engineering Department at Zagazig University (ZU) implemented an undergraduate course titled "Construction Project Management (CPM)." This two-semester course has been offered since 1983. The goal of the course is to provide a project-based, practice-oriented opportunity for students to deal with various engineering and management aspects of real-world construction projects. The course involves a mix of laboratory, class discussions, lecture activities, and a term project. Industrial participation has been sought to present real-world projects to students. The term project is carried out by student teams. A real-world project is assigned to each team. Every individual student works on one aspect of the assigned project, while coordinating with the rest of his team. At the end of the term project, each team submits a written report that documents aspects including cost estimating, method of construction, planning and scheduling, resource management, control systems, and other special studies. In addition, each team gives an oral presentation, which is attended and evaluated by practicing engineers and faculty members. The course gives exposure that is very similar to what graduates encounter in a construction/contracting firm. This paper describes the course philosophy and organization.

Keywords: *Construction, Project management, Capstone course, Education, Civil Engineering, Curricula.*

الملخص

يقوم قسم هندسة و ادارة التشييد- كلية الهندسة بجامعة الزقازيق بجمهورية مصر العربية بتدريس مقرر دراسي خاص بادارة مشروعات التشييد للطلبة في مستوى التخرج. وقد كانت البداية في تدريس هذا المقرر والـذي يمتـد تدريسـة لفصلين متتابعين في عام ١٩٨٣. والهدف من هذا المقرر هو تزويد الطالب بخلفية علمية عن الجوانب المختلفة لهندسة وادارة التشييد واعطاءه فرصة للتطبيق على مشروعات فعلية تحت التشـييد. و يشـتمل المقـرر علـى مـزيج مـن المحاضرات و المناقشات وورش العمل. وكعنصر اساسي في هذا المقرر يتم دعوة شركات المقاولات للمشاركة بتقـديم المشروعات الفعلية تحت التشييد. ويتم تقسيم الطلبة الى مجموعات حيث يسند الى كل مجموعة مشروع فعلى باحـدى الشركات. ويقسم العمل بحيث يقوم كل طالب بالمجموعة بتناول جانب محدد من العمل بالمشروع ودلك بالتنسـيق مـع

باقى أفراد مجموعته. ويقوم الطلبة بتقديم تقرير عن عملهم بالمشروع يتناول جوانب مثل تقدير التكاليف، طريقة التنفيذ، التخطيط والجدولة، ادارة الموارد، أنظمة التحكم، ودراسات خاصة أخرى. وفي نهاية العام تقوم كل مجموعة من الطلبة بعمل عرض للمشروع ونتائج عملهم والذى يقوم أعضاء هيئة التدريس بالاضافة الى مهندسي المشروع بتقيمه. وهكـذا يتعرض الطلبة في هذا المقررالىما يتعرض له الخريجين الحديثين عند عملهم في شركات التشييد و المقاولات. هـذا، ويقوم البحث الحالى بعرض فلسفة وتنظيم هذا المقرر الدراسي بالاضافة الى أمثلة من المشروعات التى تم تناولها.

1. INTRODUCTION

The traditional curriculum of civil engineering education has organized the faculty, students, study programs, and research according to functional areas, such as structural engineering, construction engineering and management, geotechnical engineering, transportation engineering, and environmental engineering. As a result, students tend to separate the subject material, treating each course as an isolated set of concepts and problem-solving strategies [Albano and Salazar, 1998].

In contrast to the traditional curriculum, the civil engineer demanded by the industry must not only be competent in engineering science, design, and other technical skills, but is also expected to understand and perform efficiently in a multidisciplinary and complex environment. This necessitates a learning environment that integrates technical background, industrial participation, communication and teamwork skills, and information technology and computer-based tools.

To fulfill the industry needs of civil-engineer qualifications, the Construction Engineering Department at ZU has initiated a Construction Engineering and Management (CE&M) Program, which is an undergraduate program for upper-level, civil engineering students. This program aims towards a more professionally oriented curriculum. It contains key elements including project-based and practice-oriented curriculum, multidisciplinary approach to the solution of CE&M problems, and hands-on experience with the practices and techniques used in the construction industry.

