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Capturing Embodied Energy: Guidelines for Building Demolition and Deconstruction – Material Salvage and Reuse of Structural Steel Components

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When structures within the built environment are slated for demolition there is a significant opportunity to deconstruct the building in such a way to allow maximum reuse of the existing materials. Many times stakeholders overlook the potential to capture and preserve the invested embodied energy of the existing materials through their reuse. At best, the designers and constructors make cursory attempts to reuse a very narrow range of materials such as concrete, wood, and masonry. This approach of selecting the “low hanging fruit” ignores the true tenets of sustainability and avoids doing the hard work in figuring out ways to reuse all of the materials for some future project. Construction and demolition (C&D) waste can make up a vast portion of the materials handled on a typical construction project. If these removed materials are not reintroduced back into the material supply chain their embodied energy is lost and must be made up somewhere along the line thru further depletion of our non-renewable resources. Increased efforts for reuse will lead to reduction in environmental damage, conserve landfill space, and decreases the strain caused by raw material mining. Structural steel has enormous potential for adaptive reuse in future building projects. Current reclamation and extraction processes are inefficient and cost prohibitive thereby deterring the reuse of structural steel components in future projects.

Key Words: embodied energy, sustainability, stakeholders, adaptive reuse, extraction

Introduction

Expansion of the built environment, the leading cause of depletion of our non-renewable resources (Kibert, 1999), must continue to develop new ways to reuse materials typically applied in the construction process or risk, at some point, the reasonable availability of a given resource to any significant extent. To date, most of the approaches to sustainability in regards to materials utilization has been in the area or recycling, not reuse. Although recycling does positively contribute to lessen the impact on the environment, it does not compare to the argument of reusing materials or products in their current state or some measure of adaptive reuse.

Building demolition and deconstruction, as part of the expansion of the built environment, has been historically approached as ‘getting rid of the old structure as quickly as possible to make room for the new facility. Until recently, this demolition process did not include, as part of its inherent steps, measures to assure reuse of as many existing materials as possible, especially when dealing with structural steel.

All materials, both new and used, contain some level of embodied energy. Most of the efforts to date have focused on capturing embodied energies thru recycling initiatives. The importance of embodied energy and other environmental impacts does not become apparent until we examine the materials from a life cycle approach, characteristically known in our industry as Life Cycle
Assessment (LCA). This unique approach, to how various products and materials affect our natural systems, could become standard procedure in the analysis and coordination of a building scheduled to be demolished or deconstructed. This paper will focus on structural steel members and how they might best be reused in construction of new facilities in the built environment and how their reuse applies the science of lessening the total embodied energy for a given project.

**Background**

Structural steel, a material widely used in the building industry for many decades, is commonly used due to some key performance characteristics it contributes as part of the construction process such as ease of erection, strength, flexibility, durability, and cost. Framing systems utilizing structural steel are recycled, recyclable, and reusable. Steel, as a material, is the most recycled product in the world with structural steel’s 97%+ recycled content (Citation) setting the pace for the design professional in the pursuit of sustainable construction. Not to diminish the efforts and results of recycling steel it still does not address the increase in embodied energy via the recycling process. In its virgin or recycled state steel does not favorably compare to other structural materials available to designers and constructors. When looking at the embodied energy of any material introduced into the design and construction process we must start at the initial creation phase and conduct an analysis of all phases of the life cycle of that material to determine its’ true impact on the environment. For structural steel, a material with very high embodied energy (See Table 1.0), knowledge of the history of structural steel technology is necessary to place its’ reuse into proper context.

The history of structural steel dates back to 1885 where it was first introduced into the construction process. At that time, due to its untested nature as a structural system, professionals in the building industry did not envision just how prevalent it would be incorporated into the vast majority of new structures in one capacity or another. The process of creating structural steel shapes that eventually end up installed within a new facility has many steps in its process before it is actually installed on the jobsite.

Steel production is broken down into three major steps; (1) production, (2) fabrication, and (3) erection. At each of these necessary steps the embodied energy is added on to produce the finished product ready for installation. Figure 3.0 shown below illustrates the many steps needed to produce structural steel components. The idea of reuse in lieu of recycling would eliminate some of the major sub-steps and thereby significantly reduce the increase in energy consumption.
The current state of structural steel reuse is limited at best. Factors such as cost, availability, and engineering requirements are real inhibitors to expanding the reuse of steel. Some areas of our industry have taken it upon themselves to look at steel not as a recycled material but as a reuse material. Firms such as BioRegional Reclaimed (BRR) in the U.K. has been leading the way in reclaiming and reusing structural steel members for new projects. They look at demolition and redevelopment projects as an invaluable source of reclaimed building materials. Often there are waste minimization or environmental impact reduction targets for the projects and with BRR’s effective planning, materials, including structural steel, can be extracted and sold profitably with minimum impact to the project schedule. BRR has developed a “pre-extraction marketing” service for demolition and refurbishment projects to find customers for the materials to be reclaimed before construction commences. The literature search found only a few companies in Canada and the U.K. taking this environmentally responsible approach to structural steel reuse.

Sustainability

A full understanding of the term sustainability is necessary to see how materials reuse in lieu of recycling brings us closer to true sustainable construction and its many positive effects on our natural ecosystems. Sustainability is defined as “meeting the needs of the present without compromising the ability of future generations to meet their needs” (Kibert, 1999). These standards include reduction in the use of fossil fuels, reduction in water usage, reduced energy usage, more efficient systems that use non-renewable fuel sources, and creating projects that simply have less of an impact on the environment and the natural systems contained therein. Sustainability is not only the appropriate stewardship for the environment we should embrace, it also produces many tangible benefits to projects owners and society as a whole. Hundreds of
studies have proven the financial advantages of going green, from reduced construction costs to lower operating costs (Lockwood, 2006).

Green buildings, a relatively new design approach within the context of the built environment, is moving us toward a re-thinking of how we construct new buildings and how they fit into our economy and natural systems. In terms of applying this set of concepts to steel construction the benefits are seemingly unlimited in scope, cost savings, and overall societal environmental improvement. With these concepts in mind, it is not difficult to see the many benefits for our industry to pursue more reuse than recycling, at least when it comes to structural steel products and components. Leadership in Environmental and Energy Design (LEED), the most widespread method used in the United States (usgbc.org) for certifying that a facility is built with consideration for the environment and energy usage, awards points on varying scales for re-use of building products extracted from buildings planned for demolition.

**Embodied Energy**

Embodied energy in building materials has been studied for the past several decades by researchers interested in the keen relationship between building materials, construction processes, and their environmental impacts (Canadianarchitect.com). All materials used in the construction project contain some level of embodied energy and the analysis of each material for its energy consumption is a standard and accepted measure of sustainability. There appear to be a number of different understandings of the term embodied energy. Basically it refers to quantitative methods of accounting for flows of energy through our environment. Traditionally considered, embodied energy is an accounting methodology which aims to find the sum total of the energy necessary – from the raw material extraction process, to transport, manufacturing, assembly, handling, testing, and installation as well as the capital and other costs of a specific material – to produce a material or product. Different types of methodologies produce different understandings of the scope and scale of application and the type of energy embodied. Embodied energy as a concept used in systems ecology seeks to measure the “actual” energy cost of an item, and the extension of the concept of its “actual” value (Wikipedia.org), i.e. cradle-to-grave. Embodied energy is measured and quantified in a number of different ways however for the purposed of comparison in this paper mega joules per m³ will be used. Comprehensive attempts should be made to account for all energy consumed to produce a product across its entire life cycle. This includes the mining and manufacturing of materials and equipment, the transport of the materials, and the administrative functions. Choices of materials and construction methods can significantly change the amount of energy embodied in the structure of a building (Greenhouse.gov). The option of choosing steel reuse in lieu of recycling makes it an attractive alternative in the contribution lessening the impact of the built environment thru reductions in the embodied energy of its components.

**Defining embodied energy**

To fully understand how the application of steel reuse is a better step in achieving sustainability, a specific accounting of the mechanics of calculating embodied energy is required. There are two forms of embodied energy in buildings: (1) **initial** embodied energy, and (2) **recurring**
embodied energy. The initial embodied energy in buildings represents the non-renewable energy consumed in the acquisition of raw materials, their processing techniques, manufacturing processes, transportation to the site, and construction installation. This initial embodied energy has two key components: (1) **direct** energy defined as the energy used to transport building products to the site, and then to construct the building and (2) **indirect** energy defined as the energy used to acquire, process, and manufacture the building materials, including any transportation related to these activities. The recurring embodied energy in buildings represents the non-renewable energy consumed to maintain, repair, restore, refurbish or replace materials, components or systems during the entire life cycle of the building.

Due to the magnitude of the previously stated factors it is not difficult to understand why reuse of steel is far more environmentally responsible than simply recycling. As buildings become more energy-efficient, the ratio of embodied energy to lifetime consumption increases which amplifies the need to head in the direction of reuse and/or adaptive reuse in lieu the simpler and more prevalent method of achieving sustainability thru recycling.

*Life Cycle Assessment (LCA)*

The materials we use to expand the built environment have many “unseen” adverse impacts. The importance of embodied energy and other environment impacts does not become apparent until we examine the materials from a life cycle approach, usually known as Life Cycle Assessment. LCA, first discussed by **Howard T. Odum** in 1960, has become an accepted practice of comprehensively analyzing each material introduced into the construction process and determining its energy use and consumption (Kibert, 2005). Assessing a value of embodied energy to each single material or product and then totaling them will allow the project team the ability to determine the overall impact a single facility will have on our ecosystems. This analysis must account for energy consumed at all stages in the cycle of each material. Each time the material is handled, modified, or altered additional energy is added to its overall sum. LCA can be applied to a whole product or to an individual element or process included in that product (Boustedt-consulting.com). An internationally agreed upon standard (ISO 14040) defines standard LCA methodologies and protocols. Along with the energy analysis a comprehensive cost-benefit analysis (Greene, 2002) should be conducted to ensure the owner’s value initiatives are met.

<table>
<thead>
<tr>
<th>Type of Material</th>
<th>Embodied Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MJ/kg</td>
</tr>
<tr>
<td>Cement</td>
<td>5.6</td>
</tr>
<tr>
<td>Concrete Masonry Units</td>
<td>0.94</td>
</tr>
<tr>
<td>Timber (kiln dried)</td>
<td>1.6</td>
</tr>
<tr>
<td>Glue-laminated timber</td>
<td>4.6</td>
</tr>
<tr>
<td>Framing lumber</td>
<td>2.5</td>
</tr>
<tr>
<td>Pre-cast tilt-up concrete panels</td>
<td>2.0</td>
</tr>
<tr>
<td>Clay bricks</td>
<td>2.5</td>
</tr>
<tr>
<td>Steel (recycled)</td>
<td>8.9</td>
</tr>
<tr>
<td>Steel (virgin)</td>
<td>32.0</td>
</tr>
<tr>
<td>Steel (imported)</td>
<td>35.0</td>
</tr>
<tr>
<td>Stone (local)</td>
<td>0.79</td>
</tr>
</tbody>
</table>

*Table 1.0 – Embodied Energy of Common Structural Materials (Canadianarchitect.com)*

7
Recycling and Reuse

To date, most of the efforts to capture some of the embodied energy that steel products possess have been in the arena of recycling. Presently, over 90% of structural steel products in use today are made up of recycled steel (EBN Web site) recovered in common building demolition processes. This is a very high percentage in comparison to other materials commonly used in the construction process. With only 10% going to component reuse it is easy to imagine how significant an impact steel reuse would have on our non-renewable resources if the percentages were reversed.

Steel Salvage/Reuse Operations

Development of a specific set of means and methods that would increase the reuse of steel components in their present extracted form would add to the embodied energy but in significantly smaller amounts as to make this type of process much more attractive to the concepts of sustainability (See Figure 1.1). Savings in time, money, and energy would be realized at many stages of the material use cycle such as in transportation, processing, and milling. At each of these points in the material cycle embodied energy is added to the total thereby producing another negative impact to the ecosystem of resource depletion.

Figure 1.0 – Embodied Energy of Reused Steel

State of Steel Recycling

The present steel recycling processes in use does provide some relief to the strain on our non-renewable resources however in the process only serve to add to the total embodied energy of the material as it re-enters the material stream (See Figure 2.0). However a quick comparison of recycling vs. reuse on the sole level of embodied energy indicates significantly less energy consumed in the reuse process; approximately 20-25% less.
Recycling vs. Reuse

When project designers, engineers, and stakeholders are looking into the use of steel within the context of their sustainability plan, logic and good business sense dictate a side-by-side comparison must be made when comparing recycling to reuse. One cannot ignore the environmental benefits as well and they must play a significant role in the overall building design equation when determining which path to take.

Pre-extraction Process

Before materials are extracted for reuse an assessment is necessary to verify the extent and quality of the materials targeted for reclamation. Suggested steps to validate the initial study are:

1. Site visit and meeting to determine the scope and location of the existing structural steel members as well as the connection detailing
2. A detailed information visit to collect samples, measurements, quantities, and description of the steel
a. Attach bar code sticker identifying its size, shape, and potential-use length
3. A meeting with the demolition/deconstruction contractor to establish the deconstruction approach and agree on the quality, timing, and possible storage of materials to be extracted
4. Removing extracted materials for planned use in upcoming project(s) or keeping on site and marketing for resale
5. Concluding report defining quantified environmental analysis benefits derived from reused steel

**Extraction Process**

1. Mobilize demolition contractor with appropriate equipment
2. Remove identified components from site
   a. Unbolt connections if applicable
   b. Cut out usable section lengths to avoid expense of releasing difficult connections
3. Ship to storage/re-fabrication facility

**Testing Process**

To attract potential designers or contractors who are thinking of reusing steel components a testing process has been developed to assure any potential customers the reclaimed steel members meet the structural and performance requirements as if they were newly fabricated steel. The following steps outline the testing process as it would be conducted in a testing laboratory:
1. Receive samples (full-size or cross-sections) from jobsites
2. Verify their chemical properties (metallurgical content)
3. Conduct yield ($F_y$) and ultimate tensile ($F_u$) strength tests
4. Compare test results to current engineering standards for the same size piece
5. Check for any signs of corrosion and correct if possible
6. Recertification for reuse

**Building Codes and Regulatory Requirements**

Meet with building code officials and engineering firms to see how we can reintroduce used steel materials back into the material supply chain and still meet the code requirements (an example is the reuse of structural lumber that currently requires a grade stamp). As with many new and innovative ideas, resistance from the general public to this kind of idea is normal and justifiable. Many market purchasers only see the initial installation costs as the most important decision factor and are unable or unwilling to look out multiple years to recognize the potential cost savings. This type of decision analysis is intrinsic in our economic education and engrained in our minds over many generations. One solution to remedy the natural hesitance is to institute some measure of government mandates for the inclusion of solar energy collection and water
reduction and/or saving measures. In order to give society the “nudge” necessary to implement these types of energy and water saving initiatives, the current building codes requirements would need to be modified to mandate incorporation of these types of resource saving propositions within the built environment. Another option would be to provide some level of tax credits or tax relief for those individuals who would voluntarily implement these sustainable systems. Either method or a combination of both would most certainly help champion the cause and invigorate the public to gravitate towards this type of environmental awareness and application.

