The Past
The Present
The Future

2007 Convention Proceedings Papers

National Association of Industrial Technology

40th Annual Convention

Edgewater Beach Resort
Panama City Beach, Florida

Tuesday October 23-
Saturday October 27, 2007

Review Process & Statistics for Presentations and Papers

This CD-ROM of the *NAIT 2007 Convention Presentation Abstracts and Proceedings Papers* is the result of the work of many authors in technology and technology management programs throughout the United States who gathered to share their work at the 40th Annual NAIT Convention, "The Past, The Present, The Future," in Panama City Beach, Florida, October 23-27, 2007. This CD-ROM includes all of the convention presentations that were accepted through peer-review for presentation and publication, and the Convention Proceedings Papers, based on accepted presentations, which were accepted through peer-review after being submitted in expanded form as complete papers.

The reviews of presentation proposals and convention papers were led by NAIT Special Division Presidents and the Focus Group Chairs and each paper was reviewed in a double-blind process by a panel of at least three NAIT members with expertise in the topical area. Using the review criteria (posted on the NAIT website), panelists evaluated and ranked each paper, and a cumulative rank-ordering system was used to help select the papers.

The *NAIT 2007 Convention Presentation Abstracts* were subject to a double-blind peer review process. In 2007, the peer-review process led to acceptance of 57% of presentation proposals (171 accepted and not cancelled or withdrawn of 299 proposals submitted).

The *NAIT 2007 Convention Proceedings Papers* went through a similar process. Authors of accepted convention presentations were invited to submit expanded versions of their presentations and the *Convention Papers* were chosen after a double-blind peer review process, with panels of at least three reviewers involved in reviewing each submission. Pursuant to NAIT Executive Board policy, no more than 50% of submissions could be accepted and review leaders had discretion to accept less than 50% of submissions in a track. In 2007, of 171 accepted convention presentations, 58 were expanded into longer papers and were submitted for the peer-review process. The double-blind peer review process led to acceptance of 43% of the papers submitted, for a total of 25 "NAIT 2007 Convention Proceedings Papers." These 25 Convention Papers represent just 14.6% of the proposals accepted for presentation at the 2007 NAIT Convention, and only 8.4% of proposals submitted.

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Administration

Advancing Graduate Education in a College of Technology Context

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Introduction

According to the National Association of Industrial Technology definition, industrial technology is a field of study designed to prepare technical- and/or management-oriented professionals for employment in business, industry, education, and government. The association's annual conference serves as a forum for presenting and discussing issues within the field. Many of the presentations focus on the technology and pedagogy related to undergraduate education at the associate- or baccalaureate-degree level. Although the association's organizational structure includes a research division, increased discussion is needed concerning the goals and delivery of graduate programs leading to master and doctoral degrees related to the field. The authors' College of Technology (COT) is in the process of redeveloping its strategic plan charting the direction of the college for further achievements in discovery, learning, and engagement into the next decade. The university and college strategic plans revolve around the mission of serving the citizens of the state, the nation, and the world through discovery that expands the realm of knowledge**,** learning through dissemination and preservation of knowledge, and engagement through exchange of knowledge. A major goal of the COT is to further develop graduate education in fulfillment of this vision.

The institution in which the COT is located is classified as a Research Intensive University and is in a unique position in the field because it offers the full spectrum of technology education programs, ranging from the AS to the PhD degree. Currently, the master of science and the doctor of philosophy degrees with a field of study in technology are administered at the college level serving eight technology departments, including: Aviation Technology; Building Construction Management; Computer and Information Technology; Computer Graphics Technology; Electrical and Computer Engineering Technology; Industrial Technology; Mechanical and Manufacturing Engineering Technology; and Organizational Leadership and Supervision. The college is going through a process of implementing individual master's degrees in the academic areas of each technology department while continuing to deliver the PhD in Technology at the college level. Such work has caused the technology graduate faculty to formulate the role of graduate education within the context of the larger university community, and articulate how graduate education in technology may differ from that of the other colleges and schools in the academy. This presentation discusses the role of academic discovery, learning, and industrial engagement in technology graduate education from the college of technology and departmental perspectives.

The purpose of this paper is twofold. This work presents a general discussion of the theoretical foundation for graduate education in technology followed by some specific applications within graduate education in the COT. The presentation represents the authors' view of the role of graduate education in: advancing the knowledge base; addressing industry's challenges in implementing and adapting technology; influencing future undergraduate education; preparing the future technology faculty; and capitalizing on the research interests of the faculty.

Advancing the Knowledge Base

Discovering, integrating, applying, and teaching the knowledge of doing are integral to undergraduate and graduate education for professions in technology, where technology is defined as those fields that apply practical knowledge in improving the human condition. Whereas the typical undergraduate technology program is more concerned with students' initial acquisition of knowledge and skill within the technical areas under study, technology graduate education is more concerned with developing students' abilities and achievements in scholarship. Boyer (1990) presented a model encouraging active participation in a wide range of scholarship for the higher education community including <u>the Scholarship of Discovery, the Scholarship of Integration, the Scholarship of Application, and the Scholarship of Teaching</u>. Such a model is particularly salient in identifying the goals of technology graduate education. In a Research- Intensive University environment, these attributes cannot be demonstrated in a course work-only graduate program. Graduate programs at such institutions require a degree plan of study designed for each student that provides learners with the requisite learning experiences to acquire knowledge and skills through a well-thought-out regimen of course work and the demonstration of scholarship by the completion of a directed project, thesis, or dissertation investigating and reporting on a significant undertaking in discovery, integration, application, or teaching related to technology.

Central to identifying the mission of graduate education in technology is the articulation of the domains of inquiry appropriate for professions in technology. Bush's (1945) work titled *Science: The endless frontier* presented a linear model representing the post-World War II view that discovery in science gives rise to applications in technology. Based on this model, the domains of basic research and applied research are seen as independent and unrelated. Whereas basic research is conducted by "scientists" for the sole purpose of understanding the nature of phenomena, applied research is conducted by "technologists" and is directed solely to solve a societal problem. Stokes (1997) presented a more robust model for the domains of inquiry, which can become the research paradigm for technology graduate education. This model considers the desire of investigators to undertake the quest for basic understanding and the consideration of the use of research and inquiry. The mission for discovery, integration, application, and teaching in a College of Technology context can be identified in a model adopted from the Stokes (1997) 4-quadrant graphic shown in Figure 1.

Research is inspired by whether or not it promotes understanding of the fundamental elements of a discipline and whether or not there is further utility to the research results once they are known. Research in its pure, basic form known to other disciplines (e.g., physics, biology, chemistry, etc.) does not typically occur in technology disciplines due, in large part, to the mission of technology-centric education and research in general. However, use-inspired basic research and pure applied research are more common, and can define that nature of scholarship in technology graduate programs. This focus is not on fundamental scientific behavior, but rather on applied usage of basic science and extension and validation of novel tools and techniques.

Considerations of use?

		No	Yes
Quest for fundamental understanding?	Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
	No		Pure applied research (Edison)

Figure 1: Quadrant Model of Scientific Research (Stokes 1997, 73)

Addressing Industry's Challenges Implementing and Adapting Technology

It is well documented that industry faces a shortage in technical talent in the areas of engineering and science due to increasing competition from foreign states and the decreasing enrollment of domestic students into those fields in our own universities (Keating et al., 2005; National Academy of Engineering, 2004). One of the key questions that many people within research universities, and specifically within technical domains, ask is how can the contemporary university partner with industry to effect change and have an impact on industry processes without changing the fundamental role of the university? These authors propose that the fundamental nature of that relationship would not change the role of the university, but rather strengthen the bond between the corporate world and academia, as well as provide meaningful experiences for students at all levels. Since many large research institutions are also land grant universities, and most states have at least one land grant university, we need to look no further than that model to draw inspiration for what is being proposed.

According to the National Association of State Universities and Land Grant Colleges (1999), the original mission of a land grant college was to provide higher education opportunities for the citizens of a particular state, especially in the areas of agriculture, the mechanical arts, and military tactics (the latter being evidence of the period in time in which this Congressional act was signed into law). By design, a set of public universities was given a charter that included engagement with industry for the betterment of society. However, this has not become a simple relationship over time, as it has evolved into an enterprise of sorts as universities compete for industrial and federal funding to support research initiatives often driven by regional economies or federal defense and energy agendas (Kennedy, 1995).

Complimentary to this larger federal initiative, Boyer (1990) has suggested a revised role for the universities based on several factors, including how faculty are compensated and provided incentives. One facet to his approach has been to delineate scholarship in certain areas: discovery, integration, application, and teaching, with the premise being that excellence in these areas by faculty makes for a more holistic experience for students and a more productive working environment. So how does this relate to graduate education and research at large universities? In the COT, the notion of the Scholarship of Application would likely be considered Engagement–with industry, federal agencies, or the community. It would involve bringing the intellectual and human resources of the university to bear in solving an applied problem that has affected the constituents or partners of the university. In the case of engagement with industry, this would likely mean funded activities to solve a specific problem. The most expeditious method for doing this type of work is to have graduate students funded to work on such projects. In a technology discipline, giving graduate students a thesis project that has real-world application is ideal. It provides them an applied scenario upon which to direct their efforts and is more in line with their course work than something that is rather esoteric in nature. However, the results of these activities may or may not be available externally due to intellectual property issues or federal controls, which should be negotiated ahead of time. While this secrecy of results may not coincide with the tenets of the original land grant mission, it is certainly a reality to the contemporary economic climate.

While engagement work with industry partners can contribute to the learning and maturation of graduate and undergraduate students, the university can also provide ongoing professional education to the incumbent workforce, which is in line with the mission of a land grant university. Practicing professionals in technical disciplines struggle to keep pace with changing technology in light of their job requirements, and universities with technical- and technology-based degree programs can address the need for professional education (Keating et al., 2005; Tricamo et al., 2003; Dunlap et al., 2003) due to the applied nature of the curricula. In doing so, they could address the ongoing training and education of engineers and technologists from entry-level positions all the way through the most senior managers and directors by providing course work that deals with project management, measurement and analysis, training and human resource development, as well as various technical areas depending on the company and faculty involved.

Influencing Future Undergraduate Education

Important imperatives for technology graduate education on research-intensive campuses are the scholarship of discovery, integration, application, and teaching and the interaction of these elements among the undergraduate and graduate programs within the disciplines. The Boyer Commission (1998) identified 10 key elements for improving undergraduate education, most of which equally apply to improving graduate education. These elements are defined in Figure 2.

Make Research-Based Learning the Standard	Use Information Technology Creatively
Involve Undergraduates in the Research Process	Culminate With a Capstone Experience
Build on the Freshman Foundation	Educate Graduate Students as Apprentice Teachers
Remove Barriers to Interdisciplinary Education	Change Faculty Reward Systems
Link Communication Skills and Course Work	Cultivate a Sense of Community

Figure 2. Elements needed to improve undergraduate and graduate education

Examples of the integration and application of these elements can be demonstrated by theme-based projects undertaken by technology faculty involving graduate and undergraduate students in executing discovery, integration, application, and teaching projects conducted in cooperation with industrial, business, or educational partners. When such projects are properly conceived and executed, vertical integration is often achieved by transferring the technology or the results of the technology to the sponsor while contributing to the scholarly achievements of faculty, graduate, and undergraduate students. Numerous examples of such projects can be identified through the directed projects, theses, and dissertations of COT graduate students and the discovery, integration, application, and teaching work of the COT faculty. Quite often, graduate students are recruited or are attracted to the programs based on the scholarship interests of the faculty.

Preparing Future Technology Faculty

Demographic surveys conducted by Zargari and Sutton (2007) document the need of institutions offering technology degree programs to have a well-qualified faculty. Their survey research demonstrates the need for providing graduate education leading to the terminal degree in the field because attaining such degrees is an important criterion in hiring, awarding tenure, and promoting technology faculty. Doctoral programs in technology to prepare future generations of faculty are limited, creating a need that must be addressed as undergraduate programs in technology offered by colleges and universities continue to grow.

The work of Golde and Walker (2006), *Envisioning the future of doctoral education: Preparing stewards of the discipline,* provides input helpful in identifying the goals of graduate education in technology in preparing the future stewards of the technology disciplines. According to their view, "a steward of the discipline considers the applications, uses, and purposes of the discipline and favors wise and responsible applications" (p. 13). Well-thought-out and-delivered graduate programs in technology should focus on increasing productivity in the scholarship of discovery, integration, application, and teaching for the professions in technology through the learning and mentoring process of quality graduate education based on discovery, learning, and engagement. Such scholarship in technology that focuses on discovering methods for extending the state of the art, integrating cutting-edge tools, techniques, and methods, applying this knowledge in business and industrial settings, and improving technology teaching contributes to the field and will help address the faculty needs of future technology programs in the colleges and universities.

Capitalizing on Faculty Research Interests

Technology faculty members who are heavily engaged in research behave in a fashion similar to independent entrepreneurs who seek funding through grants to advance their research. Much of this funding is used to hire graduate students to engage in much of the research work, which leads to theses, directed projects, and dissertation topics that can lead to presentations and publications and further advances in the research. This cyclical process results in focused recruiting of graduate students into the program, funding to support graduate students, scholarly publications, course development, and advances in the application of technology. Prospective graduate students in the field will find the work of Baylor, Ellis, and Redelfs (2000) to be a helpful resource in choosing the appropriate institution and program when considering undertaking an advanced degree. The authors suggest the prospective graduate students ask themselves some of the following questions (p. 7):

- Does the faculty exhibit special strengths and research qualities through their graduate advisees, published works, and funded research?
- Are the libraries, laboratories, computers and other research facilities adequate for your educational needs?
- How senior are the professors in your area, what are their interests and what will their availability be?
- Does the department of interest offer a sufficiently large and varied curriculum to allow you a broad offering of courses and options?
- What are the degree requirements? Number of hours of coursework required? Major exams? What are the expectations for a thesis or dissertation?
- How long will it take to complete the program?
- What is the completion rate of the general graduate population?

Application

Based on the discussion of scholarship in technology, the COT graduate faculty has identified a range of student outcomes. The outcomes presented in Figure 3 are used to communicate student expectations in technology graduate education and provide a foundation for accreditation review.

Each graduate student should be able to:
Envision, plan and conduct research and development activities
Identify, analyze, evaluate and synthesize research
Evaluate technologies and technology-related programs
Assess individual performance with, and understanding of, technology
Communicate effectively and employ constructive professional and interpersonal skills
Function effectively in one or more of the technology disciplines

Figure 3. COT graduate student outcomes

Although there is no specialized accreditation agency for graduate programs in technology, such programs must respond to the institution's regional accreditation. In the case of the COT programs, the accreditation criteria of the North Central Association -Higher Learning Commission, Handbook of Accreditation (2003) standards apply and the institution is scheduled for reaccreditation in 2010.

Masters-level COT graduate students are given the option of conducting a directed project or a thesis using an on-campus or a weekend model to demonstrate attainment of the program's learning outcomes. On-campus students are typically funded as graduate teaching or research assistants while weekend students typically work in industry related to the COT and receive a combination of in-plan and on-campus instruction. According to the COT Graduate Student Handbook:

> *The directed project was originally defined as an applied research project that was more extensive and sophisticated than a graduate-level independent study and less formal than a masters thesis. The overall objective of the requirement was to engage each graduate student in a study, typically industry or business focused, which is sufficiently involved as to require more than one semester to conceive, conduct, and report. The focus is to be placed on a topic with practical implications rather than original research (p. 13).*

Graduate students looking to conduct more formal inquiry, or who intend to pursue the doctorate after completing the masters, are encouraged to follow the thesis option to demonstrate the program's learning outcomes. The COT Graduate Student Handbook has the following explanation of a thesis:

> *A master's thesis in technology is a significant piece of original work, typically involving research, a formal written description of that research, and an oral defense of the research. Typically, the thesis contributes new knowledge to the discipline, against the backdrop of what others have contributed to the topic as well (via the literature review). The tone should be scholarly, with a primary audience of other researchers (p. 15).*

COT doctoral students demonstrate achievement of the learning outcomes by completing course work designed to further develop their scholarly abilities and by completing a PhD dissertation that is a significant piece of original work conducted by the student under the direction of an appropriate graduate faculty committee, resulting in scholarship of discovery, integration, application, or teaching that contributes to the knowledge base of the field. Technology PhD recipients pursue careers in higher education, business, industry, and government regionally, nationally and internationally.

Conclusion

The work of Applegate (2002) titled *Engaged graduate education: Seeing with new eyes* offers inspiration that can be applied to graduate education in technology when he discusses the role of three important attributes for improving higher education, namely vision, passion, and action (p. 4). The vision for technology graduate education presented in this paper centered on the scholarship of discovery, integration, application, and teaching. The COT graduate students and faculty are challenged to pursue this scholarship with passion, thus improving undergraduate and graduate education for the professions in technology, integrating the unique contributions of technology in the academy while contributing to the further development of the knowledge base in the field. Finally, there needs to be a commitment to action. Such actions can include demonstrated commitment to continue process improvement in education, lifelong learning, and scholarly productivity of the professionals in the field. Graduate students and academics in technology facilitate this action by developing and pursuing clear agendas for the scholarship of discovery, the scholarship of integration, the scholarship of application, and/or the scholarship of teaching.

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Industry & University Collaboration for Training Tomorrow's Leaders

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Abstract

Through this paper the audience will see how a major tire manufacturer managed projects involving both employees and students for their mutual benefit, while providing university students hands-on experiential learning. Students are motivated by being exposed to a potential employer as well as being able to earn industry sought-after certifications in lean manufacturing and six-sigma. As technology becomes more complex in a highly competitive world market, there is an ever-increasing need in industry for personnel that have interpersonal, leadership, and technical skills that are necessary for solving quality, cost, and delivery problems. In recognition of this need, Bridgestone Firestone management established a collaborative training program with Middle Tennessee State University (MTSU) that supports the company's total corporate culture growth to a leaner organization. The administration of projects driven by the six-sigma "DMAIC Culture" that involves students, six-sigma yellow belts, green belts, black belts, Kaizen teams, maintenance and production personnel in many business and process areas is also illustrated in this paper including tangible results that directly affect the bottom line.

Introduction

Industry Technology Needs

Employers often hire graduates from accredited degree programs. The technical content of these programs is dictated by accreditation standards that provide evidence of a minimum set of qualifications for the potential employee. Employers then provide extensive additional training in topics such as six sigma and lean manufacturing to bring the new employee in-line with company requirements.

Accreditation is intended to ensure quality as evidenced by the U.S Department of Education's statement "The goal of accreditation is to ensure that education provided by institutions of higher education meets acceptable levels of quality" (Boles 2004). Accreditation agencies, such as the National Association of Industrial Technology (NAIT), ensure the quality of technically-oriented programs in areas such as Industrial Technology with many technical disciplines represented. On the other hand, industrial employers often hire employees from technically-accredited programs, such as engineering, where there seems to be a mismatch between job duties and accreditation goals. Most accredited engineering programs do a fine job at preparing graduates for engineering design positions and to continue into a research-oriented graduate program. For example, ABET, Inc., states that accreditation ensures "Employers that graduates are prepared to begin professional practice." However, many engineering graduates are hired into positions that require little or no engineering design capability. In some cases, engineering graduates are preferred over technology graduates even when technology graduates are a better fit for actual job requirements. Industry-recognized certifications can serve as a powerful tool to persuade these employers to take serious look at technology graduates.

Industry-recognized certifications help industries seeking technology needs above and beyond the requirements of accredited programs and level the playing field between engineering graduates and technology graduates competing for industrial and manufacturing jobs. So, now the problem is how to provide these certifications within the time limitations imposed on hard-working technology students.

How then can students earn certifications through "industry involvement?" Student tours of industries both here and abroad certainly are useful for general knowledge, but does that accomplish the mission of a program designed to teach students interpersonal, leadership, and technical skills needed for their success in high technology industrial or business systems? Likewise, the use of industrial internships is not educational if the work assignments do not provide students experiences that allow development of skills required for high-value specialty knowledge positions. In order to be successful, experiential learning requires careful design and collaboration by both the university and industry involved.

Student Experiential Learning

Experiential learning can best be described as, "that learning process that takes place beyond the traditional classroom and that enhances the personal and intellectual growth of the student. This education can occur in a wide variety of settings, but it usually takes on a 'learn-by-doing' aspect that engages the student directly in the subject, work or service involved," as defined by the Experiential Education in the College of Arts and Sciences, Northeastern University, 1997.

According to Cantor (1995), quality learning should be defined by what students do, not by what faculty do in the learning process. Cantor also believes that experiential learning activities are natural motivators for students and this motivation leads to students being more involved in the learning experience. Two people credited with the experiential education movement are philosopher John Dewey and educator Ernest Boyer. Dewey thought that education should be reinforced by experience, and suggested that the "quality of the experience is as important as the experience itself" (Katula and Threnhauser, 1999). Boyer encouraged educators to develop the scholarship of engagement. He said that higher education must build collaborative partnerships, improve all forms of scholarship (Boyer, 1990a), and provide opportunities for students to contribute to the common good (Boyer, 1990b).

Some critics question whether experiential education really does enhance student learning and whether all experiential education programs provide valuable learning experiences. In their study, Katula and Threnhauser (1999) found that sometimes cooperative education experiences do not enhance student learning because they are not effectively integrated with the students' discipline. There is also some concern that study abroad experiences are no better than students' personal travels abroad (Katula and Threnhauser, 1999).

Alternatively, many researchers strongly believe that enhanced student learning results from experiential learning programs. Internship students have the opportunity to take responsibility for their own professional and intellectual development and they learn to connect their coursework with their work experience. Steffes (2004) suggests that an internship program generally encourages students to view themselves as more connected to their education and helps them to develop an understanding that education is essential to their future lives. The internships that are the most useful for students are carefully planned and monitored to ensure that students are engaged in discipline-related work activities. According to Bucher and Patton (2004), experiential learning helps students understand how theory is applied to real situations.

Mission and Vision

Through the hard work and diligence of a Middle Tennessee State University Industry Advisory Committee over the past three years, a new program was designed with the mission to "teach students interpersonal, leadership, and technical skills needed for their success in many various industry or high-technology business systems." The Engineering Technology and Industrial Studies (ETIS) Department Chair, Dr. Walter Boles led the way by defining the vision (Boles and Gore, 2004) which is best explained in Figures 1 and 2 that follow:

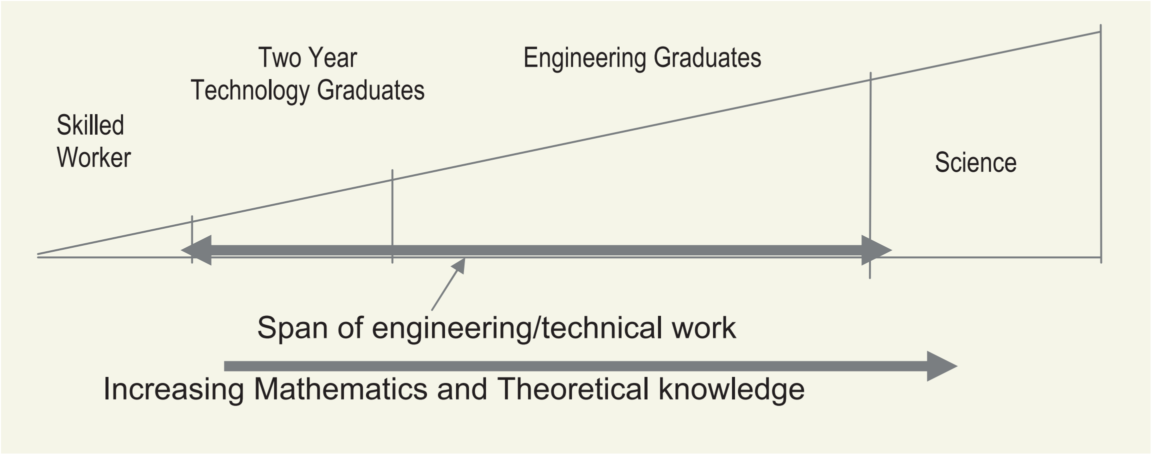

Figure 1. The "Old" Model of Technology versus Engineering

In Figure 1, this model of technology and engineering shows the situation 30 to 40 years ago when engineering graduates covered the span of technical work between the two-year technology graduate and the area of pure science. It illustrates that more mathematics and theoretical knowledge is required as the work content changes from "skilled" to "science." Engineers were expected to be "hands-on" as well as being prepared for R&D and applied sciences.

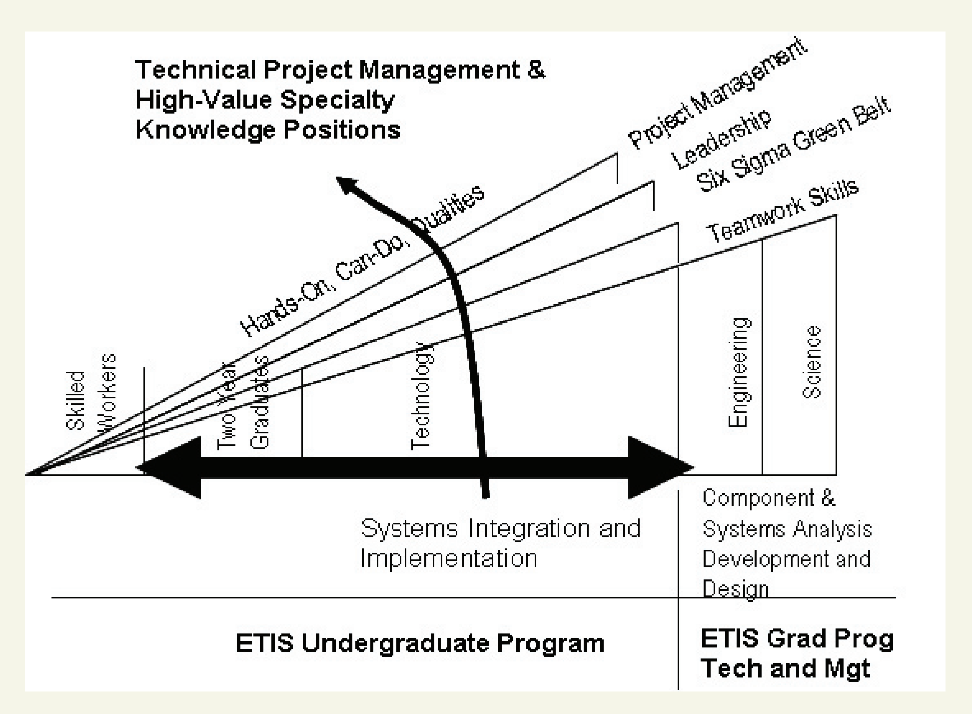

Figure 2. A "New" Model

As shown in Figure 2, today's engineers are pushing the envelope into the applied and theoretical sciences area and are expected to handle complex systems analyses as well as development and design. The "gap" between the skilled worker and pure engineering graduate is now covered by the Industrial or Engineering Technology under-graduate program that focuses on systems integration and implementation issues that require more "hands-on" problem-solving skills than theoretical knowledge. Graduates of technology programs are sometimes overlooked for positions for which they are highly qualified. "Providing these undergraduates with significant industry-recognized certifications will help overcome this phenomenon," according to Dr. Boles.

Competencies & Learning Goals

From this vision and mission, four applicable core competencies were established that requires the student to:

1. Communicate effectively, clearly and precisely.
2. Solve problems through thinking logically, critically and creatively.
3. Use teamwork to seek and share innovative knowledge and perform tasks effectively.
4. Develop leadership/soft skills to lead projects, subordinates and/or teams.

Coursework was developed that provides the tools and in-class simulations; however, it was clear that "real world, hand-on" experiences were required to reinforce classroom learning, develop the basic skills needed by industry, and achieve the core competencies at the same time. Several learning goals were established based on the "New" Model (refer to Figure 2). Each student must:

- Master "lean" techniques to improve productivity in any operational system such as manufacturing or healthcare.
- Understand and use the six-sigma methodology to define, measure, analyze, improve, and control quality in any operational system.
- Perform industrial engineering systems analyses involving work measurement, process layout & material handling.

To go beyond the classroom requires collaboration with industry partners to setup projects that can meet the needs of both the industry partner and the student. In the Appendix, Table 1 gives a listing of key MTSU corporate partners and Tables 2 and 3 summarize the types of student projects with a typical list of deliverables.

Assessment

As pointed out in a paper at the NAIT 2006 conference, assessment of experiential learning for technology students means something only "if the information is collected in a systematic, objective manner …" (Trautman 2006). Fortunately, information collection in the case of six sigma, is a relatively simple process, since certification requires the student candidate to complete a "Greenbelt-level" six sigma project with deliverables detailed during the "define" charter development phase. However, most Greenbelt-level projects require a minimum of 2 to 3 months to complete. Initial efforts at certification were not very successful due to the limited time that a student has during the semester for work outside the university. This limitation resulted in some projects being started but never completed, and others stretched out into the summer when students had more time available. The highest success rate came from the non-traditional student already working as a full-time employee in the company where the project was being conducted.

Industry Collaboration

Background

Early in 2006 the 6-Sigma Process Manager at Bridgestone Firestone North American Tire, LLC, La Vergne plant, contacted Middle Tennessee State University (MTSU) to propose collaboration between the two organizations. The Plant Manager at Bridgestone Firestone had decided that MTSU should be involved in the tire company's six-sigma programs as well as any other areas of mutual interest. After a joint meeting, Bridgestone Firestone saw several advantages to pursuing this relationship with MTSU:

- Utilize university resources to support corporate quality & lean initiatives.
- Obtain knowledgeable student labor (6-Sigma, Value Stream Mapping, Lean Mfg.)
- Obtain feedback from a different perspective (new set of eyes).
- Opportunities to strengthen employment base.
- Networking opportunities:
    - Manufacturing Excellence Program
    - Board of Engineering Development
    - Co-present with MTSU at the NAIT convention

Initial Effort

Several students taking the six-sigma and lean manufacturing courses during the spring semester 2006 were provided the opportunity to work with Bridgestone Firestone on six-sigma and value stream mapping projects. These projects were ongoing projects in various stages of completion (see Table 4 in the Appendix for the six-sigma projects and Table 5 for the tracking matrix), and were not completed during the spring semester. Due to other coursework, the students could spend very little time doing the project work on-site at the Bridgestone Firestone plant (an average of 2 to 3 hours per week); so, the work was carried over into the summer of 2006. Students and company Blackbelts co-presented their projects in mid-September 2006, and several projects are expected to be completed during the summer of 2007. Because of their desires to obtain certifications these students worked on their own time without any paid internships and the company was pleased with the results of their efforts. However, both Bridgestone Firestone and MTSU believed improvements in this program were necessary to provide additional time and motivation for students to complete projects and earn their certifications in a timelier manner.

Current Strategy

The company studied its vision of managing six-sigma projects and how resources were allocated to get the bottom-line results required. This concept is shown in Figure 3 with "MTSU Students" as one of its foundations.

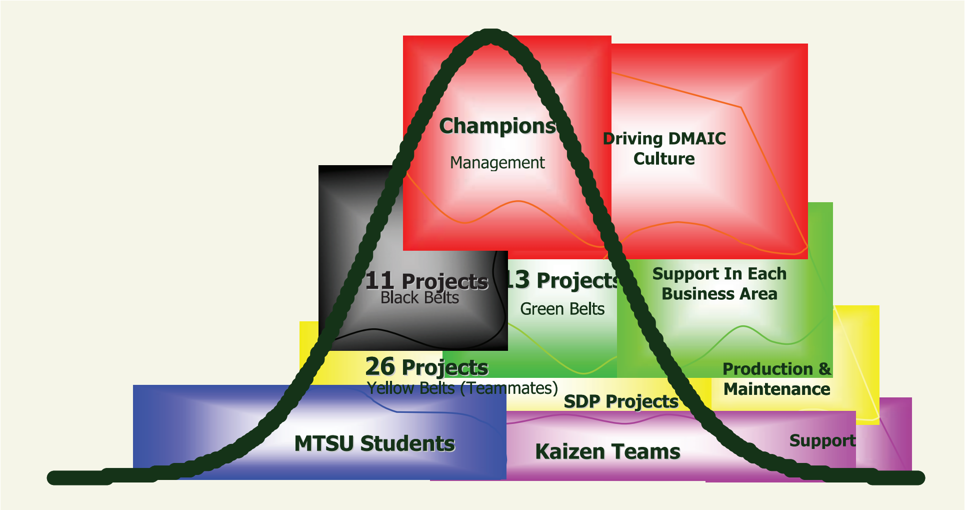

Figure 3. 6-Sigma Vision – Define, Measure, Analyze, Improve and Control (DMAIC)

In order to improve the integration of MTSU students within this structure, Bridgestone Firestone funded internships to provide the motivation for students to be able to spend more "face" time on-site and become more a part of the project teams to which they were assigned. To support this strategy, MTSU decided to change the curriculum to specifically require internships as part of the experiential courses in both lean and six-sigma in order to achieve the learning goals discussed previously.

Administration

Projects are driven by the six-sigma "DMAIC Culture" (Define, Measure, Analyze, Improve, and Control) involving students; six-sigma yellow belts, green belts, black belts; Kaizen teams; and maintenance and production personnel in many business and process areas. Administration of these project and personnel is the key to being able to achieve financial results projected at over $2 million dollars in 2007 (a more than a 26.5% increase over last year).