This curriculum includes a number of courses aimed at developing a student insight into the interrelationships among constructors, construction managers, consultants, and owners. Among these courses is the CPM course. CPM course requires teams of few students to address different aspects of real-world projects including contracting methods, method statement, cost estimating, bid preparation, planning, scheduling, cash-flow forecasting, control systems, and special studies. Teams are required to prepare detailed reports and deliver oral presentations to communicate the results of their work. Term projects are accomplished with the participation of industrial sponsors, who provide the students with technical assistance and guidance during data collection.

This paper introduces the authors' experience with the CPM course, which has been offered since the academic year of 1983. The course philosophy, development, organization, and key elements are outlined. In addition, a partial list of the studied real-world projects is given, which are diversified in nature, scope of work, and requirements. These diversified projects were carefully selected to cover the spectrum of the construction industry and thus, enhance the accumulated experience within the program.

2. COURSE PHILOSOPHY AND DEVELOPMENT

CPM course was established as a part of the curriculum of the CE&M Program at ZU. The objectives of CPM course include developing the ability to deal with various engineering and management aspects of construction projects, increasing student knowledge of the factors that influence economic construction, and increasing student awareness of the roles of project teamwork.

In this course, students are organized into teams. Each team is required to simulate the construction of a real-world project using a comprehensive approach of construction engineering and management. Teams tackle various engineering and management aspects involved in the construction of the assigned projects. In addition, they conduct studies for integrating construction knowledge into certain decision-making processes, such as constructability evaluations and value engineering. Through conducting these studies, teams are stimulated to use quantitative construction criteria to assess various alternatives. Finally, they present their results in the form of project reports and oral presentations, which are considered as a basis for evaluating their work.

Almost all Egyptian universities include an undergraduate project-based course, which is mainly concerned with the aspects of engineering design. Most of these courses include fictitious projects that do not actually exist. Conversely, CPM course handles real-world construction projects, thus, achieves a strong link between the university and the construction industry.

3. COURSE ORGANIZATION

Table 1 shows the CPM course schedule. The course extends for two semesters and a 4-week term project period. The first semester is devoted to topics related to basic managerial skills essential for construction project managers. Two-hour class meetings are scheduled once a week totaling 12 class meetings throughout the first semester. The activities during the second semester are divided into class meetings and site visits. By the mid of the second semester, projects are selected, teams are formed, class meetings involving training on planning and scheduling software are held, and site visits are started. The CPM course is organized in four types of activities including laboratory, class discussions, faculty lectures, and a term project with industry involvement.

Table 1. CPM Course Schedule

Class (1)	Topic (2)	Due (3)
	(a) Semester I	
1	Course introduction	-----
2	Technical report writing	-----
3	Technical report writing	Lab 1 & presentation
4	Making effective presentations	-----
5	Making effective presentations	Lab 2 & presentation
6	Problem solving techniques	-----
7	Problem solving techniques	Lab 3 & presentation
8	Decision making	-----
9	Decision making	Lab 4 & presentation
10	Creative thinking	-----
11	Motivation	-----
12	Teamwork	-----
	(b) Semester II	
1	Computer applications to construction project management	-----
2	Primavera Project Planner (P3) package	-----
3	Primavera Project Planner (P3) package	-----
4	Primavera Project Planner (P3) package	-----
5	Primavera Project Planner (P3) package	Lab 5
6	Selection of projects and formation of project teams	-----
7	Site visits	-----
8	Site visits	-----
9	Site visits	-----
10	Site visits	-----
11	Site visits	-----
12	Site visits	Data collection status
	(c) Term Project Period (4 weeks)	
1	Basic project engineering and management	-----
2	Basic project engineering and management	Project status presentation
3	Special tasks for each team	Project status presentation
4	Report writing	Final report
	(d) Course Evaluation	
-	Project presentations	-----
-	Course evaluation	Students grades

3.1. Laboratory

During the first semester, four laboratory assignments are used as applications to the basic managerial skills essential for construction project managers including technical report writing, making effective presentations, problem solving techniques, and decision making. In addition, another lab assignment is introduced in the second semester, which includes computer-based applications to project planning and scheduling.

