

## **Moving an Academic Simulation closer to a Heavy Construction Industry Tool by adding an Equipment Management Module**

Thomas M. Korman<sup>1</sup> and Hal Johnston<sup>2</sup>

<sup>1</sup>Associate Professor, Ph.D., P.E., P.L.S., M.ASCE, Department of Construction Management, California Polytechnic State University, San Luis Obispo, 1 Grand Avenue, San Luis Obispo, CA 93407-0284; PH (805) 756-5612; FAX (805) 756-5740; email: tkorman@calpoly.edu

<sup>2</sup>Professor Emeritus, C.P.E., Department of Construction Management, California Polytechnic State University, San Luis Obispo, 1 Grand Avenue, San Luis Obispo, CA 93407-0284; PH 805-756-2613; FAX (805) 756-5740; hjohnsto@calpoly.edu

### **ABSTRACT**

It is often difficult in a business setting to provide a "learn by doing" atmosphere where finances are involved. Most businesses allow their employee leeway in making decisions, but not enough so that balance sheets and future business opportunities are affected. Simulations allow students in an educational environment to experience tasks and the results of their decisions, which they will be asked to perform upon graduation. In the construction industry, many employees are hired that do not have the training or coursework at the university level that provides them access to such simulations. New employees are often placed in a position, trained to do the daily tasks, but not enough time is available to provide them with the opportunity to experience the entire operation of the business. The simulation, Construction Industry Simulation (COINS), has many of the decision and overview tools but in the Heavy Civil construction sector, a major area key to successful management is equipment management. Decisions regarding renting, leasing, and buying equipment, where to dispatch equipment, and what equipment to have in a company's fleet, all affect the profit of a project. This paper describes the process for integrating equipment management into the existing COINS simulation.

### **INTRODUCTION**

Experiential learning is learning through reflection on doing, which is often contrasted with didactic learning. Experiential learning is related to, but not synonymous with, experiential education, action learning, adventure learning, free choice learning, cooperative learning, and service learning. While there are relationships and connections between all these theories of education, importantly they are also separate terms with separate meanings.

Experiential learning focuses on the learning process for the individual (unlike experiential education, which focuses on the transactive process between teacher and learner). An example of experiential learning is going to the zoo and

learning through observation and interaction with the zoo environment, as opposed to reading about animals from a book. Thus, one makes discoveries and experiments with knowledge firsthand, instead of hearing or reading about others' experiences.

Experiential learning requires no teacher and relates solely to the process of the individual's direct experience. However, though the gaining of knowledge is an inherent process that occurs naturally, for a genuine learning experience to occur, there must exist certain elements. According to David A. Kolb, an American educational theorist, knowledge is continuously gained through both personal and environmental experiences. He states that in order to gain genuine knowledge from an experience, certain abilities are required:

- the learner must be willing to be actively involved in the experience;
- the learner must be able to reflect on the experience;
- the learner must possess and use analytical skills to conceptualize the experience; and
- the learner must possess decision making and problem solving skills in order to use the new ideas gained from the experience.

**Experiential Learning Business Simulations.** Business simulations, for educational and training purposes, have historically been scenario or numeric based. Most business simulations are used for business acumen training and development. Learning objectives include: strategic thinking, financial analysis, market analysis, operations, teamwork and leadership. The business gaming community seems lately to have adopted the term business simulation game instead of just gaming or just simulation. The word simulation is sometimes considered too mechanistic for educational purposes. Simulation also refers to activities where an optimum for some problem is searched for, while this is not usually the aim of an educational game. On the other hand, the word game can imply time wasting, not taking things too seriously and engaging in an exercise designed purely for fun. The concept of simulation gaming seems to offer the right combination and balance between the two. Simulation gaming is also the term that the educational gaming community has adopted.