Organization

For example, the following elements are required to establish the organization to manage six-sigma projects:

- Leadership & support of top corporate management.
- Full-time dedicated site project Blackbelt manager.
- 6-Sigma trained leaders.
    - Leaders responsible for reporting to the 6-Sigma Manager bi-weekly and during the monthly plant management review.
- 30 minute bi-weekly standing meeting in each business area.
    - Involve yellow belts and students as appropriate in the bi-weekly meetings.
- Initiate activities and resources for projects to progress through the DMAIC roadmap (QE, IE, EE, ME, IT Support, Tech Eng, Maintenance).

Training

Training is required at all levels – from upper management down to the production technician. (See Appendix Table 6 for the Bridgestone Firestone ambitious training timeline). The company's support for internships and university training for students is part of the overall investment needed to assure success. (It is interesting to note that "success breeds success" as indicated by the number of calls from production technicians that desire to be part of the program).

Follow-up

Follow-up is necessary to manage successfully. Weekly meetings are held by the project leaders plus bi-weekly meetings with the Six-Sigma Process Manager to review the following:

- Project status overview
- "Champion" informed and drive accountability
- Forum to mention and remove obstacles
- Kudos, share results
- Promote DMAIC culture all business areas

The 6-Sigma Process Manager has quarterly reviews – first month with plant management staff, second month with "Belts" presenting to plant management staff, and third month with "Champions" presenting project accounts to plant manager.

Semi-annually invitations go out to corporate executives to attend presentations by Yellow Belts who share the results of completed project with peers and management. Also, at these meetings, Green Belts are presented with their certifications and a Six-Sigma Executive Presentation Award Ceremony is held at the same time to recognize superior projects and performance.

Summary & Conclusions

Training tomorrow's leaders requires a collaborative effort between industry and the university. The competencies and skills desired from university graduates by today's modern industries can be achieved through proper application of several factors:

- Use of internships that are directed toward projects utilizing initiatives such as six sigma and lean manufacturing in order to develop the skills desired by industry through true experiential learning as well as investing in potential future new hires.
- Curriculum design by the universities that support student competency development through direct application of classroom knowledge to the experiential-learning workplace.
- Administration of student interns within the corporation in a way that not only recognizes the importance of experiential learning and internships, but also understands how to organize, track and follow-up projects.

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Appendix

Company	Six Sigma	Lean	Layout	Other
Bridgestone Firestone				
Middle TN Medical				
Johnson Controls				
Cumberland Swann				
General MiTlls				
MAHLE				
Square D				
Stinger Medical				
Asurion				
Tridon				
TN Board of Regents				

Table 1. Key Partners

	Project Deliverables (examples)
	Project charter – team development CTQC "Tree" – voice of the customer Gauge R&R – data collection Six Sigma Toolset – e.g. SPC Charts Correlation or Regression analysis; Hypothesis tests; Design of Experiments FMEA & Prioritizing, Corrective Action Matrix, System Dynamics Mapping Control Plan, SPC, Visual Controls, Final Report/Presentation to Industry Partner

Table 2. SIX SIGMA Industry Project

Project	Project Deliverables (examples)
Lean	Value Stream Maps (Current & Future states); Factory Physics © Analyses (Little's Law & Internal Benchmarking)
Layout	Design of process to improve flow – e.g. using Group Technology (cell design)
I.E. Systems	Time/Motion Work Measurement Study of process to improve efficiency and/or ergonomics
Project Mgmt	Development of Gantt, CPM, and project plans to support all other projects.

Table 3. Other Industry Projects

Updated 8/10/06			Project Cost		Result	Comment	DMAIC/6-Sigma	Acc. Sign Off	Product, lbs or dollars saved	<3sigma	90%	
		Year	Soft Dollar	Hard Dollar						>3sigma	50%	SIGM
	Improve Plant Calendar Inventory accuracy	09	$30,000		Cost Avoidance	Averaging 3 rolls a year in scrap due to bloom .005% improvemen	DMAIC			3σ		Gree
TIRE ASSEMBLY	HOT Reduction on U-1 tams	06			Cost Avoidance		DMAIC					
	Reduction of SPA defective Liners from T/A	06			Refinement	Needing help from Stock Cutting Kaizen Team $300g	6-Sigma					
	Increase Tam Utilization on SOT constructio	07	$108,000		Improve Bekido	Jamie Brown Black Belt Project	6-Sigma			<3σ		
	Reduce size change time TBR	13			Improve Bekido		6-Sigma					
	Increase Tam Cycle Tam - PSR	15			Improve Bekido		DMAIC					
	Increase Tam Cycle Tam - TBR	14			Improve Bekido		DMAIC					
	Reduce Unbalance scrap 4R93 - TBR	08	$38,090		Cost Avoidance	Highest balance scrap tire - 30 avg monthly	6-Sigma		180		0.011	Cure-
	Reduce Off Center conditions in PSR	11	$111,540		Cost Avoidance	High Scrap condition - 250 avg monthly	DMAIC		1500		0.051	Cure-
	RFV and Bal Reduction-Alignment		$236,088						1044			
	Reduce waste due to poor turn-up TBR	08	$38,090		Cost Avoidance	06 360 tire projection to be cured scrap, Avg 80 green scrap	DMAIC		180	3σ	0.005	Cure-
	Reduce GT scrap due to buckled tread PSR	13	$96,640		Cost Avoidance	High Green Waste scrap cause - 175 avg monthly	DMAIC		124[illegible]	3σ		Gree
	Reduce #29 conditions due to abnormal coverage TBR	09	$65,337		Cost Avoidance	High abnormality 750 buff, 400 rework, 50 scrap monthly	6-Sigma		7200	2.63 - 2.86	0.52	BRS
	Reduce Barcode placement errors TBR	07	$28,438		Cost Avoidance	High Rework condition - 100 avg monthly	DMAIC		600	3.20 - 3.39	0.04	Rewo
	Reduce Beadset scrap - TBR	09	$5,762		Cost Avoidance	Green scrap waste condition	DMAIC		50	3σ	0.001	Gree
	Improve builder Splice accuracy 14's TBR	11	$10,413		Cost Avoidance	5th Highest rework - 160 avg monthly	DMAIC		960	3.13 - 3.32	0.055	Rewo
	Improve builder Splice accuracy 14's & 78's PSR	08	$108,269		Cost Avoidance	Highest rework condition - 2032 avg monthly	6-Sigma		21492	2.67 - 2.90	0.42	Rewo
	Reduce Occurrence for Missing Air Supply S	07	$6,555		Cost Avoidance	Body ply carts high, save 20 min a fix from Contracts standpoint	DMAIC		12144	1.79 - 2.67		NVA
	Reduce Lot Trace Barcode Errors	07	$7,902		Cost Avoidance	Average 22,000 per month in lost barcodes	DMAIC		105			
	Reduce T/R green waste PSR	13			Cost Avoidance							
	Reduce T/R green waste TBR Conveyor	12	$51,452		Cost Avoidance				224			
	Reduce Open and Cross Bldr conditions 60's TBR	14	$116,193		Cost Avoidance	4th Highest T/A scrap condition - 90 avg monthly	DMAIC		540	3.29 - 3.48	0.03	Cure-
	Reduce Open and Cross Bldr conditions 60's PSR	14	$158,046		Cost Avoidance	4th Highest T/A scrap condition - 350 avg monthly	DMAIC		2100	3.02 - 3.23	0.07	Cure-
CURING	Reduction in 42's Pinched Bladder	06	$252,783		Cost Avoidance	Scrap Tire Cost - 2nd Highest Abnormal condition	DMAIC		1179	3.04 - 3.35	0.06	Cure-
	Reduce Mechanical Related Scrap off 51" pre	07	$57,816		Cost Avoidance	Michelle Curry Collins Black Belt Project	6-Sigma		1266	?	0.4	Cure-
	Reduce O-C time on TBR presses	06	$169,342		Improve Bekido	Dana Davis Green Belt Project starting in Nov 06	6-Sigma					
	Reduce Mold Size change time TBR	08			Improve Bekido		DMAIC		0.06		0.06	
	Improve Maint response time	09			Improve Bekido		DMAIC		0.22		0.22	
	Reduce Bladder Size change time TBR	07	$50,000		Improve Bekido	Bladder change efficiency improvement	DMAIC					
	Reduce Molding condition 53's PSR	09	$60,697		Cost Avoidance	2nd Highest condition - 1400, B 275 R, 225 scrap avg monthly	DMAIC		1650	3.11 - 3.31	0.345	BRS
	Reduce Molding condition 48's PSR	09	$21,880		Cost Avoidance	Highest condition - 1050 rework, 225 scrap avg monthly	DMAIC		6215	2.67 - 2.89	0.25	RS
	Reduce Mold Lube buff condition 20's TBR	13	$14,510		Cost Avoidance	High buff condition - 325 avg monthly Scrap save 44 year	DMAIC		1950	2.90 - 3.11	0.107	Buff
	Reduce Green Waste Causes PSR	11			Cost Avoidance	06 ytd .045 in green waste,	6-Sigma			3σ	0.01	Gree
	Increase Bladder life PSR	10	$50,000		Improve Bekido	Increase Bladder Retirement by 15%	DMAIC			<3σ		
	Increase Bladder life TBR	10	$120,000		Improve Bekido	Increase 20% over 270 cure 06 avg	6-Sigma			<3σ		
	Reduce chokotei PSR	07			Improve Bekido	Reduce Short time delays by 25%	DMAIC			3σ		
	Reduce Loading & Unloading related Scrap 50's PSR	12	$45,783		Cost Avoidance	PSR scrap item - 150 avg monthly	DMAIC		900	3.28 - 3.47	0.03	Cure-
	Improve Leak detect accuracy	11	$106,827		Cost Avoidance	Highest scrap condition - 350 avg monthly	6-Sigma		2100	3.03 - 3.23	0.07	Cure-
	Reduce Alarms scrap TBR	11	$245,296		Cost Avoidance	2nd highest scrap condition - 190 avg monthly	DMAIC		1140	3.08 - 3.28	0.06	Cure-
	Reduce Curing Ring Repairs - Both	08			Cost Avoidance		DMAIC					
FINAL	~~Improve Balance Dot application 2006~~	06	$130,900		Cost Avoidance	3 OE customer Concerns in 2005 - Customer Satisfaction	6-Sigma	√ Kellrooney				
	Reduction of S-#25 on TBR	06	$59,194		Cost Avoidance	Re-handling of Product from Whse and Added Labor	DMAIC		4582	1.89 - 2.76	2.61	
	Improve ASRS HOT do to overhangs	06	$59,775		Cost Avoidance	ASRS system improvement	6-Sigma		1287.6			
	~~Reduce 30C Alpha Miss 2006~~	07		$344,000	Refinement	Alpha miss running in the 90% Refinement comes out of QA	6-Sigma	√ J. Bryant	Refinement			
	Reduction Scrap abnormal 77's PSR	07	$211,212		Cost Avoidance	Highest scrap condition for Final Finish .18% to .018%	DMAIC		4152	2.60 - 3.31	0.162	Cure-
	Improve PL job effectiveness TBR	07	$4,348		Efficiency Improvement	Non-Value added activity - not meeting required job duties	DMAIC		437.5		0.5	
	Improve TUO machine efficiency	07			Efficiency Improvement	Staggering work assignments and 5x5 sorting	DMAIC					
	Improve PL job effectiveness PSR	07	$1,988		Efficiency Improvement	Non-Value added activity - not meeting required job duties	DMAIC		200			
	Reduce Classification errors PSR	08	$35,405		Cost Avoidance	2 tire avg per day - out for entire year	DMAIC		696	3σ	0.008	Cure-
	Improve Balance Mark Accuracy PSR	08			Quality Improvement	Customer Satisfaction	DMAIC			3σ		
	Improve Inspection Accuracy TBR	12			Quality Improvement	Datastream from Sort and Returns from Whse	6-Sigma			3σ	Beta miss dat	
	Improve Inspection Accuracy PSR	13			Quality Improvement	Data Stream is at 2nd Inspection - Beta miss not acc	6-Sigma		22	2.65 - 2.88	Beta miss dat	
	Reduce Scrap Abnormality 70's PSR	08	$21,247		Cost Avoidance	2nd highest abnormal condition - 120 avg monthly	DMAIC		700	3.33 - 3.52	0.024	Cure-
	[illegible]	10	[illegible]		[illegible]	[illegible]	DMAIC		[illegible]	[illegible]	[illegible]	[illegible]

Page 3

Table 4. Master Project List

Project	6 sigma / D	Belt/			Define &	Analyze	Improve	Control	When	When	
Reduction in .061 from #2 body ply cutter											
Improvement in balance dot application											
Reduce dump stock - Triples											
Dump stock reduction - PSR Extrusion											
Reduce XOC Alpha											
BP insert placement on #1 body ply cutter											
Stuck Stock											
Green waste reduction - TBR stock cutting						31-Jul	30-Nov	30-Jan	5/31/2007	5/31/2007	Nee
Reduce SPA defective liners from Tire Assembly						31-Jul	30-Nov	15-Dec	12/15/2006		Col
Reducing whse overhangs						30-Jul	30-Sep	1-Jun	7/1/2007		
Reduce WSW grind scrap		Yellow Belt				15-Sep	31-Oct	15-Nov	11/30/2006		
Increase PL Job Effectiveness	DMAIC	David Nelms - Yellow Belt	Ron Jones	C-Collins	1-Aug	31-Aug	31-Oct	30-Dec	1/30/2007		Non
Increase SOT Tam utilization	6 Sigma	Jamie Brown David Grey	Bobby Duke	Brown	30-Oct	30-May	30-Jul	15-Aug	9/30/2007		200
Reduce Mechanical Scrap off 51" Presses	6 Sigma	Michelle Curry-Collins Marvin Wreh	Ron Jones	C-Collins	30-Oct	30-Jan	30-May	15-Jun	8/15/2007		Reduc
Reduce PSR green waste due to buckle tread	6-Sigma	Gary Farmer	Bobby Duke	Brown	15-Dec	30-Apr	30-Jun	30-Aug	10/30/2007		
IT process Project	6-Sigma	Claudia Yamamoto	Dan Perterman	Leonard	1-Mar	30-May	30-Jul	30-Sep	11/1/2007		
Improve Plant Water System	6-Sigma	Mark Haws	Ken French	Leonard	1-Mar	30-May	30-Jul	30-Sep	11/1/2007		
Reduce TBR Assembly Green Waste	6-Sigma	George McNeal	Bobby Duke	Brown	1-Mar	30-May	30-Jul	30-Sep	11/1/2007		
Improve Calendar Inventory											

Project Selection Criteria

Will the project Improve:
Our product to our External/Internal customers?

Improve Variation?

Improve Capacity/Bekido?

What is the dollar impact of the project?

Does the process have a rich data stream?

If no, How easy and quick can you achieve one?

Is there another project in process effecting the problem?

Role of the Project Champion:
Guide the selection and monitoring of projects
Ensure alignment with company priorities & goals
Ensure that the project is data driven
Remove obstacles
Ensure that Black / Green Belts are given sufficient time
Guide the selection of Black / Green Belt candidates
Require answers with data support
Take an aggressive role and drive accountability

Table 5. Master Project Tracking Matrix

6σ Black/Green/Yellow Belt Training Timeline

Activities	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Black Belt Champion Training	TBD	Corporate Level									
Champion Training	As Needed During Monthly Mgmt Review										
Black Belt	2	5	7	9	12	14	16	18	18	18	18
Green Belt	1	6	9	12	15	18	21	24	27	30	33
Yellow Belt	6	20	40	60	80	100	120	140	160	180	200
IQS 21 Training	New Hire Orientation ~ 12 Hour DMAIC										

Table 6. Six-Sigma Training Timeline

Linking Technology and Environment in Industrial Technology

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Abstract

Industrial Technology (IT) is not neutral. It is value laden with societal and our own non-technical values. Technology and society mutually shape each other. Responsible Industrial Technologists should look beyond 'technological fixes' and see the link between technology and environment. IT curricula and courses are often designed without incorporating the impact on the environment. The need and necessity of incorporating environmental components in IT are explored so that our programs will be in the forefront of creating an eco-technological environment. A tool chest with few examples to link technology and environment in IT is provided as a starting point. Linking technology and environment in IT should be viewed as only one part of a balanced approach to consciously shape an eco-technological world that balances private and public interests. IT curricula and courses that link technology and environment certainly deserves the attention of Industrial Technology leaders who like to evoke limitless care and consideration from current and future IT leaders and students who care about the world they live in and develop, design, and deploy IT products, processes, and systems based on sound ecological principles and values.

Introduction

Technology is as old as human race. Volti (2006) defines Technology as "a system that uses knowledge and organization to produce objects and techniques for the attainment of specific goals" (P.6). Our technological marvels such as Airplanes, Automobiles, Mobile phones, factory systems, iPods, and iPhones excite and terrify us. Often we accept technological solutions with more faith and less understanding. We rarely question the impacts of our technology and technological systems on spiritual, social, philosophical, economical, political, and last but not the least, the environmental dimension. We often fail to include the environmental costs into the equation as we look for technological solutions. It seems that we are hooked to growth without considering the environmental ramifications. Even if we pay attention to environment it is often only when the effects are in our back yard. As we see the rapid rise of globalized society, we are beginning to question our wisdom of leaving out the environmental dimension in our decision making process as we pursue new and better Industrial Technological systems. Sad, but it true that most of Industrial Technology (IT) programs have not weaved environmental dimension into their courses.

National Association of Industrial Technology (NAIT) in their 2006 Accreditation Handbook defines Industrial Technology as "a field designed to prepare technical and/or technical management-oriented professionals for employment in business, industry, education, and government" and goes on to define the activities that are done by IT professionals. This definition and activities does not reflect the link between the human-built world and the natural world. This connection and linkage is more and more vital to be incorporated into our programs to prepare our graduates to be wise stewards of our one and only blue-planet for their children and future generations. This brief paper will explore the avenues of incorporating environmental elements into IT curriculum and courses.

Necessity of Environmental component in Industrial Technology

If we accept technology as something that extends human potential and as Nye (2006) pointed out that technology matters because it is inseparable from being human and that we are intimate with technology from birth, then we can't ignore its impacts on environment. In the social history of American Industrial Technology, technological optimism was brimming to the limit and most of the IT curricula embody material progress belief based on technology. We rarely move away from technological fixes into sustainable technological solutions. In the 1933 Chicago's "Century of Progress" Exposition, the importance of machine was in the slogan "Science Finds–Industry Applies—Man Conforms." We tended to think in terms of mastery over nature. With the contemporary awareness of environmental impacts, we are moving away from the age of machinery to the age of eco-technological world. As Nye (2006) asked the question 'Sustainable Abundance or ecological crisis', we need to see "people as part of nature, and nature as part of culture" (P. 107). Yes, we can use Industrial Technology to fix our problems and take growth as a given, but according to Cohen (1995) the number of people the Earth can support depends on what people want from life. The question of whether Industrial Technological solutions assure abundance does not have a cut and dried answer. As Nye (2006) pointed out, the answer is open-ended and it depends on human choices. So it all the more important for IT educators like us to prepare students with a curricula that recognizes moving away from thinking about creating a new technology to thinking about its responsible and effective application (Deutch and Lester, 2004). Also Deutch and Lester (2004) realized that responsible and effective application of technology behooves us to look beyond disciplinary boundaries and to incorporate the elements of "scientific, engineering, economic, manufacturing, organizational, legal, political, and increasingly, international considerations". The environmental considerations permeate all these considerations in an increasingly connected global village of Friedman's (2005) 'The World is Flat'. As we are becoming more and more aware of the planet under stress, it is all more vital for IT professionals to be the pioneers and forward-looking thinkers to consider environmental issues as we prepare our students to be eco-technological minded professionals in their chosen fields.

Framing Environmental Issues in Industrial Technology

Our IT profession should realize that environmental concerns influence profoundly all aspects of our field including design and practice of products/processes/systems. We need to look beyond 'Reduce, Reuse, Recycle' mantra and have to understand the stages where more energy is consumed in the life cycle of a product. For example, it is tedious to spend more time in recycling if most of the energy consumption is in the material, manufacturing, and/or use stages. We need to draw on basic science, technology, and engineering principles to approach an Industrial Technology (IT) problem, and design an eco-friendly solution that eliminate and/or reduce environmental impacts. This consideration for eco-friendly IT approach calls for framing environmental issues and solutions in trans-disciplinary, interdisciplinary, and multi-disciplinary scenarios. So IT programs should be pioneers in cooperating with Humanities, Social Sciences, Engineering, and Science disciplines for appropriate technological solutions taking into considerations the design, development, and deployment of technology in an eco-friendly way. Ultimately it is imperative to train out students to note the political and public policy processes involved in any Industrial Technology (IT) solutions and appreciate the non-technical elements involved in any complex technological solutions.

Incorporating the elements of environmental issues in Industrial Technology

According to Ashby et al., (2007) our "present-day material usage already imposes stress on the environment in which we live" and "*Design for the environment* (DFE) is generally interpreted as the effort to adjust our present product design efforts to correct known, measurable, environmental degradation; the time-scale of this thinking is 10 years or so, an average product's expected life. *Design for sustainability* (DFS) is the longer-term view: that of adaptation to a life style that meets present needs without compromising the needs of future generations. The time-scale here is less clear—it is measured in decades or centuries—and the adaptation required is much greater" (P.480). This long-term view of sustainable industrial technology should help students see that they do more than solving technological problems, building things, and making stuff for global consumers! Most of the environmental issues can be classified into the following broad categories:

- Materials
- Manufacturing
- Use
- Disposal
- Energy

Rubin (2001) stressed that energy is perhaps the most pervasive of all environmental impacts and "the quantities and types of energy that a society uses directly affect environmental quality" (P.11). A general rule of thumb is that any Industrial Technology solution that minimizes energy requirements for a particular product/service/system will be beneficial for the global environment. The relevance of a basic understanding of conservation of mass and energy should not be overlooked as we (re)design our Industrial Technology courses/curricula to reflect our genuine concern for the environment.

Tool chest to link Technology and Environment in IT

<u>Life Cycle Analysis and Assessment</u> (LCAA): Students need to see the "big picture" of how their decisions in various IT fields as defined by NAIT such as Manufacturing Technology, Electronics Technology, Communication Technology, Construction Technology, Design Technology etc., affect the environment. From 'Cradle to Grave' approach to 'Cradle to Cradle' approach of designing and deploying, and assessing solutions becomes paramount. The goal is to minimize the energy requirements whenever possible in material extraction, material processing, manufacturing, use and waste management (Rubin, 2001). According to Ashby et al., (2007), "a rigorous life-cycle analysis examines the life cycle of a product and assesses in detail the eco-impact created by one or more of its

phases of life, cataloging and quantifying the stressors" (P.483). The environmental 'stressors' are any waste including solid, liquid, and gaseous types such as CO_2, SO_x, NO_x, and other environmental contaminants. Rainey (2006) suggested that it is "a multi-stage input—output model that examines all of the inputs, outputs, and impacts – including materials, products, wastes, and emissions" (P.304). A better understanding of this invaluable tool is relevant to IT professionals and students. This vital tool will help future Industrial Technologists to be aware of the necessity of 'eco-profiling' their products and processes holistically.

Principles of Industrial Ecology (PIE): Graedel and Allenby (1995) offered the following definition for Industrial Ecology,

> *Industrial ecology is the means by which humanity can deliberately and rationally approach and maintain a desirable carrying capacity, given continued economic, cultural, and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surroundings systems, but in concert with them. It is a systems view in which one seeks to optimize the total material cycle from virgin material, to finished material, to component, to product, to obsolete product, and to ultimate disposal. Factors to be optimized include resources, energy, and capital.*

Jelinski, et al., (1992) modeled a systems description to Industrial Ecology similar to Biological Ecology which is defined as the scientific study of the interactions that determine the distribution and abundance of organisms. According to them, an industrial ecosystem model has the central domain with interacting four nodes (see figure 1 below): the material extractors or growers, the material processor or manufacturer, the consumer, and the waste processor. Also note that the flows within this industrial ecological system and its nodes are much larger than the external input (resources) and output (waste) flows. It is important to realize that models are an approximate portrayal of reality!

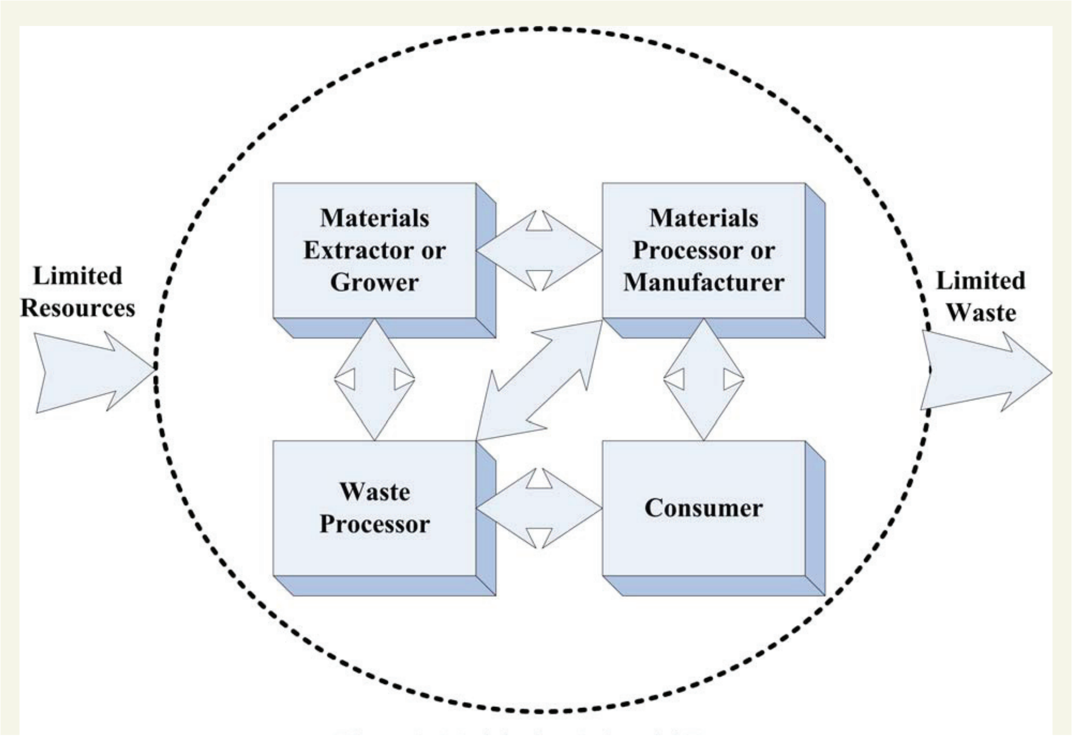

Figure 1. Model of an Industrial Ecosystem. Source: Jelinski, et.al, 1992 (redrawn by Balsy Kasi)

Design and Deployment of Green Industrial Technology (DDGIT): As noted earlier, throughout a product life cycle and/or Industrial Technological systems, the goal is to rethink, redesign, and redo to reduce the environmental impacts without sacrificing our business, social, moral, and ethical obligations. The philosophies of Green design and deployment should be considered by Industrial Technologists. Although we can't accurately predict the ramifications of our actions, we can adapt easily if we use the principles of Green (engineering) industrial technology. This philosophy of designing and deploying green industrial technology is consistent with the concept of sustainable development as originally defined by World Commission on Environment and Development (WCED, 1987),

> *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*

As noted earlier, Design for the Environment (DFE) and Design for Sustainability (DFS) relates to sustainable development definition given above. The key technique for implementing DFE and DFS strategies in Design and development of green industrial technology (DDGIT) products and processes is life-cycle analysis and assessment tool (LCAA) mentioned earlier.

Technological and Environmental Modeling (TEM): Neils Bohr, the Nobel-laureate physicist once said, 'Prediction is very difficult, especially if it's about the future.' However, appropriate TEM modeling with appropriate input variables can help industrial technologists to make appropriate decisions. Modeling should not lull Industrial Technologists into an escape from reality. Models should be used not just to predict but to adapt as needed. Pilkey and Pilkey-Jarvis (2007) suggested that "a model is a numerical analogue—a set of equations that describes the relationships between parameters that control a process" (P.24). Both qualitative and quantitative modeling can be used judiciously by IT professionals and students to understand the link between technology and environment. As Berg and Hager (2007) noted, it is difficult to assess our impacts on the environment. One simple tool uses the three factors, number of people (P), affluence per person as a measure of the consumption or amount of resources used per person (A), and the environmental effects of the (industrial) technologies used to obtain and consume the resources (T) to determine environmental impact (I) in the following well-known IPAT model (Berg & Hager, 2007, P.10):

$$I = P \times A \times T$$

Surely, Industrial Technology products/processes are much more complex to model by simplistic models and equations. A prudent user should be aware of the quality of data, problems of bias, and probabilistic nature of predicting risk and rewards (Pilkey & Pilkey-Jarvis, 2007).

Technological and Environmental Policy Analysis (TEPA): Industrial Technology does not exist in vacuum and technology is not neutral. Technology and society mutually shape each other and often the diffusion of technology depends on the power distribution in society. Given human-nature, the reactions such as 'not in my back yard' (NIMBY) and 'not in my turn of office' (NIMTOO) should not be surprising especially if the industrial technology product/process impacts one community at the expense of another. This problem should be approached with care with tools such as Risk Analysis, Cost/Benefit Analysis, Scientific and Technological Assessment, Public education/involvement, and political action. As we link technology with environment in Industrial Technology, we should not ignore the dynamic connection between economics and environment.

Conclusion

Industrial Technology programs and courses seldom link technology and environment. In an increasingly connected global village, this link can't be overlooked. IT professionals and students should be the leaders in incorporating environmental and technological ethos for a sustainable eco-technological world. A successful IT program will train students to consider environmental ramifications of their decisions as they design, develop, and deploy Industrial Technology products, processes, and systems in their community and beyond. The tools and suggestions provided will be a good place to start as we relate our passion for technology and environment to our colleagues and students. A prudent Industrial Technology educator in their role as a leader will guide and help students to see the link between technology and environment as they blossom into exemplary Industrial Technology Leaders in their community and beyond.

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Student Learning Enrichment: A Case Study of Senior Projects in Industrial Technology

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Abstract

Deductive teaching/learning is commonplace in higher education, particularly in the realm of technology, science, and engineering. Deductive methods begin with theories and progress to the applications of those theories. Inductive teaching/learning is a method in which topics are introduced by presenting specific observations, case studies or problems, and theories are taught, or the students are helped to discover them, only after the need to know them has been established. Inductive teaching/learning methods are consistently found to be at least equal to, and in general more effective than, traditional deductive methods for achieving a broad range of learning outcomes. (Prince and Felder, 2006). The inductive method is prevalent in undergraduate student projects, where student discovery is based upon a "need to know" facts, concepts, examples, patterns, etc. in order to complete a project. This paper discusses the inductive method as applied in a senior capstone course in the Department of Industrial and Engineering Technology (IET) at Morehead State University. Students are expected to design and develop a comprehensive technical project, following a carefully constructed timeline, and report that project through a written report, oral presentation, and poster exhibition. This paper details the pedagogical approach used in this "student project" course. Further, the paper provides several "best" examples of recent completed projects. The paper is intended for an audience of academics and/or industry personnel in the realm of industrial technology and/or engineering technology, especially those interested in utilizing projects to better prepare students for the ever-changing industrial environment.

Introduction/Problem Statement

Effectively measuring the success of an educational curriculum and its elements is necessary but problematic. While many methods are available for evaluating a curriculum, there are few that truly gauge the success of an academic program or individual courses within a program. According to Hilda Taba, "A curriculum usually contains a statement of aims and of specific objectives; it indicates some selection and organization of content; it either implies or manifests certain patterns of learning and teaching, whether because the objectives demand them or because the content organization requires them. Finally, it includes a program of evaluation of the outcomes" (Oliva, 1982, p.7). Evaluating outcomes or "outcome-based evaluation" is effective for student and program assessment as well as the assessment of the elements of a curriculum, its individual courses. It not only validates student learning, but also enables faculty to revise and refine courses or curricula to attain desired outcomes.

In 1997, Morehead State University performed a major revision of its general education program. A component of that revision was a required "culminating event" in each student's curriculum during his/her senior year. This "integrative component" was to "crystallize the student's thinking in their major area of study." Each academic department was to develop its own culminating capstone course for departmental seniors. The capstone course was intended to provide an opportunity for students to demonstrate that they had achieved the goals for learning established by their major department and educational institution.

A problem facing the faculty in Industrial and Engineering Technology (IET) was to identify an effective method for assessment for a capstone course. Being a culminating course, the faculty wanted to assess not only the student, but also the course and overall program. This course provided an opportunity if only the appropriate evaluation methods were developed and properly applied. The course had to be designed to assess the students' command, analysis and synthesis of knowledge and skills from their entire curriculum. The capstone course had to integrate learning from the courses in the major with the courses from the rest of the academic experience. The overall method chosen to fulfill these lofty goals was a project-based course.

Literature Review

Traditionally, student achievement is assessed by examination, which usually measures one's cognitive ability to recall and understand knowledge. Another effective method of evaluation is the student project, which allows for the application of learning. Such projects are usually limited in scope and closely related to competency in a single course. The testing or "multiple exam" method of evaluation is normally formative, which means that it is used during actual instruction to track progress and understanding. In comparison, the project is summative evaluation. That is, its role is to assess learning and skills generally mastered in a course.