3.2. Class discussions

Most class meetings are started with a discussion period. Material for discussion is based on completed laboratory assignments and term project status reports. Each team is required to make a presentation, which serves as a stimulus for additional class discussion. In addition, the reliance on team presentations enhances skills, including self-trust, cooperation, and communication.

3.3. Lectures

Since the course was developed to create an interactive learning environment, very short time is allocated to formal lectures. Lecture topics include creative thinking, motivation, and teamwork.

3.4. Term project

At the mid of the second semester, students are organized into teams of about 4 to 6 students. Each team is assigned a real-world project and is required to simulate the construction engineering and management aspects of the project. Project information are collected through interviews with project staff during scheduled site visits. Information include project contract, bill of quantities, method of construction, construction drawings, available resources, construction rates, project constraints pertaining to construction cost and schedule, and special considerations for equipment and material procurement. Each team develops the term project over a four-week period under full supervision of a faculty members. This insures involvement of the faculty member in almost all activities performed by the team. The following sections outline the key elements of the term projects, examples of the project offerings, and the results of the feedback.

4. KEY ELEMENTS OF THE TERM PROJECT

4.1. Project selection

Huge projects that are broad in scope and employ advanced technology are generally selected. Characteristics that should be present in a candidate project include:

- Constituting a major engineering project constructed in Egypt, with preference to heavy construction projects.
- Requiring considerable interaction between the construction engineering and management aspects.
- Challenging in its conditions and requirements.
- Being under construction, so that students can watch and document the method of construction.
- Perceptiveness of project manager to cooperate with the student team.

During the past 17 years, since 1983, over 60 projects have been selected which covered the whole spectrum of construction projects. Most of these projects are publicly owned and were constructed by big national and international contractors. A partial list of the most prominent projects is given in Table 2.

4.2. Scope of project work

The scope of project work includes basic project management functions and special studies. Project management functions include estimating project costs, documenting method of construction, planning and scheduling, resource management, and preparing cash-flow forecasts. Special studies are occasionally performed based on the project conditions and requirements. Examples include studying of formwork systems, conducting value engineering studies to select between alternatives, devising project cost control and quality control systems, resolving traffic problems during project construction, performing project time reduction, and portraying site layout.

4.3. Term-project supervision

Each student team is closely supervised by a faculty member assisted by one or two teaching assistants. The supervisor adopts the role of project facilitator, with responsibility for tasks including arranging for contacts with industry sponsors, participating in technical discussions, outlining project management strategy, and monitoring project status. Supervisors meet regularly with team members at scheduled times to discuss the progress of work in projects.

4.4. Interaction with industry

Achieving interaction with industry has been one of the major goals of the term project. The large number of offerings, since 1983 to date, has revealed strong and increasing industrial interest in the course and especially the term project. The work of student teams is collaboratively evaluated by industry people and faculty members.

4.5. Term-project evaluation

At the end of the term project, each team is required to submit a report and give an oral presentation. Presentations are professionally prepared using computer-based presentation software, charts, tables, and animation. Every student participates in the presentation and gives a summary of his assigned engineering and/or management tasks. Sponsor's staff and other practicing engineers are invited to attend the oral presentation and participate in the evaluation of the work of project teams. Open, detailed questions are allowed, which provide feedback and insight related to the actual project.

4.6. Course grading

Formal examinations are not required for CPM course. The final grades are based on the following distribution of activities; 50% for the class participation including laboratory assignments and class discussions, and 50% for the term project. The term project grade is distributed as follows; 30% for the final report and 20% for the oral presentation (10% for individual students and 10% for the team as a whole).

5. EXAMPLES OF STUDIED PROJECTS

This section presents a brief description of four of the term projects [Construction 1983–2001] which include; (i) Evaluation of soil grouting techniques, (ii) Construction of Al-Warrak Bridge, (iii) Evaluation of formwork systems, and (iv) Construction of 26th of July Corridor.

