

## **Enhancing Construction Engineering Education Using Internet based Tools**

**Anil Sawhney, Prawit Rotsawatsuk, and André Mund**  
**Western Michigan University**

### **Abstract**

This paper describes the work being performed as part of a three-year project that has been funded by the National Science Foundation (NSF) and Western Michigan University (WMU). The goal of the project is to enhance the undergraduate construction engineering education. Enhancements will be accomplished by developing: 1) an Internet-based Interactive Construction Management Learning System (ICMLS) and 2) an advising and mentorship program that will enhance practitioner-involvement. The primary undertaking of this project is to incorporate practical content in the construction engineering curricula thus bridging the gap between the classroom and the construction site. The proposed system provides a simple tool for students to gain practical knowledge of construction processes and construction equipment. The paper provides an overview of ICMLS and related developments. Discussion of the Internet based tools adopted in this project is also provided.

### **I. Introduction and Background**

Construction is a very large and diverse business and is a significant employer, cash generator, and contributor to the local economy. Growth and the replacement of people leaving the labor force will add more than 68,000 new positions for civil engineers by the year 2005, according to a recent forecast of employment trends<sup>1</sup>. Attracting talented high school graduates and imparting the best possible civil and construction engineering education is critical to the future of the U.S. construction industry.

In the early 1980's the construction industry faced increased national and international competition, stringent governmental regulations, and an environmentally conscious populace. The industry also encountered issues such as organized labor, challenges of new technologies and new materials, and construction of complex projects. These forces emphasized the value of strong engineering and management skills required for delivering high quality constructed facilities. That, in turn, added a new dimension to the profession and led to the evolution of a group of professionals among civil engineers who practice construction management.

As a direct response to the needs of the construction industry, universities around the nation started undergraduate and graduate curriculums in civil and construction engineering that provide more emphasis on construction engineering and management<sup>2,3</sup>. The initial response consisted of 1) incorporation of course modules related to tools and techniques required for managing construction projects into the civil engineering

undergraduate curriculum; 2) development of an undergraduate degree in construction engineering and management; and 3) development of graduate level programs in construction engineering and management. This research project—aimed at future “managers of construction”—primarily targets the undergraduate civil and construction engineering curricula.

## II. Construction Engineering Education

Over the past few years national organizations such as American Society of Civil Engineers (ASCE), American Society of Engineering Education (ASEE), National Science Foundation (NSF), and National Research Council (NRC) have sponsored numerous studies to gauge the current status of undergraduate engineering education and to develop an agenda for improvement. These studies have identified a number of major issues such as: 1) faculty development; 2) practitioner involvement; 3) development of integrated curriculum; 4) focus on diversity; 5) new approaches to assessment of faculty, students, courses, and curricula; 6) broader and flexible curricula; and 7) utilization of active learning approaches<sup>4,5</sup>. It is clear from these studies that the current civil and construction engineering curricula are often inadequate in preparing students for the complex process of construction. Some weaknesses include: limited access to construction practitioners; curriculum demands that do not permit the inclusion of issues of importance to construction; few opportunities to experience or participate in the actual construction process while in the university; and limited use of advanced computing tools for instruction. Recommendations of the industry advisory councils and accrediting agencies clearly indicate the need to incorporate practical components in the undergraduate construction education. This project addresses these issues through the development of an integrated educational framework that will expose the civil and construction engineering students to the complexities of the construction site.

## III. Overview of ICMLS

The research project is centered on the development of an Internet-based Interactive Construction Management Learning System (ICMLS) that will utilize: 1) active learning approaches to bridge the gap between the classroom and the construction site; 2) advanced Internet based computing technologies to bring the complexities of the construction site to the classroom; 3) knowledge and expertise of construction professionals through an advising and mentorship program.