### **COstruction INdustry Simulation (COINS) – An Educational Gaming Simulation for Construction Management.**

Construction Industry Simulation (COINS) is a computer simulation built to simulate the business environment for a construction company. The players, participants, play the role of contractors, competing in a market with variable demand for construction work. The simulation immerses students into the day-to-day operations of a construction company, requiring them to manage specific aspects of the company with the goal of procuring and managing construction work in terms of its planning, scheduling, and resource allocation. Students have a choice between commercial construction company, a heavy construction company, or a company that does both. Players are required to set up a complete business strategy including the following tasks:

- examine available information

- determine the best portfolio of jobs to bid on
- create strategies to improve bonding limits
- set strategies to create negotiated work
- develop bid prices for desired jobs
- monitor their financial position as work progresses
- monitor and create strategies to improve company’s appraisal metrics
- choose and modify their construction methods to meet due dates and reduce costs
- interpret their competitors' strategies
- respond to changing conditions and situations proposed to the company and driven by the decisions and actions of the company

Each company acts as a construction firm within a competitive environment that has a fluctuating demand for construction jobs. Firms that perform about average will be asked to negotiate various work. The game may be played for as many periods as time permits, each period representing two months. There can be any number of participating companies in addition to the internally simulated "unknown contractors". Five different types of jobs are potentially available for bidding on both the heavy and commercial side.

**Table 1 – Job Types**

Commercial Building Projects	Heavy Civil Projects
<ul style="list-style-type: none"> <li>• Apartment buildings</li> <li>• School buildings</li> <li>• Office buildings</li> <li>• Hospital buildings</li> <li>• Industrial plants</li> </ul>	<ul style="list-style-type: none"> <li>• Highways</li> <li>• Bridges</li> <li>• Site development</li> <li>• Mass excavation</li> <li>• Underground utilities</li> </ul>

Each period the simulation generates a list of jobs available for bidding and creates an Estimated Time and Cost Report for each job. Using the this information, each company must decide which jobs to bid on, the bid price, and which of the five methods to use for each of the activities. All jobs will have up to nine activities (Both Heavy and Commercial). These activities are:

**Table 2 – Construction Activities**

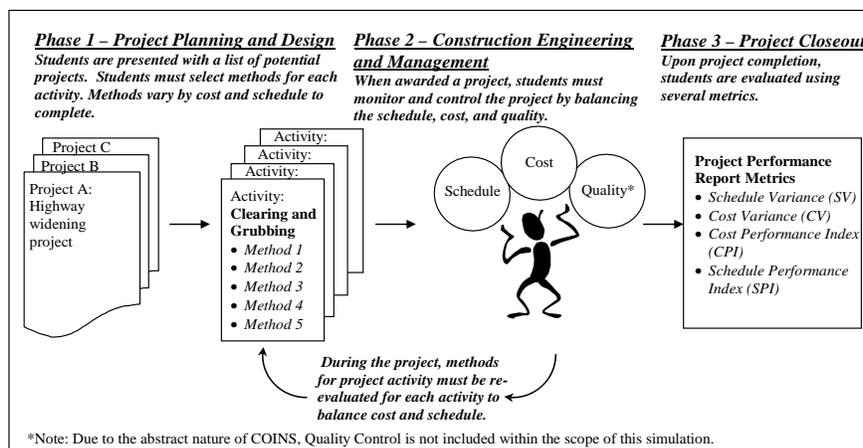
Commercial Building Projects	Heavy Civil Projects
<ul style="list-style-type: none"> <li>• Excavation</li> <li>• Foundation</li> <li>• Basement</li> <li>• Framing</li> <li>• Closure Roof</li> <li>• Siding</li> <li>• Finishing</li> <li>• Mechanical and Electrical</li> </ul>	<ul style="list-style-type: none"> <li>• Clear and Grub</li> <li>• Rough Grading</li> <li>• Excavation</li> <li>• Underground piping</li> <li>• Concrete (Form and Place)</li> <li>• Backfill and Compaction</li> <li>• Aggregate Base</li> <li>• Paving</li> <li>• Finish Grading</li> </ul>

Every activity has five (5) different construction methods that vary in time and cost. The fifth method is generally use of a subcontractor. All five methods of Activity No. 9 (Mechanical and Electrical) are generally subcontracted. The Estimated Time and Cost Report gives labor and material costs and the amount of time required for every activity using each of the five methods. Heavy construction bids are generally unit price bids while commercial bids are lump sum.