By its very nature, a project-based capstone course is an outcome-based method of evaluation. It not only assesses previous cognitive learning in the major, but also provides a forum that allows an instructor to assess the student's overall collegiate learning experience. Since, in addition to cognitive skills, learning can occur in two other domains (affective and psychomotor,) a project-based capstone course allows for a mix of evaluative styles that assess the broad range of the students' past experiences (Kemp and Smellie, 1989).

A project-based course is an in-depth opportunity for the student to demonstrate accomplishment of the full spectrum of learning. It is, therefore, critical that the capstone course contain a wide and balanced variety of expectations. The student is given the opportunity, through the project medium, to analyze and apply the accumulated learning and display creative products and solutions to requirements presented by the course. A useful model for such expectations is Bloom's Taxonomy of Educational Objectives (Bloom, 1956). These progressive levels of objectives are recall of knowledge, comprehension, application, analysis, synthesis and evaluation. The last three levels are higher-order intellectual activity. They are concerned more with the how and why of learning rather than the what. By requiring students in the project-based capstone course to reach objectives beyond application, they achieve more outcomes of learning.

The reality of higher education today is that students' major programs cannot exist in isolation from the rest of their education. Schools are recognizing that they "should be accountable not only for stating their expectations and standards, but for assessing the degree to which those ends have been met" ("The growth of a model college," p.31) (Boyer, 1987) As Blanchard and Christ (1993) state in *Media Education and the Liberal Arts,* "the outcomes method [of assessment] is the most tangible and rational measure [of learning]" (p.13). Project-centered courses in higher education are learner-centered (also known as student-centered) and outcome based. The project-based course provides the means to measure the imposed responsibility on students for their own learning much more effectively than the traditional lecture-based deductive approach. In these type courses, students learn by fitting new information into existing cognitive structures (Prince and Felder, 2006).

Pedagogical Approach and Elements

Student projects are an important part of the curriculum in the Industrial and Engineering Technology (IET) department. This pedagogical approach provides outcome-based assessment of student teams in many classes and individual students in the senior capstone course. In many courses, students work in small teams (typically three to five students) to tackle realistic problems. The key goal of these team projects is to determine how well a student can develop and solve appropriate technical problems in the team environment. Student teams are commonly required to set and maintain a project work schedule, work collaboratively with team members, cooperatively write project reports, and often orally present the project methodologies and results.

The senior capstone course in the IET department, IET 499C - Senior Project, is a project-oriented, outcome-based course where students individually work on a selected technical problem. While students gain the "team" experience in projects in previous departmental courses, they are expected to fully develop and solve a comprehensive technical problem individually for IET 499C. The IET faculty unanimously agree that individual project work is the only means of effectively assessing individual students. Individual students draw all previous learning together and in this single experience to demonstrate the achievement of the educational goals of the department and university.

Course Purpose, Goals, Competencies

The primary purpose of the course is to determine the ability of the potential graduate to solve an appropriate technical problem and report those findings in several venues. A secondary purpose is to help the IET department determine whether graduates are prepared to enter the world of work. The course goals are to enhance students' abilities to communicate under some pressure, to research and present information more efficiently and to think at the higher levels required in responsible positions in business and industry.

Students successfully completing the course, defined as those with a grade of 'C' or higher, will gain the following competencies. The successful student will (1) demonstrate the ability to identify a technical problem and a potential solution; (2) demonstrate the ability to maintain a schedule of regular technical progress; (3) demonstrate the ability to follow the scientific method in the completion of an extensive written report; (4) demonstrate the ability to make sound technical decisions based on practical considerations; and, (5) demonstrate the ability to present technical results both orally and by poster exhibition.

Course Schedule

The course occurs during a sixteen (16) week semester. A breakdown of tasks for each week of the semester is provided in Figure 1.

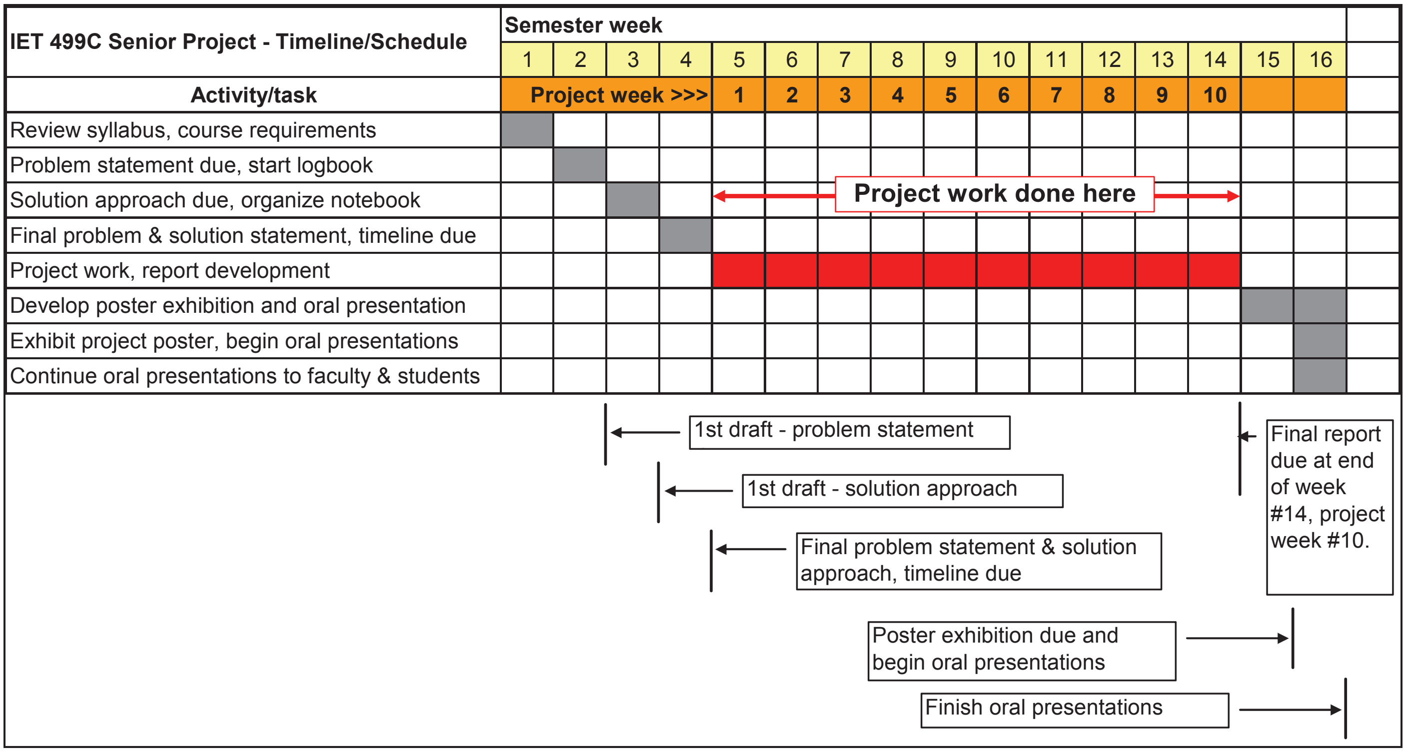

Figure 1 - Capstone Course Timeline/Schedule

Course Requirements

The capstone course is centered on a comprehensive technical project each student must design and develop. Each student must complete several written and oral components in order to satisfactorily fulfill the course requirements. Those major components, detailed below, are: (1) problem statement; (2) solution approach and project timeline; (3) project report; and, (4) poster exhibition and oral presentation.

Problem Statement

The problem statement provides and overview of the technical problem and basic approach for solving the problem. It is typically one to two pages in length (double-spaced) and contains the following elements: (1) purpose or intent of project; (2) thorough, yet concise description of problem and need for problem solution; and, (3) approach to solve the problem including five to eight major steps to be accomplished with a brief description of each step (1-2 sentences).

Solution Approach

Based on the overview and major project steps described in the problem statement, the solution approach must contain a detailed explanation of steps to solve the problem. For each major project step (5 - 8), the explanation must contain measurable and objective statements that are sufficiently detailed to clearly identify the work to be done and an estimated time, in weeks, to perform the work. Each step must contain statements that are measurable, action-oriented, and time limited. For example, an appropriate portion of a major step description would be "complete orthographic and assembly views using CAD software resulting in drawings and accompanying printouts to be completed by the end of the third week of the project."

Timeline: Shown in Figure 1, weeks five through fourteen of the sixteen-week semester are designated as the ten weeks of the actual project work. Each student writes two iterations of both the problem statement and solution approach, including a project timeline or schedule. This timeline contains the number of weeks each of the five to eight major steps of the project will occupy. These documents are reviewed and approved by the IET 499C instructor and student's academic advisor. Upon approval, the student begins the project work at the start of the fifth week of class. The work then progresses, according to the approved student's timeline.

Progress Reporting: Each student is required to maintain frequent and ongoing contact with the IET 499C instructor and his/her academic advisor. Both versions (draft and final) of the problem statement and solution approach are approved by the academic advisor prior to submitting to the course instructor. During the ten-week project duration (weeks 5-14), each student must meet with the course instructor weekly and academic advisor biweekly.

Report Content

The project report is developed and written progressively during the semester. The report is divided into sections described in the student's solution approach steps (5 - 8 sections). An example of the sectional layout of a project report is shown in Table 2.

Each section of the project report must contain a detailed written description (i.e. narrative) of research, analytical, design, and development methods used. Each section must be completed according to the timeline in the student's *Solution Approach* during the ten-week project time (i.e. weeks #5 - 14). In other words, the report must be written and individual sections completed as the project progresses.

1. Logbook sheets and copy of timeline (bar chart format).
2. Course information (syllabi, checklist, etc.)
3. Problem statement and solution approach (all copies - latest version first).
4. *Research and measurement*
5. *Material selection*
6. *System configuration/computations*
7. *Drawings - sketches and CAD*
8. *Schedule and/or process flow*
9. *Cost estimation*
10. Conclusions and recommendations: How well were the solution approach steps completed? How could the project be better accomplished?
11. References list in APA or MLA format for citations. No fewer than 5 and no more than 10 references used in context of report from at least 3 different types of sources.

These are **examples only**. Students use steps developed in their own solution approach. Each of these sections must contain a detailed written narrative of analytical methods used.

Table 2 – Project Report Example Sections

Student must complete the work and provide the written report (i.e. tables, drawings, computations, written descriptions of analytical approaches) in individual sections as the project progresses on a weekly basis. For example, assume *Research and Measurement* is specified as a project step to be completed by end of first week in the project (according to student's timeline). At the end of week #1 in the weekly update meeting with the IET 499C instructor, the student must provide evidence of the: (1) research completed including a detailed narrative with appropriate references; and, (2) measurements with data placed in appropriate format (i.e. table) and detailed narrative.

At the end of the 10-week project duration, end of week #14 of the semester, the completed project report is due from the student. This report, graded by rubric, makes up 50% of the student's overall grade in the class (see *Student Assessment* section below).

Poster Exhibition and Oral Presentation

Students must prepare a poster exhibition of their project and submit at the end of week #15 in the semester. The poster exhibition must thoroughly yet concisely explain their project on one standard size, tri-fold, cardboard poster. Further, students orally present their project to other IET 499C students, IET faculty, and others during the final week of classes. Computer projection must be used in this 8.5 to 10 minute presentation.

Student Assessment

The class is assessed as: (1) problem statement and solution approach - 15%; (2) project written report - 50%; (3) poster exhibition - 10%; (4) oral presentation - 15%; and, progress reporting - 10%. The report, poster, and oral presentation are each graded with rubrics distributed to students at the beginning of the semester. Each of the elements being assessed is required and must be satisfactorily met by each student. A minimum score for the "problem statement and solution approach" is 75% and for the "progress reports to class instructor and advisor" is 80%. A standard grading scale is used of 90% or higher = 'A' grade, 80 – 90 = 'B' grade, and so on.

IET 499C Example Projects

An example project, from 2007 Spring semester, involved a student who, in a chemistry class, became aware of the problem of unsafe drinking water in remote or storm-damaged areas. This student researched the requirements for a portable, battery-powered, water treatment module. The research included comparisons among the modalities for removing toxins and particulates from tainted water, the battery requirements needed to achieve practical flow rates through the module, and the mechanical design requirements to render the module truly portable. The student researched, designed, built, and successfully tested a device utilizing several modalities for water treatment simultaneously.

Many students decide to take on a senior project that not only exemplifies the integrative nature of the capstone course, but also dovetails with their outside activities and enthusiasms. One student recently designed a coaxial cable-based audio "snake" to replace the tangle of bulky audio cables found in many live music venues. In this project, the student researched the types of analog multiplexers available in integrated circuit form, as well as the proper signaling format to encode the audio bitstream onto the coaxial cable. The student was able to take advantage of some recently acquired simulation software to troubleshoot and debug his design for interference and timing hazards that could have rendered the multiplexed audio signals undecipherable. The project resulted in a design and a formatting strategy that worked correctly.

Zero impact development design refers to construction design approaches that attempt to enhance the natural hydrology of land during the development design stages. In this third and final example, a student performed a project to match/improve upon the predevelopment hydrology setting in a hypothetical area intended for high density residential development. The student researched the water conservation techniques used to provide hydrological improvements in stormwater surface flow (peak flow and accumulated runoff) as a result of development. He then completed hydrologic analyses and several water retention designs, plus he described construction procedures that enhance fresh water conservation in residential developments. His project also included a detailed cost estimate and construction schedule of the hydrologic work.

Conclusion

The IET 499C senior capstone course recently celebrated its tenth anniversary and is offered on a semester basis within the IET department. The most experienced IET faculty, typically full professors, direct the class. IET 499C has gained a well-deserved reputation as one of the most rigorous senior project classes offered at the University. Successful students, upon graduation and in a career in industry, attest to the rigor of the course and how well the course prepared them for their careers in industry where technology managers commonly are immersed in project-oriented work. Just as important from the pedagogical and assessment viewpoint, the course as organized at Morehead State University has led to a model of assessment of learning outcomes for graduating seniors. This model features extensive progress reviews by more than one faculty member during the project, and summative evaluations of each student's project by all faculty members of the Department.

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Construction

Bid Mark Ups in the Construction Industry: An Application of an Alternative Approach to Allocate Risk at the Bid Phase of the Construction Project

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Abstract

Exculpatory clauses are often used in construction contracts to shift potential risks of construction from one party to another. Hartman (1998) and Khan (1998) suggest that Canadian contractors use a risk premium between 9% and 19% to alleviate the risks associated with accepting exculpatory clauses. This paper presents results of a research study conducted on U.S. contractors to identify and quantify risk premiums they use to mitigate the risk associated with accepting exculpatory clauses. The results show that contractors added risk premiums between 7.2% and 27% for accepting identified risks for the study. The study also did indicate that there was a reduction in the bid amount of 23% between group A contractors' and group B contractors' lump sum prices. Based on the reported results, an alternative approach was recommended with the goal of reducing project costs. Also, recommendations were made to owners to better control for the identified risks.

Introduction

Exculpatory clauses are statutory clauses that shift potential risks from one party to another. The party assuming the liability of a risk is expected to have the necessary experience, knowledge and capability to manage and control that risk. Fisk and Reynolds (2006) state that "the principal guideline in determining whether a risk should be transferred to another is whether the party assuming the risk has both the competence to assess the risk and the expertise necessary to control or minimize it" (p. 268). For example, in a design-bid-build project delivery method, the designers are expected to be liable for the drawings and specifications, while the contractor is responsible for the construction methods and means. Conversely, owners are responsible for making payments on time with no delays.

Typically, it is the owner who seeks to shift a particular construction risk to the other parties (designer or contractor). When they do that, owners use exculpatory clauses in the construction contract. Powell (200) argues that exculpatory clauses take various forms. The exculpatory clause may state that the owner is not responsible for any damages or delays. Conversely, the clause may provide that the owner is not liable for any misrepresentation or inaccuracy of the plans, specification and/or soil report presented to contractors bidding on the construction project. According to Khan (1998), exculpatory clauses are often found in "both the instructions to bidders and in the terms and conditions which form the agreement between the owner and contractor" (p.1).

Hartman (1998) and Khan (1998) suggest that contractors in North America use a risk premium between 9% and 19% as part of their contingency plan to alleviate the risks associated with accepting exculpatory clauses. Hartman added that contractors have risk premiums incorporated in: the risk of doing business, subcontractor prices and unit rates.
Therefore, the project cost to the owner will be more than it should be due to inappropriate risk allocation techniques.

Owners have an interest in using exculpatory clauses with the perception of reducing project costs. They tend to use those clauses to shift risks of construction to the contractor. However, the evidence suggests that using these clauses may have a negative impact on the project final cost. According to Mohamed and Hartman (2000), when contractors are faced with such clauses they use either hidden or explicit charges to mitigate the risk associated with accepting exculpatory clauses. These hidden charges are designed to increase the bid price to compensate for the perceived level of risk.

Research and Null Hypothesis

The data for this study was collected from two groups of contractors. Group A included contractors who were presented with a bid package with exculpatory clauses. Group B included contractors who were presented with a bid package with a separate list of identified risks. In the pursuit of this study, two null hypotheses were developed:

- H_{o1}: There was no statistically significant difference between group A contractors' lump sum price and group B contractors' lump sum price (calculated by adding the contractor base bid price to the price of separated risks).

- H_{o2}: The real interval of confidence for each exculpatory clause (that allocate risks for: Design errors, differing site conditions, construction errors, risks of payments and no damage for delays) was equal to zero.

Industry Survey

This study was based on a mailed, self-administered experiment for data collection. The research study was conducted with U.S. contractors to identify and quantify risk premiums they use to mitigate the risk associated with accepting five exculpatory clauses. Those clauses allocate risk for: design errors, differing site conditions, construction errors, risks of payments, no damage for delays.

This study was limited to the following: Design-bid-build project delivery method, the standard form of agreement between owner and contractor as published by the American Institute of Architects (AIA) document A201 and the aforementioned five exculpatory clauses.

Data for this study was collected from two groups of contractors. Group A included contractors who were presented with a bid package with exculpatory clauses embedded in the contract language. Group B included contractors who were presented with a bid package with a separate list of identified risks.

The study compared the bid prices obtained from the two groups of contractors, with different bid packages for the same project, using the t-test statistic for independent samples technique to test the first research question. The study used a one-sample t-test statistics to test the second research question.

This researcher used the 'ACME' convenient store construction project (please contact the author for a complete description of the project) as a basis for contract documents in the pursuit of the study. The project was bid as a lump sum contract. Project documents were developed to meet the requirements of the study. The project delivery method employed was design-bid-build. The modified documents identified a scope of work to include excavation work, foundation work, steel structure work, and masonry work. To control for variability of bids due to differences in profit and overhead, the contractor's profit and overhead were established at 10%. Furthermore, to control for variability due to differences in quantity of work, this researcher provided participants with a quantity take off for the scope of work.

Participants in the study were divided into two groups: group A and group B. Each group had at least fifteen participants. Contractors/estimators in group A were furnished with a lump sum bid package with exculpatory clauses incorporated within the project documents. The contractors/estimators in group A were asked to prepare a lump sum price based on the bid package provided to them. In addition, contractors/estimators in group A were furnished a sealed follow-up questionnaire regarding the risk premiums they added in their bids for each identified risk. Contractors/estimators in this group were asked to complete the questionnaire immediately after they finished bidding the project.

Contractors/estimators in group B were furnished with a base bid package with a separate list of identified risks. The contractors/estimators in group B were asked to prepare a base bid price that excluded these risks from the bid and to provide a unit price or a percentage appropriate for the identified risks. The lump sum price for group B was calculated by adding the contractor base bid price to the unit price or percentage for accepting the identified risks.

To validate the research instrument for this study, a panel of experts comprised of three experienced estimators was utilized to ensure that the research instrument was in conformance with standard practice within the construction industry.

Results

The bids and questionnaires were completed by estimators in the responding companies. Respondents had an average of 21 years of experience in estimating and a range from 3 to 38 years; hence, they had the required professional experience to complete the study. In addition, participants had an average of 40% of their work in a competitive bid environment; hence, they were familiar with the competitive bid environment. Finally, participants' average project value was $140 million per year with a range from $1 to $700 million.

Table 1 includes descriptive statistics for the values of the lump sum prices for the two groups. The results of the descriptive statistics indicated that there was homogeneity of variances for these variables of the study. The results also indicated that the mean lump sum price for group B was lower than the mean lump sum price for group A.

Table 1 Descriptive statistics for the values of lump sum prices.

Group	Mean ($)	Standard deviation ($)
Lump sum price		
A	330,572.00	200,296.00
B	254,213.00	95,929.20

Table 2 shows descriptive statistics for the percentages of the risk premiums for design errors, differing site conditions, construction errors, payments risks and no damage for delays risks for both groups.

Table 2 Descriptive statistics for added percentages of risk premiums

Group	Mean (%)	Standard deviation (%)
Design errors		
A	6.58	10.4
B	4.05	6.7
Differing site conditions		
A	4.58	7.66
B	4.85	3.82
Construction errors		
A	1.47	2.95
B	1.03	2.61
Risk of payments		
A	1.81	3.59
B	2.75	5.61
No damage for delays		
A	4.47	5.55
B	2.59	2.17

The results of the descriptive statistics indicated that there was homogeneity of variances for these variables of the study. The data from table 2 suggests that the mean risk premium contractors added for Differing site conditions and risk of payments is higher for group B contractors. Further, table 2 indicated that the mean risk premium contractors add for design errors, construction errors and no damage for delay is lower for group B contractors.

Results from Null Hypothesis 1

The first null hypothesis compared the lump sum price obtained from group A and group B. It stated that group A contractor's lump sum price does not differ from group B contractor's lump sum price. Table 3 reports the results of the independent sample t-test. The t-test analysis suggested that there was no statistical significant difference between the lump sum price obtained from contractors in group A and contractors in group B $t_{(N-2)} = 1.332$, $p = 0.198$. Therefore, we fail to reject the null hypothesis of no difference between group A and group B contractors' lump sum price.

Table 3 Independent sample t–test

	T value	Degrees of Freedom	P value	Effect size
Lump sum price	1.332	28	0.198	0.486

Results from Null Hypothesis 2

The second null hypothesis inquired whether we could determine the 95% confidence interval for the additional percentages that the contractor used for selected exculpatory clauses.

Table 4 shows the result of the one-sample t-test statistics to determine the 95% confidence interval for risk premiums added for each of the identified risk for this study for the two groups. The results showed that for both groups, the total 95% confidence interval for risk premiums added for the identified risks for this study was 7.2 % - 27%.

Table 4 One-sample t-test statistics for risk premiums added by the two groups

	95% confidence interval of the difference	
	Lower	Upper
Design errors	2.07	8.56
Differing site conditions	2.49	6.94
Construction errors	0.23	2.28
Risk of payments	0.54	4.01
No damage for delays	1.95	5.12

Discussion and Conclusion

Based on the results of the study, it was concluded that there was no statistical significant difference between bid prices obtained from group A contractors and group B contractors. However, the researcher found that the mean lump sum price obtained from group B contractors was $76,359 lower than the mean lump sum price obtained from group A contractors. This represents a 23% decrease in the bid amount for the project. Furthermore, the effect size for the lump sum was 0.486 (see table 3), which is considered moderately high. According to Cohen (1988) the effect size is a measure to determine the practical significance of research findings.

A 23% decrease in the bid amount with an effect size of 0.486 is considered a sizeable figure in today's high competitive construction industry. The small sample size might have a large impact on not achieving a statistical significant difference in this study. Consequently, the difference might have statistical implications on the population, which means that the difference (23%) may have been present in the population. As a result, this finding demonstrated a practical implication in the construction industry.

The results indicated that contractors may add risk premiums to their bid price when they were forced by exculpatory clauses to assume risks. The average of risk premiums identified by this study population could be as low as 7.2 % and as high as 27% of the project cost. The results of this study provided estimated-based data which are similar to the findings of previous qualitative study conducted by Hartman and Khan. The study indicated the contractors add risk premiums between 9% and 19% when they assume risk.

The statistical analysis for this study confirmed that identifying risks at the bidding phase of the project did not significantly affect risk premiums contractors added for assuming these risks. While there was not a statistically significant difference, a measured higher dollar value for risk premiums added by group A was identified in three areas of risk, namely: design errors, construction errors and no damage for delays.

When risks have not been identified, the premiums are hidden within the bid price, which means that the owner is unknowingly paying more for his/her project, when perhaps it may not be necessary. Further, contractors might be inclined to use higher risk premiums, when they could hide those premiums within the bid price.

However, when risks were identified, contractors were more inclined to use lower risk premiums for assuming those risks. Therefore, the owner would have a clear and a comprehensive understanding of what risks he/she was willing to shift to the contractor. Consequently, the owner would have better information to aid him/her in the decision making process regarding what he/she would pay the contractor in case these particular risks were materialized during the construction phase of the project.

The descriptive statistics indicated that the ranking for the highest two mean risk premiums added by contractors were as follows:

- Design errors
- Differing site conditions

The aforementioned ranking of differing site conditions and design errors were similar to earlier studies by Khan (1998) and Rogers (2006), where they stated that the differing site conditions clause was the most commonly used in construction contracts. Further, the clause ranked first in the cause for higher risk premiums. Kumaraswamy (1998) reported that design errors ranked first cause for construction claims. Therefore, contractors add higher premiums when they assume these types of risks to mitigate their negative effect on the contractors' profitability.

According to Mohamed and Hartman (2000), amounts of risk premiums added by contractors depend on the contractor risk behavior. Contractors who are more risk averse will use higher risk premiums to minimize their exposure to risk at latter stages of the project. Contractors who are risk takers will use lower or no risk premiums when assuming particular risks.

Recommendations

The owner can use the findings of this study and previous studies as a tool for his/her decision making process towards what risks he/she should assume and what risks he/she should transfer to the contractor. The owner's decision must be based on whether he/she is willing to be liable for expenses incurred if the assumed risk is materialized. Or, whether he/she is willing to shift the risk to the contractor and pay the ensuing risk premium, regardless whether the risk materializes or not.

Further, the owner may consider assuming certain risks, for which contractors may add higher risk premiums. This makes the owner responsible for the cost of the risk only if that risk does occur. Consequently, the owner may end up saving risk premiums he/she is obliged to pay if the contractor is forced by the contract to assume risks.

Therefore, the owner may consider retaining risks associated with design errors and differing site conditions. Alternately, the owner may consider shifting risks for construction errors, risk of payments and no damage for delays to the contractor.

Recommendations for an Alternative Approach for Allocating Risks

The results of the study suggest a 23% reduction in dollar amount in the average lump sum price when the project risks had been identified and separated during the bid phase of the project. This is a considerable figure in today's high competitive construction market.

In order for the construction industry to capitalize on the findings of this study and a previous study by Jergeas and Hartman (1996), the following steps for an alternative approach are presented. First, the owner with the help of the architect/engineer must identify the risks associated with the project. Second, bidders must be asked to provide a base bid price that excludes all identified risks. The base bid shall be the price for materials, labor and equipment. Third, bidders must be asked to provide risk premiums for the identified risks. Fourth, bidders must agree to accept the owner's allocation of risks. Fifth, the owner must analyze and adjust bids to produce the most cost-effective combination of base bid and risk allocation for the owner. Sixth, the contractor must be informed before signing the contract, which of the identified risks it is expected to assume. The contractor's sole compensation in case one and/or all risks it assumed is/are materialized will be based upon the premium provided by the contractor for those risks. Seventh, for all risks assumed by the owner, the owner should base payments on the actual costs incurred plus 10% for overhead and profit.

Application of the New Approach

To examine the new approach, the researcher randomly and independently selected five bidders from group B and applied the new approach to establish a successful bidder. Table 5 shows base bid prices, risk premiums for the identified risks and lump sum prices for the selected five bidders.

Table 5 Bid details for five bidders

		Risk premium for					
Bidder #	Adjusted Base bid $	Design errors %	Differing site conditions %	Construction errors %	Risk of payment %	Damage for delays %	Lump Sum $
1	226,435	1	2.8	0	0.5	0.5	228,699
2	151,690	10	7.5	3	11	3.1	177,629
3	230,261	25	10	0	5	5	253,287
4	243,383	10	10	0	20	5	304,228
5	175,987	0	2	0	0	4	183, 026

According to the findings of this study, the two highest risks contractors add premiums for are risks associated with differing site conditions and design errors. Therefore, the owner is recommended to retain those risks. Consequently, the owner is recommended to shift risks for construction errors, risk of payments and no damage for delays to the contractor. By adopting the recommendation of the alternative approach, the lump sum prices for the five bidders are calculated (Table 5). (This is achieved by adding risk premiums for construction errors, risk of payments and no damage for delays to the base bid price). The table shows that the lowest bid is bidder number 2.

By applying the alternative approach, the owner signs a construction contact with bidder number 2 for $151,690. The terms of the contract states that the contractor is responsible for building phase one of the convenient store for the assigned amount. The contractor will be responsible for risks associated with construction errors, risk of payments and no damage for delays. In case these risks are materialized, the contractor sole compensation from the owner is the agreed risk premiums clearly stated in the contract (3%, 11% and 3.1% respectively). Furthermore, the owner is responsible in case risks associated with differing site conditions and design errors are materialized. The owner is obliged by the contract to pay the contractor all direct costs plus 10% for overhead and profit.

The owner, by applying the new approach, establishes a partnership with the contractor. The partnership is based on an open, clear and mutual understanding of the contract terms and risks linked to the project, which leads to build trust between the contracting parties. Trust is expected to reduce future conflicts that may result in reduction in change orders and litigation costs.

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A Comparison of Chinese and American International Construction Industries

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Abstract

The U.S. has long been a dominant player in the export of construction services to foreign countries. In recent years, China has emerged as the seventh leading country for building construction projects overseas. They are winning a growing number of international contracts and have claimed market shares in over 180 countries, including a small number in the United States. Moreover, 46 Chinese contracting companies have emerged among the top 225 contractors in the world. Competition with large Chinese construction companies has become more challenging for projects in both China and around the world. This paper explores China's international construction industry. Current trends and barriers are examined along with government policies. In addition, Chinese and U.S. construction import/export tendencies are compared and their implications are discussed.

Introduction

The U.S. has long been a dominant player in the export of construction services to foreign countries. In recent years, China has emerged as the seventh leading country for building construction projects overseas. Additionally, they are winning a small but growing number of contracts in the United States. Moreover, China and the U.S. represent the top two domestic construction markets in the world. Competition with large Chinese construction companies has become more challenging for projects in China, U.S. and around the world.

This paper explores China's international construction industry. Current trends and barriers are examined, along with government policies. In addition, Chinese and U.S. construction import/export tendencies are compared and their implications are discussed.

China's Construction Industry

By some measures, the Chinese construction market is considered the largest in the world at $391 billon in 2005 (Conway, Crandall, Ryan, Khalil, 2005, p.7). At first glance, the U.S. market appears larger by almost three times at $1.1 trillion in 2005. However, when square footage is compared to cost, China comes out on top. Conway et al. (2005) reports that the cost per square foot for buildings in Shanghai is about $70 compared to New York where it is $550 (p.7). In relevant terms, the $391 billion is equal to (or exceeds) the trillion dollar U.S. market.

Industry Growth

Construction within China has been expanding at 7% per year for both 2004 and 2005 (U.S. Department of Commerce, 2005, p. 2). This growth has been affected by both internal and foreign influence on the Chinese economy. Domestic initiatives such as the build-up for the 2008 Beijing Olympics and Western Development Strategy have driven internal growth. Moreover, entry into the World Trade Organization (WTO) in 2001 and foreign direct investment have influenced the economy externally.

Preparation for the 2008 Olympics has created the need for large-scale infrastructure and building construction within and around the municipality of Beijing. The Western Development Strategy was launched in 1999, with the aim of increasing growth in more inland regions of the country and reducing the wealth gap between the rich and poor. Under this program, the central government is spending billions of renminbi on infrastructure improvements to the region's roads, railways, and telecommunication. The areas covered by the project include the provinces of Shanxi, Shaanxi, Qinghai, Sichuan, Gansu, Yunnan and Guizhou, the regions of Ningxia, Xinjiang, Tibet and Inner Mongolia and the municipality of Chongqing. Combined, those regions account for 57% of China's land mass, 23% of the population and 20% of the GDP (U.S. Department of Commerce, 2005, p. 6).

Chinese Government Control

The construction industry in China is market driven to an extent. However, for the most part different levels of the communist government play a dominant role in controlling it. For example, they solve infrastructures issues by decree instead of by legislative means (Gepfert, 2007, p. B6). Furthermore, a key factor in China's industry composition is the various governmental divisions that "own" and operate construction enterprises. The divisions historically have been organized into three categories: State Owned Enterprises (SOEs); Urban and Rural Collectives (URC's); and Rural Construction Teams (RCT's) (Sui Pheng, Hongbin, 2003, p.589). Extensive government involvement creates a lower cost basis for projects because the government can absorb any losses. They use the state-owned construction firms to "keep competition fierce and profit margins low" (Conway et al. , 2005, p. 7). As of recently, more firms have become privatized but the vast majority are still government owned. The top five Chinese international contactors are compared to their top five U.S. counterparts in Table 1. All the listed Chinese companies are SOE's and are sponsored, by Provinces, Municipalities, or Special Administrative Districts. The U.S. firms are private enterprises. The Chinese contractors listed in Table 1 averaged $11.98 billion in overall yearly business volume compared to $10.16 billion for U.S. firms. These amounts include both domestic and foreign contracts.