5.1. Project I: evaluation of soil grouting techniques

This special study was conducted by a four-student team as a term project in the academic year of 1994/1995. The objectives of this study include; compiling information concerning the advantages and limitations of different grouting techniques, and application of the knowledge gained to real projects to check whether the appropriate technique was used for each particular situation.

The literature review revealed that the most commonly used grouting techniques include; Low pressure grouting and micropiles, Jet grouting (T1, T1-S, and T2 techniques), Compaction grouting, and Chemical grouting.

Four projects were considered for application, namely; Water sump in El-Tal El-Kabeer water treatment plant, Sultan-Ghouri mosque, Azab tower, and Al-Zahed mosque. In each case, the ground water control technique in use was evaluated as far as suitability and economics are concerned. The first project, which is a water sump, is briefed below.

Table 2. Partial list of the most prominent studied construction projects.

Project Name	Contractor	Volume of Work (L.E. million)	Duration (month)	Year of Study	Scope of work											Group Size	% Completion by Time of Study
					Cost Estimating	Method of Construction	Site Layout	Planning and Scheduling	Resource Management	Time Control System	Cost Control System	Quality Control System	Cash-Flow Forecasts	Traffic Management	Special Studies		
Intake Structure, Abu Sultan Electric Power Station	Arab Contractors Co.	1.6	18	1983	*	*		*	*	*	*		*			2	50
Military Officers Housing	Arab Contractors Co.	31.0	24	1984	*	*		*	*	*	*		*			3	30
Clinker Grinding Mills, Helwan Cement Factory	Arab Contractors Co. (Civil Works)	15.0	24	1985	*	*		*	*	*	*		*			5	50
Roud El-Farag Bridge (Superstructure)	Bridges Dept., Arab Contractors Co.	27.0	60	1988	*	*		*	*		*	*	*			5	20
Roud El-Farag Bridge (Substructure)	Bridges Dept., Arab Contractors Co.	32.0	60	1988	*	*		*	*		*	*	*			5	40
Ismailia Olympic Swimming Pool	Arab Contractors Co.	3.0	10	1989	*	*		*	*	*	*		*			4	50
Ismailia Cultural Center	Arab Contractors Co.	3.0	24	1990	*	*		*	*	*	*		*			4	50
Blasting in Construction	Arab Foundations Co. (VIBRO)	-----	---	1990		*									*	1	---
Caissons Construction, Ameria Tunnel Pump Station	Christiani & Misr Conc. J. Venture	60.0	36	1991	*	*		*	*		*	*	*			4	90

Cairo Ring Road, Sections 5 & 6	Arab Contractors Co.	80.0	60	1992	*	*		*	*	*	*		*			5	20
Fakous Court Complex	Arab General Contracting Co.	5.0	32	1992	*	*		*	*	*	*		*			4	40
El-Khalafawy Station, Cairo Underground Metro	Inter-Infra Consortium	40.0	20	1994	*	*		*	*	*	*		*			5	90
Anshas Water Treatment Plant	El-Nasr Utilities & Erections Co.	4.5	18	1994	*	*	*	*	*	*	*		*			4	90
El-Ataba Station, Cairo Underground Metro	Inter-Infra Consortium	60.0	36	1995	*	*		*	*	*	*		*			5	50
Evaluation of Soil Grouting Techniques	Foundations Dept., Arab Contractors Co.	-----	---	1995		*									*	4	---
Cost Control System for Grouting Projects	Foundations Dept., Arab Contractors Co.	-----	---	1995							*				*	4	---
Ext. to Sixth of October Bridge (Cable Stayed Construction)	Bridges Dept., Arab Contractors Co.	26.0	18	1996	*	*	*	*	*	*	*		*			4	20
Ext. to Sixth of October Bridge (Flying Shuttering Construction)	Bridges Dept., Arab Contractors Co.	55.0	26	1996	*	*		*	*	*	*		*			4	10
El-Moneeb Bridge (Cantilever Carriage Construction)	Bridges Dept., Arab Contractors Co.	212.0	48	1996	*	*		*	*	*	*		*			5	30
Al-Warrak Bridge	Bridges Dept., Arab Contractors Co.	214.0	36	1996	*	*	*	*	*				*			4	10
Bridge Maintenance Management, Case Study: King Khaled Bridge	Bridges Repair Dept. Arab Contractors Co.	-----	---	1997		*	*	*	*					*	*	4	---
Evaluation of Formwork Systems (Value Engineering Study)[a]	----------	-----	---	1997		*									*	4	---
26th of July Corridor Project	Roads Dept., Arab Contractors Co.	30.0	6	1998	*	*		*	*		*		*	*	*	5	50
Suez Canal Bridge, Approach Spans	Bridges Dept., Arab Contractors Co.	500.0	42	1998	*	*		*	*	*	*	*	*	*		7	30