**Phase 1 - Project Planning and Design.** Students begin the simulation in Phase 1 by being presented with a list of potential projects to review. Considering market conditions, student teams proceed by selecting a project to plan and then designing a project control system for the project. This is accomplished by selecting methods for each project activity and balancing the schedule and cost considerations. In Phase 1, students compete against their peers as well as the simulation’s virtual companies for award of the project. Award of projects is based on the team’s accuracy and proximity to the simulation’s internal estimate. Teams that are not initially awarded a project for their efforts must continue with the simulation, refining their plans, until their plans are awarded a project. Thus, the COINS simulation enables students to learn from their mistakes.

**Phase 2 – Construction Engineering and Management.** When a student team is awarded a project, they enter Phase 2. In Phase 2 student teams must manage their project by monitoring and controlling the project activities, analyzing the schedule and costs in reference to the methods to the activities they selected for each activity. Throughout the duration of their project, students are presented with real-life scenarios which they must respond to, thus measuring, testing, and validating the design of the project control system. Therefore, students are able to utilize their knowledge and hone their skills at controlling the process through modifying their project control system. The simulation provides feedback to the students which they then can use to continuously improve their model throughout the duration of the simulation.

**Phase 3 – Project Closeout.** Phase 3 begins after students have completed each activity for their virtual project. They have the opportunity to evaluate their performance using several predefined metrics, including Schedule Variance, Cost Variance, Cost Performance Index, and Schedule Performance Index.



**Figure 1 – Project Phases**

As mentioned above, one of the first activities for the students is to determine what positions will make up their main office overhead. This is reevaluated each period, and hire/fire activity is performed by the team. A report is given to the company telling them how they are handling their personnel and its requirements. Work scheduling is very important in the selection of the methods so projects can be completed by the contractual deadlines, and the costs reduced as much as possible. Each bid price submitted should cover all the firm's direct and indirect job expenses, its main office overhead costs, and the desired profit. At the end of each period the simulation will determine which company is awarded each available project. The lowest bid will not necessarily win since the computer takes into account several other factors:

- Is the firm's cash-on-hand adequate to provide enough liquidity with regard to the bid price?
- Is the bid price below a minimum amount, computed by the program? If so, then the bid will be disregarded as irresponsible and be rejected.
- Is the bid price higher than the unknown contractors, the presence of this simulated company assures a competitive, uncertain environment with realistic bid prices.
- Is the firm within its bond limits?

Companies must monitor their financial situations as the game progresses, forecasting and completing progress payments, and potential needs for loans. In any period, participants have the option to ask for information on weather forecasts, material prices, labor and material availability, and market projections. These requests for consulting services have a cost and are charged against the firm's financial account. Using the information obtained from these reports, companies can determine the best strategy to proceed for each individual job.

At the end of each period, teams receive a progress report for the previous two-month period, giving a statement of the firm's work progress on each of its jobs during that time. It shows the amount of work completed as well as the expenses incurred for each activity in every one of the company's projects. The amount of work completed during a period depends not only on the methods selected for the various activities, but also on uncertainty factors during that time such as the weather conditions, labor availability, and the fluctuating cost of materials.

An end-of-period financial report is also provided to the participants showing the expenses incurred during that period. It lists amounts spent on direct construction services, bidding costs, delay fines, taxes incurred, and interest on borrowed money. It also shows payments to the contractor by the owner according to the payment requests and gives total cash-on-hand at the end of the period. Each firm may at any time apply for a loan to improve its financial situation. Loans granted are amortized over a one year time period. Changes in company ratios are also logged along with changes to the company's appraisal metrics.