**Conclusions and Summary**

There are many approaches project owners and stakeholders can take to contribute to the betterment of our ecosystems through responsible stewardship in material use and reuse. Options such as recycling, reuse, and adaptive reuse all have an important role to play in recognizing our resources are indeed limited and sooner rather than later we must find ways to reuse those non-renewable resources extracted from our earth. Steel reuse is a next logical step in applying technology and engineering concepts to reduce the overall embodied energy of a new structure and thereby reduce the growing demand on the limited natural resources that are currently (but not unlimited) at our disposal.

**Recommendations for Further Research**

From this research I would hope others to follow could: (1) expand the knowledge base of potential reuses of structural steel members in both industry and academia, (2) develop new, or advance existing testing procedures that would lead to increase reuse of this type of material, (3) develop a standard set of design, demolition, and deconstruction specifications for application and use on a wide range of construction projects as it relates to this type of material reuse, (4) develop a recertification process in collaboration with code officials and design engineers which would enable our industry to realistically reuse most of the recovered structural steel members, and (5) quantifying the positive environmental impacts associated with structural steel reuse.
References

EBN website: http://www.buildinggreen.com/


An Interactive Way To Teach Construction Terminology

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In many courses the terminology must be introduced and explained before moving on to other topics. How to approach this varies by the instructor, the course, the text being use and the difficulty of the terminology. It is important to not only understand the meaning of a term but how it relates to other terms that are being introduced. The technique presented in this paper uses a technique that assists people to remember names: name association. Instead of names, it is the terms from an introductory construction courses that are associated. The technique is explained and illustrated through an example. An adaptation of the technique, used in an estimating class for the discussion of a contractor’s decision to bid, is also presented.

Key Words: Education, Construction, Terminology, Engaging Students, Educational Tools

INTRODUCTION

The technique presented in this paper is a modified form of a technique used to remember names: name association. In that technique the person employing the technique uses some characteristic or distinctive feature of the individual to assist them in remembering the name. In the technique presented in this paper, used to remember construction terminology, it can be the individual who defines that term, the definition that was presented by the individual or the relationship to other terms that helps in remembering the term.

Course Background

CE3332, Fundamentals of Construction Engineering, is a three credit class open to sophomores that is required for all Civil Engineering students in Civil and Environmental Engineering (CEE) at Michigan Technological University (Michigan Tech). It is offered in the fall, spring, and summer semesters with approximately 60 students in the fall and spring class and 15 students during the summer. Many students have had limited exposure to construction and so their understanding of industry terminology may be limited. In order to bring students to some level of understanding there has to be some terminology introduced. The technique presented in this paper has been used since the Fall Semester of 2000. In addition to the Civil Engineering students taking the class, there are usually some students from other areas such as Mining Engineering, Geological Engineering, Mechanical Engineering, Electrical Engineering, Chemical Engineering and Business. Many of these non CEE students take the class because they are interested in construction, have worked in construction, or plan to work in the industry. This wide range of students and varying experience levels of those students necessitates an understanding of terminology early in the course. The technique presented in this paper is done in the third and fourth lecture periods after an introduction lecture and an industry overview lecture.
As this may be the only construction course that many Civil Engineering students at Michigan Tech take, it was decided that the course should cover a broad range of topics that Civil Engineers would need not only if they worked in construction but for consultants or owners. As a result there are many topics covered that may have a course dedicated to them in larger programs or Construction Management programs. These topics include a construction overview, contracts, cash flow, equipment ownership, equipment productivity, estimating, quality and safety. A topic that is covered in more depth is planning and scheduling. Course grading is based on tests (75%), assignments (15%) and a scheduling project (10%). The textbook in use at the present time is *Construction Management, 3rd Edition* (Halpin, 2006). The terms used in this exercise can be found in the text.

**DESCRIPTION OF TERMINOLOGY EXERCISE**

The exercise works best when the class meets in a room where everyone can face each other in a circle as shown in Figure 1. At Michigan Tech this is in the Ballroom in the Memorial Union. The exercise has been used in other locations like a large conference room and even the classroom. However, there is more excitement and anticipation from the students when they do no meet in the regular classroom. The ballroom also easily accommodates the class of 60 students. Other locations would work for classes of different sizes. The chairs are arranged in a circle so all students face each other and makes everyone an equal participant and equal distance from the instructor versus the traditional classroom where students in the front may be considered more accessible to the instructor than students further back. At Michigan Tech the Memorial Union Staff has been extremely helpful in setting up the chairs in a circle. This request is made when the room is reserved.

*Figure 1  Circle of Students in Terminology Exercise*

During the previous lecture the class is reminded to read the assigned readings from the textbook as the majority of terms can be found in the text. As students come to class the day of the exercise they are handed a sheet with the terms listed as shown in Figure 2. Note that terms
could be added or subtracted as the individual course dictates. Once the majority of students have arrived the instructor has students count starting with one and working around the circle until the counting reaches the number of terms in the list. As shown in Figure 2 the count ends at 38. Since there are approximately 60 students the counting starts again at 1 and continues until all students have been assigned a number. Students that are assigned duplicate numbers are to work with each other to complete the exercise. Any late arriving students are added to the end of count or can assist students that cannot define the term that they have been assigned. The benefit of combining teams of students with like numbers is that this provides an opportunity for students to meet other students in a class.

**In Class Terminology Exercise**

<table>
<thead>
<tr>
<th>1. Design Build</th>
<th>2. Retainage</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Construction Management</td>
<td>4. Payment Bond</td>
</tr>
<tr>
<td>5. Lump Sum Contract</td>
<td>6. S-Curve (Not the one in Grand Rapids)</td>
</tr>
<tr>
<td>15. Time Extension</td>
<td>16. Competitively Bid Contracts</td>
</tr>
<tr>
<td>17. Change Order</td>
<td>18. Responsible Bidder</td>
</tr>
<tr>
<td>19. Performance Bond</td>
<td>20. Cost + % of Cost</td>
</tr>
<tr>
<td>23. Liquidated Damages</td>
<td>24. Private Work</td>
</tr>
<tr>
<td>27. Mobilization</td>
<td>28. Unbalancing a Bid</td>
</tr>
<tr>
<td>31. Notice to Bidders</td>
<td>32. Constructability</td>
</tr>
<tr>
<td>33. Design – Bid – Build</td>
<td>34. Addenda</td>
</tr>
<tr>
<td>35. CM@Risk</td>
<td>36. Substantial Completion</td>
</tr>
<tr>
<td>37. Changed Condition</td>
<td>38. Punch List</td>
</tr>
</tbody>
</table>

After being assigned a number write the definition of your term below. Identify which term(s) it is related to. Be prepared to present your definition and how it relates to the term defined immediately before it was defined. The order of presentation will be determined as the discussion develops.

---

*Figure 2 List of Terms Used in Exercise*
After the room has settled, because of the moving of students to find their partners, further clarification of the instructions is provided. They are told that they are to define their term and identify several other terms that it might be related to. Usually ten to fifteen minutes is sufficient for this. Students are permitted to use their texts if they have brought them. In many instances texts are shared with other students as someone finishes with their text. Some students are unable to define or relate their term and instructor input is provided. Based upon observations over the years this exercise helps reinforce the need to read the text as those students who have read the text (as told to the instructor) find the exercise of defining and relating easier. For those students who have not yet purchased the text it, in some cases, makes them consider purchasing it.

When the majority of students have completed their work the interactive part of the exercise begins. The question is posed by the instructor as where do we begin. Usually, one student is courageous enough to start and is rewarded by not having to relate their term to another. The student defining their term is asked to stand when they present their definition as shown in Figure 3. Usually they are asked to provide their name as this assists the instructor in remembering names. After a term is defined the instructor may have to further clarify or put into context the term as rarely is the definition provided by the students perfect. In many instances the instructor tries to coach the students to assist in this clarification. Once the instructor is satisfied that the term is satisfactorily defined the following question is posed to the class: Where do we go from here? This attempts to solicit a response from the students that believe that their term should be defined next as it relates to the term just defined. The first few terms are hard to get anyone to volunteer but after a few definitions there are several students eager to define their term. As the instructor does not want to control the exercise students are selected at random to be next.

An “ideal” progression through the list might be: Project Delivery Systems, Design – Bid – Build, Design Build, Construction Management, and CM@ Risk. This could then be followed by the different types of contracts such as: Lump Sum, Unit Price, and Negotiated.
However, ideal rarely happens and the progression through the list is at times unrelated. After hearing the student’s reasoning the instructor may or may not agree. Clarification may be necessary. In some cases the instructor will tell students that they should have gone at some different point of time. Since the process of selecting students is random the opportune time may pass for a term to be related. Usually there are several terms at the end of the exercise that are not related to the immediate previous term. The instructor asks what would have been a better point in time for the term to be defined.

Throughout the semester there are many instances that the terms listed in Figure 2 are part of class discussions. Examples of this are the effect of mobilization on cash flow or the discussion of front end loading on unit price contracts. This repetition helps in understanding the terms and relating them to other topics.

**Evaluation**

Two methods of evaluation of student understanding have been done. One is to make the initial definition an assignment in class. Students are given two copies of Figure 2: one to keep for themselves and the other to turn in and be graded. Another method is to have students write a paragraph on the exam using the terms from Figure 2. This question is shown in Figure 4. In other instances all of the terms were provided and the students were required to select 8 or 10 terms to write in a paragraph. The intent of this question is to see how if they can relate the terms. This can be accomplished when students understand the definitions.

The following is a partial list of terms that was provided to you in class and discussed in class. Using the 10 terms correctly write a short paragraph that categorizes/classifies these terms and relates the categories/classifications. This paragraph must be comprehensible and the flow must make sense and be correct. Use the space below. **Underline** the terms in your paragraph. A figure or concept map may be used to supplement the text.

<table>
<thead>
<tr>
<th>a) Design Build</th>
<th>b) Negotiated Contract</th>
</tr>
</thead>
<tbody>
<tr>
<td>c) Construction Management</td>
<td>d) Design – Bid – Build</td>
</tr>
<tr>
<td>e) Lump Sum Contract</td>
<td>f) CM@Risk</td>
</tr>
<tr>
<td>g) Unit Price Contract</td>
<td>h) Project Delivery Systems</td>
</tr>
<tr>
<td>i) Cost + % of Cost</td>
<td>j) Guaranteed Maximum Price</td>
</tr>
</tbody>
</table>

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*Figure 4 Exam Question*
MODIFICATION OF EXERCISE FOR USE IN AN ESTIMATING CLASS

A modification of the exercise is used in CE4333, Estimating, Planning and Control. CE4333 is a senior elective in Civil Engineering. The topic being covered is the contractor’s decision to bid on a project. The modification is that the students do not define the term but they tell a story that builds upon what was said earlier. The sheet that the students receive when entering class is shown in Figure 5. Usually the story gets fairly outrageous but the understanding of the terms is enhanced by the exaggeration of the students. If an instructor were hesitant to do this in class they could easily adapt it using the definition exercise discussed earlier. The procedure for doing the exercise is similar to that presented earlier.

Define your term in the context of a contractor’s “decision to bid”. **Circle** the term you are defining.

<table>
<thead>
<tr>
<th>1. Bidding Time/Bid Date</th>
<th>2. Surety Bond/Bonding Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Business Plan</td>
<td>6. Other Projects to Bid</td>
</tr>
<tr>
<td>7. Equipment</td>
<td>8. Supervision</td>
</tr>
<tr>
<td>11. Competition</td>
<td>12. Relationship of Parties</td>
</tr>
<tr>
<td>15. Quality of Documents</td>
<td>16. Suppliers</td>
</tr>
<tr>
<td>17. Subcontractors</td>
<td>18. Location of Work</td>
</tr>
<tr>
<td>19. Prequalification</td>
<td>20. Licensing</td>
</tr>
<tr>
<td>23. Completion Date</td>
<td>24. Type of Contract</td>
</tr>
<tr>
<td>25. Owner</td>
<td>26. Time of Year</td>
</tr>
<tr>
<td>27. Labor Force</td>
<td>28. Project Financing</td>
</tr>
<tr>
<td>29. Profit</td>
<td>30. Complexity</td>
</tr>
<tr>
<td>31. Type of Work</td>
<td>32. Size of Project</td>
</tr>
</tbody>
</table>

After forming groups (if necessary) of two, write the answer to your term below on both papers. Turn one in, save the other to use for discussion. You will need to integrate your term into a **story**.
SUMMARY

The first time that the author did this exercise in class was very unsettling as the instructor relinquishes control of the class. However, the experience has truly been rewarding and the author is unsure who enjoys this exercise more: the students or the instructor. There is generally considerable laughter during these exercises and the author believes that laughter enhances the learning experience. Many former students mention this exercise and remember their term years later. Additionally, the exercise has developed a bit of folklore as students who have taken the class communicate with students that are currently taking the class and ask if the exercise has occurred yet and if so what term they had.

Currently a study is being performed to compare the results of student understanding using the technique described in this paper compared to a traditional lecture of terminology.

References

A Simplified Risk Analysis for Design-Build Construction Projects

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Construction Projects are being implemented under different contract systems in the Midwest. Negotiated design-build has been a popular contract system in recent years. It provides various advantages through entailing the contractor to be responsible for the whole project. However, design-build turns out to be a risky system for both owners and contractors unless the risks are identified, analyzed, and analyzed through the project execution. This paper proposes a simplified schedule and risk analysis model to help construction estimators. A hypothetical case study was used to demonstrate the applicability of this simplified model. The developed model showed marked enhancement in analyzing the risk of project schedule and cost overruns.

Keywords: risk analysis; Design-build; Construction; Simplified approach

Introduction

In a negotiated contract, decisions on pricing strategies are based on contractor’s experience, intuition, and personal bias. There is a lack of practical models that could quantify risks on construction projects. Xu et al. (2001) proposed an approach to the risk assessment of contractor’s pricing strategies while Tummala et al. (1999) formulated a risk management process (RMP) model to evaluate the risks associated with project cost in different phases of the project life cycle. Songer et al. (1997) suggest risk analysis tools like Monte Carlo simulation for evaluating uncertainties on construction projects that are procured by either design-build, construction management, or built operate and transfer methods. Dawood (1998) developed a simulation model using risk management techniques to estimate activity and project durations. Mak et al. (2000) conducted a survey on the usage of risk analysis techniques in determining the contingency allowance in project cost estimating. But, there is no special consideration made to the risks on DB type construction projects.