	China firms	dollars	U.S. firms	dollars
1	China Railway Engineering Corp.	15.36	Bechtel	14.61
2	China Railway Construction Corp.	14.43	Centex	12.98
3	China State Construction Eng'g Corp.	12.53	Fluor Corp.	10.79
4	China Communications Construction Grp.	9.34	KBR	8.83
5	China Metallurgical Group Corp.	8.24	Kiewit Corp.	3.60

Table 1. Top Five China and US International Contractors 2005 (in Dollars, Billions)

Note. From The top 225 international contractors. (2006, December). Engineering News-Record, 8, 46-51.

Construction Exports

China is expanding its presence in the international construction market. They seem to be tapping into experience gained from a 20-year domestic building boom. In 2004, around 180 Chinese contractors constructed projects overseas (Murphy, 2004, p. 30). It is evident that they are raising their international profile, perhaps at the expense of U.S. contractors. For example, in 2001 there were 40 Chinese international contractors in the top 225 in the world. The number increased to 46 in 2005 (Reina, Tulacz, 2006, p.4). Conversely, U.S. contractors in that group decreased from 79 to 52 during the same period. (see Figure 1)

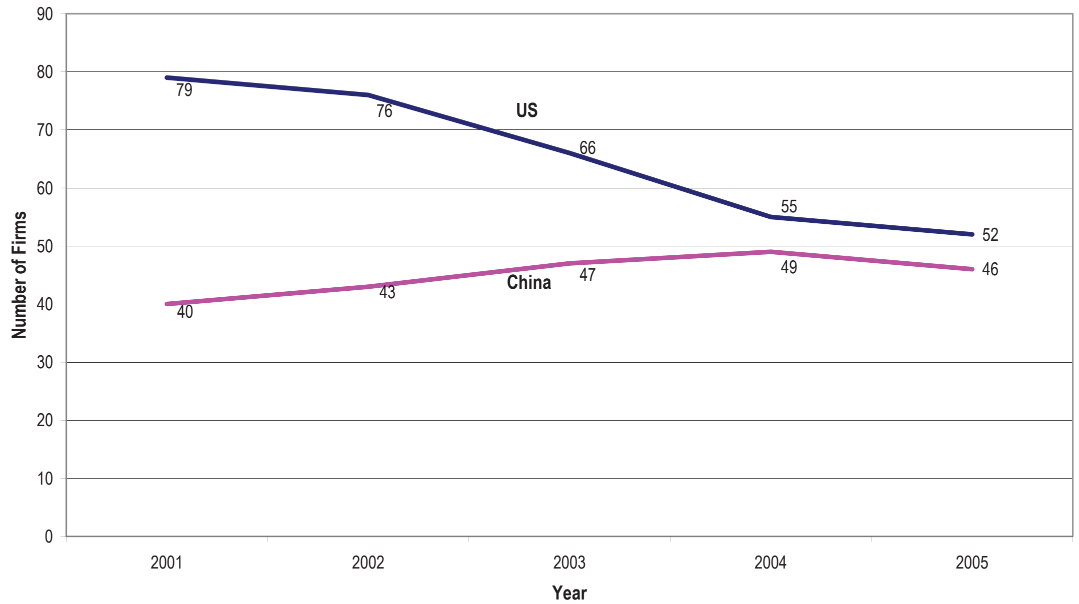

Figure 1. U.S. & China construction

(Number of firms in top 225 international contractors).[1]

China's overall construction export volume improved dramatically from $5.9 billion in 2001 to just over $10 billion in 2005 with an increase of 70%. However, the U.S. is still the world leader in construction exports as they increased from $21.84 billion in 2001 to $34.84 billion in 2005. Table 2 indicates country breakdown for international construction based on annual business volume in 2005. Note how the U.S. ranks first and China ranks seventh.

China has vast experience in infrastructure work. They engaged in a wide range of projects including the New Chinese Embassy in New York (Shanghai Construction Group), road and tunnel work within China (China Communications Construction Group), the new passenger terminal in Hong Kong (China State Construction Engineering Corp.), railroad construction in China (China Railway Construction Corp.), and the building of sewage treatment plants in United Arab Emirates (China Railway Engineering Corp.).

American	$34.84
French	$28.97
German	$21.84
Japanese	$16.03
British	$12.73
Spanish	$12.59
Chinese	$10.07
All Others	$6.76
Italian	$5.89
Dutch	$5.17
Turkish	$3.69
Korean	$2.40

Table 2. Country Breakdown of International Construction Business Volume 2005 (In Dollars, Billions)

Note. From The top 225 international contractors. (2006, December). Engineering News-Record, 8, 46-51.

China's competitive advantage on the international scene includes very low wages for management and skilled workers. In the past twenty years, an estimated 3 million Chinese construction workers have been employed outside their home country. Chinese firms now represent low-cost international rivals to U.S., European and Japanese construction firms.

US and China: Foreign Contracts in Asia

Chinese construction companies have been very active on the Asian international scene for several years. From 2001-2005, China has been outpacing the U.S. in that part of the world (see Figure 2). China completed $5.07 billion of construction work outside their home country in Asia for 2005 compared to just $3.30 billion for the United States. This trend may be attributed to China's strategic location in the geographic area. Overall, Chinese contractors ranked second in the Asian market behind Japan who completed about $7.4 billion of work in 2005.

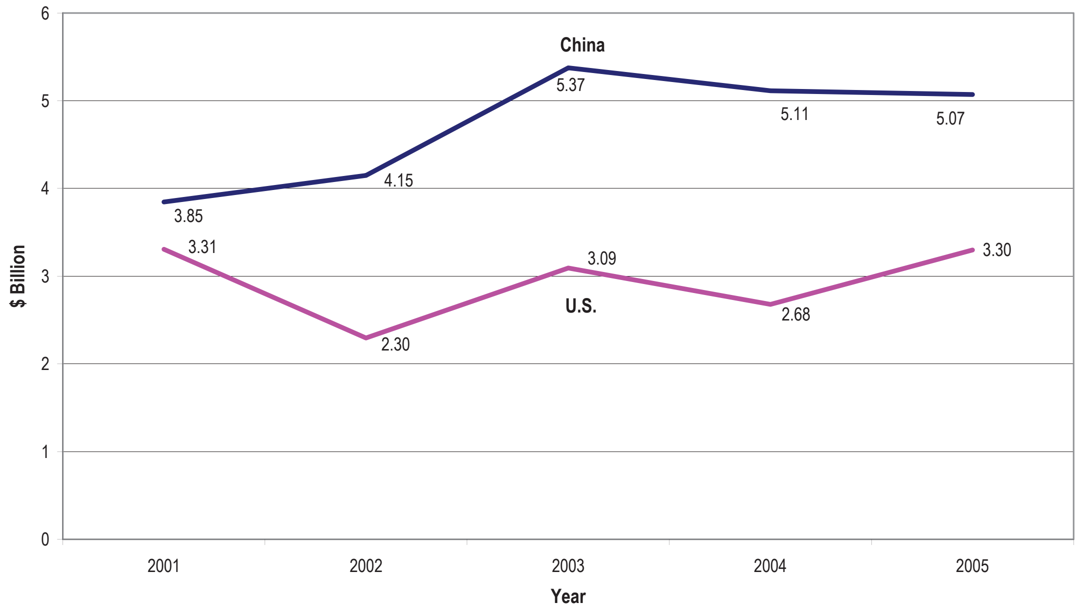

Figure 2. U.S. & China
(Construction involvement in Asia)[2]

US and China: Foreign Contracts in Africa

According to Reina et al. (2006), the leading country constructing projects in Africa was France with approximately $3.6 billion of work in 2005 (p. 4). France has been successful due to its association with former colonial territories and the involvement of French companies in oil and gas exploration. China ranked second with about $3.2 billion of contracts in Africa for the same year.

China has been targeting the African construction market in recent years. They have been undertaking mostly contracts involving infrastructure, road building, civil projects, and oil and gas exploration projects. In 2001, the U.S outpaced China in Africa by $1.7 billion. However, in 2005, China completed $3.23 billion of construction work in Africa compared to just $2.33 billion for U.S. firms (see Figure 3). The change in market position may have been caused by several factors. Experts claim that China has undercut their foreign competitors by exploiting their supply of cheap labor. A similar advantage was used by South Korea 20 years ago (Reina et al., 2004, p. 34). Chinese companies have also been working hard to establish themselves in the region as reputable contractors willing to take on the tough projects. Additionally, according to Reina et al. (2001) quality is less of an issue in choosing contractors for 60% of the projects in Africa (p. 66). China seems to be willing to take risks on projects with tight budgets. Moreover, while other contractors are struggling with not getting paid by African governments and moving on to serve private sector clients, Chinese firms are taking contracts as a way to build political favor with certain African governments.

It is interesting to note that in 2005 France operated in Africa with nine construction firms, while China utilized 38, and the U.S. 14 (Reina et al., 2006, p. 28). The higher number of Chinese contractors implies that they are likely engaged in a greater variety (and perhaps smaller sized) projects than those of the U.S and France.

Chinese Construction in the U.S.

In the last five years, China has begun to establish a presence in the U.S. construction market. Some domestic constructors are alarmed that state-owned communist construction companies have gained a foothold in the United States. At this point, the Chinese companies have secured a number of relatively small projects in the United States. According to ENR, from 2001-2005, their construction revenue in the U. S. averaged only $123.2 million per year. The China Market in the U.S. has fluctuated but their presence cannot be ignored (see Figure 4).

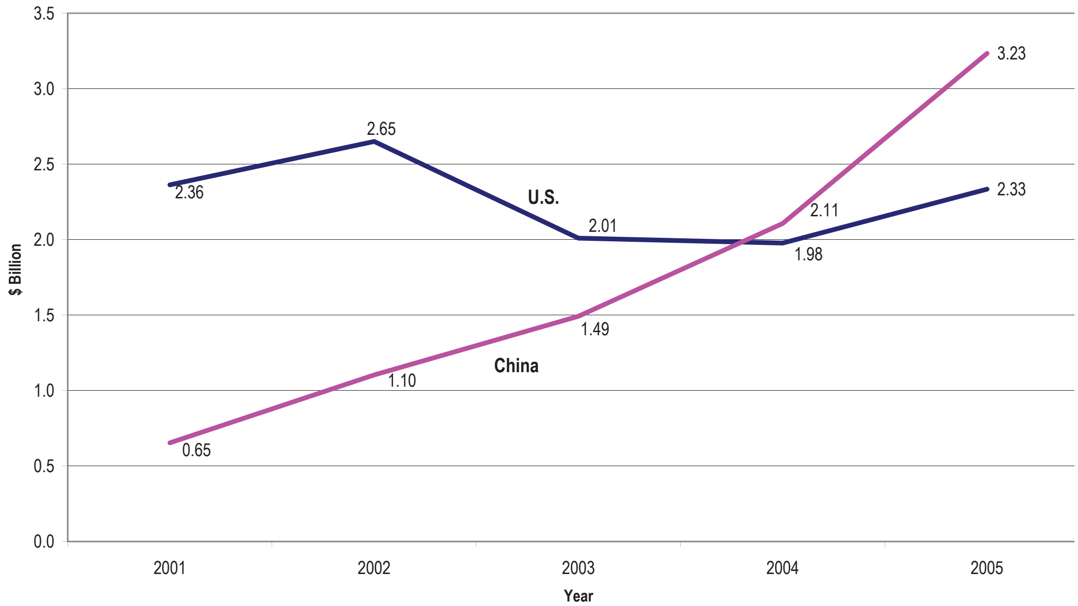

Figure 3. U.S. & China
(Construction exports to Africa)[3]

Recent Chinese projects in the U.S. for 2004 included a $190 million office and retail complex in New York's Harlem district along with three schools in South Carolina ($37 million) which were all won through competitive bidding by China Construction America (CCA). South Carolina was so pleased with the work of CCA, they signed additional contracts on four more schools. In 2004, CCA completed a total of $115 million dollars in contracts in the United States. Similarly, Shanghai Construction Group recently broke ground on a $110 million office complex in Flushing, NY. There are also plans for a refrigerator factory to be built in South Carolina for Chinese state-owned appliance manufacturer Haier. China Construction America has a stated goal of achieving $700 million of contracts in the U.S. by 2010. Hence, there is much speculation about more competition from China in the U.S. on the horizon. However, wholly foreign-funded builders make up only .05% of the U.S. market share (Donghui, 2005, par. 6). Many foreign contractors have established their footing in the U.S. by acquiring existing contracting firms to conduct work here. It is yet to be seen to what extent Chinese construction firms will employ such tactics.

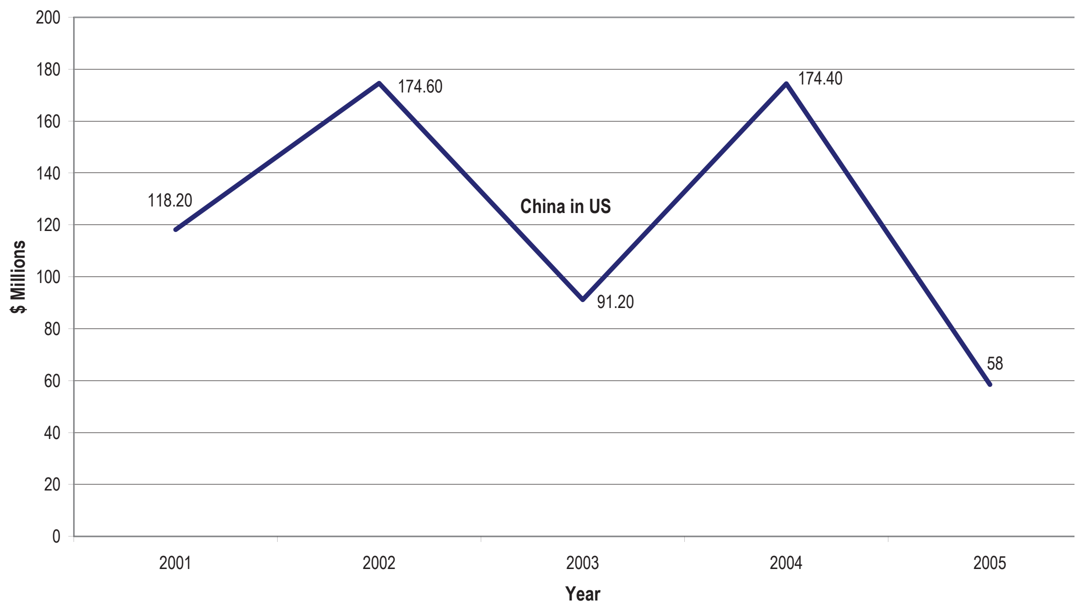

Figure 4. China Construction
(Construction exports to U.S.)[4]

China's Construction Imports

China's domestic construction market revenue was more than $390 billion dollars in 2005. In the same year, about $13 billion or just 3% was handled by foreign contractors. Projections suggest that by 2015 there will be about $1 trillion of domestic work in China with about $40 billion or 4% left for international contractors (The Freedonia Group, 2006, p.45).

According to the U.S. Department of Commerce (2005), the Chinese construction industry somewhat lacks experience in high-end projects. They suggest that U.S. and foreign construction companies may find opportunities in large scale integrated projects, such as high-rise buildings and infrastructure (p.2).

China entered the WTO in 2001. However, foreign contactors complain that they are not given full access to the Chinese markets today (McGregor, 2006, p. 4). Strict restrictions called Decree 113 were imposed by the Chinese government starting April 1, 2004. The new requirements which are promulgated through the Ministry of Construction include rigorous licensing rules that are difficult to meet. Additionally, the maximum contract value for foreign construction firms has been set at five times the registered capital. This requires, for example, a company to place $1 billion of capital in China for a $5 billion project. Another restriction requires large numbers of foreign staff to stay in China for 3-6 months. This uncertain legal framework results in a high-risk market that has discouraged many foreign competitors from considering work in China.

Partnering

Chinese companies are engaging in many joint ventures, project based collaboration and strategic alliances along with mergers and acquisitions. This is a means of getting involved in both foreign and domestic projects in which they lack the resources to undertake the project alone (XU, Bower, Smith, 2004, p.45). Doing so allows contractors to work together with their shared resources to undertake larger projects.

For the most part, foreign companies active in China are required by law to operate as joint ventures, or in an advising capacity only. Wholly foreign-owned enterprises are restricted to only foreign funded projects, or projects in which Chinese companies cannot complete independently due to technical difficulties. Foreign firms are able to get a foothold into the market via joint ventures which allows them to better deal with the legal constraints and market conditions. (Reina et al., 2004, p.34). However, being established in China via a partnership requires building good relationships that involves patience, commitment, and time to develop, with a special emphasis on paying close attention to the local culture and regulations (U.S. Department of Commerce, 2005, p. 2). International competitors claim that joint ventures are dictated by Chinese law in order to give Chinese contractors access to foreign construction technology, management expertise, and skills transfer. Conway et al. (2005) suggests that partnering or joint ventures are favored by the government as a way to "shorten the learning curve and limit the cost of acquiring technical knowledge" (p. 7). This strategy suggests that as time goes by, less and less foreign expertise will be needed for successful Chinese construction projects. In these joint ventures, foreign firms are finding that Chinese partners have the uncanny ability to get the skills they desire without giving their partner a larger share (Reina et al., 2004, p.34). Moreover, Chinese contractors can use the new knowledge acquired to compete against foreign contractors (including their partners) on projects outside of China.

Japan's Shimizu Construction is one of the few international companies who see promise in China's construction market. Their success has been tied to Japanese manufacturing companies who set up shop in China. Their strong relationship with Japanese domestic clients and the desire for China to expand their manufacturing base has led to a profitable experience for Simizu. Typically, Shimizu projects in China are fully funded by Japanese enterprises.

Predictors for the Future

In the future, it appears that China and the U.S. will continue to be the two largest construction markets in the world (see Figure 5). By 2015, China will likely reach $1 trillion per year in their domestic construction market, with an increase of about by 2.5 times from the level in 2005. The U.S. market is predicted to double from 2005 to 2015 to reach $2 trillion per year (The Freedonia Group, 2006, p.45).

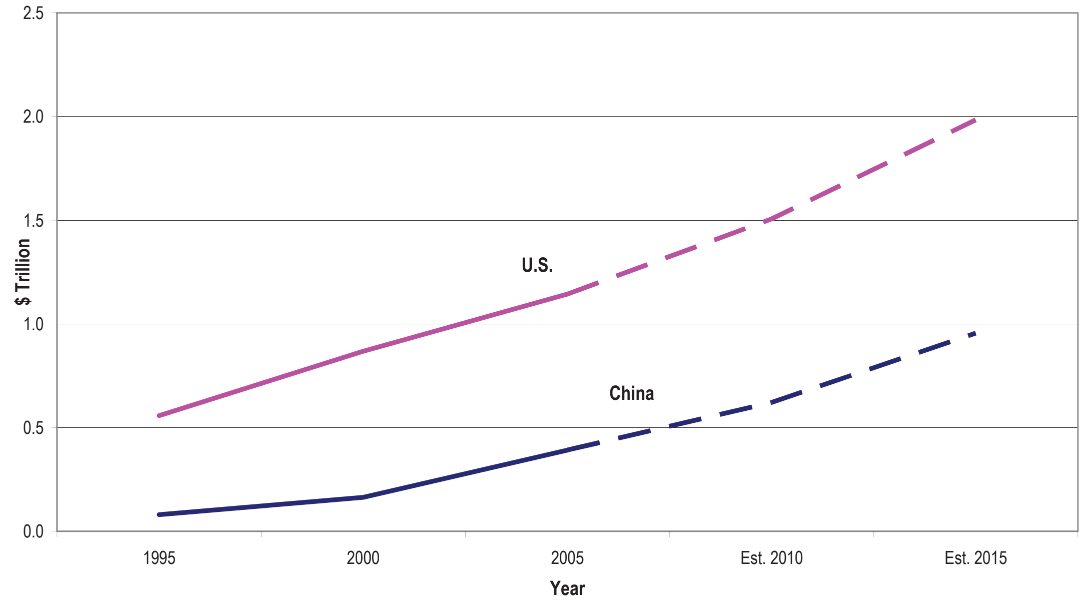

Figure 5. U.S. and China construction
(Domestic expenditures in home country)[5]

Experts also claim that China will continue to increase its activity with international construction as well. Chinese firms are expected to export up to $64 billion per year of construction services by 2015. It is evident that competition on the international scene from Chinese companies is here to stay.

Opportunities for foreign firms operating in China will continue to climb as well. Chinese construction imports are expected to triple from 2005 to 2015 to reach $40 billion (see Figure 6).

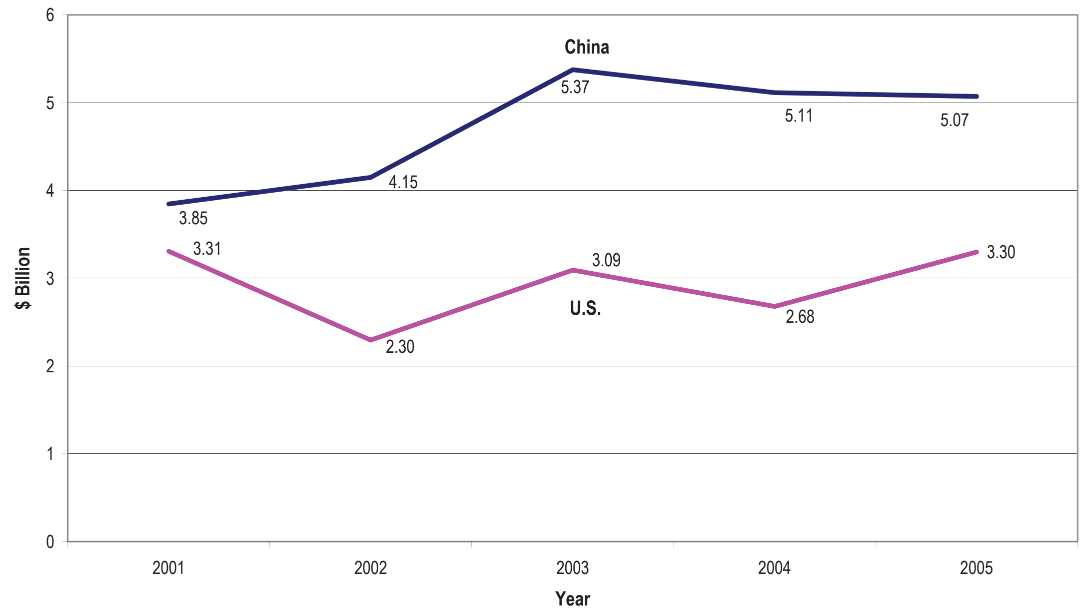

Figure 6. China Construction
(Import and export revenue)[6]

Conclusion

The Chinese construction industry has evolved into a major participant in the global construction market. They have climbed to seventh position in the world for construction exports. American firms have taken notice of the competition from Chinese contractors in the U.S., China and around the world.

As expected, China is very solid in the Asian construction market. However, their strong position in Africa should also be noticed. China's economic boom of this century has stimulated an ever-growing need for oil to feed their expanding markets. It has been suggested their construction activity in Africa is politically tied to the oil rich nations on that continent.

Moreover, the Chinese domestic market is the most important in the world. Unfortunately, increased government control in the form of Decree 113 has made it difficult for foreign contractors to participate in Chinese projects. Nevertheless, the demand is so enticing that many international firms are getting involved in various forms of collaboration. At this point, foreign contractors hoping to tap into the Chinese market should consider joint ventures as the likely scenario.

Overall, international construction companies have been hopeful to crack the Chinese domestic construction market. At the same time, they are wary of Chinese contractors competing in the international market. It is now generally accepted that China and its state owned construction firms are major players in their home market and throughout the world.

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4. the same results (see Footnote 1)

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6. the same results (see Footnote 5)

Construction and Demolition Waste Study Performed by the Construction Club

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Introduction

Through a grant from the Local Chapter of the Construction Specifications Institute, the Construction Club at the University was charged with investigating the possibilities for recycling construction and demolition (C& D) waste in the Springfield, Missouri area. The undergraduate students charged with the investigation (Rebecca Adair, James Darby and Tony Brune) gathered information from local contractors, waste haulers, business organizations, city officials, Missouri Department of Natural Resources and several internet sources. The students were task to:

- Provide estimates of current C & D waste now entering landfills in the area.
- Identify the amount of C & D that could possibly be diverted from the waste stream.
- Identify C & D waste and the respective recycling opportunities presently available.
- Research and make recommendations for recycling opportunities not now available.
- Identify financial impacts of recycling versus dumping of C & D in the waste stream.

Estimate of Construction and Demolition Waste

Most of the information presented in this section was taken from the Missouri Waste Composition Study (MWCS 1999) that was conducted from 1997-1999 through a grant from the Missouri Department of Natural Resources. Fourteen landfills were observed, however the Springfield City Landfill was not Included in the study. The incoming solid waste was classified into five different components. (Municipal Solid Waste, Construction, Demolition, Industrial, and Other) The landfills selected were a representation of all landfills in the state. Percentages of components were found to vary by demographics. Larger metropolitan areas such as Kansas City and St. Louis had similar percentages of waste. The smaller metropolitan areas of Columbia and St. Joseph had similar breakdowns as did the rural areas. Springfield would fall into the small metropolitan category. The percentages of each classification were then combined to form statewide averages as shown in Figure 1.

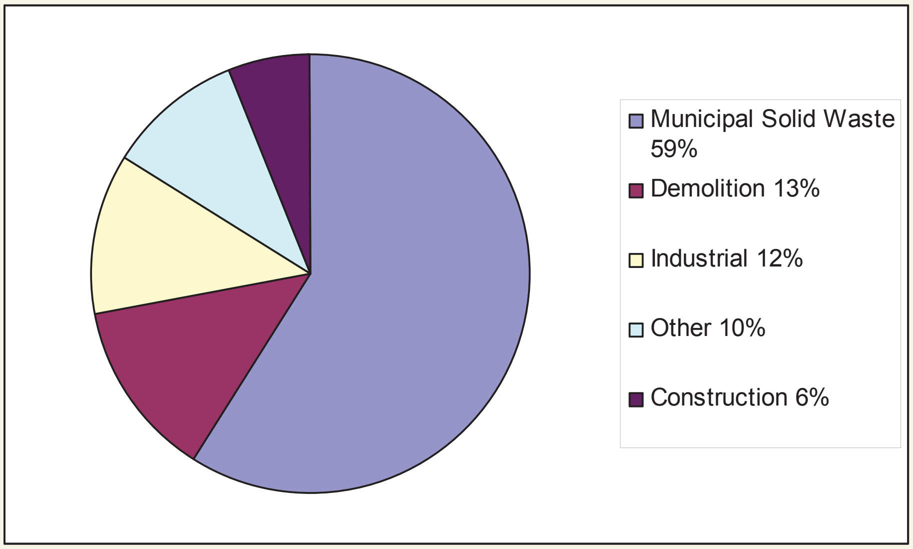

Figure 1 Total Solid Waste from Missouri (pg 169 of MWCS 1999)

Construction waste is broken down into 7 main categories wood, drywall, masonry, metal, plastic, and cardboard (see Figure 2).

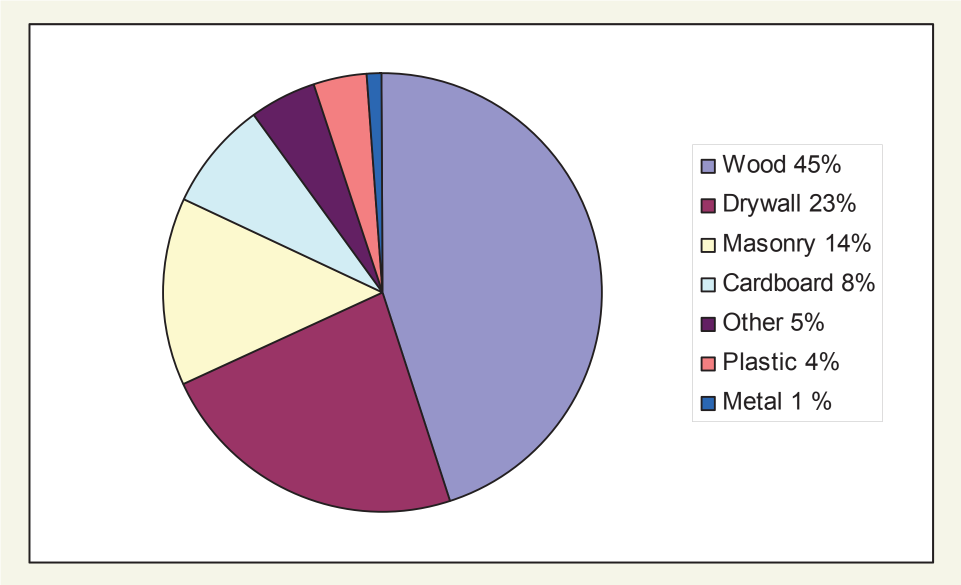

Figure 2 Construction Waste Percentages in Missouri (page 169, MWCS 1999)

Demolition waste is broken into 7 main categories wood, drywall, roofing, masonry, metal, carpet and other (see figure 3).

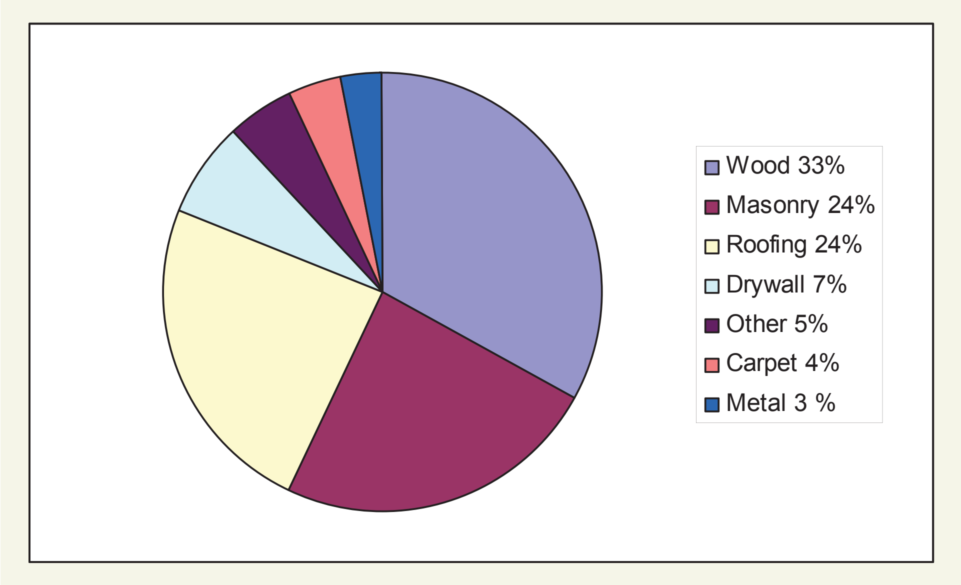

Figure 3 Demolition Waste Percentages in Missouri (page 171 MWCS 1999)

Since the solid waste stream produced by Springfield goes to several different disposal areas, it is difficult to estimate the ratios of the components. For the purpose of this study the statewide averages were used for comparison of C&D waste generated in the Springfield area. If the figure of 1500 tons of waste generated daily in Springfield is applied to the statewide averages then the breakdown for annual tonnage of C& D waste could be estimated as shown in Figures 3 and 4..

