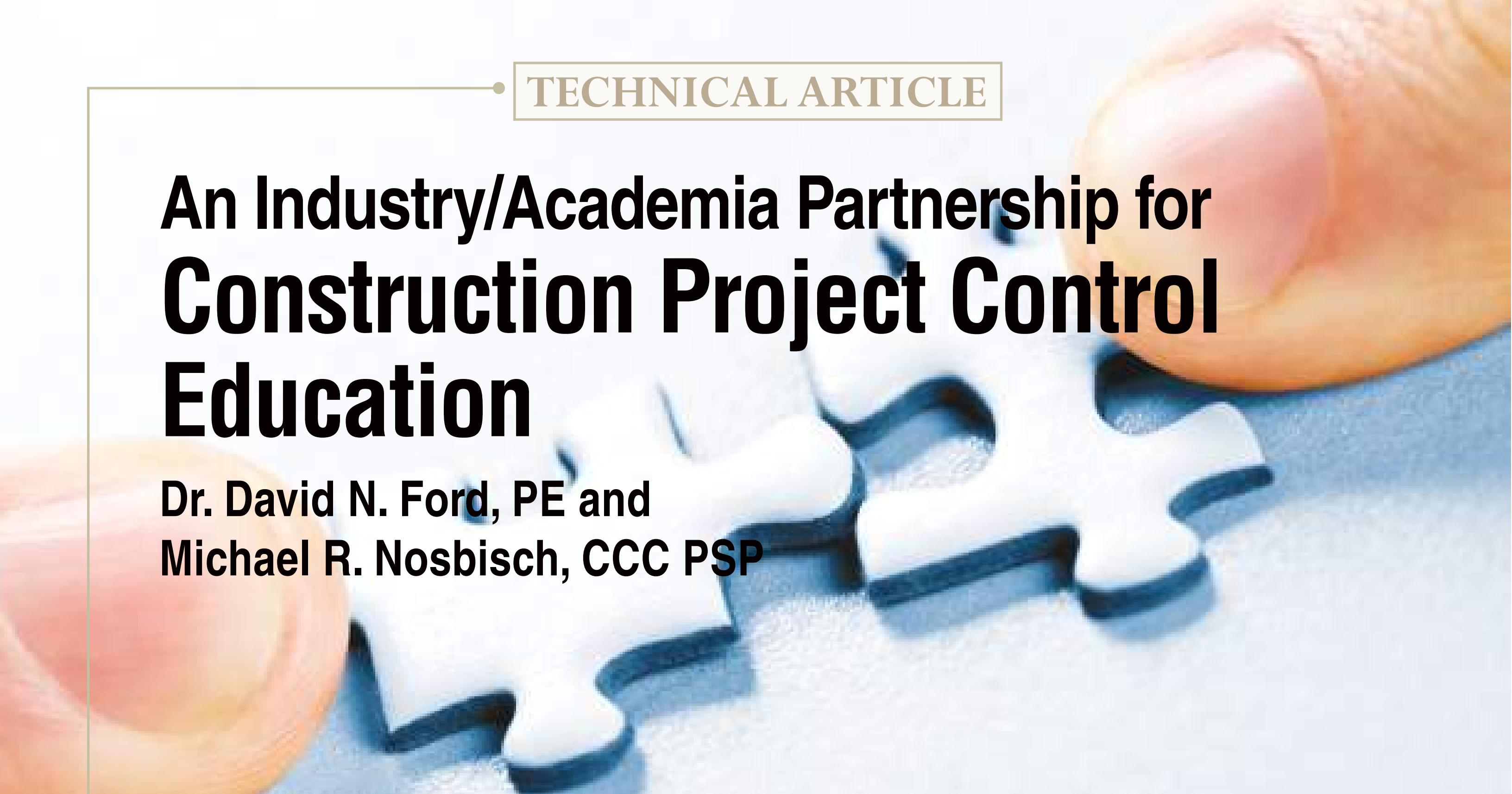

An Industry/Academia Partnership for Construction Project Control Education

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Abstract: The effective and efficient education of construction project control engineers requires the integration of industry practice with academic theory. In 2008, AACE corporate sponsor, Parsons Corporation, and the Construction Engineering and Management Program at the Zachry Department of Civil Engineering, at Texas A&M University, partnered to develop a graduate level Engineering Project Control course. The course uses an actual Parsons project as the basis to bridge from construction project control theory to practice. Case studies repeatedly place student teams in realistic project control practice circumstances in which they apply a variety of project control tools and methods to the Parsons project. Post-case discussions transfer learning across teams and link practice and theory. The critical roles of deep understanding of an actual project, streamlined project information, and creating safe places for experimentation for learning have been revealed over four years of teaching the course. Future work can use other actual projects, develop computer based tools to accelerate project control learning, and develop similar approaches for practicing project controllers. This article was presented at the 2012 AACE International Annual Meeting in San Antonio as DEV.1072.

Key Words: Construction, education, project control, practice and theory

Construction project success depends upon many factors, including project planning, finances, and management. Among these factors, effectively and efficiently controlling construction projects is a critical part of project management that adapts active projects to meet or exceed performance targets. Project control requires the application of several diverse sets of knowledge and skills to a wide variety of information types and sources.

For example, forecasting the schedule and cost impacts of a proposed scope change requires the application of knowledge about the construction operations required to the scale and nature of the project and proposed change to estimate cost and duration changes. The resulting information is then used with scheduling and cost estimating tools, methods, and skills to forecast impacts on total project performance. In addition, variances of projects from their initial plans often create many indirect impacts, such as a scope change requiring previously installed work to be removed or relocated. Recognizing, understanding, and addressing indirect impacts require additional project control abilities. Project control engineers apply a plethora of theories, tools, and methods (referred to hereafter as theory) to specific project conditions to recommend actions for improved project performance.

Project control engineers have traditionally learned their basic theories in formal educational settings and learned how to apply them to projects through work-related experience. While effective, this approach to developing project controllers is very slow, requiring many years of experience to generate expertise. This is primarily because of practice conditions that limit the experience gained on each project, limit reflection and review of experiences for learning, and strongly penalize failure, which discourages experimentation and therefore learning.