The Internet-based Interactive Construction Management Learning System provides a simple tool for students to gain practical knowledge of construction equipment and construction processes. It will be utilized in the undergraduate civil and construction engineering curricula to enhance the learning process. The key features of the ICMLS are: 1) the system uses Internet as its launching medium, and 2) it utilizes multimedia databases, hypertext, 3D modeling, and simulation to provide students with an interesting and realistic view of the selected construction processes and construction equipment. ICMLS uses an interactive and adaptive learning environment to train students in the area of planning of construction processes and equipment. The system is process-oriented and mimics the challenges faced by a construction manager on a real life construction project. It allows students to apply their knowledge of construction materials and methods, estimating, scheduling, resource allocation and utilization, fleet size determination, productivity and cost calculations, and decision making in relation to construction

processes. The internal structure of ICMLS is shown in Figure 1. Internally, the system consists of a construction process database, a construction equipment database and a construction scenario database.

The construction process database has been divided into two broad categories that include building construction and heavy construction. Construction processes such as slurry wall construction, jet grouting, concrete placement using a pump etc. are included in this database. The primary information stored in this database for individual processes will include the following: 1) construction method and technology; 2) materials used; 3) equipment used; and 4) underlying work tasks and their sequencing.

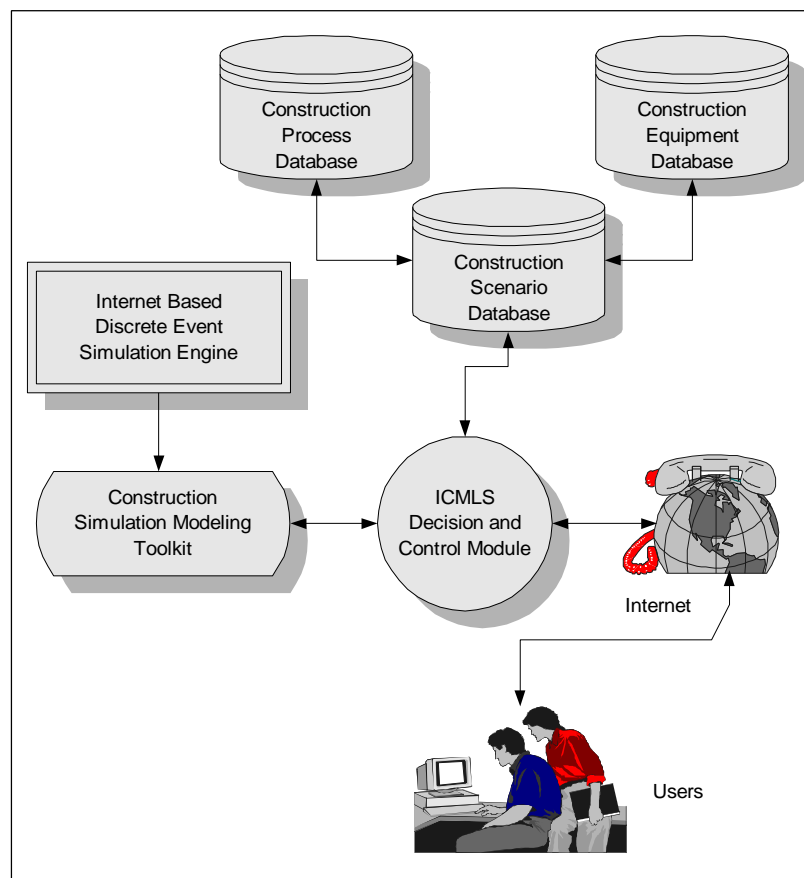


Figure 1: Internal Structure of ICMLS

The construction equipment database has been divided into categories that include excavation, lifting and hoisting, tunneling, etc. Information from construction equipment manufacturers is being collected for this database. The database in its final form will include information such as equipment model and make, productivity, construction technology associated with the equipment, and multimedia representation of the equipment.

The construction scenario database contains a number of real world scenarios that will be used in the interactive mode of ICMLS. Figure 2 shows a sample scenario from the construction scenario database. This database is internally linked to the construction process database so as to synchronize the two databases.