El-Tal El-Kabeer water treatment plant involves the construction of a water sump with a length of 40 m, a maximum width of 22 m, and an area of approximately 565 m^2. The bottom of the sump was designed to rest at a depth of 20 m below ground level. However, soil borings indicated that the final ground water table is almost at the ground level. Thus, water seepage problem is anticipated during the construction process. Moreover, uplift force is also anticipated to apply at the bottom of the sump. Therefore, an effective method to control ground water was of vital importance.

The construction of the sump actually used T1-S jet grouting technique. However, two other alternatives were suggested by the student team including; Low pressure grouting, and T2 Jet grouting techniques. The actually executed technique was compared with the two suggested alternatives based on the construction cost and time. Comparison indicated that the use of T2 Jet grouting technique would have been more suitable for its less construction cost and duration.

5.2. Project II: construction of Al-Warrak bridge

This term project was prepared by a four-student team in the academic year of 1995/1996. Al-Warrak bridge is one of the largest bridges in Egypt, crossing the Nile River at Al-Warrak District of Cairo. It constitutes a section of Cairo Ring Road, with a total length of 2,073 m and a width of 45.0 m divided into two separate directions. Its total cost is 214 million Egyptian Pounds (L.E.), and its estimated construction duration is 54 months. The superstructure of the Nille-crossing part is constructed using cantilever carriage system, whereas the rest is constructed traditionally. The work site was so restricted that only the narrow area under the ramps and over-land spans was available. Thus, site layout planning was given special importance. The construction schedule was divided to four milestones, namely; start of cantilever carriage work, completion of one direction above ground, completion of one direction of the bridge, and completion of the whole project. These milestones divide the construction duration to stages. For each stage, the student team prepared a special site layout, taking into consideration the required space for storage and the spaces available in that stage. The basic calculations were made according to the principles of site layout planning, found in many publications [Davis, 1982 and Chudley, 1977]. Site layout planning was described in detail in another paper [Gab-Allah et al., 1997].

In addition, management aspects of the term project included; estimating project cost, documenting the method of construction, planning and scheduling using the linear scheduling method (LSM), compiling material requirements, and preparing project cash-flow forecasts.

5.3. Project III: evaluation of formwork systems

This special study was conducted by a four-student team as a term project in the academic year of 1996/1997. This study evaluated the formwork systems used in the construction of

buildings in Egypt. This involved the procedure followed to select the formwork for a certain project. The study was conducted in three main stages; Survey stage, Evaluation stage, and Application stage. The survey stage enumerates the horizontal and vertical formwork systems commonly used in Egypt. Horizontal formwork systems included; Traditional formwork, Props and Telescopic light weight, Shore brace, Early striking system, Table form system, and Tunnel form system. Vertical formwork systems included; Traditional wood system, U-form system, Vari-form system, Major slim soldiers, and Slipform.

In the evaluation stage, both horizontal and vertical formwork systems were evaluated to select the most suitable system for a particular project. The weighted evaluation technique was used for this purpose. Weighted evaluation [Dell'Isola 1982], is a formally organized approach for making decisions that require the analysis of several criteria, including economic and non economic factors. The evaluation was based on eight criteria, including; Structural system, Building shape and size, Construction cost, Construction progress rate, Ease of construction, Local practice, Site conditions, and Availability of resources. These criteria, along with their relative weights, were developed through a small-sample survey, including 10 design and construction engineers.