Project control education approaches that reduce these barriers can improve and accelerate project controller development. One approach is to create formal educational settings that bridge the gap between project control theories and their application in practice. This increases education effectiveness by improving the quality of learning experiences and increases education efficiency by providing quasi-practice experiences to future project controllers before they start work, thereby

Figure 1 — Example of Typical Baghdad Infrastructure

Photo by Lt. J. Wisdom

accelerating project controller development.

This article describes a successful industry/academia partnership that integrates project control theories with project control practice in a graduate level engineering course. The next section describes challenges in bridging project control theories and practice in education. The course overview and structure is described, followed by a description of the construction project used in the course. Case studies illustrate how the course integrates theory and practice. These descriptions are used as the basis for the lessons learned from developing and offering the course. Finally, conclusions are drawn about the benefits and costs of the course and suggestions for future work are provided.

Challenges in Bridging Theory and Practice in Project Control Education

Several challenges have hindered the effective teaching of project controls in formal education settings such as in university courses. A primary challenge is created by the tight interaction of project control and project operations. Effective learning about engineering project control requires a deep understanding of the project's operations and practices. This requires that students deeply understand one or more actual projects.

However, given the limited time available in most courses, student interaction with project information must also be limited. This is because the size and complexity of most development projects can easily overwhelm many students, reducing learning to the fact that project complexity can overwhelm project control efforts. Therefore carefully controlling and managing the project information used to integrate project control practice and education is both critical and difficult.

Project complexity creates other challenges in integrating project control practice into formal education. Projects are both statically and dynamically complex. Static complexity relates to the diversity and intricacies of the individual parts of a system and the processes required to produce those individual parts. Many construction projects create or procure hundreds of very different components. However, the dynamic complexity of projects creates even larger challenges for teaching project control. Dynamic complexity relates to the interaction of a system's parts into a single, operational whole that evolves over time [4].

A primary contribution of project control to project success is the integration of the many diverse parts into a single, operating facility. In contrast to the dynamically complex nature of project control, formal educational settings are better at transferring knowledge, understanding, and skills about isolated parts of systems than system interactions (e.g. a single beam vs. a large structure or masonry operations vs. building construction). Overcoming the challenges of teaching about the dynamic complexity of project control is critical to improving project control education.