The number of studies related design-build contract system is increasing as the application of this project delivery method expands. Rowings et al. (2000) surveyed on electrical contractors regarding many different aspects of design-build and how those factors impact their business. The survey revealed several important trends and preferences among electrical contractors. One area identified in the survey worthy of note is that many of the electrical contractors felt ill prepared to embark on design build with their current understanding of the issues.

Chan et al. (2001) identified a set of project success factors for design-build projects and examined the relative importance of these factors on the project outcome. One of the factors he found to be important is risk assessment in design-build projects. However, the numbers of studies that combine the risk analysis/management and design–build subjects are still scarce.
Based on the author personal experience with Midwestern Construction Company, This paper proposes a simplified schedule and risk analysis model to help construction estimators to perform risk analysis process, as a step of project risk management system, for Design build projects. A hypothetical case study was used to demonstrate the applicability of this simplified model. The developed model showed marked enhancement in analyzing the risk of project schedule and cost overruns.

Risk Management and Analysis

The definition for risk is elusive, and its measurement is controversial (Lifson and Shaifer 1982). There is no consistent or uniform usage of the term risk. Often times, risk is interpreted in association with uncertainty. In this sense, risk implies that there is more than one possible outcome for the event, where the uncertainty of outcomes is expressed by probability (Al-Bahar 1988). In project management, risks are typically associated with cost, schedule, safety and technical performance (Rao et al. 1994). For the purpose of this study, risk is defined as the exposure to the chance of occurrences of cost or schedule growth as a consequence of uncertainty.

Risk management is a quantitative systematic approach used to manage risks faced by project participants. It deals with both foreseeable as well as unforeseeable risks and the choice of the appropriate techniques(s) for treating those risks. The process of risk management includes three phases: risk identification, risk quantification, and risk control. The process is a continuous cycle that consists of risk analysis, strategy implementation, and monitoring (Minato and Ashley 1998).

Risk Analysis

Risk analysis is needed to determine the potential impact of the risk. Risk analysis techniques are grouped into two main categories: quantitative and qualitative (Flanagan & Norman, 1993; Vaughan, 1997). They both benefit from the data produced by risk identification but the qualitative approach consumes the gathered information through direct judgment, comparing options, and descriptive analysis. In contrast, some of the quantitative risk analysis techniques incorporate uncertainty in a quantitative manner to evaluate the potential impact of risk. In this process, an analyst integrates information from numerous sources through quantitative and/or qualitative modeling, while preserving the uncertainty and the complex relationships between the elements of information (Rao et al. 1994).

Research methodology

The project begins with identifying the main features, major application deficiencies and summarization of the encountered risks. Afterwards, schedule risk analysis and cost risk analysis are subsequently performed for these risks. A stochastic risk analysis Technique, similar to Monte Carlo simulation, was utilized in both schedule risk and cost risk analysis steps. Microsoft Excel was used to simulated the data and perform the required analysis.
Spreadsheet Modeling

The simplified spreadsheet solutions developed by Hegazy and Ayed (1999) was used a platform for developing the risk analysis model after deforming the required schedule calculations. These spreadsheet models provide opportunity to achieve the project duration and total project cost range in percentiles at the end of simulation with taking into account the identified risks and their effects on activity durations and costs. They have also the following basic characteristics:

**Schedule risk model:** The model consists of all project activities, their relationships, and their minimum, likely and maximum durations (Figure 1). **Cost risk model:** The model consists of all price items with their units that constitute the total price. It leads the user to enter the minimum, maximum and likely production amount and unit price of every price item (Figure 2).

Case Study

A hypothetical case study was used to demonstrate the applicability of this simplified model. This Hypothetical project includes the design and construction of a 12000 square food commercial property that will be used a Fast food retail restaurant. It was a negotiated job and the owner wanted his bid after 10 days. According to the CPM Calculations and the parametric estimation of the project, the estimator can submit his bid for $1,273,300 that can be executed in 131 days.

This case study will help the author to illustrate the negative effects of the lack of risk identification and risk analysis of Design Build construction projects. It should be emphasized that there are some deficiencies in the application of design build contract system for this specific project due to the short time allowed for preparing an estimate for this project. In order to clarify the scope of the study, the major risks that have to be taken into consideration along the risk analysis are summarized in Table 1:

Table 1: Risk Identification/Classification Table

<table>
<thead>
<tr>
<th>Risk No.</th>
<th>Risk description</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Changes in quantity/scope of work</td>
<td>Duration &amp; cost</td>
</tr>
<tr>
<td>2</td>
<td>Design changes</td>
<td>Duration</td>
</tr>
<tr>
<td>3</td>
<td>Delay in design</td>
<td>Duration</td>
</tr>
<tr>
<td>4</td>
<td>Subcontractor or Vendor delays or default</td>
<td>Duration</td>
</tr>
<tr>
<td>5</td>
<td>Weather conditions</td>
<td>Duration</td>
</tr>
<tr>
<td>6</td>
<td>Owner Financial problems</td>
<td>Duration &amp; cost</td>
</tr>
<tr>
<td>7</td>
<td>Inadequate quality of work and re-work delay</td>
<td>Duration &amp; cost</td>
</tr>
<tr>
<td>8</td>
<td>Sub-soil Stability conditions</td>
<td>Duration &amp; cost</td>
</tr>
<tr>
<td>9</td>
<td>Safety</td>
<td>Duration &amp; cost</td>
</tr>
</tbody>
</table>
In order to build up the schedule risk analysis mode of the project, the simplified spreadsheet solutions developed by Hegazy and Ayed (1999) was used a platform to develop the deterministic CPM calculations. Extra columns with a simulation-like algorithm were coded in the spreadsheet to add the ability to run different cycles of simulation on the model. The triangular probability distributions, with likely-minimum- maximum activity durations, were represented.

**Figure 1:** Schedule Risk Model of the Project
Figure 2: Cost Risk Model of the Project

The cost risk analysis spreadsheet model was developed in MS Excel as shown in Figure 2. The estimate was executed based on a simple floor plan that the estimator sketched with the owner in the scope clarification meeting. The likely, minimum, and maximum amount values were
decided with the estimator experience and historical records from other projects. The price items were represented by means of triangular probability distributions.

**Results and Comments**

Deterministic Schedule analysis has shown that the project can end at 131 days. However, after running the simulation, Table 2 shows that the probability of finishing this project in time is close to 17%. This is a proof that the project is sufficiently risky regards to schedule under the current conditions.

**Table 2: Simulation Results of Schedule Risk analysis model**

<table>
<thead>
<tr>
<th>Project Duration (days)</th>
<th>Frequency</th>
<th>Cumulative %</th>
</tr>
</thead>
<tbody>
<tr>
<td>118.1</td>
<td>1</td>
<td>1.00%</td>
</tr>
<tr>
<td>124.93</td>
<td>3</td>
<td>4.00%</td>
</tr>
<tr>
<td>131.76</td>
<td>13</td>
<td>17.00%</td>
</tr>
<tr>
<td>138.59</td>
<td>24</td>
<td>41.00%</td>
</tr>
<tr>
<td>145.42</td>
<td>12</td>
<td>53.00%</td>
</tr>
<tr>
<td>152.25</td>
<td>13</td>
<td>66.00%</td>
</tr>
<tr>
<td>159.08</td>
<td>14</td>
<td>80.00%</td>
</tr>
<tr>
<td>165.91</td>
<td>6</td>
<td>86.00%</td>
</tr>
<tr>
<td>172.74</td>
<td>12</td>
<td>98.00%</td>
</tr>
<tr>
<td>179.57</td>
<td>0</td>
<td>98.00%</td>
</tr>
<tr>
<td>More</td>
<td>2</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Similarly, Deterministic Schedule analysis has shown that the total project cost is $1,273,300. Figure 3 illustrates the simulation results for the cost risk analysis model. This shows that the bid of that project at $1,273,300 was likely to happen with a probability close to 2%. Such a risky bid value has naturally converted the project from a profitable project to an unprofitable one to the company.

A question may come into mind at this point: How would the estimator select the appropriate project duration and project cost among the various values with different probability percentiles. The answer would be that the decision would be related to the risk attitude, experience, intuition and risk identification capabilities of the contractor and his staff.

Finally, the author has to mention that these results are preliminary and the model need to be validated and the selection criteria for the Minimum, most likely, and maximum values and the selection of the activity or price item distributions should be examined.
Figure 3: Simulation Results of Cost Risk analysis model

Conclusion

In this study, basic information and relevant literature have been presented related to risk, risk management/analysis, and Design Build construction contract system. Subsequently, a hypothetical project has been examined from the contractor (Design-build firm) point of view. This analysis covers risk identification, schedule risk analysis, and cost risk analysis. Risk analysis was be used by developing a spreadsheet models using MS Excel. And the simulation algorithm was simply coded on the spreadsheet.

The results conclude that taking simple methods for estimating bid values or schedule for design bid project would be a risky way of doing business. The results from the schedule risk analysis model and the cost risk analysis model indicated that it is necessary to do a risk analysis for design build projects. As a contractor (Design build firm), in order to be able to prepare and submit a bid for these types of projects, Knowledge and experience on design build system are required to success. In addition, Risk management and analysis should be performed during the decision making process to determine the bid price.
References

Student Defined Learning Objectives as Applied to Purdue University’s Construction Engineering and Management Senior Design Class.

Thomas M. Brennan Jr., PE  
Dr. Thomas Seager  
Construction Engineering and Management  
Purdue University

The article presents an applied strategy for implementing a student defined Construction Engineering and Management Senior Design course at Purdue University during fall 2006. The students’ input has been used to structure the learning objectives, classroom activities, and assessment criteria for the course. Under normal engineering classroom conditions the students are expected to make a series of submissions in response to predetermined classroom assignments. In the new class structure students are tasked with establishing a project team, proposing and defending a project selection, assessing other student projects, assigning work objectives, reviewing the performance of their teammates, and finally determining the types of submittals required throughout the course. As in the past, final project presentations will be assessed by a jury of professionals at the end of the semester. We hypothesize that the restructured class will better prepare students for careers as construction professionals by strengthening their ability to formulate their own problems. Preliminary findings indicate that a significant portion of the class has selected projects that are much more challenging than those assigned in previous year’s classes. Although more challenging and novel learning objectives have been selected by the students, they require additional research and preparation from the Instructors. As part of their chosen projects students have also requested supplementary software tools to enhance their final presentations and learning objectives. Teams that had requested and justified their needs for such tools have been provided them as requested. On the other hand, some students have expressed frustration with the lack of predefined assignments and have had difficulty adjusting to an unstructured classroom.

Introduction

Planning a course requires definition of three different facets: learning objectives, learning activities, and assessment of student progress and teaching effectiveness (see Figure 1). In undergraduate engineering courses, the relationships between these attributes are generally defined by the Instructor’s goals at the objective node (Felder and Brent 2003). Based on a definition of objectives, classroom activities (assignments) are constructed to facilitate learning and students are assessed on the quality of their work as well as in exams. Generally, assessment feedback lags learning activities, making adjustments to the objectives or activities difficult. In a traditional classroom structure this scenario works well because the objectives are determined based on a single disciplinary subject. However, in a capstone course the linear structure of objectives-activities-assessment has at least two shortcomings:

1. It fails to allow diagnosis of student needs prior to design of objectives or learning activities. In a capstone course, a variety of student experiences must be synthesized. However, students are typically on different graduation paths and have different prerequisite coursework experiences. In the traditional
model, it may be impossible to know which students have excelled, which have not and where the needs of the group lie until it is too late to adjust learning objectives.

2. An important part of a capstone experience should be teaching students to formulate problems, rather than simply solve those presented by the Instructor. When objectives, activities and assessment experiences are designed entirely by the Instructor in a linear fashion, students may not be sufficiently challenged to formulate problems independently and consequently be less prepared for their imminent professional challenges and longer-term career development.

The purpose of this article is to present a method that departs from the traditional classroom structure by allowing senior design students to participate more fully in the design of their own course objectives, learning, and assessment activities.

![Figure 1: Relationships between three attributes to define a class structure.](Adapted from Felder and Brent 2003).

**Background**

Although the traditional model has some shortcomings, redesign of a capstone course in construction engineering management must meet at least three challenges:

- Applying the concept of “design” to construction problems that typically engender mastery of management tools rather than traditional civil engineering problem solving skills such as sizing structural members, pavement thickness or pipe diameters.
- Motivating students who are on the verge of starting their professional careers, and are actively seeking employment during the semester.
- Encouraging students to take responsibility for their own learning environment to better prepare them to become life-long learners.

To some extent, each of these challenges is addressed in the literature of engineering or higher education and a synopsis of each as they relate to this course is summarized in the paragraphs below.

By definition, design problems are prescriptive. To assess the relative merit of design alternatives, the designer must keep in mind the needs of the client for whom the design is being developed (Dym et al. 2005). However, the idea of design can be lost in a construction
management course. Although it is clear that construction engineers weigh alternatives, select design variables and assess the relative merits of these with respect to the needs of the client (such as least cost or shortest schedule), the customary business model is different than in consulting on industry. Moreover, the residue of the construction engineer’s design is not permanent or obvious to the client, as the design is typically related to methods of delivery, rather than to permanent structures themselves. Nonetheless, it should be understood that students are not only resource or contract managers; they are engineers and should be challenged as such. Our hypothesis is that allowing students the freedom to work in a less constrained educational environment, i.e., requiring students to formulate their own problems and design unique solutions will better prepare construction engineers to work in a professional setting that is often similarly unstructured. The critical challenge is to strengthen the experience of “generat(ing), evaluat(ing), and specify(ing) concepts for devices, systems, or processes whose form and function achieve clients’ objectives or users’ needs while satisfying a specified set of constraints” (Dym et al 2005).

Motivating seniors can be difficult in the waning months of their academic careers. The challenge with the senior design class is giving the students a means to understand the ways that a senior design capstone experience will benefit their personal and professional development. “If students (especially those extrinsically motivated) are made aware of the direct correlation between the skills they naturally learn from a college classroom environment and those core competencies or transferable skills needed to succeed in various positions within the business world, they may be motivated to actively participate in their education or even perhaps strive toward some form of intrinsically motivated behavior” (Aloisio 2006). By allowing the students to decide their own projects and teams, we hypothesize that students may draw a stronger correlation between the college course and the freedom the exercise in their professional lives (e.g. choosing an employer).