**PROBLEM SCENARIO**

You are the project manager for an office building project that consists of 5 floors. The flooring system for the building is one-way solid slab system. Quantity of concrete to be poured for each floor is 185 CY.

**OBJECTIVES**

Selection of a concrete placement process suitable for the project. Determination of the equipment cost, duration of the concreting activity, and generation of site instructions for the selected placement process.

**CLICK A TOPIC FOR MORE INFORMATION**

[SITE PLAN](#)

[CONCRETE PUMP](#)

[ADDITIONAL PROJECT INFORMATION](#)

[TOWER CRANE](#)

[CONCRETING PROCESS](#)

**CLICK A STEP TO START THE SESSION**

[DEVELOP A SIMULATION MODEL](#)

[PRINT SCENARIO](#)

[VIEW OUTPUT](#)

[PRINT RESULTS](#)

Figure 2: Sample Construction Scenario

In addition to the three databases, ICMLS consists of the decision and control module that provides centralized control. This module controls the interaction of the students with ICMLS and provides complete session management. Internet-based discrete event simulation engine and construction simulation modeling toolkit are the other two components of ICMLS. Both these modules provide interactive features to ICMLS. Internally, these components have been developed using JAVA programming language. More information about these modules is provided in the section titled "Internet-based Tools used to Develop ICMLS".

As described earlier one of the key features of the work being performed as part of the project is the idea of practitioner involvement. This is being accomplished by the formulation of a project advisory committee that consists of nineteen members—representing five contractors, two sub-contractors, four owners, four construction industry organizations, and four design consultants. The project advisory committee is guiding the development of ICMLS. Figure 3 shows the framework that has been adopted for practitioner involvement for this project.

#### IV. Student Interaction with ICMLS

In the second and third year of the research project, strategies to integrate ICMLS into the civil engineering, construction engineering, and two-year transfer degree programs in civil and construction engineering will be developed.

From a student's perspective, ICMLS can be utilized in three modes—1) browsing the construction process database, 2) browsing the construction equipment database, and 3) participating in an interactive session. Figure 4 illustrates the student interaction process.