Imperfect or incomplete project control theories, tools, and methods also hinder the integration of practice into project control education. Practice and the challenges encountered there often do not fit easily into the basic theories, tools, and methods taught in many project management courses. For example, bridging from the critical path theory to schedule control requires

Figure 2 — Example of Typical Baghdad Construction Photo by Parsons Corporation

addressing the challenges of changing and multiple critical paths. Effective project control education must include the challenges of applying theory.

Engineering Project Control Course Overview and Structure

In 2008, AACE corporate sponsor ,Parsons Corporation, and the Construction Engineering and Management Program in the Zachry Department of Civil Engineering, at Texas A&M University, partnered to develop a graduate level engineering project control course.

The course differs from most project management and project control courses in that it uses a single actual Parsons project as the basis for repeatedly bridging from project control theory to practice. The context of the course is a construction project which behaves differently than initially planned. The instructor (Dr. David N. Ford, lead author of this article) sets the course focus in the first class period in which the students are told that the entire course seeks to answer only one question, "What should the project manager do, and why?," but to answer that question well.

To implement this philosophy, student teams are repeatedly placed in challenging circumstances, similar to those experienced by practicing project managers and project controllers. This is accomplished through a sequence of case studies based on the course project that put students "in the squeeze" created by a project control challenge.

Class periods are used to discuss material and methods needed to address the current project control challenge, or student teams work on the current case study. Course topics and the case studies approximately follow the construction of a typical project, starting with the awarding of the construction contract to the general contractor, and ending with project closeout.

The primary topics addressed in the course include:

- sources, types, and uses of information for project control;
- project baselines;
- the design realization process;
- construction project contracts and project control;
- modeling project status and forecasting project performance;
- project analysis for project control decision making;
- project control action alternatives;
- managing subcontractors; and,
- managing project risk.

The Case Study Project: A Mock Iraqi Village

The course uses the Mock Iraqi Village project ("the project") to bridge from project control theory to practice. The operational need that generated the project was the large number of US military casualties in the Iraqi War, resulting from improvised explosive devices (IEDs) [2].

At the beginning of the war, little training about IEDs was provided and these homemade devices were responsible for 60 percent of combat deaths [2]. One officer on active duty in Iraq (and a student in the course) described the threat in 2008 as, "...suicide IEDs are the biggest threat as they are using women to deliver the bomb and there are cultural restrictions about searching women. Whereas we had one or two per year in the past years, this year we have had 39 female bombers [3]."

In response to the IED threat, the US military spent $500 million on IED training initiatives, including the course project. The US Army's Corps of Engineers designed and built a mock Iraqi village at Fort Irwin in the Mohave Desert in California. The Army Corps of Engineers procured design and construction services from the Parsons Corporation.