The above evaluation scheme was applied to four projects, namely; Mubarak Youth housing project, Palm Beach project, Bibliotheca Alexandria project, and Greater Cairo wastewater project. Then, each formwork system was ranked against each criterion using another survey, with ranks from 1 (poor) to 5 (excellent). Ranks are multiplied by their respective criteria relative weights and these products are added up to obtain a score of each candidate system. The system that exhibits the maximum score is the optimum. The optimum formwork systems for these projects were Props and Telescopic system, Props and Telescopic system, Early striking system, and Vari-form system for Mubarak Youth housing project, Palm Beach project, Bibliotheca Alexandria project, and Greater Cairo wastewater project respectively.

5.4. Project IV: construction of 26th of July corridor

This project was studied by a five-student team as a term project in the academic year of 1997/1999. The 26th of July Corridor is considered one of the most important national and civilized projects in Egypt. The highway length is 14 km, and its width is 34 m, divided into three lanes in each direction and a 7-m wide middle median. The road surface is about 6 to 8m above ground level, to prevent the establishment of random communities along the corridor. The road embankment represents the major cost element in this project. A major consideration was to make the best use of equipment capabilities, especially the compactors, which have a basic effect on the quality and cost of the highway construction. The main objective of this study was to obtain the optimum number of compactor passes that will economically achieve the density required for the embankment.

To achieve the study objective, the study was divided into six main tasks including; finding the optimum moisture content and maximum dry density of the soil, preparing laboratory samples with different moisture contents and exposing them to different number of blows, finding the relationship between laboratory effort and number of passes of compactors, calculating the compaction capacity for each alternative, calculating the time and cost of each alternative, and evaluating the results and selecting the optimum number of compactor passes.

Aspects of the term project included; estimating project cost, documenting the method of construction, planning and scheduling using the LSM, preparing cash-flow forecasts, outlining project cost control system, and analyzing traffic flow.

6. RESULTS AND FEEDBACK

During the past 17 years of offering CPM course, the real practices and problems of the construction industry in Egypt have been explored. Students were tailored to the specific needs of the Egyptian construction industry, and were well prepared for working in this industry upon graduation. This has made graduates more preferable by most construction/contracting companies in Egypt. These companies have hired a large number of graduates.

6.1 Changes Made to the Course

In the earlier years of course offering, the selected projects were tackled globally as one complete package, in which all project management aspects were applied. Later on, projects were first analyzed to identify their characteristics and concentrate on the techniques that are more effective in achieving the objectives of each specific project. An in-depth application of such techniques was then conducted. In addition, special studies were also introduced according to the needs of each project.

Moreover, the project period in earlier offerings extended for 8 weeks after the second semester. During this period, students were required to collect data, analyze data, prepare schedules, write reports and make presentations. In later offerings, the project period was shortened to 4 weeks. To overcome this limitation, students were allowed to visit sites and collect the required data during the second semester, the 4-week period was devoted to the actual project work.

7. CONCLUSION

This paper has presented an improved approach for the teaching Construction Project Management courses. This approach is represented by CPM project-based course that is being already offered for a long time. The CPM course was introduced within the CE&M program at the Construction Engineering Department, Zagazig University. This improvement involves exposing the students to real-world construction engineering and management practices.

There are several positive aspects of this program including; the team work closely approximates the situation in the construction industry, students develop a better appreciation of the interaction of various engineering and management areas, and students have the capability to write a comprehensive report and present ideas to audience. In addition, most construction/contracting companies in Egypt have become aware of the distinctive capabilities of the program graduates.

The enthusiasm of the students has been very rewarding. Most of the students really commit themselves to this course, devoting over 20 hours per week on the project (outside class) during the two semesters, increased to over 60 hours per week during the term-project period. Students are all really proud of their accomplishment. Upon graduation students already have the confidence to undertake similar professional-level work.

However, there are some challenges of the CPM course. It requires more faculty time and effort than a traditional course, particularly during the term-project period, which requires close supervision and guidance throughout all phases of the project. It also requires full coordination with industry personnel, whose cooperation is very essential for conveying the practical experience to the students. In addition, the limited time frame of the project does not allow the students to practice real application of project monitoring and control systems.

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