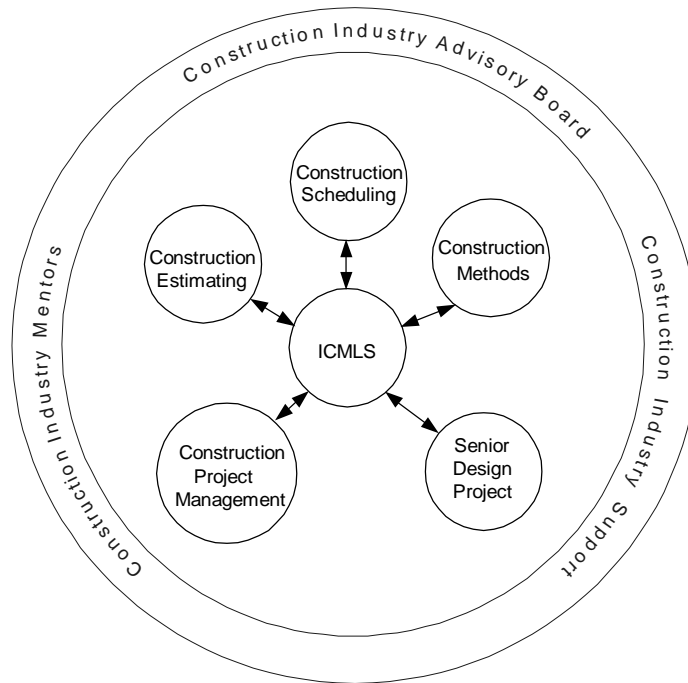


Figure 3: Practitioner Involvement Framework

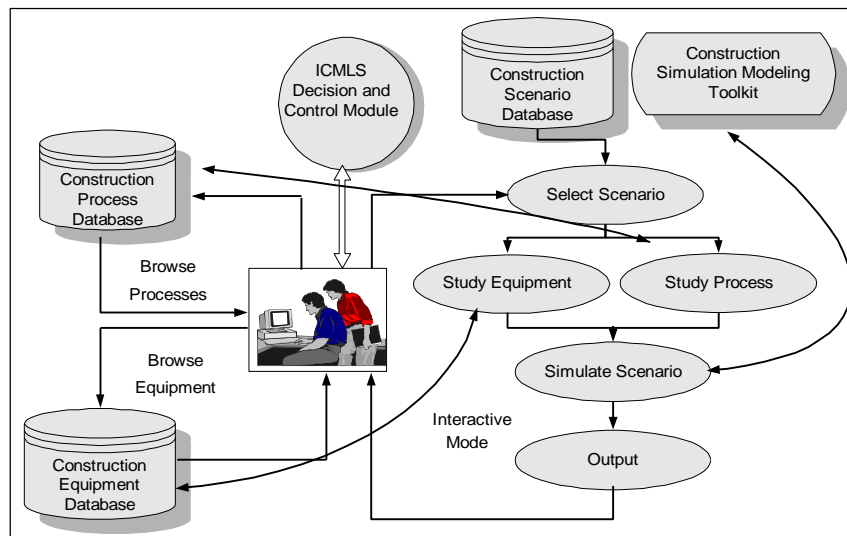


Figure 4: Student Interaction

## V. Internet based Tools used to Develop ICMLS

ICMLS uses standard and advanced Internet-based development tools. It utilizes Hypertext Transport Protocol (HTTP), Hypertext Markup Language (HTML), Common Gateway Interface (CGI), server side scripting, Java applets, and Internet Database Connection (IDC). These tools are considered standard tools in the development of ICMLS. The standard Internet tools listed above provide limited interactivity in ICMLS. In order to accomplish student interaction with ICMLS the Virtual Reality Modeling Language (VRML) and Java-based simulation have been utilized.

**Virtual Reality Modeling Language (VRML):** The Virtual Reality Modeling Language (VRML) is a three-dimensional (3-D) modeling language that can be used for describing 3-D shapes and scenery (also called a virtual world) on the World Wide Web (WWW)<sup>6,7</sup>. VRML can be defined as a 3D analogue to Hypertext Markup Language<sup>8</sup>.

VRML files are text files that contain information regarding the objects and linkages between objects in a virtual world. It can be applied to a number of areas including web-based entertainment, 3-D user interfaces to remote web resources, 3-D collaborative environments, interactive simulations for education, virtual museums, virtual retail spaces, and more. The ability to animate, to play sound and video within the virtual world, to interact with the virtual world and to control and enhance the virtual world with scripts, allows development of dynamic and sensory-rich virtual environments on the Internet<sup>9</sup>. These features of VRML can be beneficially utilized to build teaching aids that will supplement classroom instruction.

As part of ICMLS the authors are using VRML to develop innovative and accessible teaching aids. The authors have developed interactive 3-D simulations that are being used to teach construction processes. As part of this research VRML based 3-D models of common construction processes have been developed and are available to the students on the WWW. Figure 5 shows an Internet based 3-D model of a column footing. Students can access this 3-D model through a web browser that is equipped with a VRML plug-in.