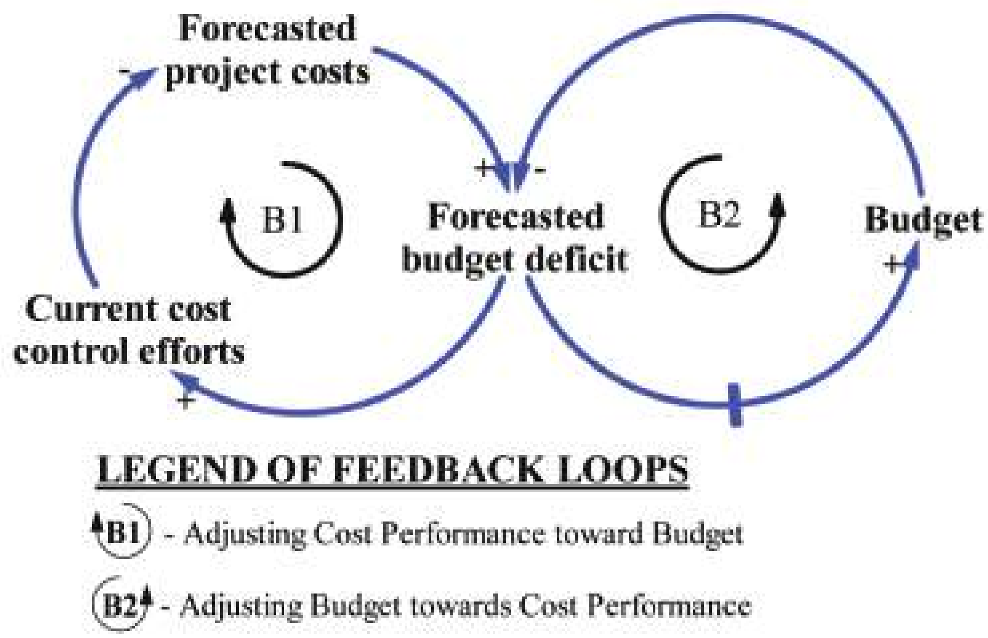

Figure 3 — Dynamic Framework of Performance for Project Cost Control

Parsons was active in Iraq prior to and during the project and provided first-hand information for concept development, such as photographs of Baghdad (see figure 1) and access to persons working there. The result was a realistic portrayal of a set of typical Baghdad shops, apartments, light industrial facilities, roads, etc.

Project design included features to facilitate training, such as hidden compartments that are used as weapons caches. Designers also faced challenges, such as designing to meet Iraqi design practices. These practices often do not meet design requirements for construction in the US.

Detailed attention was also paid to closely mimicking the construction materials and methods used in Iraq, which often differed significantly from the US practices that the contractors who would build the mock village use (see figure 2). Examples include the manual fabrication of bricks, and use of broken masonry in final construction.

Near the beginning of the course, students are provided the project's complete plans, specifications, and a contract between the owner and general contractor. The first part of the course is used to familiarize students with these documents and develop a project baseline (cost estimate and schedule based on a scope) in preparation for the first case study. Additional information on project conditions and progress is provided to students during the course, as required for the case studies.

The actual project was much more complex than can be described and understood in a one-semester course. Therefore, several alterations were made to actual project information for its use in the course. Primary among these was using a reduced portion of the project scope to keep student workloads reasonable and reduce repetitive work (e.g., quantity takeoff in estimating). In addition, one actual project objective, creating a testbed for new IED detection technologies, was ignored to focus on the training objective.

These project information changes allowed the instructor and students to focus more deeply on an instructor-selected set of common project control issues. This was preferred to an approach that addressed a broader range of information in less depth.

Project Control Case Studies

The first case study addresses contract management and negotiation. Student teams play the role of the general contractor's project manager. This manager simultaneously faces a delay in getting the notice to proceed, with an inflexible completion deadline; and is requested to sign a no-cost, no-time change order. The change order allows the Corp of Engineers to change design elements in response to new information about IEDs.

Student teams are required to prepare the contractor's written response to the request, and prepare for a meeting with the Army Corp of Engineer's contracting officer to resolve the issues. Student teams sequentially meet in class with the contracting officer (role played by the instructor). Discussion highlights the positions and strategies of the meeting participants and methods for reaching mutually acceptable solutions.

Preparing this case requires students to delve deeply into the plans and contract to construct arguments as the basis for negotiation with the client. Student teams typically identify the most common clauses and arguments (e.g., right to time extension with change) and one or two potential paths forward, but never all of the potential components of a solution.

In this case, the teamwork forces students to develop deep understandings of the facility, relationships as defined by the contract, and to search for acceptable and operational solutions. The mock meeting with the owner forces students to rigorously defend their work and reveals the multitude of potential components and designs of a solution.

The closing discussion brings out take-away lessons, such as the relative amounts of influence of the contractor and owner in the negotiation, and the constraints and opportunities created by differences in participant objectives.

The second case study addresses project control when progress does not fully meet performance targets. Project control in this case study is separated into three activities, each of which is the basis of a mini-case study. The three activities include:

- Monitoring and analysis of current project status compared to the project plan.
- Forecasting project performance at completion. And,
- Analysis of causes of variance of actual performance from planned performance.

Student teams play the role of engineers assigned by the general contractor's CEO to analyze and report on project performance. Students are provided time-series planned progress information for seven project parts and actual progress information for those parts, to a time about half way through the project.

Analysis with simple comparisons and the earned value management (EVM) method reveal a wide variety of performances across the seven project parts and the project as a whole. Forecasts of final performance using EVM indicate poor project performance and suggest a contradiction, that some individual project parts will be completed after the project is completed.

This provides an opportunity for the students and instructor to address the strengths and weakness of this common project control method and the challenges in its application. Students investigate an alternative method (earned schedule analysis), that can address some of these challenges.