Incorporating students into design of the course objectives and learning and assessment activities, as well as choosing their own projects and teams will create a greater sense of ownership in their projects and sense of responsibility for their education. Quoting Coffman, “Whose responsibility is it for learning to occur in the classroom? The responsibility belongs to both the Instructor and the students.” (Coffman 2003). At the near conclusion of the students’ college experience, the responsibility for learning in the classroom should have almost entirely shifted to the students. At this point in a student’s academic career it is partially the student’s responsibility to know what is expected of them. D’Aloisio states that “A criterion for work is thoroughly explained so students have a clear vision of what is defined as quality work” (Aloisio 2006). Our take on this is that students have had work experience and not only understand what quality work is, but have developed the skills to create quality work. In a capstone class, the students should have the responsibility to decide on a good project, provide constructive input for classroom activities, and be able to assess the quality of work created by other students. Applying design, motivation, and encouraging responsibility are the motivations for the re-structuring of the fall 2006 Senior Design Class in Construction Engineering and Management.
Comparison of Class Structures

We hypothesize that a non-traditional method of assigning class work will better prepare students for careers as construction professionals by strengthening their ability to formulate their own problems. Within the restructured program, students are now tasked with the development of a project team/company, choosing an existing out-for-bid project, justifying the benefits their project brings to the class and team, obtaining publicly available plans and specifications, and ultimately preparing a final bid submission with project specific deliverables defined by each team (see Table 1). The student’s tasks are performed under the guidance of the Instructor with the bulk of the project procurement performed by the students. Although student teams are allowed to choose their projects for senior design, not all projects are allowed to proceed to final bid. Only successfully defended projects as defined by the Instructor with student input will be considered for final submission. The project selection process encourages competition within the classroom. The projects selected by the team far exceed the types of projects that would have been presented by the Instructor (see Table 2). Team members whose projects are not selected must decide upon an approved project and reconfigure their teams to meet the requirements of the new project.

<table>
<thead>
<tr>
<th>LAST YEAR’S CLASS</th>
<th>INFORMATION</th>
<th>THIS YEAR’S CLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provided to the students on the first day of class.</td>
<td>SYLLABUS</td>
<td>Undefined until week six (except for contact information).</td>
</tr>
<tr>
<td>Selected and researched by the instructor. Information provided to the class on the first day.</td>
<td>PROJECTS</td>
<td>Researched and nominated by students. Projects are presented to the class and selected by the students.</td>
</tr>
<tr>
<td>Assigned by instructor.</td>
<td>TEAMS</td>
<td>Selected by the students. Teams are flexible and can be changed during week 5. The ability to change teams is not presented prior to allowing the change.</td>
</tr>
<tr>
<td>Researched, purchased, and provided by the Instructor.</td>
<td>PLANS &amp; SPECS</td>
<td>Once selected, students purchase plans and specs.</td>
</tr>
<tr>
<td>Assigned and Scheduled by Instructor.</td>
<td>SUBMITTAL</td>
<td>Cooperatively assigned with Instructor and Student input. Students select their submittals from a list of nominations.</td>
</tr>
</tbody>
</table>

Table 1: Comparison of information provided in previous classes vs. the re-structured class
<table>
<thead>
<tr>
<th>LAST YEAR’S CLASS</th>
<th>THIS YEAR’S CLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TENNIS CENTER: New construction on a tennis facility located on Purdue’s campus.</td>
<td>KENTUCKIANA MEDICAL CENTER: New construction of a medical center within a medical campus located in Southern Indiana of a medical facility.</td>
</tr>
<tr>
<td></td>
<td>CLARION MEDICAL CENTER: New construction in area around Indianapolis, Indiana of a medical facility. Project is design build, and a student project team has decided to pursue this project.</td>
</tr>
<tr>
<td></td>
<td>SCHOOL EXPANSION: Expansion of an existing school in Northern Indiana.</td>
</tr>
<tr>
<td></td>
<td>CLARKSVILLE LIBRARY RENOVATION AND EXPANSION: Renovation of an existing library along with an expansion to the library west of Chicago, Illinois.</td>
</tr>
</tbody>
</table>

Table 2: Comparison of Projects used for senior design in last years class versus the re-structured class

Students are motivated to convince the class that their project is worth bidding so as to avoid restructuring their team. Once the projects are selected, the students must choose from one of the approved projects and design solutions for their construction project that meets the objectives of the customer, or Instructors in this example. The final bid submission and estimating requirements for a project are determined by the individual teams based on the proposed business structure of the respective team. Standard deliverables are used as a minimum bid submission benchmark for grading purposes. But teams are expected to build upon these minimum deliverables to provide items that are unique to their particular project. By implementing a diverse project selection, the class can determine for themselves which projects best suits their education requirements. In allowing teams to reconfigure their structure and competitively choose and defend their project selection, a better environment conducive to learning the construction bid processes is created. Through the application of these methods the class structure evolves in a manner that accounts for the types of projects chosen, the learning objectives of the students in a given year, and the course requirements by the school. Our preliminary findings are that the course is perceived to be more work than previous configurations, but that many of the students welcome the challenge of defining and meeting their own learning goals.

Throughout the course, information is offered to the students to promote the idea that projects can have value added and that the Owner is hiring them to provide a professional service. Because the Owner may not always know what is best for their project, emphasis on the role of a construction manager or contractor is made in the class to promote the idea that they have to ability to demonstrate ways to add value to a project. Teams are requested to define their roles as a construction manager or contractor, and are then required to justify how they can provide the best product to the Owner based on their organization type. It was difficult to relay to the
students that they had the ability to present ideas to the Owner that could add value to the project even though it may not have been outlined in the Owner’s specifications. We have encouraging the students to try and understand the project from the perspective of the Owner’s need and to be prepared to recommend design, construction, or agreement alternatives that would better serve those needs. This same method was applied to the type of agreement that would best serve the Owner. There was some consternation among the students when requested to consider other agreement methods beyond lump sum.

The final class schedule is presented in Table 3. This schedule was developed in part by the chosen projects, and finalized six weeks after the start of the semester. The format of the schedule involves weekly lectures, guest speakers, team presentations, and laboratory meetings, all of which are designed to evolve the objective-activities-assessment relationship. The ultimate goal of the schedule from the student perspective is to obtain enough information to make a final presentation. The Instructors are there to help the students meet their goal, but it is still the student whose input helps define the schedule. The class activities have also been outlined in Table 3. The student assessments are defined by the team activities in the form of submittals and presentations. Any presentations made by the teams are assessed by the Instructors as well as the other teams. All feedback obtained from the students is documented and submitted back to the presenting team. The students are graded not only on their performances, but on the feedback they give. The feedback the students provide is also assessed, and based on the peer assessments, the activities in the schedule can change. A few the items listed in the schedule warrant additional explanation. Noted under Lab 13 is freestyle submittal with items such as BIM (Building Information Modeling), LEED (Leadership in Energy & Environmental Design), MWBE (Minority and Women-owned Business Enterprise), and Partnering. In addition to the regular submittals, the students are required to select one of the four options and integrate their selection into their project. Some of the freestyle submittals, specifically BIM and LEED, were added based on student input. Lecturers who could elaborate on BIM and LEED were scheduled at the request of some of the students (see weeks 7 and 11). The lecturer in week 7 is from the USGBC (United States Green Building Council), which is the agency that is responsible for the LEED program. The resulting schedule can still be changed depending on the requirement of the students. The instructors remain available to students, and will to obtain any information, within reason, a team may require to complete their project in a manner the students see fit.

By analyzing the relationship between assessment and activities, and accounting for the student input into these attributes, a mutually beneficial objective is developed for the class. Although it had taken a portion of the semester to create the schedule, this is not necessarily a bad thing regarding students learning. Without the schedule, students are forced to express their views about what should be occurring in the class. Their expression is by design, and it allows the instructors to get instant feedback from the class so as to be able to finalize the class structure. The reactions and input of the students coupled with the analysis of relationship between activities allows the infrastructure to finalize the structure of the class.
Date | Lecture / Lab Topic
--- | ---
**WEEK 1** | Lecture 1: Review Class Requirements (Quiz 1: What sort of criteria do owners consider when selecting a contractor or construction manager? Would owner’s be willing to pay more for a more ‘qualified’ contractor? How do owners assess qualifications?)  
Lab 1: Complete proposed company business package (i.e., statement of qualifications).
8/30: Lecture 3 – Reviewing Quiz 1 responses
**WEEK 2** | 8/30: Lecture 4 – Guest Speaker Mike Witteveen w/Tecton: Building (and rebuilding) your CM firm.  Differentiating yourself from the competition.  Adding value for the owner.  
Lab 2: Project Proposals justification (Company Packages, Company Benefits, Owner Benefits)
**WEEK 3** | 9/06: Lecture 5 - Company Presentations: 15 Min Limit w/15 minutes of questions.
Lab 3: Project Presentation 15 Min Limit (Con’t)
9/11: Lecture 6: Company Presentations (Con’t)
**WEEK 4** | 9/13: Lecture 7: Acceptable Projects Announced
Lab 4: Obtaining contract docs. (i.e., plans & specs).
9/18: Lecture 8: Bid Documents (Bid & Performance Bonds). Hand in list of submittals required by contract docs.
**WEEK 5** | 9/20: Lecture 9: (Job Fair)  
Lab 5: Guest Speaker: Mike Duwel w/Holder: Reading RFPs, RFQs, preparing proposals & prequalifications.
9/25: Lecture 10: Advantages & disadvantages of different forms of contract inc. lump sum, cost plus, GMax., shared savings, etc.
**WEEK 6** | 9/27: Lecture 11: Preconstruction submittals schedule  
Lab 6: Submit blank Bid Form from plans & specs, a blank proposed alternate bid form that shows what you think the ideal contractual relationship for this project should be and a cover letter explaining why.
**WEEK 7** | 10/02: Lecture 12: “Buying out” a job (e.g., defining scope & work packages). (Hastak)
10/04: Lecture 13: BIM modeling workshop (Brennan).
Lab 7: Work on subcontractor bid packages
10/09: FALL BREAK ------------
**WEEK 8** | 10/11: Lecture 14: Subcontractor prequals & submittals (Hastak)  
Lab 8: Subcontractor bid packages due by 5:20P.
*Note: CEM using 3153 from 4:00 till 7:00
10/16: Lecture 15: Owner/Designer/Builder interviews (Seager)
**WEEK 9** | 10/23: Lecture 17: Quality, testing & inspection (Hastak).
11/01: Lecture 20: see 3 Nov speaker (Brennan)
- November 3rd USGBC Speaker Brendan Owens (Time TBD)  
Lab 11: Safety Program Submittal Due
**WEEK 10** | 11/06: Lecture 21: Dr. Galloway (Old Masters).
11/08: Lecture 22: Partnering (Hastak)
Lab 12: Quality, Testing & Inspection Submittal Due
**WEEK 11** | 11/13: Lecture 23: Cost Engineering & Submitting Alternates (Hastak)
11/17: Lecture 24: Resource-loaded scheduling (Dunston?)
Lab 13: Freestyle submittal (LEED, BIM, MWBE, or Partnering) due.
**WEEK 12** | 11/20: Lecture 25: Subcontractor meetings
11/21: THANKSGIVING BREAK
**WEEK 13** | 11/27: Lecture 26: Final proposal submission procedures.
Lab 10 (Con’t): Written proposals due, inc. Company Package (e.g. quals), Site Plan, Schedule, Detailed Estimate of General Conditions, Alternates and Price.
**WEEK 14** | 12/04: Lecture 28- Final Presentations & Oral Exam (Optional over Exam Week)
12/06: Lecture 29- Final Presentations & Oral Exam (Optional over Exam Week)
Lab 15: Final Presentations & Oral Exam

**TABLE 3: Schedule for fall 2006 CE 425**

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Summary

The type and quality of projects presented by the students is something that would not have been possible in previous senior design classes. Presenting a potential library renovation with expansion would not have been accepted by the class as a whole. Yet the challenge offered by this particular project was specifically chosen and successfully defended by one of the teams. More importantly, two other teams chose this particular project for their senior design project. Although there were less technically challenging projects, those students who wanted to challenge themselves had the ability to do so in a way that would not have been previously possible. All of the projects chosen were more challenging than any project that could have been developed by the Instructors.

It appears that there is a shift in workload from the Instructor to the student, but this interpretation is not entirely true. Although the Instructor’s workload appears to be reduced, a greater workload is distributed throughout the semester. The role of the Instructor has diverged from classroom teacher to classroom coach in that it is the skills and motivations of the students that define the class and not those of the Instructor. It is more difficult for the Instructor to adapt to a students requirement then it is for the students to adapt to one syllabus designed by the Instructor. This shift is what defines the Instructor’s role in the newly restructured classroom. And by allowing the Instructors to be guides throughout the course, it is believe that motivated students, who are taught to understand the responsibilities of determining their own requirements, will be more adept at designing solutions to construction management problems. Our objective as Instructors is to justify the hypothesis and develop a class that will better prepare students for careers as construction professionals by strengthening their ability to formulate their own problems. After comparing the previous year’s class, we believe that this class is on their way to meeting the objective, but those results will be assessed at the conclusion of the fall 2006 semester.

References


Teaching BIM (Building Information Model) in a Construction Management Program

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It is now widely recognized that BIM (Building Information Modeling) will take over 2D-based CAD systems. BIM is a new building design and documentation methodology that makes the construction process easier and faster for everyone involved. It allows all of the graphical and non-graphical building information for a construction project to be readily available by the use of relational databases. With the emerging concept of BIM, AEC (Architecture, Engineering, and Construction) professionals face new opportunities for enhancing efficiency and refining the practice of building construction. AEC professionals admit that the basic concept of BIM is sound and is the direction in which the AEC industry needs to move.

However, there is no accepted instruction strategy for teaching BIM in AEC-related curriculum. The Department of Engineering Technology at Western Illinois University recently offered a residential design course employing Autodesk Revit Building Version 8.0, a BIM-based software, to its current undergraduate students in the Construction Management program. This paper describes some key insights into the successful employment of BIM in construction educational environments. This paper also introduces several pedagogical challenges from the course.

Key Words: Building Information Model, Parametric CAD, Autodesk Revit, Residential Design

Introduction

In the early 1980’s, architects began using geometry-based CAD (Computer-Aided Design), such as AutoCAD. This change continued with the introduction of object-oriented CAD, such as Architectural Desktop in the early 1990’s. With the emerging concept of BIM (Building Information Model), AEC professionals face new opportunities for enhancing efficiency and refining the practice of building construction. BIM is a new building design and documentation methodology that makes the construction process easier and faster for everyone involved. It allows all of the graphical and non-graphical building information for a construction project to be readily available by the use of relational databases. AEC (Architecture, Engineering, and Construction) professionals admit that the basic concept of BIM is sound and is the direction in which the AEC industry needs to move.

However, there is no accepted teaching strategy for educating BIM in AEC-related programs. The Department of Engineering Technology at Western Illinois University recently offered a residential design course employing Autodesk Revit Building Version 8.0, a BIM-based software, to its current undergraduate students in the Construction Management program. This paper describes some key insights into the successful employment of BIM in the environment of construction education. This paper also introduces several pedagogical challenges from the course.
What is BIM (Building Information Model)?