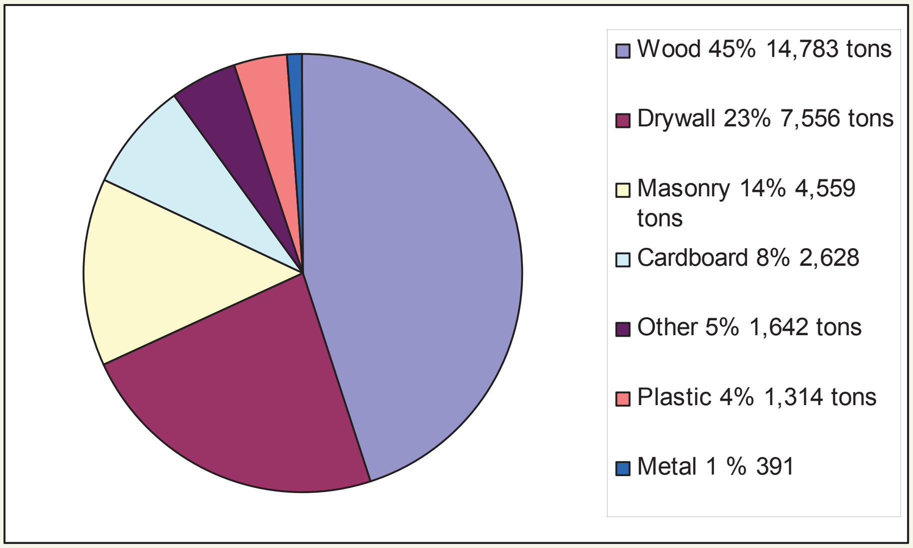

Figure 4 Estimated Construction Composition for Springfield

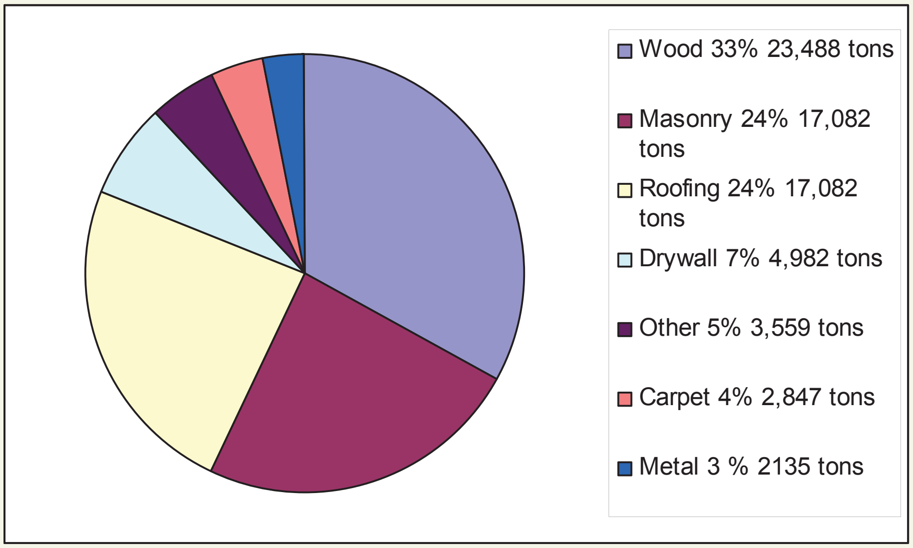

Figure 5 Estimated Demolition Composition for Springfield

C&D Waste That Can Be Recycled From Springfield's Landfills

Combined State Averages for C&D Waste (Figure 6)

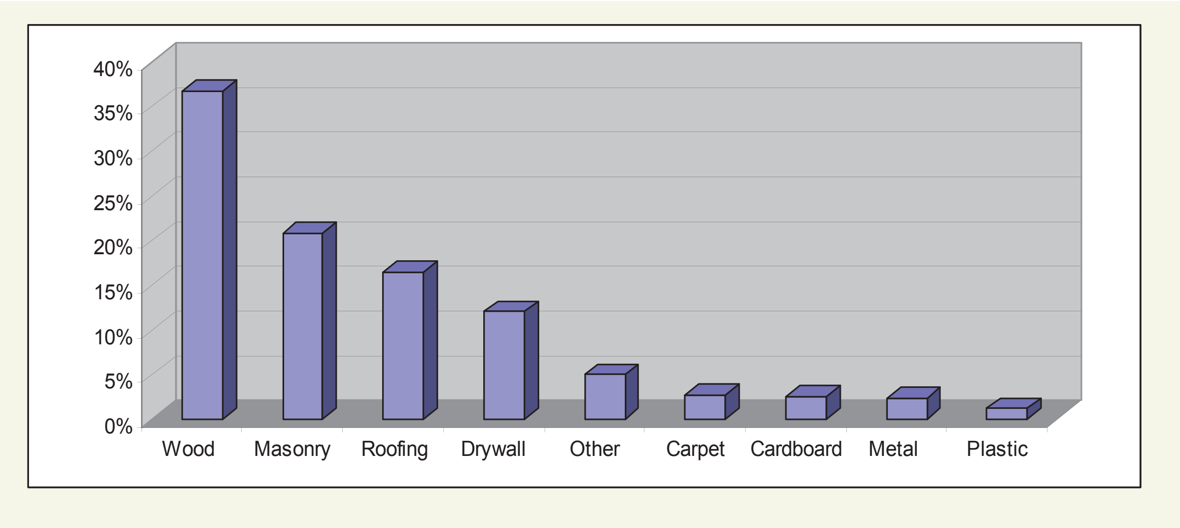

Figure 6 Combined State Averages for C & D waste

1. Wood: with an estimated 38,271 tons produced, is the largest component in C&D waste. Until recently, demolition wood was a bit of a problem to recycle. Most places didn't want demolition or used wood unless it was free of nails and other debris. Manually removing nails by hand is very labor intensive. Now a modern age of grinders and crushers can pulverize anything. The remaining ferrous pieces can be magnetized out and all that is left is good mulch. Contractors have the option of working with a composting facility like Advantage Waste to divert most wood scrap. The new construction waste generally consists of framing drop offs. These pieces are fairly clean and tend to occur in great quantities at one time making them easier to recycle.
2. Masonry: The second largest component with a combined estimated tonnage of 21,681. Most masonry could be diverted from the landfill. Clean masonry can be dumped at no charge with permission from the city at the old quarry downtown. Bricks and blocks can be salvaged and reused, donated, or resold. Other rubble can be crushed and reused on site or hauled to other sites for fill.
3. Roofing: Is the third largest component and has an estimated tonnage of 17,082. The majority of roofing waste is asphalt composition shingles from tear-offs. This is the main component that does not have a current outlet in the Springfield area, but the technology is simple and close. The Peerless Landfill and Resource Recovery in St. Louis, takes asphalt shingle roofing, crushes it up, then sells it to an asphalt company which uses a 5% recycled mix for paving.
4. Drywall: Is the fourth largest component with an estimated 12,538 tons. This is another item that has not had an outlet until recently. One option for drywall is to reuse scraps in the production of new drywall. Unfortunately there isn't a plant close to Springfield that does this, and the cost of transportation would be prohibitive. Composting is another option. The city of Columbia has been grinding drywall with their mulch mix for several years with good results. Gypsum is a great soil amendment especially in this part of the country. Contractors now have the choice of using the facility through Advantage Waste to divert drywall scrap from the landfill.
5. Carpet: At an estimated 2,847tons, carpet is not as big of component as some others. However, nationally it's estimated that 2 million tons make it into landfills. Carpet recycling is growing as more end products are being developed. Some manufacturers offer to recycle old carpet when new carpet is purchased through them. The carpet is shipped off to recycling plants to be re-made into new carpet or even automobile parts. Although very successful, the cost to recycle the carpet fibers is rather expensive. Kansas City and St. Louis are the closest locations that offer this service.
6. Cardboard: An estimated 2,628 tons are produced here annually. Cardboard is relatively easy to recycle, and several options are currently available in Springfield for recycling cardboard. One is Midwest Fibre Sales Corporation. They will bring a container to the job site for a delivery and monthly rental cost, and empty it as needed. Another local option would be using Advantage Waste as the hauler and having it composted.
7. Metals: Although a small portion of the waste stream at an estimated 2,526 tons annually, metals are absolutely something that should not be going into the landfill. Demolition contractors are offering to dispose of buildings at no

charge to the owner and possibly even pay to get the job just so they can have the steel. Scrap iron is bringing $450/ton locally (as of march 2005). There are several metal recycling centers. Commercial Metals Company will bring a container to the job and may wind up paying the contractor depending on the amount recovered.

8. Plastics: At an estimated 1,314 tons, this is the smallest component of the C&D waste stream. The majority of plastic produced is from five-gallon paint or adhesive buckets. Clean #1 and #2 buckets can be dropped off at the local city recycling centers. Buckets can also be reused for other purposes like tool caddies and storage containers.

See appendix B for a list of contact names and numbers for recycling of materials.

Disposal and Recycling Cost Comparison

One the most important factors influencing the disposal decision will be cost. Most contractors and construction workers are used to throwing every bit of waste from a construction site into container without any thought of separation. For recycling to be more cost effective, the waste must be sorted to some degree. That requires labor. Obviously a demolition project will cost more for disposal because of the quantity of materials and labor needed to sort them. But savings or even profits could be earned depending on the amount of materials recovered, reused, or sold.

This section addresses the cost comparison between regular disposal at landfills and diversion. Explicit numbers on the cost of recycling certain components of the C&D waste stream, such as metal and drywall, in Springfield were used when available. For others such as wood and masonry, national averages from the Associated General Contractors website were used (http://www.agc.org/index.ww).

Each of the following graphs represents one component of the waste stream, and a cost comparison for recycling the material versus regular disposal to a landfill. The column on the left of each pair is the cost of disposal while the column on the right side of the pair is the cost or reward of recycling. The cost of regular disposal was taken at $35 a ton which is the average for the commercial haulers in the Springfield area. The cost of recycling depended on the individual component. These prices were then multiplied by the estimated quantities of construction and demolition produced in Springfield annually to show the total costs of recycling versus disposal:

1. Wood, Total costs of disposal of demolition wood are higher than construction due to the greater quantities involved. New construction quantities could be reduced by better material management methods. According the AGC, the national average of the cost of recycling wood is 40% lower than disposal costs (see Figure 7)

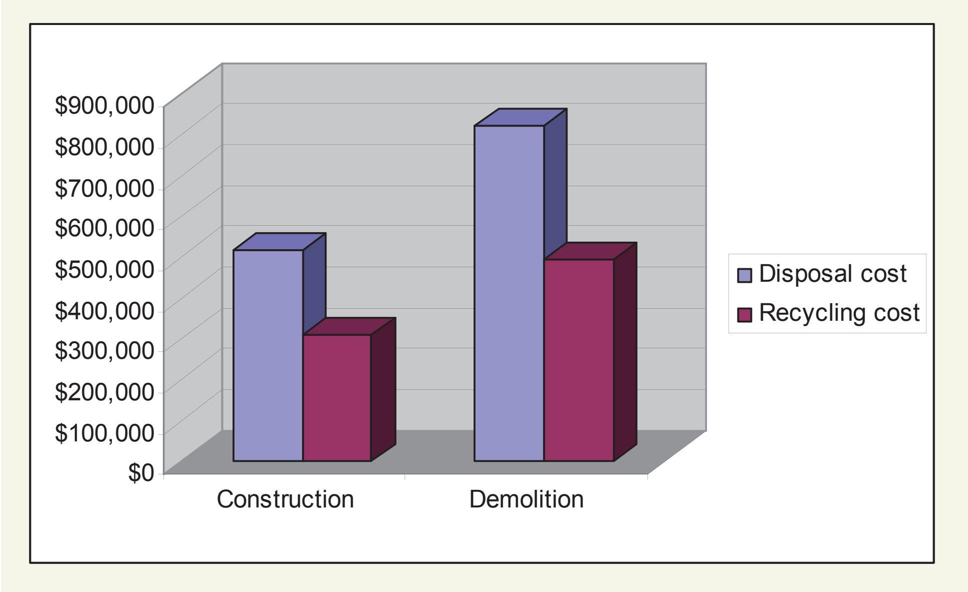

Figure 7 Comparisons of Wood Disposal Cost Verses Recycling Cost

2. Drywall Comparison New construction produces the greater amount of waste. Again, better material management methods lower the quantity of waste generated. Demolition drywall is more labor intensive and therefore more costly to reclaim. For drywall recycling, a fee of $25 per ton was utilized as a comparison to regular tipping fees. A savings of $10. This number is Advantage Waste's proposed fee for collecting drywall. They will be able to take clean or demolition drywall and grind it up into mulch and compost. These prices do not take into account the cost of labor for sorting the material (see Figure 8).

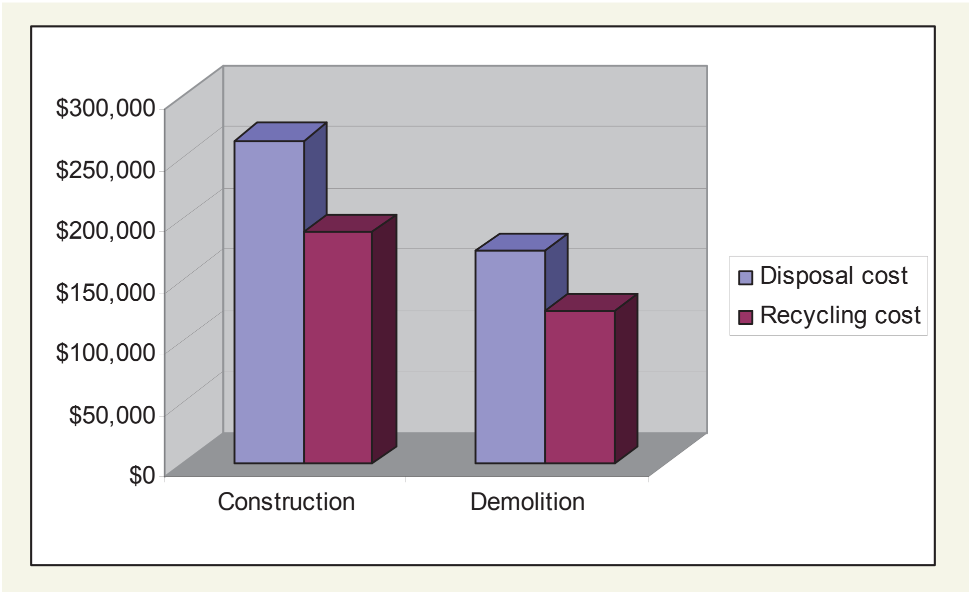

Figure 8 Comparisons of Wood Disposal Cost Verses Recycling Cost

3. Metal Comparison Metal is becoming a more valuable material with the recent hike of steel prices. Demolition jobs have proven to be worth while due to the amount of metal that may be found in the building. According to the December 2004 issue of Engineering News Record, "Scrap steel exports have roughly doubled since 2000 to about 12 million tons in 2004." Metal can be very economically beneficial when recycled. The rate used to figure the reward for recycling is $0.56 a pound. This is an average, quoted from Commercial Metals of Springfield, for all the different types of metals that can be recycled. As the chart shows (Figure 9), if all the metal waste was diverted there would be a substantial reward.

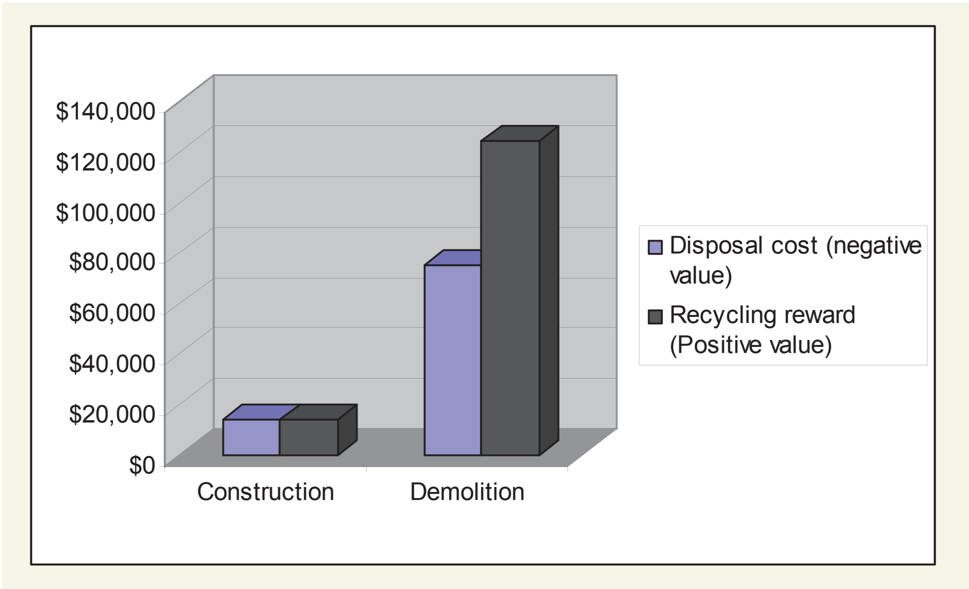

Figure 9 Comparisons of Metal Disposal Cost Verses Recycling/Recovery Awards

4. Masonry Comparison This is a little harder to make monetary comparisons because every job would be different. For New construction the masonry waste would be mortar and scrap bricks or blocks. Again, close scrutiny of material management would cut down on the quantity produced. The extra material could be crushed and backfilled on site saving the hauling fee.
5. For demolition projects, the best recovery method for masonry is to crush and reuse the material as backfill on site. A company in Toronto used most of their concrete rubble generated from a remodeling project as backfill on a 900-ft-long terminal pier saving $664,000 mostly on trucking costs. Reusing the material on site saves on trucking costs of hauling it away, and the added expense of purchasing and hauling in backfill, In Springfield, clean masonry can be dumped at the quarry for free, but the cost of trucking it there would have to be determined and compared to tipping fees.
6. Roofing Comparison Currently there aren't any facilities in the Springfield area that recycle roof waste. St. Louis is the closest facility. Asphalt composition shingles are ground up and added to asphalt mixes for paving. Contractors still have to pay regular tipping fees to dispose of the material, but recyclers usually offer a discount if the load is free of plastic and other trash.
7. Cardboard Comparison Although not heavy, cardboard takes up a lot of room in disposal containers. If cardboard was diverted from trash bins it would save a lot of room and valuable space for companies wanting to throw heavier objects into the bin. For $20 a month, Midwest Fibre Sales will deliver an eight cubic yard cardboard recycling bin to any job site.

Conclusion:

Recycling metal can easily cover the cost of regular disposal fees. Any labor cost incurred from sorting the metal out could be covered by the rate of return from recycling. Recycling wood can save a company up to 40% rather than rather then the waste disposal method. Recycling drywall can generate a savings of approximately 30%. Recycling companies can have variable rates throughout the state and the time of year. Companies also have different requirements for how to sort materials. One company taking wood from your project will ask for nails to be removed from the lumber while others have the technology to take the nails out for free. Recyclers are willing to help make your trash disposal easier and cheaper. Recycling not only helps on a short term return basis but also long term. Prices of new material may be stabilized by increasing the amount of material being recycled, and materials made from recyclable material generally cost less to produce than using new natural resources. If more materials are produced from recycled materials there is less demand for natural resources, the less demand on natural resources the less the chance of a price hike on construction materials.

Recommendations

1. There is a growing interest from different factions in the Springfield area for construction and demolition recycling, which is really part of a bigger movement for sustainable building. As the third largest, and most beautiful city in the state, it's time for members of the construction community to step up and make a commitment to build sustainable projects.
2. Education, information and communication will be the keys to the future. Change of how anything is done in the construction field is usually met with skepticism to say the least. New methods and ideas take some time to be accepted by people. Sustainable building including C&D waste diversion is beginning to take hold in the area and it will only continue to grow. This can be evidenced by the phenomenal nationwide growth of the LEED program. With Springfield being the 131st largest city in the nation, it is sure to receive its share of LEED projects. That will bring with it an increase in the demand for consumers of recyclable waste.
3. Contractors, architects, owners, sub contractors, city representatives, and the Department of Natural Resources, will need to be brought together and dialog on the opportunities for diverting waste from the landfills. Architects can design and specify certain methods and materials that are more sustainable. Owners will have to be sold on the idea that a sustainable project is either equal in cost to a regular project or that any extra cost will be quickly recouped. Contractors and sub contractors will have to be educated as to what is expected of them. They will have to start thinking about the waste that will be produced and where it will go.

Immediate recommendations to follow this study would be;

Education

- Make presentations at the local trade organization meetings to begin educating the members on the opportunities for recycling
- Follow up on the economics of the Discovery Center project and Alberici Headquarters projects and disseminate the cost information on such projects in a timely manner to interested parties
- Have architects work with owners to incorporate items into specifications to require or suggest reduction and diversion of

waste, and the use of materials that are made from recycled items.
- Work closely with the city Solid Waste Management Division and the department of Natural resources to find increasing outlets for waste.

Material Diversions

- Wood: as the largest combined component of the C&D waste stream, a goal should be set to divert at least 50% of wood waste by reducing waste, reusing scraps, or mulching.
- Masonry: as the second largest component of the combined C & d waste stream, a goal should be set to divert 90% from the landfill, by reusing the material on site or hauling it to the old quarry downtown or other fill site. Investigate the possibility of having a mobile crusher available to area contractors
- Roofing: investigate the possibility of working with a paving company to grind and reuse asphalt in their mix.
- Drywall: set a goal to divert at least 50% of the drywall by reducing waste, reusing large scrapes or mulching
- Carpet: investigate the possibility of working with a carpet manufacturer to collect carpet for reuse. Another option is to specify using carpet with a recycled content on jobs.
- Cardboard: set a goal to reduce at least 50% of the cardboard from projects, by composting, or recycling.
- Metals: set a goal to reduce at least 90% of all scrap metal by diverting to local recyclers
- Plastics: set a goal to divert 50% of the plastic waste from projects by reusing or recycling

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Evaluating Construction Losses – Cost of Quality, Value Loss and Waste

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Introduction

The issue of loss in construction is a critical component of quality analysis. Correctly assessing the magnitude of construction loss is one of the principal metrics on which the entire construction quality argument hinges. If industry's assessment of construction loss is wrong, or imprecise, then the justification for quality programs may be over or understated.

Previous research has viewed losses in construction from the perspective of the construction service provider (contractor, vendor, etc), and deal mostly with the cost of quality, rework, waste, waiting time, material handling inefficiencies, etc. The general analysis of the cost of quality, and productivity loss in previous research states that 'some reason' causes the construction service provider (contractor holder) to do certain work tasks more than once, or less efficiently than originally planned. Basically, rework or efficiency loss required more labor and material than planned to correct or restore a task to its specified condition.

These observed incidences of losses are then aggregated across the project or program, and reported as a per cent to total of the project cost. This per cent to total figure is then extrapolated across larger construction industry expenditures for countries, regions, municipalities, and etc. This research suggests another method for assessing the impact of losses in construction.

Types of Losses

Project cost losses in previous research have been accumulated and reported as an aggregation of rework, non-conformance correction, and cost of quality expenditures. We can define these 'losses' as inclusive in the Costs of Quality (COQ) definition, which is the costs of non-conformance prevention, quality appraisal, and rework.

Value loss occurs when a contract purchaser receives less than the purchased value expressed in the contract documents. In Koskela and Bertelson's (2002) transformation, flow, value model, the client purchases value in terms of a contract arrangement with trade contractors. Value loss occurs when the client receives less than what he purchased. If a contract purchaser purchased $10mm worth of bridge construction, and they received bridge value of $9.875mm, then the value diminishment was $125k. Abdul-Rahman's (1997) survey addressed how a contract purchaser's value could be diminished. Respondents to his survey stated that the costs of construction failures are usually born by the contract purchaser (client) because of the existence of "unrecorded failures" and their impact on the client's life-cycle costs. Patton (2006) describes these 'unrecorded failures' as the diminishments that degrade the clients purchased value. Patton's (2006) research showed diminishments of 16.84% across $110mm in capital construction projects in 2005. This 16.84% is the 'potentially possible' value that Koskela (2000) referred to, and was reported as value diminishments in Patton's (2006) study. These diminishments are from un-restored defects.

Problem Statement

Previous research has discussed value loss and project loss as approximately equivalent units. However, this research questions whether typical observed COQ occurrences are losses to the project or contractor at all. Further this study states that COQ acts to restore value to the project, and should not be counted as value diminishments – at least in the short term. This research will show that contractors anticipate rework and inefficiency costs in their bid proposals through buffering, and therefore the observed losses are actually planned waste, not losses. Further, the research will show that the 'best available value' of the client can be achieved short-term, regardless of this planned waste.

How Construction Losses are Measured

Previous researchers have typically assessed the magnitude of construction loss in varying degrees, but for the same purpose – usually to justify a quality program. Burati et al (1992) found that non-conformance costs were 12.4% of the total cost and Lam et al (1994) stated that quality costs can make up from 8% to 15% of the project costs. The Construction Industry Development Board reported that contractors spend between 5% – 10% of the project's costs in rework (CIDB, 1989). Hart (1994) claims that more than 25% of the costs can be cut from most constructed facilities and Latham (1994) agrees. Latham's (1994) research stated that there was so much waste in the UK construction industry that construction costs would have to be reduced by 30% of if it were to survive as a competitive UK operation. Roberts, (1991) stated that quality appraisals can lead to a reduction in construction failures from 10% of project costs to less than 2% of total project costs. Ledbetter (1994) estimated the COQ at 11.2% across twelve projects. Willis and Willis (1996) also found deviation correction was 12% of total installed costs. Love and Li (2000), Abdul-Rahman (1996), Aoieong et al (2001) and Barber et al (2000) all determined that the COQ were between 3% and 6% of project costs.

The consistent approach in this previous research is to then assign a cost to the observed incident of loss, and then calculate a per cent to total for the project. In most of the research analyzed, the researcher then broadens the assumptions of the per cent to total loss across the construction expenditures for a certain agency, municipality, sector, industry, or country. Love and Li (2000) reported rework costs from Australia could be approximately 10%. They extended that per cent across the total 1998 annual construction expenditure of Australia of $43.5b, to determine that the cost of rework in Australia was $4.3b (Love, Li 2000).

Methodology to Determine Buffer Levels

In October, 2006 sixteen prime contractors met with a large commercial developer in Amelia Island, FL to discuss engineering and value initiatives. One of the initiatives discussed was risk premium on large site work contracts. Because the client used exculpatory contract clauses to transfer risk to the contractor, and the prime contractor used the same strategy to transfer risk to the site contractor, an effort to quantify this risk premium was made. Risk premiums were generally defined as a strategy to account for concealed conditions, severe weather, unknown material or sub-contractor shortages, or other extreme conditions. From the discussion on the magnitude of risk premium, the discussion broadened to include 'buffering'. Buffering is different from risk premium in that buffering is typically used to account for the contractor's own historical level of rework, defect correction, and inefficiencies. Buffering therefore could be defined as planned waste, and risk premium could be defined as planned risk. Both risk and rework – if unplanned in the bid proposal – would financially encumber the contractor. Depending on the project type, the magnitude of risk premium and buffering could be staggering. It became obvious from the contractor survey, that the client (contract purchaser) could be paying up to 25% or more of the total contract value for planned contingencies. It was determined that magnitude of the buffer on the building contracts were about 2% for the general contractor, and about 10% - 15% for the sub-contracts. Site work risk premiums and buffering were higher than building construction. The results of the value engineering symposium were issued and published to the staff construction team and the prime contractors in attendance.

Are Rework and Cost of Quality Costs 'Losses?'

Rework and COQ may possibly impact a contract holder's profit potential, but they do not appear to always represent direct losses to the contractor or the project. Unless the contract holder's baseline expectation for productivity loss, and for rework is known, researchers have no idea if these 'costs' are losses at all. In fact, these incidences of rework and non-conformance cost may be within the planned waste 'buffer' discussed above. According to the prime contractor survey above, the sub-contractor may have included the planned waste as part of his original bid proposal as a buffer.

It is firmly established in previous research that contract holders expect some rework, and some productivity loss. Barber, et al (2000), Koskela (2000), Love et al., (1999), Love and Li (2000) all state that quality defects, waste, rework and productivity loss are pervasive, endemic and thoroughly inherent in construction process. In fact, Arbulu and Tommelein (2002) state that waste is "omnipresent" in the construction process. Perhaps most descriptive is Schonberger's (1990) editorial comments on the intrinsic nature of construction: "One industry, construction, is so fouled up as to be in a class by itself. Delay, lack of coordination, and mishaps (especially return trips form the site to go from the site to get something forgotten) are normal, everyday events for the average company." Koskela (2000) emphasizes this in his new Production Theory application, "presence of waste [in construction] is pervasive."

If inefficiency and waste are so "inherent", "endemic", and "omnipresent" in the construction process as previous researchers contend, then 'flexibility' (Howell, Ballard 1998b), and buffering (Koskela, 1999) are the only reasonable strategies available to a contract holder to mitigate inevitable rework or productivity loss. Ballard and Howell (1998a) pointed out that the current quality improvement strategies (lean) result in large buffers because of the uncertainty with supply and use rates. Additionally, Ballard and Howell (1998a) add that buffers are the result of unreliable work flow. The sixteen prime contractor's response to the value symposium questionnaire seemed perfectly aligned with this inherent condition.

Critics of this construction loss model will state that the buffers represent waste, planned or not. Further, because construction dollars are paid for non-value added work, then the buffers cause the cost of construction to be artificially elevated, without a corresponding benefit. Abdul-Rahman (1996) described the potential problem of large, non-value adding buffers in his research of non-conformance costs: "…if every sub-contractor has a problem similar to [preventing and correcting errors in construction] in this project, then the mark-up cost of construction would have to be high for the subcontractor to be in business at all." However, this research proposes that this may already be the case. The contractor's buffering amount may already be excessive by Abdul-Rahman's standard. We must assume that Abdul-Rahman's observation of the sub-contractor not securing bolts to hinges was not an anomaly. These observed incidences must be happening throughout the construction process, across every project and it must be assumed that sub-contractor's are submitting proposals accordingly. If the sub-contractor is already buffering his bid proposal to compensate for this typical project occurrence, then Latham's (1994) and Hart's (1994) seemingly excessive estimates of construction overpayment (30% and 25% respectively) seems now altogether sensible.

Rework Incident Analysis

The following example is analyzed to determine if and how a real example of rework impacts the sub-contractor's project budget, and if this rework can really be acknowledged as a loss at all. This observed incident follows closely the definition of rework offered by Love et al (1999): "Rework is the unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time." The buffer level used in this analysis is the lower limit from the contractor survey listed above (10%).

Table 1: Rework Analysis

	Rework Incident 2 - Honesdale, PA (2006) – Footing contractor installed a stem wall on a footing for an out-door landscaping building without reinforcing tie-ins. After an RFI, the designer replied that the existing installed condition was non-conforming and would need to be brought into conformance with the original design. The concrete contractor removed the stem-wall and reinstalled the stem wall with reinforcing steel which was embedded into the footing. The footing contractor spent 4 days with a crew of four, and multiple pieces of equipment to replace the stem wall at a cost of $16,157. The overall contract for the footing, stem wall, and flat work was $688k.						
	Cost of Rework	Total Sub-Contract Value	Cost of Work Installed/ Cost of Product	Assumed Buffering or Risk Premium @ 10% of total contract value.	OH&P for Sub-contractor at 6% of Contract Value	Did Cost of Rework Exceed Buffer or Risk Premium?	Discussion
Cost to Contract Purchaser (Client)	0	0	0	0	0	0	Value was restored to the Contract Purchaser through rework. Only if the deficiency had persisted un-restored would this have led to a value diminishment to the contract purchaser.
Cost to Prime Contractor	0	Na	na	na	Na	0	Prime contractor directed the RFI process and ultimately the rework by his sub-contractor. Prime contractor incurred no loss.

Table 1: Rework Analysis

	Cost of Rework	Total Sub-Contract Value	Cost of Work Installed/ Cost of Product	Assumed Buffering or Risk Premium @ 10% of total contract value.	OH&P for Sub-contractor at 6% of Contract Value	Did Cost of Rework Exceed Buffer or Risk Premium?	Discussion
Cost to Subcontractor	$16,157	$688,000	$577,920.00	$68,800.0	$41,280.00	No	Sub-contractor corrected non-conforming work after it was determined that the installed work could not be approved as a legitimate substitute. Work was done concurrent with other tasks and schedule was maintained.

Source: On site work shadowing, Honesdale, PA Sept., 2006.

Discussion

This rework analysis demonstrates that the buffer each contractor carries in their bid proposal was not exceeded in the example of rework observed on site. In this example, the cost of the rework did not exceed the reported buffer level and could not be counted as a project loss, nor did it degrade the purchased value of the client.

Resistance to Adopt a Quality Program

During these previous research projects, researchers were often frustrated by a construction company's lack of interest in reducing the incidences of losses observed on the job site. Aoieong et al's (2002) research stated that none of the projects his team observed had set up a quality system. It was observed in this research that the general contractor was unconcerned with the cost of quality from the sub-contractors. The general contractor was only concerned with the end product, and as long as rework or failure costs corrected the defects, then the end product was restored to its original value. From the sub-contractor's perspective, they were not enthusiastic about a quality program. In fact, most of the sub-contractors interviewed by Aoieong and his research team would rather allocate resources to correcting the defect, rather than establishing a quality program (Aoieong, et al, 2002). The lack of concern for this cost could be that the occurrence of rework occurs normally within the contractors buffering level. Alwi, et al (2002) also expressed disbelief at the low priority waste incidences were given by the on-site project respondents. Love and Smith (1999) also expressed disappointment with the "culture of complacency" in correcting construction defects from their research. One plausible reason for this apparent ambivalence would be that the contractor or sub-contractor adequately buffered their respective bid proposal to compensate for incidence of their own historical inefficiencies and rework.

Reported Impact

In 2000, the total U.S. construction industry expenditures were $900b (Bogdan, 2000). Therefore, for a construction purchase of $900b, the expectation would be to receive construction value of $900b. If contractors must use buffering and flexibility to plan for their own rework and productivity loss, then the client, owner, or municipality is actually purchasing value inclusive of this buffering. In other words, for purposes of their own risk management, the client (owner, municipality, agency, etc) accepts the proposal from the contractor inclusive of the buffering and risk premium as their best available value, although possibly not the best theoretical value. In other words, there is value to the client to transfer risk to the contractor, and for the contractor to plan for contingencies. The contractor's buffer for errors, and the risk premium are implicitly accepted at the time of contract execution as part of the best available value.

The owner's value will not be diminished by a sub-contractor's rework costs. The project value will only be diminished if deficiencies are unreported and uncorrected (Patton, 2006). This model emphasizes that rework seeks to restore value to the contract purchaser. It is incongruous therefore, to ascribe an observed incident of rework as a loss against the total construction expenditure for a country, region, or agency based on the per cent to total COQ from a specific project or program.