- Financial Liquidity
- Financial Success
- Responsibility
- Pace

- Ethics
- Name Recognition

At the end of a period, the firms examine their Progress Reports and decide on the effectiveness of the methods chosen for the various work activities. If they wish, they may change them and specify different methods for the following periods. The choice of methods allows companies to utilize slower but cheaper methods if they fear budget overruns, or faster but more expensive methods if meeting contractual deadlines is the main concern. In addition, overtime may be used to speed up certain activities, greatly increasing the labor costs. Firm must be concerned with the amount of liquidated damages on each project as they vary from project to project.

At the conclusion of the simulation, the program provides each participating company with final reports, forecasting the expected results of any on-going projects or their position at that point in time. It also shows the final total worth of the firm. Teams should consider maximization of profit as one of their main objectives, and one of the primary criteria used to evaluate each firm's performance. As the simulation progresses, evaluations of company ratio, and appraisal metrics can be used to determine successful completion of the simulation.

**Equipment Management Module.** The developers of COINS have recently completed integrating a new module, the Equipment Management Module (EMM). Prior to this addition, the simulation only allowed teams to allocate personnel resources for each project. With the EMM, each project and each activity of a project will have an equipment requirement. Each method for that activity will have a different number and size requirement. During the work procurement phase, a company does not have to have the equipment required in its fleet but if they get the project, the activity cannot be started or accomplished without the right equipment. If the project is bid with larger or additional numbers of equipment and this is not congruent with the actual fleet composition, the company can proceed but with a time and cost penalty.

This statement above is the driver in front of the module. A need arises from either computer feedback or the student's (company's) decision. A company wants to build its fleet for the future or needs a piece of equipment for a project they just received. The decision is to Buy, Rent, or Lease (type & capacity of equipment). This is where the module begins. A Company will be given capital to accomplish this task at the start of the game. It is the instructor's decision, i.e. \$2,000,000, alone with an additional \$1 or \$2 million to operate the business. They can immediately start buying/leasing equipment, or renting. A company can buy, rent or lease equipment to build their fleet which can also accelerate projects or help them make bid-time decisions.

**Bidding.** Projects are scheduled based on their network dependencies. Each of these networks has nine activities with an equipment requirement attached to every activity. Companies will know how the project should be built and what equipment is needed for the activity. The size and number of equipment will determine the speed of project and the cost. Each method will have specific equipment numbers and sizes. During the bidding process, each activity has five (5) different methods that the

company team can select. Slower activities are less costly due to the fact that these have smaller equipment and fewer equipment units.

**Project Management (Equipment Dispatching).** Dispatch (sending of equipment to a job site/scheduling equipment to jobsite) is not in this module and instead is connected to the company's fleet data base.

- In and off jobs
- Cost of transportation
- Availability

**Owning and Operating Costs.** The equipment in the company's fleet will also need to have a cost associated with the equipment that represents the owning and operating costs for that piece of equipment.

**Equipment Availability.** Almost all new equipment is available. Used equipment is what is on the available List. Rental equipment is generally just the most used equipment. These three different areas of equipment must be available to the companies' to buy and rent from. Equipment will move from one of these locations to the company's fleet. In the fleet equipment must be identified as Rented, Owned, or Leased.

Two examples of used equipment websites to be used in this simulation are: <http://catused.cat.com/en/> and <http://www.machinerytrader.com/>. Equipment has two major heading, first the categories and second the brand.

**Fleet Management.** The major home for equipment will reside in the company's fleet management table. The fleet will grow and shrink based on the needs of the projects, or strategic purchasing of equipment to be fit to a market place, or be more competitive in that market place.

- status
- new equipment available for purchase or lease
- used equipment available for purchase or lease
- rental equipment available

The question of buy, rent, or lease should look similar to the personnel section. First, a listing of all the equipment, a second page with a description and a clickable buy, rent, or lease; and finally a printable page of the specific piece of equipment.

- Equipment Categories
- Equipment Name

## SUMMARY

A "learn by doing" atmosphere where finances are involved provides students an educational environment to experience tasks and the results of their decisions. In the construction industry, many employees are hired that do not have the training or coursework at the university level that provides them access to such simulations. New employees are often placed in a position, trained to do the daily tasks, but not enough time is available to provide them with the opportunity to experience the entire

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