BIM (Building Information Model) is a new approach of “Virtual Building Construction” based on parametric CAD technology. It is a building design and documentation methodology that significantly improves building design practice and makes the construction process easier and faster for everyone involved. It allows all of the graphical and non-graphical building information for a construction project to be readily available by the use of relational databases that store, access, and retrieve all of the information about building components. The relational databases specify relationships between the various building components to quickly and effectively produce digital representations for the building project. The relationships are predefined based on architectural functions. It also allows any and all components of the building model to be constantly responsive to changes and automatically regenerates the model.

Figure 1 shows an example of the Properties window that explicitly manages component-related information using various parameters. The information in the Properties includes materials, size, geometric positions, structures, and other constraints.

Figure 1: Screen shot of a wall properties window.

The concepts of BIM are implemented by AEC professionals working in the field of building design, construction, and facility management. The primary advantages of using BIM is that it is a quicker, cheaper, and more efficient way of storing construction information for not only architects, but also builders, engineers, and anyone else who needs access to building information. BIM is getting more attention because BIM offers lots of benefits; saves time and money, improves productivity, produces more detailed and accurate drawings, allows for better design decisions faster, produces high-quality construction documents, and ultimately provides more business opportunities. BIM solutions allow architects to devote more time to design rather
than drafting resulting in more precise and accurate construction documentation. There are lots of successful case studies of AEC firms that are using BIM solutions. Examples include SOM (Revit Building), HKS (Revit Building), RTKL (Revit Building), and NBBJ (Bentley Architecture).

**BIM Software: Autodesk Revit Building**

There are lots of BIM-based software; Autodesk Revit Building (Revit), ArchiCAD, Bentley, and SolidWorks. The Freedom Towers project, one of the most important construction undertakings in the United States, is producing construction documentation by using Revit. Disney World has used this software to complete some of its projects and reports it as a successful tool. Many architectural firms, such as SOM, RTKL, and HKS are currently testing to employ Revit as the next generation of CAD system.

Revit is a sophisticated, industry-specific modeling software that is slowly taking over older drafting systems like AutoCAD in the AEC industry. Based on the concept of BIM and parametric CAD technology, Autodesk Revit is able to link building information to 2-D or 3-D models, and rendered models as geometrical outputs.

The most obvious strength of Revit is the fact that it is directly customized for the AEC industry, not being a generic solution for many other purposes. For example, AutoCAD is much more versatile in general drafting, but as for construction design, Revit is much more sophisticated. Revit uses building components such as walls, doors, and windows as opposed to geometric entities such as line, square, or circle. A good example of this illustration is the fact that a soffit under an overhang can be installed in Revit (See Figure 2). The real world material application built into Revit is not possible with AutoCAD. Having the ability to keep information coordinated, up-to-date, and accessible in an integrated digital environment gives architects, engineers, builders, and owners a clear vision of all their projects, as well as the ability to make better decisions faster – raising the quality and profitability of every project.
During fall 2005 semester, the Department of Engineering Technology at Western Illinois University offered a residential design course employing Autodesk Revit Building Version 8.0, one of the BIM-based software, to its current undergraduate students in the construction management program. The construction management program has approximately 200 undergraduate students and produces 40 graduates every year. The course is designed to teach architectural programming, schematic design, the functions of various materials and their synthesis in residential building structures, and the development of construction documents for residential building types. Construction management students gain working knowledge about residential design and construction through this course.

This course was open to any student who had already taken an introductory AutoCAD course and was enrolled in the construction management program. Twenty undergraduate students registered for the fall 2005 semester course. They were required to attend lectures and labs, and work on all class assignments. As a part of the course requirements, they developed a residence using Revit as a term project. The author was solely responsible for the course, and duties ranged from preparing lectures, supervising individual projects, grading quizzes and exams, and designing web-based course interfaces.

Autodesk Revit Building Version 8.0, one of the BIM-based software, was employed and taught in the course. The course started from freehand sketching and architectural diagramming to help students understand the basics of architectural design. Then, several lecture sessions were given to the students about residential construction materials, methods, and systems. Seven lecture sessions conducted by the author were devoted to Revit tutorials. After obtaining the necessary
knowledge-base, students started their own design projects. At the end of the semester, students produced graphical presentation boards and made presentations about their project (See Figure 3). Two residential builders were invited to evaluate the students’ final projects. Students completed a short survey concerning the use of Revit. The survey was distributed on the last day of the semester as a part of the final exam and is primarily designed to obtain feedback about the perceptions of software usability, ideas, and satisfaction.

Student Perception: Revit VS Geometry-based CAD

In the survey, most students reported that their experience with the software was very enjoyable and that the software is well-designed to enhance the efficiency of building construction. Most students were eager to learn the new software because they wanted to master the latest technology before competitive situation. The answers from the survey also indicate that the students’ perception about the software is very positive from the following aspects:

Students had already taken an introductory CAD class, so they know how time-consuming it is to create a building in AutoCAD. The students were also impressed by the fact that repetitive drafting tasks are significantly reduced by reusing building components on all project drawings. Building components can be changed through various parametric properties setting. The parameters also include non-graphical information about the building components. For example, vapor barriers can be placed under concrete slabs by changing “Slab Properties” if needed (Figure 4).

Figure 3: An example of students’ project.

Figure 4: Concrete slab properties.
A change made on any building component in a drawing is immediately reflected on every other drawing with the click of a button instead of revising all drawings. When new building components are added, Revit immediately applies the changes and regenerates all the project drawings to be consistent with one another. For example, when a student makes a change on a certain type of exterior wall in the first floor plan, it automatically makes the change in all the same type of exterior walls on the section details. All of the building components such as walls, floor systems, windows, and doors are stored in a database enabling quick changes to the entire project that would conventionally take huge amounts of time in geometry-based CAD. Students realized that using parametric building components compared to geometric entities is a much faster and more efficient way to create a building design.

Revit manages all of the project drawings in a single file (See Figure 5). It is also possible to review all the project drawings including 2-D drawings, 3-D drawings, rendered drawings, and animated walkthroughs. In Revit, a section cutting line can be added to cut a section anywhere and automatically have a section drawing. In AutoCAD, each section must be drawn manually.

![Figure 5: Project drawing browser.](image)

One of the most tedious tasks in the architectural design process is compiling schedules. The developers of Revit understood this fact when they developed Revit (Fox and Balding 2005). For example, all windows should be counted, categorized, and organized to compile a window schedule. Revit automatically produces various schedules for doors, windows, and room finishes upon placement of certain building components thereby reducing the chance of scheduling errors. The Students really enjoyed this function when they prepared their presentation boards.

Students were interested in Revit’s intelligent error message function which recognizes when something is structurally incorrect. AutoCAD does not have this function either. Revit also shows an error message when there is a conflict among building components. This messaging
system can eliminate unknown errors that cause time-consuming changes after project
construction has begun.

Revit also has the capability to create interior or exterior 3D perspective views and rendered
models of the building. Students were happy with the fact that they can create rendered
perspectives without any additional training. The rendering process of Revit is much simpler
than other rendering software. Although the graphic quality is not sufficient for sophisticated
commercial renderings, it is suitable to create renderings for client feedback.

Figure 6: An Example of Rendered Interior View.

Pedagogical Challenges

The analysis of student comments from open-ended questions revealed improvements that can be
made in the software for better functionality.

Level of Knowledge Required to Learn Revit

One thing that the students did not enjoy was that it was difficult to learn many of the Revit
functions as a beginner. From the start of the semester, it was complicated for the students to
learn the tools of Revit, such as Properties, Stairs, Floor openings, Footings, and Foundations
because these tools associate with many parameters that require expert construction knowledge
and are not easily understood by the students. Vandezande (2004), CAD manager of Skidmore,
Owings & Merrill, said “the senior team members with less computer experience, but greater
knowledge of design and constructability seem to fare better with these tools than some of the
younger designers.” This is because Revit produces a model that contains a lot of technical
information. With Revit, architects need to make clear decisions about all the building
components during the design phase to properly use BIM.

Several students pointed out that Revit should develop an easier user interface or self-
exploratory mechanism for the Properties windows for beginners. The students feared changing
some of the parameters by opening “Properties” windows because the windows reveal so many
technical details that are confusing for the students lacking technical expertise. For example,
even though it is easy to draw using Revit, the students who did not have prior construction
experience had trouble with the foundation walls and footings.
Lack of Reference Materials

Students did not like the fact that there are not enough textbooks and reference materials available for them. Even though Autodesk provides several online materials and online discussion boards, the students wanted to obtain more knowledge from written materials when immediate help was needed.

Mimic Construction Sequences

Students did not like that the walls must be drawn before the footings and foundation are in place. They prefer to fully mimic construction sequences. The students also expected Revit to employ more structural systems, such as rafters, beams, and trusses.

Intelligent Error Detection and Correction

Revit partially embeds design rules in the model for intelligent error detection. Recognizing that Revit is rapidly expanding its capabilities, students would like a version of Revit that would detect their mistakes and propose solutions to correct them. The problem is the possibility of unrealistic design solutions. In fact, students feared that Revit allowed them to draw something that could not be built in the real world. For instance, Revit should not allow a load bearing wall without supports because it is not possible in the real world. As an example, Revit lets students draw a slab with a hundred foot span without proper beam support. It would be great if Revit displayed a message to let them know what the load factor is and gave some suggestions for proper beam locations necessary to build the structure. This is important information that the builder needs to check on the plans. Another example is the garage. Revit allows the design of a garage that is not large enough for a normal car. Furthermore, students expect the more intelligent functions to provide in-depth technical support. This would help students learn how to build a properly constructed building.

Limited Component Database

The answers from the survey indicate that students felt Revit is too limited by the databases. Although there is an abundance of materials and components that can be used in Revit, students still believe there should be more options to build a “virtual construction model.” Ibrahim and Krawczyk (2003) also pointed out that we need to wait until new components are available on the market if a new building is to employ creative and innovative design solutions. It is possible that certain brands of materials and components are not available when you want to use them according to project specifications. There are many new styles of construction being developed today and Revit should fully represent all of them.

Conclusion

As the end of the semester is approaching, students have realized how Revit enabled them to finish their final project before the due date by keeping all of the building information.
coordinated, reducing repetitive drafting tasks, and keeping all of the project drawing organized. This course has allowed the author to become familiar with many pedagogical challenges of implementing BIM and encouraged the author to participate in endeavors to meet those challenges. This course also gave invaluable insights about teaching BIM in a construction educational environment.

BIM is not merely new software or a new drafting technique; rather, it provides important and inter-related models of construction, such as design, construction technology, and facility management. All of the students think that the basic concept of BIM is sound and the direction in which The AEC industry needs to move. Students also pointed out that supporting technology will continuously improve to resolve current shortcomings. After introducing BIM, students were eager to learn seriously because they wanted to master the latest technology before competitive situation. This course definitely helps them expand their knowledge of the AEC industry.

Another issue is how to set up a new course based on the concept of BIM. Teaching BIM requires higher construction expertise based upon practical job experience. The course would provide industry-required knowledge to prepare students for successful careers in the AEC and AEC-related industries. To accomplish this goal, instructors should place more emphasis on the use of BIM through restructuring the format of drafting courses to deliver the working knowledge necessary to properly teach BIM.

Reference


Teaching Spanish to Construction Managers

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A new course, Hispanics in Construction, is being developed as a senior-level undergraduate elective, and as a continuing education course for the local construction industry. The course objective is to prepare construction management graduates who have little or no prior foreign language training to communicate with Spanish-speaking workers on construction job-sites, and to understand cultural differences that may lead to miscommunication. The course content will emphasize construction safety. Development of course materials and pedagogy will be examined.

Key words: Spanish, Hispanic, foreign language, construction safety

Introduction

Communications between English-speaking construction management personnel and their Spanish-speaking workforce is a growing concern, particularly with regard to jobsite safety issues. The number of Hispanics in the U.S. has increased steadily in the last few decades. In 1980, Hispanic population accounted for 6.4% of all U.S. residents (McManus, et al., 1983). In 2000, that number had increased to 12.4%, or 35.3 million of the 281.4 millions U.S. residents, with Mexican Americans making up 58.5% of all residents of Hispanic origin (http://www.census.gov/prod/2001pubs/c2kbr01-3.pdf). While the most sizeable Hispanic populations still tend to be in the border states of the Southwest and in Florida, Hispanics represented between 6 and 24.9% of the population in several unexpected locations, including counties in Georgia, North Carolina, Iowa, Arkansas, Minnesota, and Nebraska. States such as Illinois and New York, and cities including Philadelphia also have large populations of Hispanic origin (http://www.census.gov). According to population projections of the U.S. Census Bureau, by 2050 24.4% of the total U.S. population will be of Hispanic origin (http://www.census.gov/ipc/www/usinterimproj/natprojtab01a.pdf). In 2004, the construction industry employed 21% Hispanic workers, significantly more than the average of 13% for all industries (http://www.agc.org/galleries/default-file/Simonson.pdf).

While the St. Louis construction workforce is not heavily Hispanic, a local construction company has encountered an increasingly Spanish-speaking workforce on projects in South Carolina, Nevada, Puerto Rico and other areas, and encouraged the SIUE Department of Construction to develop a course to improve communication between English-speaking management personnel and Spanish-speaking workers. While the immediate need could be met through a short course, the Department of Construction advertised the course, titled “Hispanics in Construction,” as an undergraduate elective, and in the first offering has attracted sufficient construction students (13) to justify offering the course. The course instructor is a native Spanish speaker whose professional expertise in architecture and construction management affords SIUE a unique opportunity to meet the perceived need for language instruction. The course will focus on practical construction-oriented vocabulary, using scenarios involving common construction tools, equipment, situations, injury-causing hazards and first aid as the basis for teaching key
vocabulary words. Cultural issues such as the major holidays that impact Hispanic workers in the construction industry, the role of religion in the work life of Hispanic workers, polite ways to address and direct workers, and other points of potential misunderstandings and conflict resulting from language and cultural differences will also be introduced.

**Review of Literature**

So-called “Survival Spanish” emerged in the mid-1970s as pre-packaged courses for various professions dealing with a growing Hispanic population in the U.S. (Lillyman, 1993). By the mid-1970s, these courses, variously titled “Commercial Spanish,” “Street Spanish,” or specifically tied to an occupation, such as “Spanish for Medical Personnel” were standard offerings at community colleges and urban college campuses in the U.S. (Honig and Brod, 1974). Command Spanish® is a commercial provider of occupational language training materials that trains and certifies instructors, and licenses institutions of higher education to be registered providers. A review of Command Spanish® providers indicates that most participating institutions are community colleges. There are four licensed official registered providers at Illinois community colleges, three in the Chicago area and one in southern Illinois, and none in neighboring Missouri.