Conclusion

Construction losses from cost of quality and value loss are critical issues for construction professionals and researchers to understand. Construction professionals, contractors and researchers need to be cautious regarding the classification of rework costs as project losses, or contractor losses. Construction losses are an important factor in determining the adoption of quality control programs. Project losses through cost of quality and value loss are different issues entirely as this research points out. Further, the level of risk premiums and buffering are important concepts for the construction professional and researcher to understand. Buffering for the purpose of planned waste enables the contractor to pay for a certain amount of COQ expenses, but it also represents another waste category in construction, and it appears to be one strategy that is preventing the wide adoption of process control or quality programs among the contractor group. Further, at the time of the contract, the client's value is expressed by the executed contract documents, which is inclusive of this buffer. In other words, there is value to the client by the contractor's buffering and risk premium on a short term basis. However, when the amount of risk premium and project buffers is examined on an aggregate level, it becomes obvious that the cost of construction is significantly overstated. This buffer -- mutually agreed to or not -- is a potential waste category and it should be examined as an area needing improvement.

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Impact of Project Environments on Project Change Management Best Practices

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Introduction

Many researchers conducted statistical analyses to reveal the correlations between best practices and project performance, and thus provided valuable recommendations to the industry about how to improve project performance by implementing best practices (Albanese 1993; CII 1986, 1993, 1994, 1999; Gibson and Hamilton 1994; Morrow 1998; Lee 2001; Lee et al. 2004; Lee et al. 2005a, b, c). As this previous research demonstrated, Project Change Management Best Practice (PCMBP) is one of the most important best practices, which has heavier impact on project schedule and cost performance than any other best practices (Lee et al. 2004).

Table 1. CII BM&M Questionnaire – Project Change Management Best Practice

No.	Project Change Management Best Practice Elements
1	Was a formal documented change management process familiar to the principal project participants used to actively manage changes on this project?
2	Was a baseline project scope established early in the project and frozen with changes managed against this base?
3	Were design "freezes" established and communicated once designs were complete?
4	Were areas susceptible to change identified and evaluated for risk during review of the project design basis?
5	Were changes on this project evaluated against the business drivers and success criteria for the project?
6	Were all changes required to go through a formal change justification procedure?
7	Was authorization for change mandatory before implementation?
8	Was a system in place to ensure timely communication of change information to the proper disciplines and project participants?
9	Did project personnel take proactive measures to promptly settle, authorize, and execute change orders on this project?
10	Did the project contract address criteria for classifying change, personnel authorized to request and approve change, and the basis for adjusting the contract?
11	Was a tolerance level for changes established and communicated to all project participants?
12	Were all changes processed through one owner representative?
13	At project close-out, was an evaluation made of changes and their impact on the project cost and schedule performance for future use as lessons learned?
14	Was the project organized in a Work Breakdown Structure (WBS) format and quantities assigned to each WBS for control purpose prior to total project budget authorization?

The Benchmarking and Metrics (BM&M) program of Construction Industry Institute (CII®) has been committed to providing construction industry "quantitative data essential for the support of cost/benefit analyses" (CII 2007). CII commenced BM&M data collection in 1996. Currently, the database represents over 1200 projects. The data recorded in this database can be basically classified into three categories of metrics: project characteristics, project performance, and project management best practice use. PCMBP is a part of the project management best practices.

CII started to include PCMBP in its database in 1997, which included fourteen elements as presented in table 1. This study aims to investigate how project characteristics influence PCMBP implementation. As in many previous studies, BM&M database is the source of data analysis. Table 2 illustrates the demographic composition of BM&M database based on respondent type, project nature, and industrial group.

Table 2. Composition of CII BM&M projects

		Industrial group				
	Project nature	Heavy Industrial	Light Industrial	Buildings	Infrastructure	Total
Contractor	Add on	153	20	4	17	194
	Grass Roots	157	22	24	13	216
	Modernization	106	11	6	14	137
Owner	Subtotal	416	53	34	44	547
	Add on	106	42	22	13	183
	Grass Roots	84	30	90	17	221
	Modernization	144	58	45	23	270
	Subtotal	334	130	157	53	674
	Total	750	183	191	97	1221

Research Motivation and Objectives

Although the efficacy of PCMBP in controlling project change cost has triggered many researchers' interest, there has not been any research performed to investigate how the implementation of PCMBP varies among different types of projects. It is highly probable that projects with different characteristics implement PCMBP to dissimilar extents so that there are some intrinsic relationships between these two factors. Answers to this question can help project management professionals and scholars identify those project areas in which PCMBP has not been widely and thoroughly implemented and thus urge upcoming projects in those sectors to follow PCMBP more and better.

It is also worth note that this research is to be explanatory instead of confirmative or predictive. The two main objectives of this research are: 1) Explore the correlation between project characteristics and implementation of individual PCMBP elements - for each single element, which type(s) of projects are more likely to adopt it than others do, and 2) Investigate the correlation between project characteristics and overall implementation of PCMBP elements - which type(s) of projects use most of these elements and/or use them to the utmost extent?

Research Methodology

The two objectives of this research can be interpreted as finding two types of statistical correlations: the first one is between a group of nominal indicator variables, each of which comprises multiple categories, and a single binary variable; the second one is between those categorical indicator variables and one interval variable with definite value range.

To study the first type of correlation, popular statistical techniques include nominal association coefficients based on contingency table such as Pearson's C, Goodman-Kruskal λ, or Cramer's *V*, two-group Discriminant Function Analysis (DFA), Structural Equation Modeling (SEM), and Logistic regression, etc. Other methods like Ordinary Least Square (OLS) regression or canonical correlation require underlying continuous dependent variable(s) and thus are not appropriate for this case.

The nominal association coefficients, however, can not measure the associations among multiple variables simultaneously so that the power of model is limited. On the other hand, Discriminant Function Analysis (DFA) and logistic regression are preferred when assessing modeling fit (Garson 2006). However, despite its super interpretability, DFA works much better when groups are of roughly equal size (Lee et al. 2005b). Unfortunately, this requirement is hard to fulfill in this research because of unequal group due to project natures. DFA also requires the same dispersions of dependent variable in independent variable groups (Cooley and Lohnes 1971), which is impossible to be met in this research as well because both the independent and dependent variables are categorical.

As an alternative to DFA, logistic regression is preferred when data are not normal in distribution or group sizes are very unequal (Garson 2006). In the investigation of the second type of correlations, k-way ANOVA is selected because it is the most suitable tool for such a situation, even though some non-critical assumptions are not met.

Data Analyses

Independent Variable Selection

Theoretical and empirical information is employed to select original independent variables to enter the models under study. The following five project characteristics variables are selected to build up the original model: respondent type, project nature, industrial type, transformed complexity, and cost category. The underlying hypothesis is that they have leverage on the extent of PCMBP element implementation. Table 3 includes detailed categories of the five variables with a brief description.

Because of distinct roles in a project, owner and contractor have different views on changes. So it is highly possible that implementation of PCMBP in owner and contractor project is statistically differentiable. Project nature probably has some correlation with project complexity, which together partially determine to what extent PCMBP elements will be used. Cost category indicates the scale of project. Since implementation of PCMBP is possibly not identical in large and small projects, it is rational to conjecture that cost category will partially determine the odds of adopting a certain PCMBP element. Project industrial type is also selected as an independent variable in that distribution of project nature and cost category may vary across different industrial sectors.

The Correlation between Individual PCMBP Elements and Project Characteristics

Binary logistics regression is conducted to find out the effect of project characteristics on project's odd of implementing each single PCMBP element. In a pre hoc examination, most of the pre-selected project characteristics variables show significant correlations with each other; hence, their individual significant correlations with PCMBP elements may come from other independent project characteristics variables correlated to both of them and the dependent variable. This is exactly the reason why cross-table nominal association coefficient measure is not used as explained in Research Methodology. In contrast, the log odds coefficients (Exp[B]) in logistic regression represent partial correlations analogously as beta coefficients in OLS do; therefore, they reflect the main effects (the unique contributions) of independent variables on the dependent variable.

Table 3. Project Characteristics Variables

Project characteristic	Category	Description and Note
Respondent type	Contractor	The respondent of this case is a contractor in this project.
	Owner	The respondent of this case is an owner in this project.
Project nature	Add on	Addition to existing facilities
	Grass Roots	Complete new construction project
	Modernization	Revamp or retrofit existing facilities
Industrial type	Heavy industrial	Chemical, Electrical Generating, Environmental, Refining/ Processing, Mining, Petrochemical, Oil & Gas, Pulp & Paper, etc.
	Light industrial	Auto mfg., Consumer prod. mfg., Electronics mfg., Foods, Pharmaceutical mfg., etc.
	Infrastructure	Airport, Electrical distr., Flood Contr., Hwy, Marine facilities, Navigation, Rail, Tunneling, Pipeline, Gas distr., Telecom/Network, Water & Waste, etc.
	Buildings	Comm. Center, Dorm/Hotel, Office, Hosp., Lab, Maintenance facilities, Parking/Garage, Phys. Fitness ctr., Restaurant/Club, Mall, School, Warehouse, Residential, Prison, Theater, etc.
Transformed complexity	Low	Complexity[1] of 0 to 3 as the respondents' original ratings
	Medium	Complexity of 4 to 7 as the respondents' original ratings
	High	Complexity of 8 to 10 as the respondents' original ratings
Cost category[2]	<= 5	Capital project or total cost of contract
	5 ~15	
	15~ 50	
	50 ~ 100	
	> 100	

1. Project complexity: 0 stands for the lowest complexity; 10 represents extremely complex project.
2. in million US dollars

The regression process for each of the PCMBP elements is identical. It is composed of three steps. In each step, influential points are detected and dropped out from model regression. In the first step, original model regression with all independent variables involved is performed on cases without missing data. In the second step, those blocks[1] of independent variables found non-significant in step1 are dropped[2] and the model is then refitted[3]. In the third step, influential points are detected again based on step 2 model and the model is refitted for the third time. If the reduced model (parsimonious model) is not significant in terms of model fitting[4], the corresponding significant full model will be reported. Interaction terms are not included in model fitting because there is not solid theoretical basis for assumptions of interaction effects and interaction terms often bring up the problem of multicollinearity.

[1] In SPSS binary logistic regression, a block of independent variables can only be entered into the model or dropped out together. This is very useful when the model includes several dummy variables representing a single underlying categorical independent variable. It is meaningless to keep only part of these dummy variables in the model.

[2] The dummy variables in one set (of the same independent variable) can only be added or dropped together and the reference variable is for the entire set, not individual dummy variables.

[3] At this step the data sets deleted in step one due to only missing data on the non-significant variable(s) will be reentered into model fitting.

[4] Because the underlying purpose of this research is exploratory, the primary concern is whether the independent variables can enable the fitted model to significantly differ from null model, which has only constant.

With regard to the basic regression settings when running the program, SPSS 14.0 only supports LISTWISE deleting data for logistic regression, i.e. the entire case will be deleted if its dependent variable is missing. In addition, all cases with any missing independent value are also dropped because " when the pattern of missing IV data is such that they occur exclusively for a proportion of subjects (p_a) the analyst may opt to drop these subjects and perform the analysis on the remainder of the sample" (Cohen and Cohen 1983). The Enter method is chosen as there is only one categorical independent variable in each block and they can be dummy-coded automatically by SPSS. The five independent variables introduced previously make up the five blocks. Standardized residuals and Cook's distances are selected to be saved for residual analysis, outlier, and influential point detection. Hosmer-Lemeshow (H-L) goodness-of-fit statistics is performed to test goodness-of-fit of individual model. Maximum iteration is set to an arbitrary large value. For example, 100 to ensure convergence and that final step is reached not because of iteration restriction.

Table 4. Categorical Independent Variables Coding

			Parameter coding			
		Frequency	(1)	(2)	(3)	(4)
Cost category	<= 5	204	1	0	0	0
	> 100	96	0	1	0	0
	15~50	201	0	0	1	0
	5~15	216	0	0	0	1
	50~100	80	0	0	0	0
Industrial type	Building	126	1	0	0	
	Heavy industrial	527	0	1	0	
	Infrastructure	56	0	0	1	
	Light industrial	88	0	0	0	
Project complexity	High	279	1	0		
	Low	87	0	1		
	Medium	431	0	0		
Project nature	Add on	244	1	0		
	Grass Root	267	0	1		
	Modernization	286	0	0		
Respondent type	Contractor	349	1			
	Owner	448	0			

Table 4 tabulates the coding of categorical independent variables for all the following models in this section. For each variable, there is one reference category that all dummy variable codes for it are zero. The following three paragraphs record how the three model regression steps are carried out for PCMBP element 1, which is "a formal documented change management process", as an example of how this part of data analysis is conducted on 14 PCMBP elements.

In step 1, when the model only contains a constant term, the reported significance is less than .001 indicating that this null hypothesis should be rejected and the out-of-model independent variables do have impact on the log odds of dependent variable (here, implementation of element 1). After putting all the indicator variables into the model, -2Log likelihood is 490.788; Nagelkerke R-square is 0.115; H-L goodness-of-fit statistics is 0.287. These indicate that the fitted model significantly differs from the null model which has only a constant, and the predicted values do not significantly differ from observed data, which means good fitness of model. Table 5 reports the fitted model after step 1.

Table 5. Step 1 Logistic Regression on PCMBP element 1

							95.0% C.I. for EXP(B)	
	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Contractor	1.117	.294	14.401	1	.000	3.054	1.716	5.437
Modernization			2.858	2	.240			
Add on	-.393	.317	1.542	1	.214	.675	.363	1.256
Grass Roots	-.522	.321	2.653	1	.103	.593	.317	1.112
Light industrial			7.592	3	.055			
Building	-1.184	.586	4.083	1	.043	.306	.097	.965
Heavy industrial	-.690	.544	1.610	1	.204	.502	.173	1.456
Infrastructure	-1.443	.627	5.304	1	.021	.236	.069	.806
Medium complexity			.086	2	.958			
High complexity	-.048	.273	.030	1	.862	.954	.558	1.629
Low complexity	.072	.375	.036	1	.849	1.074	.515	2.243
$50MM ~100MM			12.766	4	.012			
<= $5MM	-1.594	.649	6.038	1	.014	.203	.057	.724
> $100MM	-1.440	.680	4.489	1	.034	.237	.062	.898
$15MM ~ 50MM	-1.172	.643	3.321	1	.068	.310	.088	1.093
$5 ~ 15MM	-.629	.660	.909	1	.341	.533	.146	1.944
Constant	4.015	.811	24.509	1	.000	55.435		

-2Log likelihood =490.788; Nagelkerke R-square = .115; Hosmer and Lemeshow significance = .287
Note: Modernization, Light industrial, Medium complexity, and $50MM~100MM are the reference categories in the respective independent variables they belong to. Owner project is the reference category for respondent type, but is not reported by SPSS because only two categories exist in this variable.

In Table 5, all project nature parameters and all transformed complexity parameters are non-significant, which implies that they do not have significant impact on the log odds of PCMBP element 1 and thus should be dropped from the model in step 2. Several cases with missing values on transformed complexity are reentered into the model thereafter and the model is refitted. In step 3, five cases are detected as influential points and then cleaned out before the model is finally refitted[5]. At last, totally 816 cases are valid for model fitting. -2Log likelihood is 470.762, which also attests model validity. Nagelkerke R-square changes to .152 and H-L goodness-of-fit statistics changes to .594, both improved. Table 6 contains the variables in the final model fitted after step 3.

[5] It is worthwhile to note that all outliers are observed as 0 while the predicted classes are all 1. In other words, according to the fitted model, all of them should've used element 1, but none of them did in fact. All of these five cases are within cost category of $5MM ~ $15MM.

Table 6. Step 3 Logistic Regression on PCMBP element 1

	B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I. for EXP(B)	
							Lower	Upper
Contractor	1.327	.309	18.391	1	.000	3.769	2.055	6.913
Light industrial			13.492	3	.004			
Building	-1.611	.644	6.255	1	.012	.200	.056	.706
Heavy industrial	-.911	.619	2.165	1	.141	.402	.120	1.353
Infrastructure	-1.915	.687	7.772	1	.005	.147	.038	.566
\$50MM ~100MM			16.927	4	.002			
<= \$5MM	-1.386	.630	4.850	1	.028	.250	.073	.859
> \$100MM	-1.534	.681	5.073	1	.024	.216	.057	.819
\$15MM ~ 50MM	-1.097	.642	2.919	1	.088	.334	.095	1.175
\$5 ~ 15MM	-.154	.670	.053	1	.818	.857	.231	3.186
Constant	3.855	.822	21.973	1	.000	47.226		

-2Log likelihood =470.762; Nagelkerke R-square = .152; Hosmer and Lemeshow significance = .594

Table 7. Effects of Project Characteristics on PCMBP Index

Dependent Variable: PCMBP index

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	101.399(a)	12	8.450	2.207	.010
Intercept	14650.960	1		3827.452	.000
Respondent type	24.703	1	24.703	6.453	.011
Industry type	67.443	3	22.481	5.873	.001
Transformed complexity	.821	2	.410	.107	.898
Cost category	12.599	4	3.150	.823	.511
Project nature	5.785	2	2.893	.756	.470
Error	3020.183	789	3.828		
Total	51962.012	802			
Corrected Total	3121.583	801			

a. R Squared = .032 (Adjusted R Squared = .018)

In this final model, besides the constant, respondent type impacts PCMBP element use most because its log odd ratio coefficient is the highest (3.769), which means the odds of a contactor project adopting PCMBP element 1 is 3.769 times the odds of an owner project would. Similarly, in the project industrial group variable with light industrial as the reference category, heavy industrial projects does not show a significant coefficient while the other two categories have odds ratios less than 1.0, which means non-industrial projects (infrastructure and buildings) are significantly less likely to use PCMBP element 1 than industrial projects and infrastructure project is the least likely to use this PCMBP element because its Exp(B) is the lowest. As to cost category, projects with budgets within 5 ~ 15 and 15 ~ 50 do not significantly different from projects within 50 ~ 100. Only super small (<=5) and super large (>100) projects have far lower odds ratio.

Table 8. Post Hoc Tests on Industry Type

Dependent Variable: PCMBP index; Tukey HSD

(I) Industry type	(J) Industry type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Buildings	Heavy industrial	-.7093(*)	.19272	.001	-1.2055	-.2131
	Infrastructure	-.2687	.31155	.824	-1.0708	.5334
	Light industrial	-.6086	.27093	.112	-1.3061	.0889
Heavy industrial	Buildings	.7093(*)	.19272	.001	.2131	1.2055
	Infrastructure	.4406	.27275	.370	-.2616	1.1428
	Light industrial	.1007	.22524	.970	-.4792	.6806
Infrastructure	Buildings	.2687	.31155	.824	-.5334	1.0708
	Heavy industrial	-.4406	.27275	.370	-1.1428	.2616
	Light industrial	-.3399	.33265	.737	-1.1963	.5165
Light industrial	Buildings	.6086	.27093	.112	-.0889	1.3061
	Heavy industrial	-.1007	.22524	.970	-.6806	.4792
	Infrastructure	.3399	.33265	.737	-.5165	1.1963

Based on observed means
* The mean difference is significant at the .05 level.

There is a single metric in BM&M database that measures a project's overall implementation of PCMBP elements - *PCMBP index*. Its value ranges from 0 to 10, of which "0" stands for no implementation at all, whereas "10" represents using all the PCMBP elements. Totally there are 802 projects eligible for this part of research. In order to control Type-I error[6], k-way ANOVA is adopted. Levene's test does not indicate heterogeneity of variances so Tukey honestly significant difference test (HSD) is used for post hoc test. The saved Cook's distances do not indicate any influential data set. There is no sound theoretical or empirical foundation to support the possible existence of interaction effects between these independent variables; so only main effects of independent variables are evaluated.

Table 7 reports the significance test on independent variables' main effects. Only respondent type and industry type have significant effects on PCMBP index; so post hoc tests are only conducted on these two independent variables. Table 8 reports the post hoc tests performed on the four sub-categories of industry type. Respondent type variable has only two levels, so there is no post hoc test for it. The observed mean PCMBP index value of owner projects is higher than contractor projects'.

Based on the comparison of observed means and post hoc test results, owner projects outperform contractor projects in overall implementation of PCMBP elements. Meanwhile, projects in heavy industrial area significantly use more and better of PCMBP elements than building projects do.

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[6] According to Bonferroni inequality, $\gamma >= 1-((1-\gamma 1)+(1-\gamma 2)+\ldots+(1-\gamma k))$, where γ stands for the simultaneous or joint confidence that all the *k* intervals are effective, $\gamma 1 \sim \gamma_k$ stand for individual confidence intervals.

Conclusions

Based on this research, the following conclusions can be drawn firmly: 1) Contractors are more likely to establish a formal and documented project change management process than owners. Building and infrastructure projects are relatively less likely to do this by contrast with industrial projects. Small (<US$5MM) and large (>US$ 100MM) projects are less likely to undertake this effort than projects in other budget scales, no matter in what phase of project; 2) Heavy industrial projects usually concern more seriously about their project scope, and therefore are more possible to establish a baseline project scope early and freeze it with changes managed against this base; 3) Building and infrastructure projects, again, less frequently have changes evaluated against the business drivers and success criteria for the project, compared to industrial projects; 4) Heavy industrial projects, in comparison with other types of projects, generally follow more stringent project change authorization process before implementation; 5) Grass roots projects, compared with add on or modernization projects, are more possible to address criteria for classifying change, personnel authorized to request and approve change, and the basis for adjusting the contract in their contracts; and 6) Building projects do worse than other projects in terms of performing change management lessons learned and evaluating the cause and impact of changes on project cost and schedule performance upon project completion.

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Definitions of Key Terms

Cook's distance, D – A measure of the influence of a case. It measures the effect of deleting a given observation. Observations with larger D values than the rest of the data are those which have unusual leverage.

Hosmer-Lemeshow goodness-of-fit statistics – Another name of Chi-square goodness-of-fit statistics, which divides subjects into deciles based on predicted probabilities, then computes a chi-square from observed and expected frequencies. If the statistic is greater than preset threshold, e.g. .05, the null hypothesis can not be rejected that there is no difference between observed and model-predicted values, implying that the model's estimates fit the data at an acceptable level. That is, well-fitting models show non-significance on the H-L goodness-of-fit test. Although this test requires sample adequacy, collapsing groups may not solve a sampling adequacy problem since when the number of groups is small, the H-L test will be biased toward non-significance (will overestimate model fit).

Levene's test – A test to check the assumption of homogeneity of variance. It is robust against non-normality.

Likert scale - A type of psychometric response scale often used in questionnaires, and is the most widely used scale in survey research. When responding to a Likert questionnaire item, respondents specify their level of agreement to a statement. The scale is named after Rensis Likert, who published a report describing its use (Likert, 1932) (Wikipedia). The most commonly used are five-point and ten-point scales, although other types such as three-point or so are also not unusual.

Log odds (logit) – Mathematically, $Logit\ (p) = \log\left(\frac{p}{1-p}\right)$, where p is the probability of an event.

Nagelkerke R-square – A pseudo R-square as a modification of Cox and Snell's R-square. It is a "pseudo" R-square because it does not reflect the variance of the dependent variable explained indeed, which is impacted by how lopside the split of dependent variable is. Logistic R-squared measure can only be reported as approximation to OLS R-square and it attempts to measure strength of association. For small samples, for instance, an R^2-like measure might be high when goodness of fit was unacceptable by the likelihood ratio test.

Odds – If the probability of a certain event happens is p, then the odds of this event is $p / (1-p)$, which represents the ratio of the probabilities of happening and not happening.

Odds ratio – The ratio of odds of two events. Mathematically, it is $(p1*(1-p2)) / (p2*(1-p1))$.

VIF – Variance Inflation Factor, a measure of multicollinearity, which equals the reciprocal of $(1-R^2)$, where R^2 is the multiple coefficient of determination of a given independent variable regressed on all other independents. Generally, a VIF $\geq$ 4.0 flags multicollinearity, when S.E. will be doubled.

-2 Log Likelihood – a.k.a. goodness of fit, deviance chi-square, scaled deviance, deviation chi-square, Dm, or L-square. $-2\log(l_0 - l_1) = -2(L_0 - L_1)$, where L_0, L_1 are the maximum log-likelihood functions of the two models under investigation. In this research report it represents the difference of null intercept-only model and the fitted model. A large -2 Log Likelihood indicates that the two models are significantly different and the fitted model does improve interpreting the observed data.

Incorporating Ethics in the Construction Management Curriculum

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Abstract

The construction industry has indicated through the American Council for Construction Education the need to incorporate ethics into the curriculum. In addition to an ethics course, there is a requirement that topics in ethics be addressed throughout the construction-specific curriculum. This paper describes how "ETHICS ACROSS THE CURRICULUM" has been implemented into the Construction Project Administration course at Southwest Missouri State University. The why Ethics was being incorporated into the Construction Management Curriculum was discussed. The students were introduced to the ramifications of unethical behavior on the construction company and its professional personal reputations. The contractors perceptive of ethics transgressions from the frequency and seriousness of the transgressions were discussed. A course impact survey was conducted. One hundred percent of the students felt that this course increase their awareness of ethics issues likely to arise in their profession or job. Surprisingly not one student felt that the course did not improve their awareness. Eighty percent of the students felt that this course change their understanding of the importance of professional or business ethics. Eighty percent of the students felt that this course increase their ability to deal with the ethical issues it raised.

Introduction

In the aftermath of Enron and other corporate scandals there has been a renewed call for the inclusion of ethics as part of the degree program. Even before these scandals the construction industry has indicated through American Council for Construction Education (ACCE) the need to incorporate ethics into the curriculum. In addition to a having an ethics course ACCE (2002), there is a requirement that topics in ethics be addressed throughout the construction -specific curriculum. This paper describes how the ethics component is being implemented into the construction management curriculum and how "Ethics Across The Curriculum" was implemented into one keystone construction management course at University.

Document the Need to Incorporate Ethics into the Construction Curriculum

The American Council for Construction Education (2002) (ACCE), Form 103, Standards and Criteria for Baccalaureate Programs, Division 3.3.2 Curriculum Categories – Subject Matter Requirements, Section 1 General Education Requirement states "Construction is concerned with people and their relationships. Thus, the ability to communicate, both orally and in writing, and the understanding of human behavior are essential assets to the constructor." The ACCE requires at least one semester hours of Ethics be taught in ACCE Accredited Construction Programs. The ACCE further states, "In addition, oral presentation, business writing and ethics must be integrated throughout the construction-specific curriculum."

Identify Relevant Topics and Resources

Jackson (2001) also performed a survey of the "Perceptions of Experienced Construction Practitioners Regarding Ethical Transgressions in the Construction. In the survey the contractors rank fifteen issues for how frequent they occurred and how serious they felt the issues was. Some of Jackson's results are summarized in Table 1.

Issue Description	Ranking by Frequency	Seriousness
Improper or Questionable Bidding	1	2
Misrepresentation of Completed Work or Value of Work	2	15
Poor Quality Control or Quality of Work	3	4
Technical Incompetence or Misrepresentation of Competence	4	9
Abuse of Company Resources	5	14
Alcohol and Drug Abuse	6	1
Abuse of Client Resources	8	5
Failure to Protect Public Health, Safety or Welfare	11	3

Table 1 Contactors Perception of Frequency and Seriousness of Ethical Transgressions (after Jackson, 2001)

In reviewing the ethical statements of construction organizations, Ohrn (2002) stated that "Moral judgments must consider all of the ramifications of the judgment. Examples of these ramifications could include:

- Will a decision adversely affect the reputation of the organization or individuals working for the organization?
- Could a decision adversely affect the organization's ability to get work in the future?
- What are the effects of a decision on our relationship with our construction partners such as the subcontractors and suppliers?"

Ohrn (2002) also stated that "Perhaps construction management education should look at incorporating the study of ethics issues into the curriculum of a broad spectrum of subjects, including as examples:

- Estimating and bidding – Is bid shopping and bid peddling appropriate behavior for a construction professional?
- Project Management – Is it appropriated to front-load the schedule values and to delay payments to subcontractor and vendors?
- Soils and Concrete – Is it acceptable to modify laboratory and field test results in order passing results or to achieve higher monetary returns on end-result payments?"

American Institute of Constructors (2003) has established a Code of Ethics. This code was developed to establish minimum ethical standards for construction professionals. Springfield Contract Associate (2003) has developed bidding procedures suggested guidelines for Owners, Architects and Engineers, General Contractors and Suppliers. The guidelines were developed to establish fair and applicable procedures to improve methods for bidding construction projects in the Springfield area. The guidelines were developed by a team from Springfield Contractors Association, the Southwest Missouri Subcontractors Association and the Springfield Chapter of the American Institute of Architects.

The above articles clearly identify some relevant topics that can be incorporated in different courses. They also identify resources such as the American Institute of Constructors and the Springfield Contract Associate that can be used in the development of topics and speakers.

Establish Where and How Ethics will be Addressed

The current Ethics course that Construction Management students are required to take is PHI 115 Ethics and Contemporary Issues. This course examines ethical principles and theories in relation to contemporary moral issues (e.g. euthanasia, capital punishment, economic justice, environmental issues, and world hunger). Through a consideration of ideals of justice and human dignity, as well as concepts of rights and responsibilities, it also explores the moral requirements for community and justified political.

Examples Incorporating Ethics into CM Curriculum (after Ohrn (2002)

- Project Administration – Is bid shopping and bid peddling appropriate behavior for a construction professional?
- Scheduling – Is it appropriated to front-load the schedule valves and to delay payments to subcontractors and vendors?
- Soils – Is it acceptable to modify laboratory and field results in order passing results or to achieve higher monetary returns on end-result payments

At the Center for Study of Ethics in the Profession, Illinois Institute of Technology, Ethics across the Curriculum Workshop, Summer 2003, they suggested that although ethics should be cover in all courses, one course in a professional program should be chosen to be a keystone course on showing ethics in the curriculum. The course needs to be evaluated and the results share with facility members. The purpose is to show other professors in the program how ethics can be also incorporated successfully into their courses. The course that incorporated "ETHICS ACROSS THE CURRICULUM" was Construction Project Administration during the Fall 2003 semester. The why Ethics was being incorporated into the Construction Management Curriculum was discussed. The students were introduced to the ramifications of unethical behavior on the construction company and its professional personal reputations. The contractors perceptive of ethics transgressions from the frequency and seriousness of the transgressions were discussed. Cases studies on 1) bid shopping (homework and class discussion) and 2) not paying your subcontractors (test question and class discussion) were covered. Listed below are materials on Ethics that were covered in CM 426 Construction Project Administration:

Incorporate Ethics as an Element of Program Assessment

General Program Assessment

Most of the faculties are currently covering some of these topics in their courses. In addition of assuring documentation of these topics on course syllabuses, test, and major assignments, we are creating individual department notebooks, tab by course number, showing the oral presentations, business writings or ethics that are being covered in our courses. This includes copies of any course assignments; reference materials used and may include test questions. Examples of material to be included in each notebook are given below:

- Case Studies
- Current Articles Discussed in Class
- Published Professional Ethics
- Class Notes / PowerPoint Presentation
- Ethical Transgressions
- Outside Readings

Assessment of "Ethics Across the Curriculum"

The student participation on the lecture material and cases studies was excellent. They performed extremely will in both the homework and the test on ethics questions. In addition, the Center for the Study of Ethics in the Profession (2003) has developed a Course Impact Survey to use for Assessment of "Ethics Across the Curriculum" as shown in Appendix A. This Course Impact Survey was given to the to the Construction Project Administration class and a summary of the results are shown in Table 2.

Issue Description	Yes	No	Not Sure
Increase awareness of ethical issues in the construction profession	100 %	0 %	
New understanding of the impotence of ethics in construction	80 %	20 %	
Increase ability to deal with ethical issues it raised	80 %	5 %	15 %
Did you have any professional or business ethics in a class before this	35 %	55 %	10 %

Issue Description	To Much	To Little	About Right
Course spend too much time on construction ethics	5 %	20 %	75 %

Table 2 Course Impact Survey 2003

One hundred percent of the students felt that this course increase their awareness of ethics issues likely to arise in their profession or job. Surprisingly not one student felt that the course did not improve their awareness. Eighty percent of the students felt that this course change their understanding of the importance of professional or business ethics. Eighty percent of the students felt that this course increase their ability to deal with the ethical issues it raised. Seventy-five percent of the students felt that just the right amount was time on professional or business ethics related to construction only five percent felt that this course spent too much. Fifty-five percent of the students stated that they had professional or business ethics in a class before this one?
Listed below is a sample of some of the comments the students made on the survey.

Increased your awareness of ethics issues likely to arise in your profession or job.

- It brought about new situations and ways of handling them that I wasn't aware of.
- Just talking about ethical issues & hearing stories about how to solve real problems.
- Never before have I been exposed to the business side of construction. I feel it is interesting to hear of instances and experiences that occur in construction business, which also shows me what to expect.
- Not many other courses deal at all with ethics. My awareness was increased just through the class discussions.
- It gave me awareness about bid shopping and ways to avoid it and why you should avoid it.
- It brought to light the fact that ethical issues are more common than I thought.
- Just talking about some real issues and getting class discussion and thoughts help with awareness.

Changed your understanding of the importance of professional or business ethics.