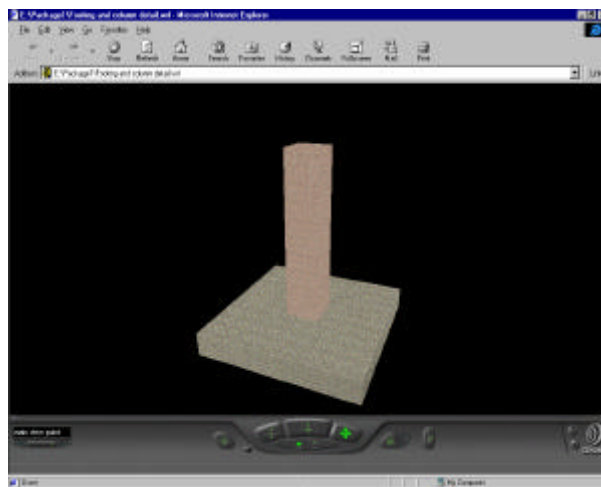


Figure 5: VRML Model of a Column Footing

The column footing is a 3-D object that the user can rotate, move, and observe in the web browser. In addition, VRML can be used to allow users to interact with the 3-D object. In the example implemented by the authors, when the user clicks on the column footing, the reinforcement details of the column and the footing are exposed. Figure 6 shows the same VRML file in the browser with reinforcement details of the column and the footing. The authors, as part of ICMLS are developing similar 3-D models of other common construction processes. These models will be internally linked to the construction process and construction scenario databases.

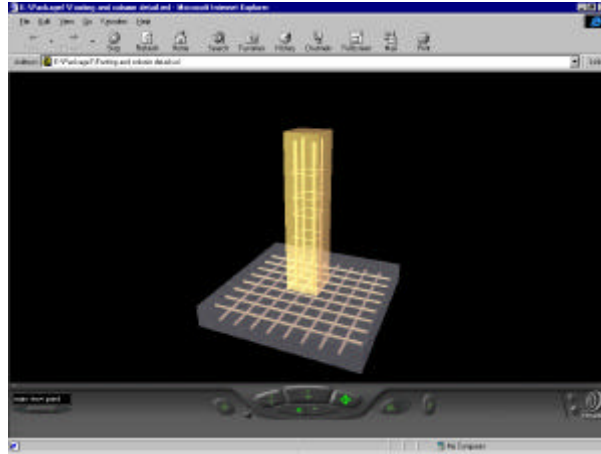


Figure 6: VRML Model of Reinforcement Details

**Java-based Simulation:** One of the key components that adds interactivity to ICMLS is discrete-event simulation. Traditionally, simulation has been defined as a tool that can be used to mimic reality and provide responses of a system under consideration to external and internal factors. Simulation has been applied in the design and analysis of construction processes by researchers and some large construction organizations <sup>10</sup>. In addition to industrial uses, simulation can also be used for educational purposes especially for civil and construction engineering education. This is based on the hypothesis that “simulated environments” can act as excellent catalysts in the learning process. In a recent study, Suda <sup>11</sup> reported that, “simulation can be a powerful trigger to learning of project management principles.”

With the advancement of computing technology and widespread adoption of Java programming language as a standard for Internet-based computing, application of simulation in education is becoming a reality. Tools are now available to allow development of "simulated environments" that are accessible to students over the Internet. In ICMLS the authors have utilized Java-based simulation to allow students to interactively manage construction processes in a simulated environment. This development is based on the Silk™ environment <sup>12,13</sup>.

The Java-based simulation component of ICMLS allows users to model common construction processes. Students select a problem scenario from an existing list displayed by the system. For example, students can select a scenario in which they are required to supervise moving of 234,000 units of earth for a canal project. Students can then utilize Java-based simulation to study the earthmoving process. They can use the session to: 1) select a fleet of equipment—in this case front end loaders and dump trucks—to accomplish the earthmoving; 2) determine total productivity; 3) determine total project cost; and 4) determine total duration of the earthmoving process. Figure 7 shows a sample screen of ICMLS for the simulation of the earthmoving process.

## VI. Significant Benefits of ICMLS

The development and utilization of ICMLS is intended to result in a series of benefits. Foremost, it will provide a problem-based multi-disciplinary learning environment for construction management education. With its interactive graphical features coupled with simulation and animation ICMLS can be a powerful trigger to learning. The simulation and animation features

will provide the students with a practical laboratory that will allow them to “get the feel” of the dynamics of the construction site. Finally, practitioner involvement by using Interactive Construction Management Learning System will be of benefit to students enrolled in the civil and construction engineering curriculum.