Occupational language courses are designed to teach workers basic skills in Spanish language for the contextual needs of a particular occupation: nurses, lawyers, teachers, school counselors, and social workers are often mentioned in the literature (Honig and Brod, 1974, Breseler and Schultz, 1980, Lillyman, 1993). Surprisingly, the need for “survival Spanish” for the construction industry seems to have been recognized only within the past few years. In their exhaustive listing of occupations that would benefit from having a foreign language as an auxiliary skill, Honig and Brod (1974) made no mention of construction workers or construction professionals. Only one paper on the topic of foreign language competency of construction management undergraduate students can be identified in the conference proceedings of the Associated Schools of Construction from 1987 to the present (Kay, 2001), and one tangentially related to foreign language in the Journal of Construction Education from 1996 to the present (Bodapati and Kay, 1999). Foreign language courses were not part of the curriculum at member schools of the Associated Schools of Construction in a survey by Kibert, et al. (1992), and surveys of needed skills of construction management graduates do not list foreign language, but focus on computing, oral and written communication (in English), practical field experience, and knowledge of construction law (Mead and Gehrig, 1995, Sounder and Gier, 2006). Foreign language competency currently is not a required element of the curriculum of construction programs accredited by the American Council for Construction Education (www.acce-hq.org).

Thus, while other professions have recognized the need for a minimal degree of foreign language competency, the construction industry seems to have arrived late at the realization that changes in the construction workforce will make foreign language skills a valuable asset to the construction professional. The Associated General Contractors’ Tool Box Safety Talk series appeared in Spanish in the late 1990s, and its guide for a basic company safety program appeared in Spanish in 1998. Melton’s *Survival Spanish for Construction* was published in 2001, and a variety of Spanish-English construction dictionaries published by R.S Means, McGraw-Hill, and DeWalt have appeared since 2001. Courses in Spanish for construction began appearing in
community colleges and as continuing education courses at universities such as the University of Alabama Birmingham in the early 21st century as well. Central Piedmont Community College in Charlotte, North Carolina teaches Command Spanish® Program called Spanish for Construction Sites, a “comprehensive Spanish language program that provides immediate access to functional language skills for non-Spanish-speaking construction site supervisors.”

**Course Objective**

The course objective is to enable students to master a basic construction vocabulary in the Spanish language in both spoken and written form, and to promote understanding of Hispanic culture. Emphasis will be placed on understanding spoken Spanish within the context of the construction workplace.

**Course Content**

Survival language courses focus on a particular need. Travel-oriented courses prepare tourists to ask for directions to cultural attractions, hotels or good restaurants. Construction managers need interact with the superintendent on the jobsite to communicate company safety policy, discuss daily activities, needed manpower, equipment and material resources, and update progress schedules. This course will focus on construction safety, and the course material will be built around typical jobsite scenarios where safety is a concern, placing the vocabulary in the context of construction to aid student learning. A list of the top ten safety issues and a copy of a company safety orientation from a local construction company, together with material from the OSHA 10-hour safety certification course are the basis for course scenarios and relevant vocabulary. Vocabulary lists from other sources will be consulted, including *Survival Spanish for Construction* (Melton, 2001), *Learning Construction Spanglish* (Eddy and Herrera, 2000), *Easy to Learn Construction Spanish* (Gumucio, 2005), and *Workplace Spanish for Commercial Construction* (Workplace Spanish, Inc., 2004). The course will use the Means Spanish-English Dictionary as the primary reference source, and will include extensive speaking and listening time outside the classroom to build skills introduced in the classroom.

A preliminary topic outline for the course is given in Table 1.
Table 1. Topic Outline for “Hispanics in Construction”

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
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<tbody>
<tr>
<td>1</td>
<td>Introduction and Hispanic Facts</td>
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<td>2</td>
<td>Personal Protective Equipment</td>
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<td>3</td>
<td>Hand Tools</td>
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<td>4</td>
<td>Site Hazards</td>
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<td>5</td>
<td>Housekeeping on the Jobsite</td>
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<tr>
<td>6</td>
<td>Hazards on the Jobsite</td>
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<tr>
<td>7</td>
<td>Common Injuries: Scaffolds, Ladders, and Lifts</td>
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<td>8</td>
<td>First Aid</td>
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<td>9</td>
<td>Trenching and Excavation</td>
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<td>10</td>
<td>Heavy Equipment</td>
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<td>11</td>
<td>Electrical Power</td>
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<td>12</td>
<td>Safety Inspections</td>
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<td>13</td>
<td>Courtesy and Politeness</td>
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<td>14</td>
<td>Drugs and Alcohol</td>
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<tr>
<td>15</td>
<td>Review and Taco Party</td>
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</tbody>
</table>

Pedagogical Considerations

A variety of instructional techniques are available for teaching of a second language to adult learners who have little or no previous experience with the Spanish language. Benseler (1980) summarized the various approaches used in college-level foreign language instruction, and concluded that there is no consensus on which approach is most effective. The proposed teaching method will most closely resemble the audiolingual approach introduced by the U.S. Army Specialized Training Program during World War II (Benseler, 1980). The audiolingual method is based on the theory that language is learned through habit, and emphasizes speaking in everyday language rather than reading, translating, or forming correct grammatical sentences. Teaching techniques include a variety of active-learning situations in which students hear, speak, see, and write new vocabulary, with emphasis on students hearing before speaking, and seeing before writing. Lillyman (1993) asserts that instruction should include intensive practice on recognition of vocabulary in class, through role-playing, one-on-one repetitive practice with a partner, and memorization of key phrases. The instructor acts as a facilitator, directing the students in activities, guiding and providing instruction, but doing little lecturing. Native Spanish speaking construction tradesmen will be recruited to assist in oral quizzing of students, and students will attend Spanish conversation hours on campus for additional listening and speaking practice. Examinations will include written vocabulary identification, with individual testing on correct pronunciation and understanding of spoken words.

Daily introduction of vocabulary will include no more than twenty new words in the appropriate context, and will build on previously mastered vocabulary. Single word commands and simple nouns will make up the bulk of the vocabulary. Mastery of grammar, parts of speech, conjugation of verbs, and other foreign language learning skills will be de-emphasized or eliminated. Listening will be done in small doses on the order of one to five minutes, and should consist of words that fit in the context of construction. A video segment from an episode of Bob the Builder® will be used as a means to introduce simple sentences and construction vocabulary,
and to interject a needed element of humor to reduce student anxiety about learning a new language.

Desired student outcomes include recognition of written words, recognition of spoken words, and the correct identification and usage of vocabulary in written and spoken form. Correct pronunciation will be emphasized. Simple subject-verb sentences and single words to identify objects or issue directions will be taught with little emphasis on changing verb tense or using correct pronouns. The objective is for the student to achieve a vocabulary of 500 key words and subject-verb phrases by the end of the course.

Classroom Resources

The classroom setting, including class size, instructor, and available resources are essential to facilitate learning a second language. A low student-to-teacher ratio is essential for learning, and recommended class size for beginning language classes is twenty. The instructor is a key component of the classroom. The instructor should be trained in foreign language instruction for adult learners. Professional associations such as the American Council for Teaching Foreign Languages (ACTFL) and Teachers of English to Speakers of Other Languages (TESOL) provide guidelines and certification of foreign language instructors. Desired characteristics for the instructor include not only fluency in the both the primary and secondary language of the students, but good organization skills and an approachable manner that does not discourage or intimidate students, who will feel anxiety about their lack of foreign language skills. The classroom should accommodate a variety of presentation media for visual reinforcement of spoken or written words or phrases. Graphics such as posters, worksheets and photographs should be available to give visual clues to the connection between written words and their meanings. Audio resources should be available to reinforce pronunciation and understanding of spoken communication. Finally, print material should be available to provide reinforcement for the visual or aural resources.

Additional Opportunities

The course is being developed as a senior-level undergraduate elective. The course will meet for three hours once weekly over a fifteen week semester, for a total of 45 instructional hours. The course will also be offered in the summer as a continuing education course in a compressed, one-week format for local construction professionals.

Conclusions

Instruction in occupational Spanish has been offered at community colleges across the United States since the 1970s, but courses aimed at the construction industry have appeared only recently. Four-year construction management programs typically do not include foreign language training, and industry surveys historically have not given priority to foreign language skills as a desirable program outcome for undergraduates. However, the growing Hispanic population and recruitment of Hispanic workers by the construction trades will increase the need for construction management personnel to have a working knowledge of the Spanish language in the context of construction jobsite situations, especially safety. The SIUE Department of
Construction is offering construction management undergraduate students and local construction professionals an opportunity to develop basic communication skills in Spanish, allowing them to work more comfortably with a Hispanic construction workforce on projects across the United States.

**References**


A Diffusion of Innovation Perspective for Construction Waste Management

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Waste generated in construction and demolition sites are disposed away in landfill sites, increasing the burden on landfill loading and operation. Waste management is getting more importance in construction industry and a warning signal has been released because of the environmental problems. Reduction, recycling and waste reuse are considered as the only methods to recover waste; however, implementation still has room for improvement. Based on the diffusion of innovation theory, this paper examines the diffusion of the construction waste management concept and innovations within the construction industry and explores factors that drive or impede the diffusion process.

Keywords: Construction, Waste Management, Diffusion of Innovation, Drivers, Barriers

Introduction

Construction and demolition debris is a large portion of waste disposed in U.S. landfills. The U.S. Environmental Protection Agency (EPA) has estimated that construction and demolition (C&D) debris accounts for 24% of all municipal solid waste (Jones, 1993). Waste from single family home construction in the United States typically produces between two and four tons of debris (Jones, 1993). Waste audits by Laquatra and Pierce (2004) confirmed that these waste volumes were still valid. Figure 1 illustrates the estimated waste for a typical 2,000-square-foot home. Beyond the sheer volume of material entering the waste stream, the toxic nature of materials such as adhesives and solvents creates a need for a separate disposal process. As early as 1990, some jurisdictions began mandating separate dump sites for such materials as C&D waste was banned from conventional landfills (Piasecki, Ray and Golden, 1990; Yost, 1995).

In addition to the environmental issues, there are obvious economic costs to builders for waste disposal. A survey by Austin (1991) indicated that 65% of home builders were concerned about the high cost of construction waste disposal. Since 1991, disposal costs have increased many folds. Waste disposal costs impact affordability of homes as well as builder’s bottom line. The good news for builders is that the robust housing market has allowed these costs to be passed along to the home buyer (Laquatra, 2004). The National Association of Home Builders (NAHB) has demonstrated that builders pay twice for construction materials that could be recycled but end up in landfills. Payment is made when the materials are purchased and fees are assessed when the materials are dumped (Yost, 1995). These costs are then passed on to homebuyers in the form of increased home prices. Aside from the costs of disposal and affordability, ethical questions related to the squandering of resources and declining availability of landfill space require that waste management be addressed systematically in new construction and remodeling.
Table 1: "Typical" Construction Waste Estimated for a 2,000-Square-Foot Home (Source: NAHB's Internet Home Page, Residential Construction Waste: From Disposal to Management, Oct. 1996.)

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight (in pounds)</th>
<th>(percent)</th>
<th>Volume (in cubic yards)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Sawn Wood</td>
<td>1,600</td>
<td>20%</td>
<td>6</td>
</tr>
<tr>
<td>Engineered Wood</td>
<td>1,400</td>
<td>18%</td>
<td>5</td>
</tr>
<tr>
<td>Drywall</td>
<td>2,000</td>
<td>25%</td>
<td>6</td>
</tr>
<tr>
<td>Cardboard (OCC)</td>
<td>600</td>
<td>8%</td>
<td>20</td>
</tr>
<tr>
<td>Metals</td>
<td>150</td>
<td>2%</td>
<td>1</td>
</tr>
<tr>
<td>Vinyl (PVC)</td>
<td>150</td>
<td>2%</td>
<td>1</td>
</tr>
<tr>
<td>Masonry</td>
<td>1,000</td>
<td>13%</td>
<td>1</td>
</tr>
<tr>
<td>Hazardous Materials</td>
<td>50</td>
<td>1%</td>
<td>-</td>
</tr>
<tr>
<td>Other</td>
<td>1,050</td>
<td>13%</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>8000</td>
<td>100%</td>
<td>50</td>
</tr>
</tbody>
</table>

To assist the construction industry, private and governmental organizations have developed process guidelines and database tools to link waste producers with firms that recycle or reuse waste materials. The EPA’s *Planning Guide for Construction and Development* (DATE) and the NAHB's *Residential Construction Waste Management* (Lund, 1996) identify ways for builders to reduce, recycle or reuse. Internet resources have been developed by many jurisdictions including Alameda County California’s stop waste program (http://www.stopwaste.org) and the California’s state-wide Integrated Waste Management Program (http://www.ciwmb.ca.gov/). The Partnership for Advancing Technology in Housing (PATH) and its information service for home builders, Toolbase, provide easily accessible resources related to waste minimization and innovative programs from around the nation, such as a Minnesota project to recycle used asphalt shingles into hot mix asphalt.

In spite of available resources, experience indicates that builders remain reluctant to invest in waste minimization. Although up to 80% of construction waste has substantial potential for recycling (Laquatra, 2004), the Toolbase website noted that actual recycling is dependent upon the financial cost/benefit tradeoff associated with collection, separation, and transportation of waste materials and the return on investment.

In this paper, the diffusion process and the drivers and barriers to Construction waste management practices are examined in terms of the theory of diffusion of innovations (DoI) by Timothy Lindsey(Lindsey, 1999). The theory provides a theoretical base for accelerating the issues affecting the adaptation of Construction waste management practices (the invocation). The paper starts with the introduction of the DoI theory. Using the DoI perspective, the paper then demonstrates how the theoretical framework can be used to investigate the diffusion of construction waste management practices in the construction industry. The concluding section of the paper explains the steps for future research using the proposed framework.
Diffusion of Innovation

Although the study of diffusion of innovations began with Tarde’s 1903 book on The Laws of Imitation. A systematic and synthesis model of the diffusion of innovations was presented by Rogers (Rogers 1962). Since that study’s publication, more than 5000 research papers have appeared on the diffusion of such diverse innovations (Haider & Kreps, 2004) such as agricultural practices (Fliegel 1993), technologies (Palmer et al. 1993), and political reforms (Starr 1991).

Rogers defines diffusion as the process by which an innovation is communicated through certain channels overtime among the members of a social system (Rogers, 2003-2005). Roger’s DOI model involves four main elements that are presented in the diffusion of innovation process: the innovation, communication channels, time and social system. A universality or similarity found amongst the various research studies on the diffusion of innovation process is that the adoption process or the rate of diffusion can be charted on an S-shaped curve, which shows the percent of adoption over time (Figure 2).

![The Diffusion Process (Rogers, 2003)](image)

**Figure 2:** The Diffusion Process (Rogers, 2003)

The slope of the S-shaped curve varies depending on the innovations under investigation. The diffusion rate has become an important area of research to sociologists. The diffusion of innovation process can be traced on a micro level as is the case of an individual particularly for a new personal product, or traced at the macro level as in the case of organizations, communities, regions or cities when considering economic development or technological advances.