- There are more ethical issues that occur in construction than I was aware of.
- My understanding was changed in that ethics is not only important for your reputation, but ethical conduct can be financially beneficial as well.
- By being aware of an ethical issue or situation, I have learned how to be a little more professional about resolving issues.
- Showed the implication of not having a good business ethics.
- It changed my understanding by using the case studies & explaining how it got handled in real life.
- Business ethics is very important and everyone should understand them. Again talking about different situations help with understanding.

Increase your ability to deal with ethical issues raised.

- By making me think gave me problem solving experience
- It increased my ability because of the example problems we did in class and as homework
- Some issues are still hard to solve, but others had discussion brought up that dealt with details I hadn't thought about before
- The course helped me to slow down and rationalize options
- Showed me different ways of dealing with ethical issues
- It mainly helped me to understand what is considered to ethical and non ethical
- Most importantly it brought to my attention some of the ethical issues the industry is facing
- It gave a background on how to handle ethics and that should help to deal with the issue
- I understand more about them then for I can deal with them in more confidence
- It made me think critically about things

Course spend too much time on professional or business.

- Well balanced between professional and business ethics
- The right amount, even though ethics could go on forever, there's no right or wrong a lot of times, just options
- Right amount- everything we discussed had ethics playing a role
- I think we spent just about the right amount of time discussing ethics. I was able to get enough information to increase my knowledge and awareness of the subject
- It brought up key issues and real life situations that we may encounter in our field without spending time on endless hypothetical questions
- I feel there was too little time spent on ethics. We had a list that specified 15 issues but talked in detail about only a few.
- It was just about right; the course makes you more aware of ethics and professionalism, but does not seem to prejudice a person in one direction or another
- Just about the right amount. The class allowed us to express views & solutions to real case studies and we received actual feedback in group discussion
- I actually think we could have spent more time discussing ethical issues.

These are very positive results, therefore we plan to expanded ethics into other courses in our program.

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Appendix A

ETHICS ACROSS THE CURRICULUM

Course Impact Survey

Course: ____ Date: ______________________

1. Did this course increase your awareness of ethics issues likely to arise in your professions or job? ____
2. If "no," what might have helped the course increase your awareness of such issues? If "yes," please explain how it increased your awareness.
3. Did this course do anything to change your understanding of the importance of professional or business ethics? ___
4. If "no," what might have helped the course change your understanding? If "yes," please explain how the course changed your understanding.
5. Did this course increase your ability to deal with the ethical issues it raised? ____
6. If "no," what might have helped the course increase that ability? If "yes," please explain how it increased that ability?
7. In your opinion, did this course spend too much time on professional or business ethics, too little, or just the right amount. Is there anything that should have been done differently? Explain. *Just about the right amount.*
8. Did you have any professional or business ethics in a class before this one?

Distance Learning & Internet

Collaboration beyond the Virtual Classroom through Wikis

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Abstract
Readers of this paper will explore strategies and resources used in the design, development, and use of wikis as virtual learning environments. While Blackboard, WebCT, Moodle, and other learning management systems (LMS), provide necessary course administration management tools and document repository capabilities, the tools incorporated into these systems provide limited collaboration opportunities. The educational power of the wiki, a participant built website, is reflected in the fact that groups can work collaboratively by contributing and editing content and adding hyperlinked resources and descriptions using a standard web browser and no other special tools. Learning communities support and encourage learner-to-learner interaction and learner-to-faculty interaction. Building learner-centered, discipline-specific virtual learning communities that extend discourse beyond the online course environment through collaborative wiki use has significant implications for students and faculty.

Wiki: Defined
The term 'wiki' may at first be thought to be an acronym or perhaps a made-up, whimsical word. Wiki, a shortened form of wiki wiki, is actually a Hawaiian term meaning quick. The term wiki refers to either the Web site or the software used to create the site. The first wiki was created by Ward Cunningham in 1995 and founded as an automated supplement to the Portland Pattern Repository (http://c2.com/cgi/wiki?WikiHistory, 2007). The original wiki page is located at http://www.c2.com/wiki. According to Cunningham, "'Wiki' is a composition system; it's a discussion medium; it's a repository; it's a mail system; it's a tool for collaboration. Really, we don't know quite what it is, but it's a fun way of communicating asynchronously across the network," (http://c2.com/cgi/wiki, 2007). A wiki is essentially web-based software that allows participants in a wiki site to easily add and change content by editing the site design and site pages online in a browser, (Ebersbach, Glaser & Heigl, 2006; Educause, 2005; Fogel, 2005; Leuf & Cunningham, 2001).

Unlike other communication methods, wikis are unique in that participants can edit the organization of the site in addition to the content itself. Wikis don't happen in real time, so participants get a chance to reflect on and refine their contributions (Fogel, 2005).Wiki participants are at once author, editor, and collaborator. Wikis represent a type of social software that makes it easy to communicate online (Ebersbach, Glaser & Heigl, 2006; Educause, 2005; Fogel, 2005; Leuf & Cunningham, 2001). This ease of use makes the wiki an ideal online collaboration tool even for non-technical participants. Wikis are widely used in business and industry and increasingly in education. They are easy, economical, efficient, and intuitive to use.

Wiki: Web 2.0
The author of the techsoup site defines Web 2.0 as "a category of new Internet tools and technologies created around the idea that the people who consume media, access the Internet, and use the Web shouldn't passively absorb what's available; rather they should be active contributors, helping customize media and technology for their own purposes, as well as those of their communities," (http://www.techsoup.org/toolkits/web2, 2007). Wikis are part of the Web 2.0 social software category. The figure below illustrates the advent of the wiki, and other collaborative Internet applications, in relation to the coining of the word Web 2.0 in 2003 by O'Reilly Media to reflect the highly interactive, socially constructivist nature of the Internet of today (Forrest, 2006).

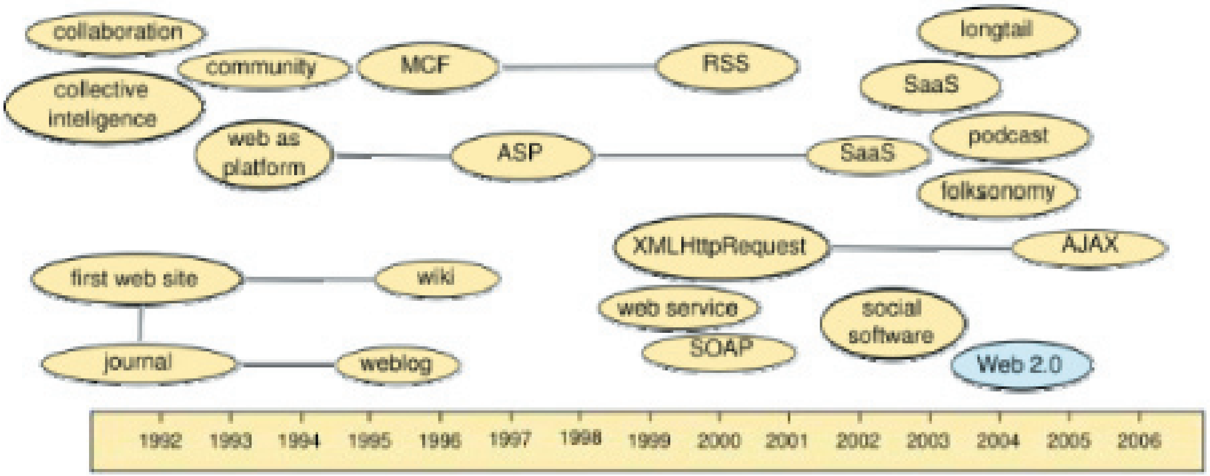

Figure 1. Buzzwords timeline (http://www.wikipedia.org, 2007).

Wiki: Features, Benefits, and Challenges

Introduction

The open, flexible nature of a wiki presents both benefits and challenges. Wiki collaboration is asynchronous in nature allowing participants to access the site and contribute anytime, anywhere providing they have Internet access. Without careful planning and guidelines, what started out as a well structured virtual learning environment can be reduced to a chaotic free-for-all as the many contributors create and edit away. Specific benefits and challenges inherent in wiki use must be considered carefully when implementing a wiki as a virtual learning environment. "Most people, when they first learn about the wiki concept, assume that a website that can be edited by anybody would soon be rendered useless by destructive input. It sounds like offering free spray cans next to a grey concrete wall. The only likely outcome would be ugly graffiti and simple tagging, and many artistic efforts would not be long lived. Still, it seems to work very well," (Ebersbach, Glaser, & Heigl, 2006, p.10).

Features

Participants have access to wiki content twenty-four hours a day, seven days a week. Students and teachers can easily edit the wiki through a browser using either wikitext (a markup language similar, but much easier to use, to hypertext markup language (HTML)) or a "What You See Is What You Get" (WYSIWYG) editor provided by many wikis. Built-in search features assist participants in locating desired content.

Wikis can be public, protected, or private which is a key consideration when creating a virtual learning environment through the wiki. A commonly known public wiki is Wikipedia. Anyone with Internet access can view, create, or edit Wikipedia pages. A protected wiki is viewable by the general public but requires authorization to participate in the wiki through editing pages and adding content. A private wiki is viewable and editable only by participants who have access authorization and a password.

Participant contributions and edits are tracked allowing authors to review changes to pages, as well as seeing who made the changes. The option to revert back to older versions if need be is also available (Ebersbach, Glaser, & Heigl, 2006; Cunningham, 2007). Varying levels of permissions can be assigned by administrators to allow individuals to view, edit, create, or delete pages (Ebersbach, Glaser, & Heigl, 2006; Leuf & Cunningham, 2001; techsoup, 2007; Wikipedia, 2007).

From a design perspective, many wikis include sophisticated site design templates. Templates may allow creators to choose between course syllabus, classroom, group project or a blank canvas among others (http://www.pbwiki.com, 2007). A table of contents can be added to pages much in the same way named anchors are used for intra-page navigation. Sidebar navigation is possible to allow participants easy access to all site pages. In addition, many wikis include site design choices (color scheme and layout) created using cascading style sheets. Depending on the wiki chosen, many wikis also provide backup services and the ability for the administrator to create a zipped backup of his or her site pages. Summary statistics, as in the table below, allow the administrator to track wiki usage including logins, page views, edits, and saves, file uploads, access by nations of origin, among others.

Jun 16th Sat	Jun 17th Sun	Jun 18th Mon	Jun 19th Tue	Jun 20th Wed	Jun 21st Thu	Jun 22nd Fri	Jun 23rd Sat	Jun 24th Sun	Jun 25th Mon	Jun 26th Tue	Jun 27th Wed	Jun 28th Thu	Jun 29th Fri	Total	
	2	36	42	38	36		3	6	39	18	45	36	6	55	United States

Figure 1. Nations of origin in the last 14 days for teamisd.pbwiki.com (as determined by unique IP addresses).

New features such as embedded spreadsheets (which can be edited directly on the wiki), voice-chat, event planning, calendars, and embedded video (including YouTube) have been added as wiki technology continues to evolve. Options for implementing a wiki include outsourcing to a third-party host, also known as a wiki farm, or building the wiki by installing software on a local server. Wiki farm features can be compared through sites such as WikiMatrix (http://www.wikimatrix.org/) and Wikipedia (http://en.wikipedia.org/wiki/Comparison_of_wiki_software).

Wikis, in some cases free, can be an attractive alternative to very costly enterprise learning management systems (LMS). Wikis are flexible, easy to use, and learn and provide a collaborative playground for participants.

Benefits

Extending discourse beyond the classroom through the wiki is a main benefit. Students and teachers, in essence, create a learning community around a particular subject. From a pedagogical perspective, wikis allow students and teachers to interact in ways that might not be possible in a face-to-face classroom environment. As with many simple concepts, "open editing" has profound and subtle effects on wiki usage and wiki participants (Educause, 2005; Leuf & Cunningham, 2001; techsoup, 2007).

The constructivist ideology of teaching and learning focuses on socially constructed knowledge (Bruner, 1990). Wikis provide an opportunity for social construction of knowledge as participants actively contribute content and then reflect, refine, and edit that content to benefit the learning of the group. "In this model students will not simply pass through a course like water through a sieve but instead leave their own imprint in the development of the course, their school, or university, and ideally the discipline," (Holmes et al., 2001, p.1).

Challenges

The content of a wiki evolves over time as individuals add and edit the information. Leuf and Cunningham (2001) write about wiki "fragility." This fragility manifests itself in the possibility of participant abuse through spam, flaming, malicious editing, and intentional or unintentional deleting of content posted by someone else is ever present. The potential for malevolent manipulation exists but can be mitigated through careful planning and the establishment of guidelines. Clear page organization and pleasing visual layout are crucial so participants will confidently know where to add content (Fogel, 2005; Leuf & Cunningham, 2001). Guidelines should be posted on the wiki to provide structure and consistency. Whether the content on the wiki is exceptional or trivial, it won't matter if the site is disorganized or confusing as a whole. Too often, wiki organization suffers from:

- Poor site design
- Lack of guidelines or rules-of-the-road
- Poorly structured navigation
- Redundant content
- Ill-defined audience

As with any online learning environment, principles of good web site design are important. Organization should be intuitive and conducive to effective learning. The needs of the participants should be considered throughout the design process. Site navigation should be consistent, clear, and effective in allowing the participants to fine their way around the site. Frustration in negotiating the virtual learning environment is a primary cause for low student retention (Gibson & Lee, 2003; Gibson, 1998).

Participants need to know what to expect from the learning experience and what is expected of them. They need to know the rules for interacting with the content, peers, and teachers. They need to know on what and how they will be evaluated. Guidelines are critical and provide the necessary structure and rules-of-the-road for interacting successfully in a virtual learning environment. While wikis are easy and fun to use, participants still need guidance on the basics.

Administering a wiki can be a challenging undertaking. Teachers are typically the primary creators and editors of content and site design on an LMS course site. When using a wiki as a virtual learning environment, the site design and page content has many authors and editors, as many students as are in the course. The administrator (teacher) must be vigilant to maintain the structure of the site, ensure content validity, and reorganize content if necessary to reduce content redundancy. For example, the same website resource or article link may be posted in several locations by several different students. While the content is useful, if it appears multiple times in multiple places, students may be confused.

Wiki should have a specific purpose and be designed for a specific audience. In the case of Wikipedia the design is consistent with a wide, general audience each of whom have the option to add and edit the site content. For a particular class, knowing the students comfort level with technology, use of the Internet, and knowledge of the course material prior to the start of the class is helpful in designing and structuring the wiki site, pages, and guidelines.

Summary
While the open nature of the wiki can be cause for concern, with appropriate planning a wiki can provide an engaging, interactive, and collaborative virtual learning environment. The administrator must provide clear expectations for cooperation. Detailed documentation on how to add content; expected etiquette; edit guidelines; and a dispute resolution process for contested edits should all be clearly stated and provided. If Wikipedia can get thousands of strangers to adjust their communication style to be consistent with the Wikipedia vision, with thoughtful planning, and emulating the spirit of Wikipedia, a successful wiki as virtual learning environment is possible and worth the effort (Fogel, 2005).

Wiki: Educational Examples
The author has successfully used private wikis over the course of the last two years in the following settings:

- Virtual learning environment,
- Group or team projects,
- Thesis or major project supervision and facilitation,
- Research.

Virtual Learning Environment
In the author's opinion, as a virtual learning environment, a wiki allows greater flexibility, greater potential for interactivity, greater access for content construction and knowledge building, and greater collaboration opportunities than an enterprise LMS. Students, unless they are granted instructor privileges, cannot edit a course site created in an LMS nor the content pages in the LMS. According to Holmes, et al. (2001), "Learning is seen as a social and collaborative activity that is facilitated rather than directly taught by the teacher. Building on constructivist theories, where students are involved in building their own knowledge, social constructivism adds an interactive dimension," (p.2). Wikis facilitate this interactive dimension.

Through the use of wikis the author has observed students who would otherwise passively sit through a face-to-face class, actively find their voice and validation from peers through collaboration on the wiki. One course wiki in particular has truly extended discourse beyond the virtual classroom, Instructional Design and Computer Courseware Design. Graduate students have continued to access and add to this wiki that was created for a class in the spring of 2006. As they have left the university and gone on to begin their careers, it has become a content resource as well as a source of advice and information from wiki participants.

Projects
The interactive multimedia projects the author requires in several classes consist of an extensive planning phase, development, testing, and deployment. Students post project ideas, technical specifications, content maps, storyboards, prototypes, and working versions of their projects on individual student pages, Students are required to provide substantive feedback to each other for each phase of the project. The ease of access and editing the wiki along with the opportunity for review and reflection prior to providing feedback have resulted in more detailed, and more substantial feedback for all participants. The use of the wiki as a work space for this project activity has been well received by the students and resulted in improved final projects.

Thesis or Major Project Supervision and Facilitation
The success with wikis as virtual learning and project environments prompted the author to use wikis with students for whom she was chairing master's thesis or major project committees. The wiki had three primary benefits in this application. First, students were able to organize their content in a manner consistent with the final document. Second, the author and student were able to discuss the research, share resources, edit, refine, and reorganize the document in a far more collaborative, effective, and efficient manner than is possible by passing a Word document back and forth. And finally, the students with whom the author has used this approach have the added benefit of version control and not having to worry about losing work due to technology failures such as a crashed hard drive or lost flash drive.

Research

Again, encouraged by the success with other applications of the wiki, the author is currently collaborating with several other faculty at my own and several other institutions in research endeavors. The anytime, anywhere nature of the online wiki reduces time and place barriers. The flexible and open nature of the wiki promotes collaboration, motivation, and synergy. Ideas are born and content created and perfected on the fly with a group of colleagues with like research interests (Gorman, 2005). Wikis provide an exciting vehicle to research and contribute to the research field of knowledge.

Conclusion

The wiki truly is a fast way to create collaborative virtual learning environments that extend discourse and learning beyond the classroom. "The possibilities for using wikis as the platform for collaborative projects are limited only by one's imagination and time," (Educause, 2005).

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Electrical/Electronics/ Computer Technology

Disaster Recovery Using Virtual Machines

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Introduction

Today, the importance of having 100% uptime for businesses and industries is clear – financial reasons and often strict government regulations for certain industries require 100% business continuity. The concept of business continuity (BC), as Microsoft defines it - "the ability of an organization to continue to function even after a disastrous event, accomplished through the deployment of redundant hardware and software, the use of fault tolerant systems, as well as a solid backup and recovery strategy" (Microsoft 2005) directly relates to an organization's ability to quickly restore and deploy IT backups and business operations in a short period of time. Disaster recovery's precedence determines the quality of restored business operations and allows for continuation of business. Nowadays, backups and server uptime are a must; however, those are not directly related and not sufficient enough to provide grounds for disaster recovery for a company. The advancement of information technologies to the level of virtual environments suggests easier deployment and restoration of IT functions once virtualization is utilized for BC management. Evident cost reduction and elimination of physical hardware components along with space savings are provided with virtualization processes (Goldworm, B., Skamarock, A. 2007); those serve as vital components for any disaster recovery process.

This manuscript presents several necessary steps to be taken before and after a creation of a disaster recovery plan. The amount of resources, administration/personnel involvement and financial costs associated with a design of a Business Continuity Plan (BCP[1]), simply do not allow for a quick and easy BCP implementation. Along with the procedures associated with a BCP design, this study suggests several concepts for BCP and BC utilizing virtualization software which allows for a significant cost and time reduction in preparation for a successful disaster recovery plan. Furthermore, it is important to understand that disaster recovery planning is a separate process from business continuity management.

Business Continuity Management Cycle

Preparation for something unknown or unexpected is a difficult task. It is a challenge for organizations to embrace every business operation and function along with the required IT support and functionality and then downsizing them to 2-3 mobile office/recovery units. Mobile office units could be contracted out via disaster recovery agreements by companies such as Hewlett-Packard, Centurion, Agility Recovery Solutions and many others. An example of a mobile office unit is presented by *Figure 1*. It is also important to realize that BC process should incorporate *every* vital business function that allows for continuity and requires extensive preparation before signing any contracts. *Figure 2* presents the Business Continuity Management Cycle which provides initial and at the same time continuous steps in BC management. The Cycle starts with assessing risks and business impacts once various threats and levels of a possible disaster are understood. Once risk assessment takes place then it is possible to realize the minimal accepted business functionality for various disaster recovery scenarios. The presented cycle is a continuous process that allows for assessment, planning, creation, testing and improvement of a business continuity plan.

[1] Business Continuity Institute defines Business Continuity Planning as Business Continuity Management (BCM).

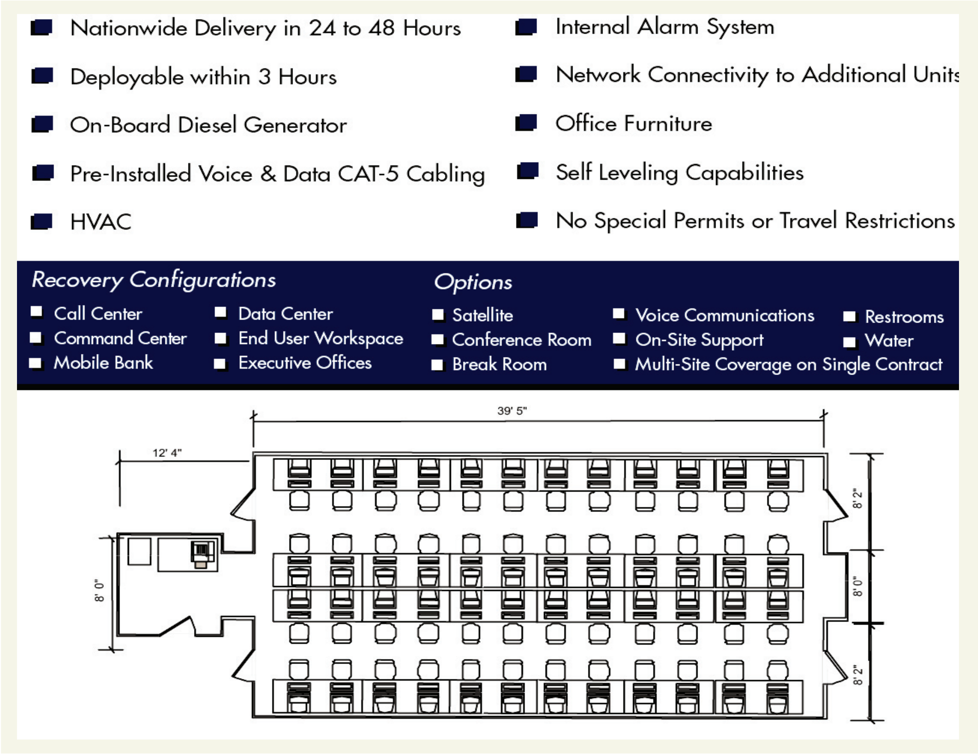

Figure 1. Mobile recovery unit.

Source: http://www.centuriondr.com/

Figure 2. Business Continuity Management Cycle.

Prior to taking any steps towards disaster recovery planning, the following questions need to be answered: 1) does a company's administration approve and support the disaster recovery planning? 2) what personnel is going to organize, manage and create the plan? 3) which essential functions need to be restored? 4) what are the federal/state government guidelines for this particular industry? Those initial questions about BCP would be addressed by a Business Continuity Committee (BCC) that should be formed as soon as the executive/administrative approval and support for BCP is obtained. Strategy development should provide detailed steps for each member of an Emergency Response Team (ERT) which should be formed by BCC.

Planning and Implementation

The following essential steps in disaster recovery could serve as a guide to BC planning; each of these steps incorporates several other processes which require a high level of commitment, time, money and organizational discipline (MIT 1995):

1. *Obtain Top Management Commitment*. Top management must support and be involved in the development of the disaster recovery planning process. Management should be responsible for coordinating the disaster recovery plan and ensuring its effectiveness within the organization.
2. *Establish a planning committee.* A planning committee should be appointed to oversee the development and implementation of the plan. The planning committee should include representatives from all functional areas of the organization.
3. *Perform a risk assessment.* The planning committee should prepare a risk analysis and business impact analysis that includes a range of possible disasters, including natural, technical and human threats.
4. *Establish priorities for processing and operations.* The critical needs of each department within the organization should be carefully evaluated in such areas as:
    - Functional operations
    - Key personnel
    - Information
    - Processing Systems
    - Service
    - Documentation
    - Vital records
    - Policies and procedures
5. *Determine Applicable Recovery Strategies.* Determine the most practical alternatives for processing in case of a disaster should be researched and evaluated:
    - Facilities
    - Hardware
    - Software
    - Communications
    - Data files
    - Customer services
    - User operations
    - MIS
    - End-user systems
6. Perform data collection. This step is the most time consuming.
    - Backup position listing
    - Critical telephone numbers
    - Communications Inventory
    - Distribution register
    - Documentation inventory
    - Equipment inventory
    - Forms inventory
    - Insurance Policy inventory
    - Main computer hardware inventory
    - Master call list
    - Master vendor list
    - Microcomputer hardware and software inventory
    - Notification checklist
    - Office supply inventory
    - Off-site storage location inventory
    - Software and data files backup/retention schedules
    - Telephone inventory
    - Temporary location specifications
    - Other materials and documentation
7. *Organize and document a written plan.* An outline of the plan's contents should be prepared to guide the development of the detailed procedures. The structure of the contingency organization may not be the same as the existing organization chart.

8. *Develop testing criteria and procedures.* It is essential that the plan be thoroughly tested and evaluated on a regular basis (at least annually). Procedures to test the plan should be documented.
9. *Test the Plan.* After testing procedures have been completed, an initial test of the plan should be performed by conducting a structured walk-through test. Types of tests include:
   - Checklist tests
   - Simulation tests
   - Parallel tests
   - Full interruption tests
10. *Approve the plan.* Once the disaster recovery plan has been written and tested, the plan should be approved by top management.

The steps in BC management presented in this chapter embrace many business functions and operations. Today, each of these operations is not functional without an extensive IT infrastructure; furthermore, industries such as healthcare endure strict government regulations for IT and business functions which further complicate disaster recovery process. If at the time of initial phases of BCP organization does not operate in a virtual IT environment it is a perfect time to utilize virtualization in preparation of a disaster recovery plan. There are many courses and even schools that provide education and certificates that allow organizations and industries to apply BCM knowledge towards disaster recovery planning.

Virtualization Applied to BCM

Virtual technologies have a broad range of contexts – operating systems (OS), programming languages, computer architecture (Nair, R., Smith, J. 2005). Virtualization of operating systems and computer architectures significantly benefits any disaster recovery process and would improve business continuity. Depending on which OS environment is used, a company should provide backup of virtual workstations, servers instead of the conventional images of computers. As it was mentioned earlier the conversion of computer systems into virtual machines at the time of BCP creates an opportunity for a company to save money, resources and time. Tools such as VMware Converter allow conversions of various computer platforms into VMware virtual machines. For example, instead of providing images of several servers to a company that deploys mobile office units, an organization should provide 1 image which contains all virtual servers. *Figure 3* provides an example of how that conversion is performed. Conversion to virtual servers would allow reduction of costs by contracting out fewer PCs identified in a disaster recovery agreement.

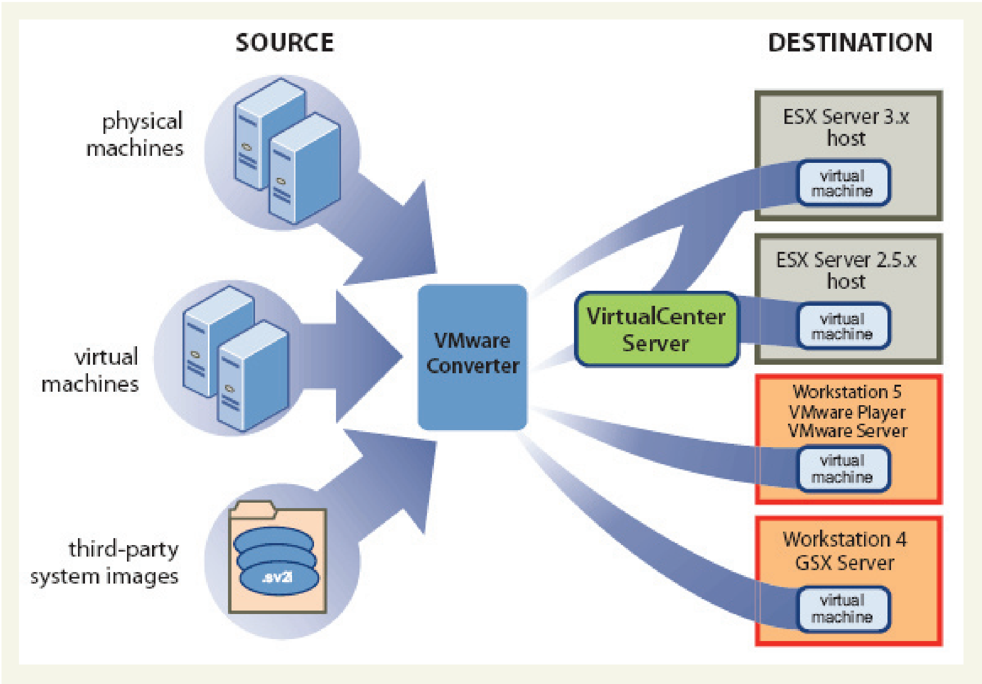

Figure 3. Performing a conversion of a physical machine into a virtual one.
Source: http://www.vmware.com/products/converter/

Virtualization concept is not a new idea. It is based on a time-sharing concept originally developed by scientists at Massachusetts Institute of Technology (MIT) in 1961 (Corbato, F. *et al.* 1961). Time-sharing creates an opportunity of concurrently managing multi-hardware and multiuser environments on a single physical machine. Today, many vendors such as IBM, Sun Microsystems, HP and others have taken this time-sharing concept further and developed virtualization scheme of various types including Integrity VM by HP (Herington, D., Jacquot, B. 2006). The advantages of modern technologies such as Integrity VM allow running any operating system inside VM that supports Integrity VM platform (Herington, D., Jacquot, B. 2006). An example of how virtualization is applied in a hosted virtualization model is shown by *Figure 4* (Goldworm, B., Skamarock, A. 2007).

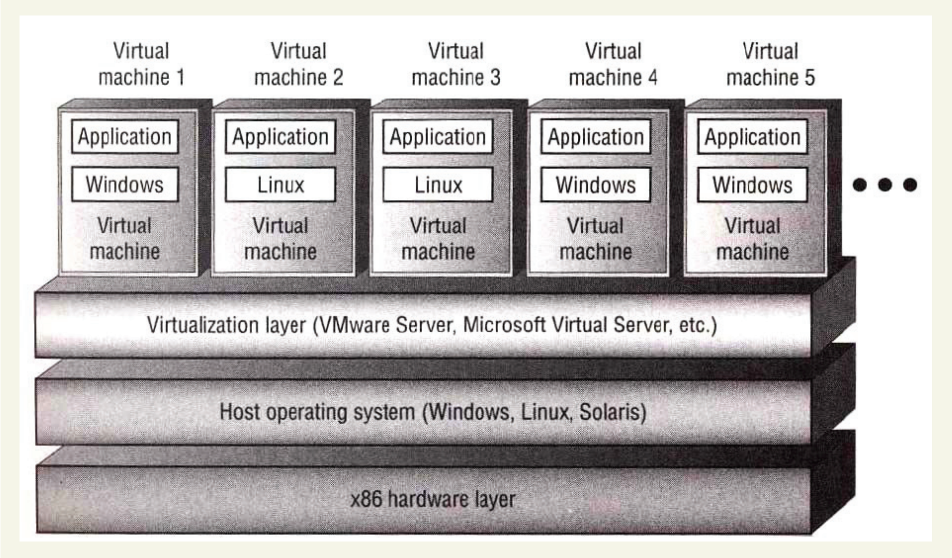

Figure 4. Hosted approach for virtual servers
Source: Goldworm, B., Skamarock, A. (2007).
Blade Servers and virtualization. Transforming Enterprise Computing while Cutting Costs. p.97

A step further in disaster recovery using virtual technologies could be taken with virtual network environment and storage virtualization. Storage virtualization allows for separation of physical management from the application software on a server which, once again cut the costs of create backup sties and backup hardware in the event of a disaster (Goldworm, B., Skamarock, A. 2007).

Conclusion

As information technologies progress continuously, it is important to realize practical applications of available IT resources and direct them towards every day operations. For instance, companies should fully deploy virtualization for disaster recovery and business continuity even if regular business operations do not require virtualization. Reduction of costs, time and resources is going to have a positive impact on business continuity management.

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A Lab View PDS v8.20 Based Novel DATA Acquisition and Interface Module for a 500W Hydrogen Fuel-Cell Power Station Unit

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Abstract
This research paper reports design and implementation of a high-resolution data acquisition and interface module for a 500 W Hydrogen fuel cell power station using LabView™ PDS v8.20 software and field point based data acquisition modules at the University of Northern Iowa. The developed data acquisition system will be used as a laboratory tool in a graduate level, Computer Aided Instrumentation class at the Electrical and Information Engineering Technology Program.