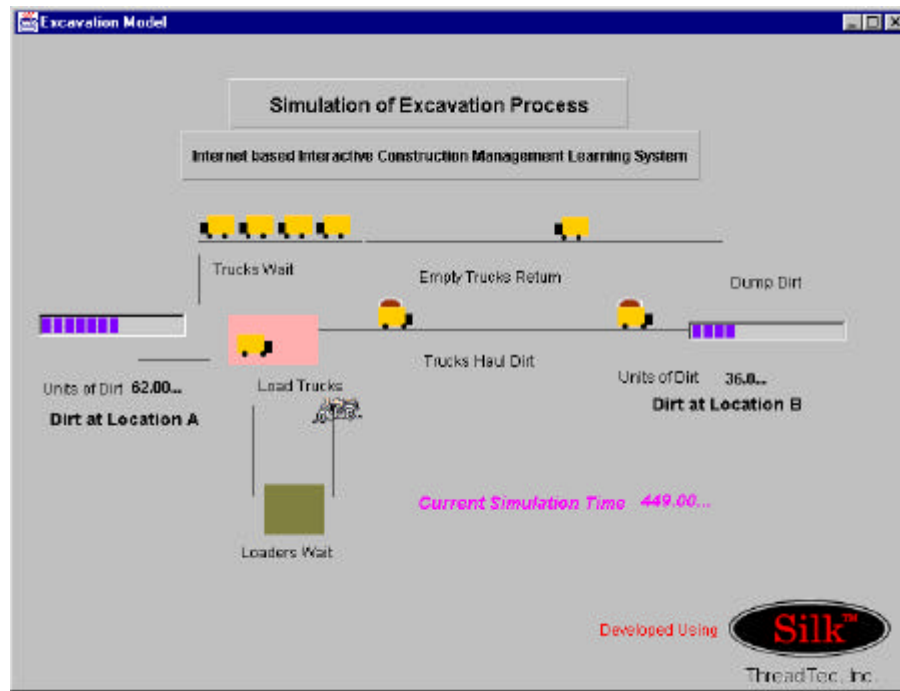


Figure 7: Java-based Simulation Example

## VII. Conclusions

The authors envision that the successful completion of this project will provide an instructional tool that clearly caters to the needs of construction engineering education. A number of benefits arise from this accomplishment. These include graduates that are better prepared to manage the complex dynamics, pressures, and demands of construction sites. More “job-ready” graduates are becoming critical to meet the demands of the construction industry. The enhanced practitioner involvement and construction industry input increases practical content/relevance of the material and can provide students with increased familiarity with the construction industry. The improved recruitment, retention, and program completion for the construction engineering program are of benefit to the university. As can be seen, ultimately all parties involved, universities, students, and the construction industry, can benefit from ICMLS. The university will generate more importance and interest as an educational institution through improved recruitment and better graduates, while the students will benefit from a better education that will ultimately also benefit the construction industry.

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## ANIL SAWHNEY

Anil Sawhney received his Bachelor of Engineering degree from India in 1987 and a Master of Building Engineering and Management degree from School of Planning and Architecture, New Delhi in 1990. He completed his Ph.D. studies at the University of Alberta in June 1994. Since then he has been working as an Assistant Professor of Construction Engineering and Management at Western Michigan University. His research interests are mainly focused on construction simulation techniques and use of computers in construction education.

## PRAWIT ROTSAWATSUK

Prawit Rotsawatsuk is a graduate student in Construction Engineering Management program at Western Michigan University. He earned his Bachelor Degree in Construction Engineering from King Mongkut's Institute of Technology Ladkrabang, Bangkok Thailand in 1996. After he graduated, He worked as a field engineer in Thailand. He is currently working as a research assistant on a funded research project titled "Internet based Interactive Construction Management Learning System".

## ANDRÉ MUND

André Mund received his Bachelor of Engineering degree from UAL in Portugal in 1994. Prior to beginning his Master of Science studies in Construction Management at Western Michigan University in 1997 he worked for a contractor in Berlin, Germany, from 1994-1997. Since his arrival at Western Michigan University he has been working first as a teaching and now as a research assistant in the Construction Management program. He is interested in the area of heavy construction equipment selection and computing and information technology applications in construction.