Rogers created adopter categories based on the time when the adaptation units pick up the innovations (Figure 3). Adopters at the same categories generally share similar characteristics.
Earlier adopting individuals or units tend to be more well-informed and knowledgeable, have higher social/community status and upward social mobility, have greater empathy, less dogmatism, a greater ability to deal with abstractions and risks, greater rationality and intelligence, higher aspirations, greater exposure to mass media and engagement in more active information seeking. The later adopters (i.e. the later majority and laggards) tend to be more sceptical and traditional in nature, and often have fewer resources to implement new innovations untested in the market.

![Figure 3: Model of Adoption Process and Adopter Categories (Rogers, 2003)](image)

**The application of Diffusion of Innovations theory in Construction**

Most individuals involved in the diffusion of innovation pollution prevention (P2)/ recycling strategies would agree that while many successful cases of construction waste management adoption have been documented, construction waste management continues to diffuse relatively slow across most construction sectors. Construction is often accused of being a laggard industry in adopting new technologies (Computer Times, 2002). For home builders, shying away from innovation may be rational behavior as there is considerable market and financial risks associate with innovation and builders therefore rely on established manufacturers who guarantee their products (Koebel et. al., 2004). Many innovative technology product start-ups servicing the construction industry go out of business as a result of slow adoption rates, even though many can offer measurable benefits to the construction industry in terms of time, cost, quality and/or safety (Taylor and Björnsson 2002).

In terms of technology diffusion, behavioral change is often the key to successful implementation of innovation. For example, instead of putting all construction waste in a dumpster, it may need to be sorted on-site to allow reuse of recycling. Or, more upstream planning could reduce the amount of post-installation waste reaching the job site. These suggested practices for P2/recycling require builders to change operational procedures.
Construction waste management is similar to many other innovations and is bound by the constraints that affect all new ideas and technologies. A summary of the reasons for construction waste management practices’ relatively slow adoption rate is provided below:

- **Prevention/Recycling is a “Hard-Sell”** Prevention/Recycling tends to be a difficult concept to sell because the benefits occur in an unknown distant future and requires real behavior change which can reduce comfort and increase complexity (Rogers, 2003).

- **Change Agent Identity** Government change agents that actively promote construction waste management are generally regarded as being “very different from” or even “hostile to” the private sector entities they are trying to influence regarding construction waste management adoption. Businesses do not normally turn to government agencies for sources of innovation (Bierma and Waterstraat, 1995).

- **Emphasis on Awareness** Most entities that are actively trying to promote construction waste management have focused on creating “awareness knowledge” of construction waste management practices. Emphasis has been placed on creating fact sheets, databases, and internet resources. These materials generally are effective at describing the advantages of various construction waste management practices. The change agents that distribute the awareness materials often become frustrated with their clients for not adopting the practices they feel that the awareness information should be adequate to justify adaptation. However many change agents fail to recognize that assistance with developing sound technical principles and “how-to” support regarding implementation of construction waste management practices are also required to ensure that the practice are adopted.

- **Optional Nature of waste management** Very few regulatory requirements have been instituted that require the implementation of construction waste management. While most potential adopters recognize its value and importance, the choice to adopt construction waste management practices remains predominantly optional, with little urgency associated with it. Consequently, Recycling/pollution prevention tends to be pushed aside in favor of more immediate compliance-oriented strategies that are not optional (Lindsey, 1998).

### Investigation of Construction Waste Management Using the D.o.I. perspective

To help mainstreaming construction waste management practices in the residential construction industry, the author will borrow the lens of the DoI theory to examine the diffusion of Construction waste management in the private residential construction industry. In this case, the innovation being investigated is “construction waste management practices” and the social system is the residential construction industry. Understandably, the diffusion process in the industry will involve all players in the industry, including home builders, renovators, contractors, subcontractors, consultants, architects, suppliers and other trade businesses. However, the author have chosen to focus the study on Builders because they are the key players that produce or make decisions in the housing communities and infrastructure, and hence have bigger impact on in the diffusion process.

An effective model for promoting the diffusion of P2 technologies was investigated to apply the diffusion of construction waste management practices in the industry. This model — called
Accelerated Diffusion of Pollution Prevention Technologies, or ADOP2T™ — is founded on time-tested innovation diffusion principles that have been applied to innovations in industries as diverse as agriculture and communications (Lindsey, 1999).

Figure 3: Accelerated Diffusion of P2 Technologies (ADOP2T) Program Planning Model (Lindsey, 1999)
A general process flow diagram or planning model describing how this could be applied to a given sector is presented in Figure 3 and is described below.

**Identify Opportunities**

A major task is to identify the types of construction waste being generated by home builders. The literature suggests two to three tons per home. Researchers are aware of some practices that are reducing the amount of waste generated, such as removing dumpsters from building sites and requiring subcontractors to dispose of waste directly. While this practice may minimize waste per home, it is still not being recycled/reused. A list of typical waste will be compiled from the research and builders will be interviewed to verify (a) types and volume of waste, (b) cost of disposal, and (c) method of disposal. Waste disposal practices will also be observed to confirm interview results.

**Identify Opinion Leaders**

Using an interview pattern, a series of interviews will be conducted with builder partners to identify barriers to implement effective construction waste management practices. As a result of the interview process, a site-specific construction waste management plan will be proposed for implementation. Although details must await research and input from builders, it is anticipated that at a minimum the construction waste management plan will encompass (a) sorting of waste materials, (b) reuse or recycling whenever practical; (c) disposal only of non-recyclables; and (d) substitute materials made of recycled components.

**Recruit Mentors**

By maintaining good relationship with the Illinois builders and the professional organizations such as National Association of Home Builders (NAHB), Influential builders will be identified and approached to establish a partnership to be mentors for other builders. They will be identified based on the leadership roles in the construction community, their willingness to adapt to new practices, and their potential to act as mentors for other builders. Home Builder partners will be vital to success in assisting and educating individual builders and businesses to prevent pollution.

**Establish Demo Sites at Opinion Leader Facilities**

Once an acceptable construction waste management plan has been developed, pilot projects will be established with partners. Work under this task will include the following activities:

a. **Plan the project** – each pilot project will present a different set of challenges, the builder will get help to develop an effective waste management plan outlines job site waste reduction goals, identifies targeted materials, describes specific waste reduction actions to be implemented in the project, and identify reuse, recycling, or disposal facilities to which materials will be taken.

b. **Estimate amount of waste expected** - using the current guides and the builder experience, the builder will estimate the project’s “waste stream”.
c. **Coordinate recycling by project phase** - as the pilot project propagates, the focus of the activities will change, and therefore waste materials and qualities will change. The builder will predict what materials will be generated and when. That will help for efficient hauling of both recyclable and non-recyclable materials.

d. **Determine what is cost-effective to recycle** - using the previously developed database for the waste materials. The builder will determine, with the change agent help, the cost-effectiveness of recycling, by calculating each material’s cost per ton for recycling versus land filling by estimating labor costs, transportation costs, hauler’s fees and tipping fees.

e. **Work with the haulers to plan collection** - Most construction sites have moderate to severe space constraints. We will work with the builder and the hauler to develop a plan to stage the job site for the most effective method for storing and collecting both recyclable and waste, positioning recycling bins at the most convenient location for the various trades to use.

**Provide Demos to Business Customers**

In order to speed up the adaptation process, we will facilitate demonstration events at each pilot site whereby other builders can see first hand how the waste management plan is implemented. Also, by working builder partners throughout the pilot project, The goal is to research and document key aspects of the pilot projects that will be needed to promote diffusion of expanded construction waste management to other Builders. This includes:

1. Types of staff, from all trades, involved in the pilot project.
2. Processes used in undertaking the pilot project (meetings, documentation, decision-making processes, etc.)
3. Metrics, cost and technical analyses used in the pilot project.
4. Pilot project outcomes – successes, failures, aides, and barriers – particularly with regard to reductions in wastes and costs.

**Conclusion**

Although there were a number of studies that looked at the innovation diffusion mechanisms in the construction industry (Koebel et al., 2004; Sexton et al., 1999), no critical studies have been constructed so far to examine the construction waste management practices using a combined quantitative and qualitative methodology of research to yield a comprehensive picture of the phenomenon. The author proposed in this paper that through the Diffusion of Innovation perspective, the phenomenon of how and why construction waste management practices as an innovation can be institutionalized in the construction industry can be studied under a coherent and systematic framework. This framework will be used to guide my further research that set out to examine the relationships between the diffusion process and the different element in the diffusion framework.

The ADOP2T model should substantially improve the diffusion of construction waste management practices because it provides mechanics to address the deficiencies that are common in other models. The key to this model’s success will center on providing the “how-to”
knowledge required for successful implementation. The ADOP2T model also offers the further advantage of providing results that are readily measurable.

References

A Course in Building Information Modeling for Construction Students

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A new course is being developed to explore the emerging field of Building Information Modeling (BIM) and how it may be applied in Construction Management. Students will learn to use software for developing three-dimensional models of buildings for estimating, scheduling and construction planning. The use of technology for recording three-dimensional information to monitor construction will be investigated, and applications for implementing virtual reality in construction will be developed. This course will require strong quantitative skills and the ability to modify simple existing computer programs to process data. Students should have completed a computer applications course that includes spreadsheet applications and three-dimensional computer-aided drafting. They are expected to have completed, or at least be enrolled in, the senior-level estimating and scheduling courses. The paper will describe the course objectives and outline and give samples of projects that will be completed by the students.

Key Words: Building Information Modeling, BIM, three-dimensional models, virtual reality, parametric models

Introduction

Three dimensional modeling and analysis software has been used by building design professionals since the 1980’s, but the resulting design drawings were still two dimensional views and sections. The adoption of computer-aided drafting did little more than convert pencil drawings to an electronic format. While the concept of using a common, solid, parametric, three dimensional computer model of all building components has been discussed for decades, the development of design software, inexpensive computer hardware, and data standards are rapidly converging to finally make this approach to building design and construction a reality in the early 21st century. Building Information Modeling (BIM) has become the accepted name to refer to this technology.

A BIM is a three dimensional computer model composed of objects associated with relevant information (AGC, 2006). For example, a simple one room structure may be modeled as a floor slab, four walls and a roof. The walls may have windows and doors. All of these entities are objects. The position, size and shape of each object are displayed in the three dimensional model. This information can be used to check that all parts fit properly and to calculate length, area and volume quantities. Associated information may include material specifications, manufacturer’s details, cost data and sequencing and scheduling data. Ideally, the BIM should be initiated by the architect with input from other designers added to it. The constructor will use the BIM to estimate, schedule and manage the construction. “As-built” detail information will be added by the constructor so that the BIM turned over to the owner can be used throughout the building’s life-cycle to manage maintenance and remodeling.
The members of the project team may all use different, special-purpose software, but all of these programs must communicate through a common data format. The emerging standard is the Industry Foundation Classes (IFC) being developed by the International Alliance for Interoperability. Popular estimating and scheduling programs, including Timberline and Suretrak, currently read and write to this format. While careful checking would still be required, automatic quantity takeoff would improve both the speed and accuracy of estimates. The schedule can also be linked to the three dimensional model to allow construction animation to enhance project planning and management. The availability of an accurate three dimensional model of the building also provides a rich set of data that can simplify and enhance layout and inspection.

Construction management programs should begin to introduce this technology to future graduates. At a minimum they should be provided with both conventional 2D plans and a BIM for a project used in upper level estimating and scheduling classes. Some students may be interested in additional coursework to learn to create a BIM from 2D plans when it is not provided by the designers. Elective courses may also be developed to prepare students to exploit the full potential of a three dimensional, solid model of the structure they are building.

The Construction Department at Southern Illinois University Edwardsville is offering a course in Building Information Modeling for the first time in Spring 2007. Students will learn to create BIMs of simple structures using off-the-shelf software and use these models for estimating and scheduling. In addition they will be introduced to hardware and methods to monitor the construction using the 3D model. Finally, they will extract information from the IFC file to create virtual reality models. Students must have completed the Computer Applications in Construction course and have completed or be enrolled in the Estimating and Bidding and the Planning and Scheduling courses. They must have strong quantitative skills in order to be able to manipulate the three dimensional data.

**Course Objectives**

This elective course is designed to challenge construction management students by providing a more detailed understanding of the technology behind three dimensional models of building structures in order to provide them with the skills to exploit these models throughout the construction process. The objective of the first phase of the course is to be able to create models of simple structures using architectural design software and develop accurate estimates from these models. In the second phase students will become familiar with the IFC format and learn to extract information about the building geometry from a file. They will use this data to create a virtual reality model of the building. The goal of the third phase is to learn to record and manage 3D data measurements taken from the structure using the BIM.

**Topics**

ArchiCAD /Revit

Software companies currently marketing software for BIM include Graphisoft and Autodesk. Graphisoft’s ArchiCAD has been a leader in 3D architectural design software for two decades. They recently introduced the Constructor program that ties objects in the 3D model to “recipes”
for estimating. Autodesk Building Solutions markets both Architectural Desktop (ADT) and Revit. While students will have access to any of these programs, the course will focus on the Graphisoft products. As these products include an integrated estimating program, they appear to be more appropriate for a course in a construction management program.

The first two weeks of the course will be spent developing basic skills for modeling in ArchiCAD. Students will work through the detailed tutorial provided in the Level 1 Training Guide. They will be assigned a project to create a model of a one-room structure.

Creating Model from 2D Plans

Graphisoft currently markets the Constructor software to general contractors for creating models of buildings for which they have 2D plans, preferably in an electronic format. In the third week students will be given an assignment to practice this concept on a multiple story building. They will continue to develop familiarity with the ArchiCAD software in the process.

Recipes

The Constructor software uses “recipes” to complete the estimate of an object. The recipe, which is similar to an assembly in Timberline, extracts quantities from the model and calculates costs based on all construction operations required to complete that item. Students will study existing examples and generate new recipes for concrete slabs and wood stud/gypsum board walls.

Estimating

In the fifth week students will complete an estimate for the one-room structure designed in Week 2 by developing the required recipes and incorporating them into the building model. The model geometry will then be modified to demonstrate the power of using this approach to quickly evaluate the cost of design changes.