Critically, the course pushes beyond the mechanics of numerical analysis to use inference diagrams, frequency analysis, and other tools to identify specific likely causes of the revealed performance problems. Some students find this final portion of the case study particularly challenging because few stepwise procedures can be applied. However, it generates critical thinking about theory and practice, and thereby creates a vital link from project control theory to project control practice.

In the next case study, student teams use the analyses and insights developed in the previous case. The goal is to design project control actions to improve the project performance for the general contractor. Feedback control is used to first provide a simple, but dynamic, framework. Within this framework, target and performance based solutions interact to address the generic problem of not meeting performance targets. This framework is specified to describe project control in different performance dimensions. Figure 3 shows a diagram used in the course to specify the framework for cost control.

In this case, students easily identify solutions that meet the general contractor objectives, but would be unacceptable to other project participants. Students are forced to constrain their proposed solutions to those that are reasonably acceptable. This is accomplished by having student team members temporarily represent different project participants.

The instructor guides a discussion of potential solutions and their impacts on different project participants. This elicits student reasoning about project control decisions, and it encourages evaluation from multiple participant perspectives. Results include an increased awareness of the multitude of acceptable solutions, the rarity of solutions that do not require tradeoffs, and the critical role of human communication, relationships, and interactions required for solution development.

Lessons Learned

The course has been taught four times with only small changes to the approach and structure described above. The development and teaching of the course has revealed several potentially useful insights concerning the integration of industry practice into formal project control education.

- Student development of a deep understanding of an actual project, by using actual project information, is critical for developing course authenticity that is based on practice and to gain the full engagement of students in learning.
- Actual construction projects are usually too large, complex, or both, to use in formal education without significant changes. Demonstrating that project complexity can overwhelm students and project managers does not help students learn about project control. Therefore, actual project information must be simplified and streamlined to facilitate learning about the educational objectives of the course.
- Extending lessons beyond project control theories to project management decision making is critical for the integration of theory with practice. This requires that students apply theory to specific and realistic circumstances that reflect implementation challenges.
- Compressing project time through case studies accelerates learning. This increases project control education efficiency.
- Creating and providing spaces for students that are significantly safer in terms of their careers, than professional practice circumstances, encourages students to experiment with many different project control approaches and potential solutions. Discussing proposed and possible solutions within and among student teams enhances evaluation and understanding. This improves the quality of project control education.
- Bridging from project control theory to practice requires the investigation of tools and methods in addition to their application. Student applications must reveal, and instructors reinforce, the strengths and weaknesses of current project control tools and methods. Students must develop critical thinking skills for evaluating project control tools and methods, as well as projects. Students must develop ways to

exploit the strengths and avoid or mitigate weaknesses of project control theories.

Focusing on the generic practitioner's challenge of developing operational and effective project management recommendations creates courses that are demand-driven. In these courses, project control approaches, tools, and methods are seen as the means to solve important problems. This focus positions project control as a critical aspect of project management and an important driver of project success or failure.

Conclusions

Parsons Corporation and the Construction Engineering and Management Program at Texas A&M University partnered to create a project control graduate course that bridges between project control theory and project control practice. Student teams repeatedly face realistic project control challenges in case studies, based on a deep understanding of the Parsons project. Although project conditions were simplified to facilitate learning, students experienced some of the complexity and variety of project control practice and decision making. Post-case study discussions improved learning across student teams and linked practice to theory.

The course was found to facilitate project control education by:

- using an actual project;
- developing a deep understanding and use of streamlined project information;
- providing an effective and efficient learning environment; and,
- explicitly relating theory to practice.

Effectively transferring project control lessons is time consuming and requires significant amounts of information, which limits the number of lessons possible in a single course. Therefore improved project control education and training tools are needed to accelerate learning.

Future work can use other projects in similar courses, develop computer aided learning environments to further improve learning, and develop similar educational opportunities directed at experienced practicing professional project control engineers. Continued efforts to improve project control education can accelerate the development of those in this critical role of construction projects. ◆

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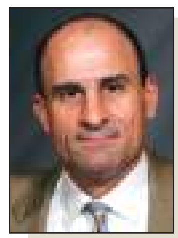

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