Industry Foundation Classes

In Phase Two of the course students will be expected to become familiar with the data that describes the BIM and is transmitted between applications. They will export an IFC file from their one-room structure and review it line-by-line to become aware of the information that it contains and how it is stored. While the average constructor will be able to transfer data between applications without ever looking at the details of this file, the capabilities and limitations will become clearer with the deeper understanding that will be gained from this study. Since it is unlikely that a construction management student will be familiar with computer data formats and there is not enough time or motivation to teach the concept in any detail, the objective will be to identify information of interest such as property definitions, coordinate locations, and axis orientations. Students will experiment with modifying these to change the model. Exercises will focus on modifying coordinate values to change the size of the structure in order to learn how to extract information about the geometry for later use.
3D GIS

Geographic Information System (GIS) technology has gained popularity over the past two decades to the point that most government planning agencies rely on these databases. Traditionally, GIS data has been associated with two-dimensional maps. The widespread addition of three dimensional entities in GIS began around the year 2000 (Smith and Friedman, 2004). The ArcView family of programs will be introduced in the class and students will study applications with the 3D Analyst extension.

Virtual Reality Modeling

Students in the course will have access to a Virtual Reality Laboratory through the Electrical Engineering Department. Since all students learn some fundamentals of programming in Visual Basic for Applications (VBA) in the Computer Applications in Construction class, they will be provided with VBA software that will read geometry data from the IFC files and convert the data to VRML format. They will be required to customize the software so that each student produces a unique project.

Image Processing

Slattery (2006) demonstrated the feasibility of using computer vision technology to monitor steel construction. A 3D model of the structure can be mapped to a digital picture and used to determine when elements are in place. The students will be expected to be able to perform the required coordinate transformations programmed in Excel to determine the pixel location in a picture given the 3D location of a point in the model and the camera location and orientation.

3D Laser Scanning

Reflectorless laser technology is now available to rapidly record the location of a “cloud” of points around the instrument. Commercially available equipment can record the location of thousands of points each second in the line of sight of the instrument. Software is available to convert regions of points into simple geometric shapes in order to create a 3D model from the point cloud. This equipment will be demonstrated in the class. Point cloud files will be read in to AutoCAD and used as a guide for producing and checking drawings.

Student Projects

Much of the class will involve developing rudimentary skills with off-the-shelf software. Students will enhance these skills by applying them in various projects. The objective of the course is not to teach them to use a particular program but to become familiar with the concepts used in this technology. The first project will require students to create a BIM of a “Shack” – a simple wood frame structure that is the basis of several exercises in the Computer Applications in Construction class (Slattery, 2003). They will complete recipes to estimate the cost and demonstrate the power of estimating from parametric models.

In the second project students will be given a program to create a simple virtual reality model of the shack from the IFC file. They will then be required to enhance this program by adding details to the building components. For example, the wall object will be used to generate the individual studs and drywall needed to show all parts of the structure. They will then generate
detailed virtual reality models of a modest home using this program and place it on a 3D terrain model.

The third project will involve inspecting a structure using both 2D digital pictures and 3D laser scans. Students will frame the walls of a one room shack, take multiple pictures and laser scans, and analyze the data using off-the-shelf software and algorithms in Excel. Simple wiring and plumbing will be added to the structure to explore the feasibility of adding these details to a 3D model.

**Conclusions**

BIM technology will be rapidly integrated in the building construction industry over the next decade. Construction management graduates will be expected to work with this technology at some level. Students with the motivation and ability to understand and manipulate various elements of this technology will enhance their value to potential employers. The proposed course will challenge students to develop these important skills.

**References**


Involving Students in a Research Project to Quantify Environmental Impacts of Kern Center Construction

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As owner of the Kern Center, a new building constructed on Milwaukee School of Engineering’s (MSOE) campus between April 2003 and September 2004, MSOE was in the position to request construction documents that made it possible to quantify flows of materials and fuels used and wastes generated during Kern Center construction. Undergraduate students in MSOE’s Architectural Engineering & Building Construction Department and graduate students in the Master of Science in Environmental Engineering Program worked collaboratively on the project. Students collected and organized construction data, evaluated life-cycle environmental impacts of materials and fuels used, evaluated the accuracy of construction daily reports, compared the benefits of recycling versus landfilling construction wastes, compared volatile organic compound (VOC) emissions from products used versus others available on the market and quantified environmental impacts of Construction Specification Institute (CSI) division 31 (site work) and 3 (concrete construction). The author will summarize findings from these student projects and benefits to students who worked on the projects.

Key Words: life-cycle environmental impacts, construction, C & D recycling, VOC emissions

Introduction

Over the past few years research findings have indicated that the environmental impacts of buildings are substantial. According to the US Green Building Council, in the United States buildings account for 36% of total energy use and 65% of electricity consumption, 30% of greenhouse gas emissions, 30% of raw materials use, 30% of waste output (136 million tons annually) and 12% of potable water consumption http://www.usgbc.org/DisplayPage.aspx?CMSPageID=291&. The United States Environmental Protection Agency indicates that in the United States, buildings account for 39% of total energy use, 12% of the total water consumption, 68% of total electricity consumption and 38% of the carbon dioxide emissions http://www.epa.gov/greenbuilding/pubs/whybuild.htm.

Less research had been done on the environmental impacts of construction. Perhaps to support more research in this area, the National Science Foundation issued a solicitation for proposals (NSF 03-510), Technology for a Sustainable Environment- Sustainable Construction Processes, in 2002. Milwaukee School of Engineering (MSOE) was in the design phase for a new building, the Kern Center, and as owner of the Kern Center, MSOE was in the position of requesting construction documents, so we submitted a proposal to quantify environmental impacts of constructing this building. Wisconsin’s Focus on Energy Program provided funding support from the beginning of construction until MSOE received National Science Foundation support for this project. Additional NSF support was received under the Research Experience for Undergraduates (REU) program.
Project Goals

The overall goal was to perform a baseline study of materials and energy used and wastes generated during Kern Center construction. Flows were to be characterized as:

- Inputs of primary building materials, fuel, energy and water
- Stocks of building materials and soil remaining on site and
- Outputs of air emissions, waterborne wastes, solid wastes and soil.

Tasks included determining what construction documents were available to us, developing a data collection methodology, determining where there were gaps in information, comparing quantities from invoices (actual amounts) with quantities calculated from site drawings (estimated amounts) and comparing pollution generated at the site with pollution embodied in materials and fuels generated off-site.

Undergraduate students were involved from the beginning in taking meter readings and collecting daily reports and invoices from the construction manager, Hunzinger Construction Company. They took site photos several times per week and cataloged these photos. We had a copy of the owner’s plans, but did not have access to subsequent modifications to these plans. Our activities could not add costs to the project. Undergraduate students organized construction documents and developed research projects from this data. Two Master of Science in Environmental graduate student projects also developed projects using these construction documents.

Student Projects

Undergraduate projects

1. Kevin Kolodziej analyzed daily reports for the number of workers on site and fuel invoices for fuel consumption over the course of construction. In his presentation, “On-site Fuel Consumption,” he showed a timeline with the number of subcontractors and workers on the site over the project. The peak weeks for the number of workers were from the end of April 2004 to mid June 2004. On the peak day, May 3, 2004, there were 133 workers on site. On-site fuel peaked during the first three months of construction during site excavation; worker fuel peaked during January and May of 2004. Over 23,000 gallons of diesel and 20,000 gallons of gasoline were consumed on this project.

2. Sanket Anturkar presentation, “Tracking Site Equipment Used on Kern Center Construction Project,” used information on numbers and types of equipment from daily reports and compared that to information from site photos. One of the project goals was to compare fuel consumption two ways. There were accurate fuel quantities on invoices, but we wanted to compare these quantities with estimates determined from average consumption for various pieces of equipment. Since it was not known how accurately the daily reports recorded equipment, Sanket compared information from daily reports with information from photos. He chose days for which there were both daily reports and photographs and analyzed 22 days during CSI
Division 31 (site work) and 55 days during CSI Division 3 (concrete work). He found that daily reports were not a reliable source of information for equipment and recommended electronic tracking of equipment in the future.

3. Robin Page’s presentation “Life Cycle Inventory for Kern Center Materials Used in CSI Divisions 3 and 31” summarized the results of her research project on life cycle environmental impacts of materials used in CSI Divisions 31 (sitework) and 3 (concrete construction). Life Cycle Analysis, which includes Life Cycle Inventories, is a tool to evaluate the environmental impact of a material or process. Publicly available data was obtained for concrete, softwood lumber, electricity, gasoline, diesel fuel, BOF and EAF steel. The impacts from materials were added to impacts from fuel consumed by construction equipment and from vehicles used for material, fuel and labor transport. Impacts were quantified as generated on site or generated off site. She found that LCA data, if publicly available, can be useful for determining environmental impacts. If not publicly available, purchased software with life cycle inventory information is available, but costly. The quality of the data provided often seems questionable. If provided by a trade association, data about a product might be skewed in order to reflect well upon the material. Data providers at present are focusing on material comparison. The producers of that material want to have better results than their competitor, so it is very likely that results on all sides are conservative estimates. Without extensive comparison it is not possible to determine how accurate the data is. If the data has been peer reviewed extensively then it seems more likely to be accurate, but as a user only, and not a developer of data, one has no way of knowing for sure.

4. Michael Jahner’s project was “Reduction of Fuel Required to get Labor to a Construction Site.” Michael, while an undergraduate at MSOE, was an intern at Hunzinger Construction Company. He analyzed fuel required to bring labor to the construction site from April through December 2003, which was about 30% of the construction project. Contractors were asked to supply names, addresses and number of workers and days worked. Assumptions included a 53 mile round trip and 18 miles per gallon per worker. It was also assumed that no one in the City of Milwaukee would carpool, no more than three persons would carpool per car (most workers drove trucks), and five miles was added to the round trip. Over 345,000 miles was driven by workers during this time; over 19,000 gallons of fuel were consumed. Two carpooling alternatives were assessed- subcontractor organized or general contractor organized. If carpooling was organized by the subcontractor, a 13% reduction in fuel was possible; if organized by the general contractor a 17% reduction was possible. He concluded that carpooling is a feasible way to reduce worker fuel emissions.

5. Mary Christiansen’s project was an “Analysis of recycling versus landfilling construction waste.” Mary analyzed the potential for landfill diversion of construction materials and cost savings if there had been construction recycling during Kern Center construction. The construction site was small and MSOE was unable to get permits allowing recycling dumpsters on sidewalks, so all material was landfilled. Based on information from invoices, about 790 tons of waste was landfilled during Kern Center construction. No information was available on the composition of that material. Mary calculated total weight from invoices, used construction waste composition percentages from WasteCap Wisconsin to calculate individual material weights, used weight to volume conversion numbers for each material to get individual volumes.
and used individual material weights and volumes to calculate cost savings and landfill diversions. She found that about 590 tons (5800 cubic yards) could have been diverted from local landfills. About $19,400 of the $41,400 spent for landfilling this material could have been avoided. She recommended construction waste recycling as beneficial and cost effective.

**Graduate Student Projects**

1. Steven Botic’s capstone research project, “Quantifying VOC’S in Products Off Gassed during the Construction of MSOE’S Kern Center and Proposed Strategies for Reducing Employee Exposure,” evaluated products that off-gassed volatile organic compounds (VOCs) actually used in the Kern Center from the time of building completion to the end of the project. Over 7200 pounds of VOCs were off-gassed during Kern Center construction from products, including paints, caulks, sports flooring and terrazzo installation. The project goal was to provide contractors with a step-by-step approach to specifying products for a construction project that perform well, are cost efficient, and have low environmental risks from off-gassing VOCs. The process started with identifying tasks. Task 1 was to identify target materials and products, Task 2 involved data collection Task 3 involved determining and environmental risk value (ERV) based both on quantity and toxicity and Task 4 was to proceed with product selection.

   Based on environmental risk values, gymnasium turf, sealants, metal primer, xylene solvent cleaner and the acrylic terrazzo sealer were selected for evaluation. Performance measures were developed for each product and alternatives were compared to the product used in the Kern Center. For example for the metal primer, ERV, direct impact resistance, adhesion, cure time, expected life and cost of the product used were evaluated and compared with three alternatives.

   In general, there were alternative products available that performed as well as products used in the Kern Center and also had lower ERVs, but they cost more. The ERV was found to be a useful tool. If is used during product selection, it can reduce worker exposures to VOCs in construction products.

2. Robert Brillhart’s project was “Assessing environmental impacts of site activities during construction of MSOE’S Kern Center: site and concrete construction,” The goal of this project was to perform a baseline study of flows of materials and emissions during CSI Divisions 31 and 3.

   Activities for CSI Division 31 included demolition of existing site improvements, site excavation, hauling of excavated material, installation of the soil retention system, installation of building foundation, and fuels to transport construction materials, fuels and site personnel to the site.

   Activities for CSI Division 3 included cast-in-place and pre-cast concrete, concrete sealants, fuels to transport construction materials, fuels and site personnel to the site.
Actual quantities of materials came from invoices and were compared with quantities estimated from plans and drawings. There was good agreement between actual and estimated values. Flows to the environment are given below.

Air emissions
- 73% of total outputs
  - 75% of the air emission outputs occurred off site
  - 25% of the air emission outputs occurred on site

Solid wastes
- 21% of total outputs
  - 77% of the solid waste outputs occurred on site
  - 23% of the solid waste outputs occurred off site

Waterborne wastes
- 6% of total outputs
  - 93% of the waterborne waste outputs occurred on site
  - 7% of the waterborne waste outputs occurred off site

Overall, almost 2/3 of the total flows to the environment of this project were attributable to pollution embodied in fuels and materials; 1/3 of the flows were attributable to on-site construction. Most of the emissions were air and almost all of these were carbon dioxide. Water flows were primarily due to washing out concrete trucks. Solid wastes were attributable to landfilled contaminated soil excavated from the site.

Benefits to Students

The most obvious benefits to the students who worked on this project included an opportunity to interface with construction workers and to have access to real-time construction information. But work on this project also gave a number of them a taste of graduate-level research and opportunities to make presentations and write conference papers. Robin Page and Sanket Anturkar submitted papers to and presented posters at the April 2004 REU Conference. Rob Brillhart gave a paper at Engineering Sustainability 2005: Next-generation technology in green construction and sustainable water use, April 10-12, 2005, Pittsburgh, PA. All gave presentations at the November 30, 2005 symposium at MSOE. Mary Christiansen, Steven Botic and I have had papers accepted at the Coventry University and UW-Milwaukee Center for By-Products Utilization International Conference on Sustainable Construction Materials and Technologies, June 11, 2007 - June 13, 2007, Coventry, U.K. [http://www.uwm.edu/Dept/CBU/](http://www.uwm.edu/Dept/CBU/). Robin Page, Sanket Anturkar and Kevin Kolodziej are now in graduate school in structural engineering. Mary Christiansen works part-time during the year at WasteCap Wisconsin, a local NGO doing construction waste recycling, and had a summer internship at a local construction firm; both involved working on construction recycling. She also plans to go to graduate school in structural engineering. Michael Jahner works as a construction manager and emailed to tell me that he had passed the LEED™ accreditation test and is the point person in his firm on sustainable construction. Steven Botic and Rob Brillhart work for environmental engineering consulting firms.
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