Introduction
The depleting fossil fuel resources and global warming impacts are leading to the research and development of alternate energy technologies. Hydrogen Fuel cell systems have a high efficiency and use easily available hydrocarbons like methane thus alleviating the fuel shortage. Since the by-product is water, vapor and heat, they have a very low environmental impact (Prabha, 2004). The hydrogen fuel cell system consists of several subsystems and a lot of effort in diverse areas is required to make it a popular choice for power generation

A fuel cell is an electrochemical energy conversion device that produces electricity from external supplies of fuel (on the anode side) and oxidant (on the cathode side). Generally, the reactants flow in and reaction products flow out while the electrolyte remains in the cell. Fuel cells can operate virtually continuously as long as the necessary fuel is maintained (Wikipedia, 2007). Additionally, while the electrodes within a battery react and change as a battery is charged or discharged, but a fuel cell's electrodes are catalytic and relatively stable.

Hydrogen Fuel cells boast many advantages when compared with conventional energy sources of today. The power from a fuel cell is derived from hydrogen, an element that is extracted from many resources. The conversion of hydrogen to electricity has no emissions. Conventional energy production requires nonrenewable fuels and produces pollutants as well. Therefore hydrogen fuel cell is a viable energy source for the future in automotive, commercial, residential, portable, and many other electrical power applications. Because a single cell generates about 1 V, most applications require more than a single cell. A fuel cell stack, composed of individual fuel cells wired in series similar to batteries, offers increased power output. Some fuel cell stacks containing thousands of individual cells are capable of generating the high voltages and currents needed for much transportation, commercial and industrial power applications (National Instrument, 2007).

Why Fuel Cell Technology?
Fuel cells are one of the most promising technologies for delivering clean and efficient power for automotive and residential applications. Until recently, fuel cells have largely been restricted to NASA space missions and a few research labs around the world. However, with increased urgency in reducing pollution and greenhouse gas emissions, a resurgence of interest in fuel cells has occurred in the scientific community. Today, governments and many corporations are making massive investments into the development of these clean power sources. Although fuel cells hold great promise for clean, inexpensive power, they are still in their developmental infancy, and a great deal of research is necessary before they are considered as viable power systems (Prabha, 2004).

Test capabilities that deliver reliable monitoring and control, and offer the benefit of a flexible configuration, are critical to these advances. The capabilities will permit scientists to easily tailor their systems to keep pace with evolving fuel-cell technology.

Typical Working Principles

A fuel cell is similar to a battery as it operates on the electrochemical energy conversion principle but there is an important difference; a fuel cell does not store fuel like a battery, but runs on a continuous supply of fuel. This makes it similar to engines, but unlike engines it does not combust the fuel giving out gases, it galvanically burns the fuel and the output is water. The efficiency of a heat engine is limited by the Carnot efficiency (Hoogers, 2003). However, since a fuel cell works on an electrochemical principle, it is not similarly limited and thus can achieve efficiency higher than a heat engine. Thus, a fuel cell achieves the continuous energy transformation from chemical to electrical form with very low pollution and high efficiency making it an excellent choice for power generation (Prabha, 2004).

Applications of Fuel Cells

Fuel cells are very useful as power sources in remote locations, such as spacecrafts, remote weather stations, parks, rural locations, and in certain military applications. A fuel cell system running on hydrogen can be compact, lightweight and has no major moving parts. Because fuel cells have no moving parts, and do not involve combustion, in ideal conditions they can achieve up to 99.99% reliability (Fuel Cell Information Resource, 2007). This equates to less than one minute of down time in a six year period. There area wide ranges of applications which are listed below (Hoogers, 2003).

1. *Stationary power*
    - Power generating stations
    - Auxiliary units
    - Distributed power generation
    - Residential use as combined heat and power (CHP) generation systems
2. *Transportation*
    - Buses, track and cars
    - Airport intra-terminal vehicles
3. *Portable electronics*
    - Laptops
    - Cellular phones

Measurement Challenges

Fuel cell test systems make a variety of measurements that require signal conditioning before the raw signal can be digitized by the data acquisition system. An important feature for the testing of fuel cell stacks is isolation. Each individual cell may generate about 1 V, and a group of cells may reach up to 10 V because in a PEM the membranes are stacked together to yield higher voltages. High-performance stacks have hundreds of cells that result in voltage measurements that require common-mode rejection of several hundred volts. Because of this, the tester must not only have many channels that are capable of reading 1 to 10 V per channel, but also maintain isolation of hundreds of volts between the first and last cell in the stack. Because fuel cell test systems also include channel counts that can range anywhere from 100 to 1000 channels, data acquisition system capable of expansion is a must. These systems also have signals that require attenuation and amplification (National Instrument, 2007). Modularity, ability to change with production and validation is also a must for the test systems. Any test system should have calibration as well to ensure valid and accurate measurements.

Based on the above criteria, it is obvious that simply monitoring the voltage is not sufficient to characterize and control a fuel cell. Monitoring current output is also necessary. Because the current output can be very high, it is usually monitored using the Hall Effect property, where the current flowing is monitored through a wire. This method requires signal conditioning and scaling to convert the data back into a current reading. Another vital parameter for PEM fuel cells is temperature. To produce energy efficiently, PEM fuel cells must operate in the range of 60 to 80 °C (140 to 175 °F). Temperature is monitored to optimize variables such as variation and correlation to increase power output. Thermocouples and resistance temperature detectors (RTDs) are good sensors for monitoring both the stack temperature and the temperature of the incoming reactant gas streams. In our hydrogen fuel cell system, all the parameters that mentioned above are explained, measured using LabView™ PDS v8.20 software and field point based data acquisition modules.

Fuel Cell Power Training

The fuel cell power system has specific power conditioning requirements to generate reliable electricity:

1. *Regulation:* The voltage from all sources of electrical power varies with time, temperature, pressure, and other factors and most importantly load current. Most electrical equipments work with a constant voltage with slight variation. A regulator using switching or chopping circuits is required to maintain a constant DC output voltage.
2. *DC to AC conversion:* This fuel cell outputs low DC voltage. However, for stationary power generation, AC output is preferred. Hence a converter would be required to boost the DC voltage and an inverter to convert DC to AC voltage.
3. *Battery backup:* A fuel cell responds slowly to change in power demand. To meet the load fluctuations, a battery or a similar energy storage device is used. In case of sudden load demand, the DC-DC converter draws the extra power from a battery and during low loads, the battery is recharged.

The DC-DC converter output forms the input to the DC-AC inverter, which produces an AC output voltage of 120/240V at 60/50 Hz. A fuel cell simulator that can emulate the fuel cell under various conditions provides an inexpensive and easy-to-use platform to test the power conditioning devices. Figure 1 is a functional block diagram of the hydrogen fuel cell system. In many applications, the gas streams are at elevated pressures, which must be monitored and managed. Pressure is measured with a pressure transducer and signal conditioning; hydrogen and airflow rates are typically measured with mass flow meters that generate pulses at a rate proportional to the gas flow rate.

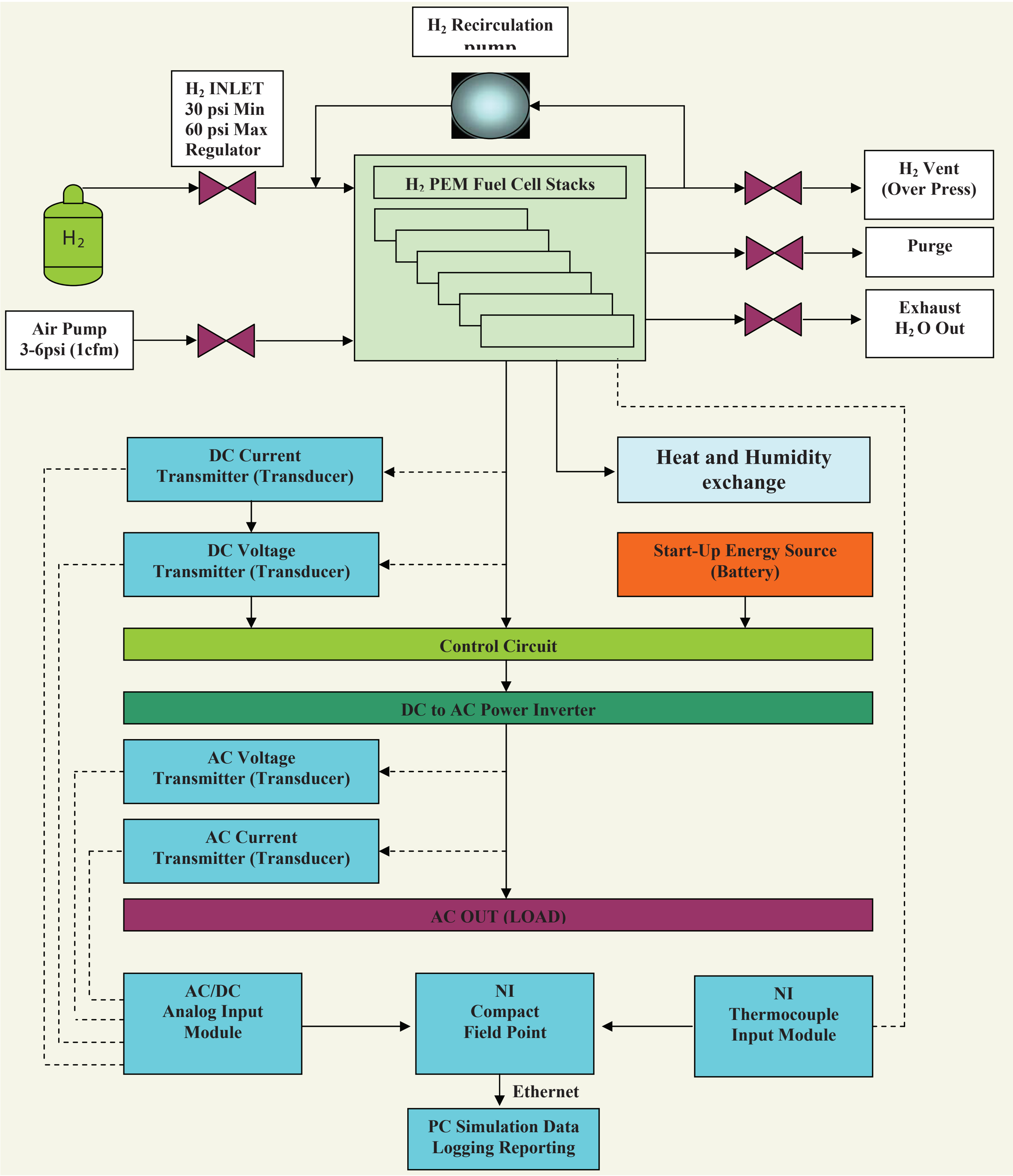

Figure 1: Hydrogen fuel cell system functional block diagram

These pulses are then monitored by a counter/timer board and scaled by software into a flow rate. Electronic regulators can control the pressure and flow via voltage or current outputs that are supplied by the test stand. The hydrogen mass flow rate measurement was not conducted for the system due to the delivery delays of the mass flowmeter sensor module. Therefore there is no hydrogen pressure flow rate data is provided, during the time of this paper presentation the tests will be conducted and results will be reported in the conference presentation.

EPAC-500 Hydrogen Fuel Cell Package

The EPAC-500 Hydrogen fuel cell system is used to conduct hydrogen fuel cell to electricity conversion which is donated by National Instruments. The EPAC-500 is a self-contained, rack-mountable 500-Watt fuel cell power source, designed for outdoor or indoor use and intended initially for industrial customers. The unit can be mounted in a standard 19" equipment rack and has 3 possible outputs - 120VAC at 60 Hz, 48V regulated DC and 48V unregulated DC. The system can be set to act as a stand-alone power source, or to self-start upon electrical grid failure. In its initial form, the unit is designed to run on compressed hydrogen from standard industrial cylinders (Hpower, 2007). The picture of the EPAC-500 Hydrogen fuel cell system with computer connections is shown in Figure 2.

Figure 2: EPAC-500 Hydrogen Fuel Cell

Software Platform for Data Acquisition

The Lab VIEW data logging and supervisory control module from National Instruments meet the needs of fuel cell researchers with its built-in high-channel-count data acquisition, data logging, interface, and security capabilities. Fuel cell test systems may require hundreds of data acquisition sensors and controls for temperature, humidity, atmospheric pressure, oxygen, and other parameters. A typical test may include a parameter such as temperature to a certain point, holding it steady, and graphing the resulting voltage and current across the fuel cell. The LabVIEW™ data logging and supervisory control module includes an extensive historical database in which all measurement and test data acquired can be saved for later review and the user can load in test data and perform interactive offline analysis and report generation. The figure 3 for interface of the NI LabVIEW™ with no load and figure 4 for the field point NI Measurement and Automation Explore software to collect readings from channels are depicted. The functions of parameters and readings from both softwares are explained. As it is shown in figure 2, Hydrogen fuel cell system draws about 23W DC power from the fuel cell stacks at no load condition. This power is needed by air filter motor, control circuit and inverter to keep the fuel cell system ready for the load condition and sudden load changes.

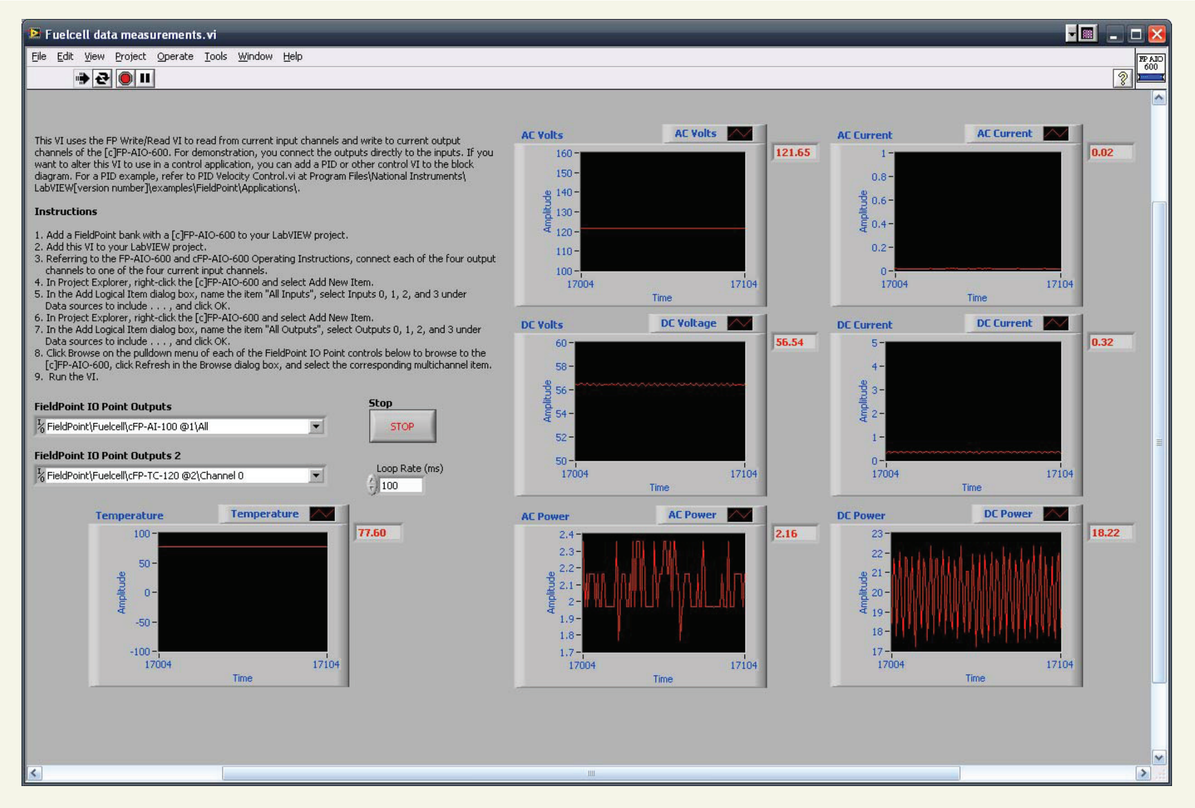

Figure 3: Screen shot of NI LabView™ interface with no load

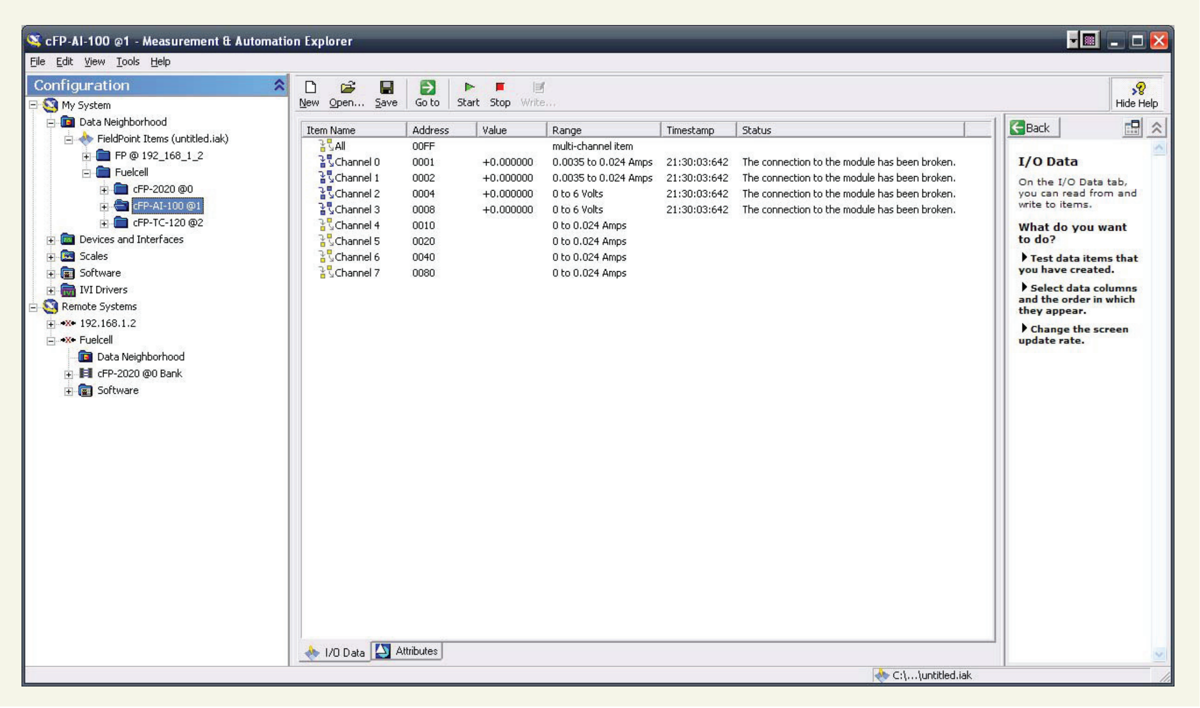

Figure 4: Screen shot of NI measurement & automation software

Hydrogen Fuel Cell Experiment as an Educational Tool

This experiment investigates the conversion of potential energy, stored chemically as hydrogen and oxygen gas, to electrical energy using PEM fuel cell with the EPAC-500W system. A PEM fuel cell produces electricity by reacting hydrogen and oxygen gas together to form water, i.e., $2H_{2(G)} + O_{2(G)} \rightarrow 2H_2O_{(L)}$ In this type of fuel cell, hydrogen is split into protons at the anode, which in practice is a thin layer of catalyst on the surface of a polymer membrane. These hydrogen ions travel across the membrane to the cathode (which is similar to the anode layer) where they combine with oxygen, and electrons that have traveled to the cathode from the anode via an external electrical "load" circuit. In order to function properly, the membrane must be a special material capable of conducting hydrogen ions (protons) but not water molecules or electrons as this would "short circuit" the fuel cell. The developed experiment investigates the relationship between voltage, current and power output for a PEM fuel cell, the effect that an electrical load (resistance) has on the average fuel cell voltage, current, power and hydrogen consumption rate, and the energy efficiency of the fuel cell. A thermocouple was embedded in the fuel cell to monitor temperature as the reaction took place (Bean et al., 2006).

In this experiment National Instruments computer-based measurement products are used for data acquisition and data logging purposes. The reason for using NI is, this company is a leader on computer-based measurement and many leading fuel cell manufacturers are using NI hardware and software tools for testing fuel cells in all phases of development. These test tools have been essential in the production and testing of many types of fuel cells including proton exchange membrane, phosphoric acid and solid oxide fuel cells.

NI LabVIEW™ Interface

Since the system output is an AC output voltage of 120V at 60 Hz, AC system efficiency will be measured and conducted. The loads are incandescent and compact florescent light bulbs, AC/DC electric motor or blender, and electrical heaters controlled by switches. These switches allow us to add or reduce the load of the system. Thus, the efficiency of the system and hydrogen flow rate from the gas tank is measured with load changes. These changes will be stored in a data file to be compared for the future work and suggestions. All necessary simulations and calculations are done with NI LabVIEW™ and Measurement Automation Explorer software. The NI data acquisition modules is placed between computer and fuel cell system to convert analog input to digital output for the field point measurement. This software recognizes channels of the data acquisition models such as voltage, current, temperature, and mass gas flow. The LabView™ field point block diagram interface is shown in figure 5. In this programming interface all the necessary calculations and algorithms are done for signal conditioning. All calculations are done on the block diagram to make reliable data output for the data files.

This Virtual Instrument (VI) uses the FP Write/Read VI to read from current input channels and write to current output channels of the module. For the actual connection, we connect the outputs directly to the inputs. If want to alter this VI to use in a control application, it can added a PID or other control VI to the block diagram.
The following steps describe the data acquisition process:

1. Add a FieldPoint bank with a [c] FP-AI-100 to LabVIEW™ project.
2. Add this VI to LabVIEW project.
3. Referring to the [c] FP-AI-100 Operating Instructions, connect each of the four output channels to one of the four current input channels.
4. In Project Explorer, right-click the [c] FP-AI-100 and select Add New Item.
5. In the Add Logical Item dialog box, name the item "All Inputs", select Inputs 0, 1, 2, and 3 under Data sources to include …, and click OK.
6. In Project Explorer, right-click the [c] FP-AI-100 and select Add New Item.
7. In the Add Logical Item dialog box, name the item "All Outputs", select Outputs 0, 1, 2, and 3 under data sources to include . . ., and click OK.
8. Click Browse on the pull down menu of each of the Field Point IO Point controls below to browse to the [c] FP-AI-100, click Refresh in the Browse dialog box, and select the corresponding multi channel item.
9. Run the VI.

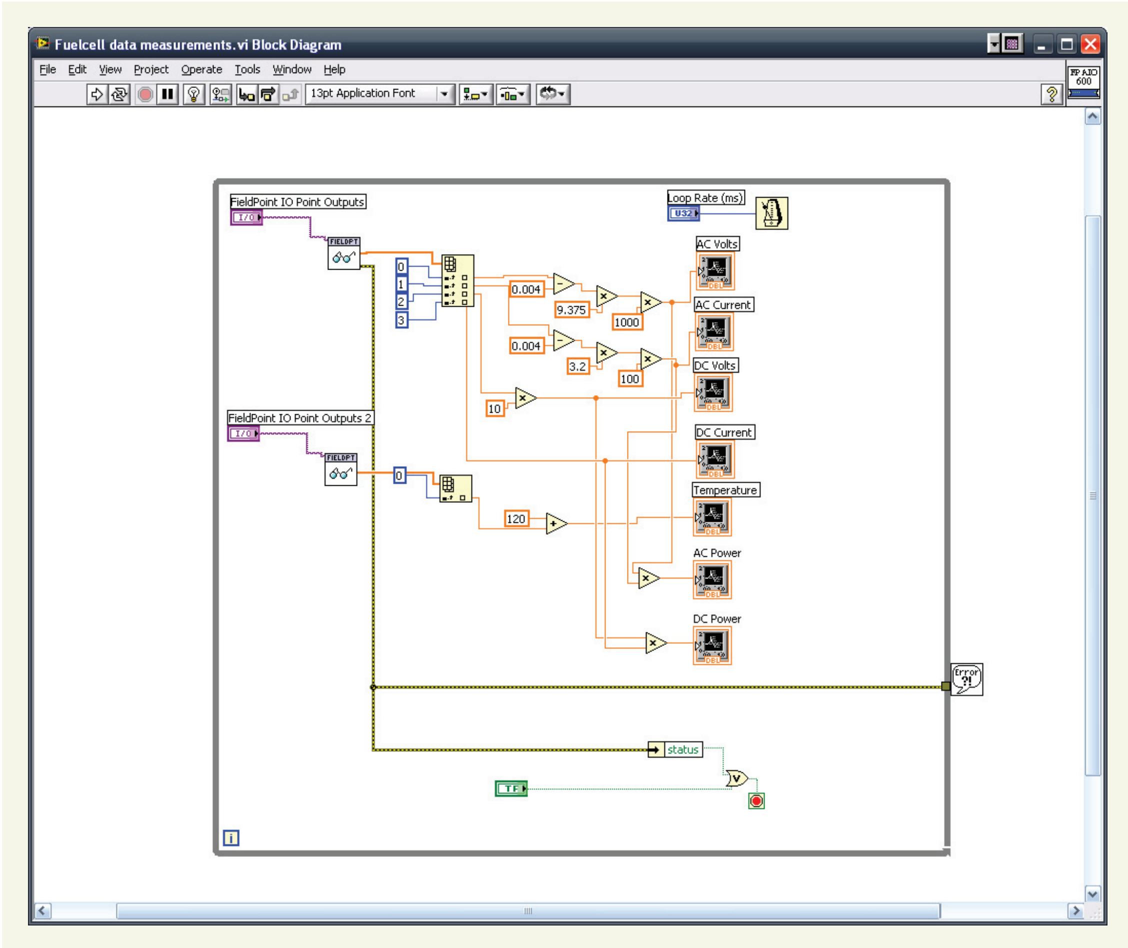

Figure 5: Lab VIEW data acquisition block diagram

Field Point Distributed Data Acquisition

National Instruments Field Point distributed I/O products are frequently used for fuel cell testing. Our system is consisted of NI Field Point tools include capabilities that improve the reliability and maintainability of the system. Since we deal very sensitive system and need accurate measurements NI local intelligence is very valuable for a fuel cell test platform because it provides onboard diagnostics and easy maintenance to maximize system uptime (National Instrument, 2007). The module names and their types are indicated in table 2 for the reference to similar applications.

Measurement	Channel Type	Signal Conditioning	Field Point Modules
Voltage	Analog Input	Isolation, Attenuation	cFP-AI-100
Current	Analog Input	Scaling, Attenuation	cFP-AI-100
Temperature	Analog Input	Scaling, Amplification	cFP-TC-120
Compact Field Point	Analog Input	Digital Output	cFP-2020

Table II. Field Point-Based Test Platforms

Case Studies for Efficiency Analysis of Sudden Load Changes

This case study includes inputs of sudden load changes considering a number of incandescent/florescent light bulbs, AC/DC electric motor/blender, and electrical heaters controlled by switches. These switches allow us to add or reduce the load of the system. Since the system output is AC output voltage of 120V at 60 Hz, AC system efficiency was measured and conducted. The loads increased and reduced with switches from 0W to 250W to compare the efficiency. By this way the efficiency of the system and hydrogen flow rate from the gas tank is measured with load changes. These changes were stored in data files to be compared for the future work and suggestions. The values derived from the tests results are arranged in Table III for the reference.

Table III. Case Study with different load changes

	No load	50W load	100W load	150W load	200W load
DC Voltage Level [V]	56.54	53.61	52.21	50.18	50.62
DC Current Level [A]	0.32	1.37	2.44	2.57	4.68
AC Voltage Level [V]	121.65	121.7	121.84	121.7	121.94
AC Current Level [A]	0.02	0.44	0.87	1.27	1.71
System Temperature [F]	77.6	92.06	100.35	112.46	121.87
D.C. Power [W]	18.22	73.37	127.36	179.1	236.69
A.C. Power [W]	2.16	53.24	105.42	154.04	208.05
Losses	16.06	20.13	21.94	25.08	28.64
System efficiency [%]	TBA	TBA	TBA	TBA	TBA

Conclusion and Recommendations

This system allows students to study the hydrogen energy from its primary source (hydrogen gas is converted to electrical energy via a fuel cell), to a storage medium (hydrogen gas via water electrolysis), to electrical generation (via a hydrogen-based PEM fuel cell), to a variety of practical user "loads," so that can characterize the efficiency of the overall process. Ultimately, graduate students are asked to consider how the hydrogen energy systems studied could be applied to develop real-world products that better serve the needs of humanity. As in the prior laboratory experiments, LabVIEW™ is used as a virtual instruments to acquire experimental data to perform the data analysis and visualization necessary to document their experimental results and justifying their product design concepts based on the observed experimental data in a written report.

The laboratory experiments were performed by teams of, typically, 2 graduate students and an advisor. It was required to run the experiment, to submit a written report. Graduate students were required to evaluate their own, as well as their fellow students', performance. A fuel cells laboratory experiment described in this paper. Students are gaining experience using computerized data acquisition systems, LabView™ virtual instrument experimental control and data acquisition and data analysis and processing using Field Point measurement software.

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Techniques of Harvesting Ambient Energy Sources & Energy Scavenging Experiments, Design and Implement an Energy Harvesting Device

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Introduction

Today, sustaining the power requirement for autonomous wireless sensor networks is an important issue. In the past, energy storage has improved significantly. However, this progress has not been able to keep up with the development of microprocessors, memory storage, and sensor applications. In wireless sensor networks, battery-powered sensors and modules are expected to last for a long period of time. However, conducting battery maintenance for a large-scale network consisting of hundreds or even thousands of sensor nodes may be difficult, if not impossible. Ambient power sources, as replacement of batteries, come into consideration, to minimize the maintenance. Power scavenging may enable wireless sensor nodes to be completely self-sustaining so that battery maintenance can be eventually freed. Researchers have performed wide spread studies in alternative energy sources that could provide small amount of electricity to low-power devices. Energy harvesting can be obtained from different energy sources, such as vibration, light, acoustic, airflow, heat, and temperature variations. Figure 1 depicts a general functional block diagram of the energy-harvesting system from different ambient energy sources.

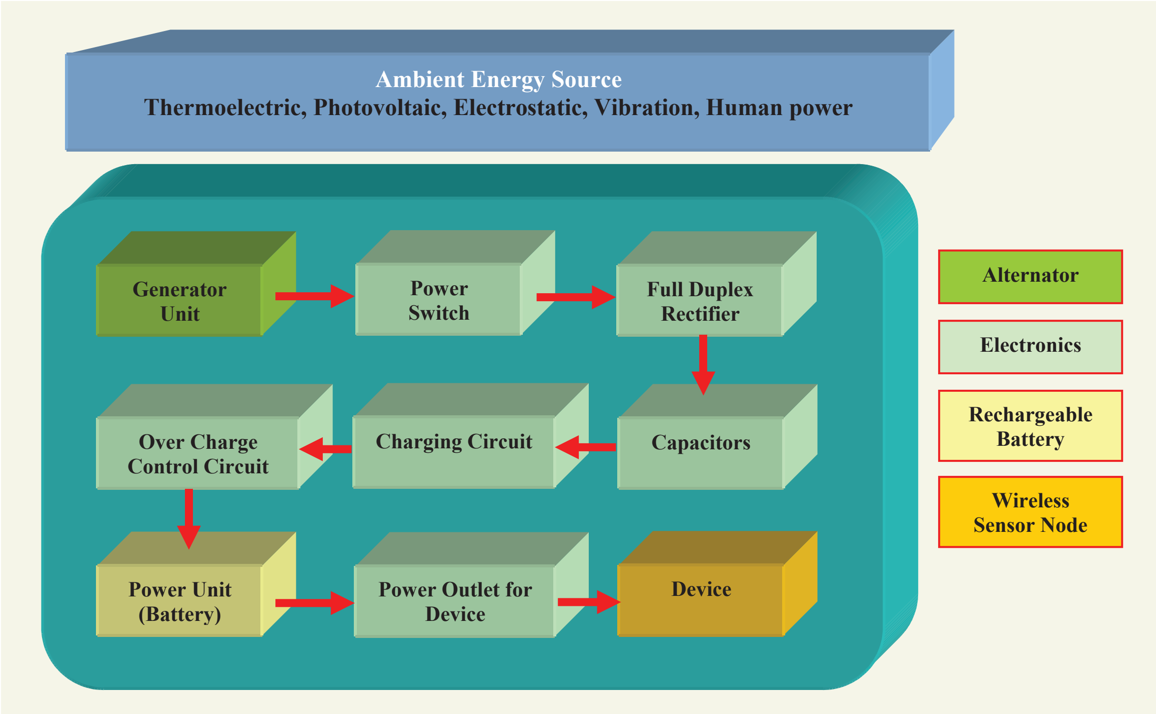

Figure 1: Energy harvesting system representation diagram

When compared with the energy stored in common storage elements, such as batteries and the environment may represent a relatively infinite source of energy. Consequently, energy harvesting (scavenging) methods must be characterized by their power density, rather than the energy density. Table 1 compares the estimated power and challenges of various ambient energy sources (Yildiz, Zhu, Guo, & Pecen, 2007). Light, for instance, can be a significant source of energy, but it is highly dependant on the application and the experience to which the device is subjected. Thermal energy, in contrast, is limited because the temperature differences across a chip are typically low. Vibration energy is a moderate source, but again dependent on the particular applications (Torres & Petty, 2005).

Table 1: Comparison of Power Density of Energy Harvesting Methods

Energy Source	Power Density & Performance	Source of Information
Acoustic Noise	0.003 μW/cm³ @ 75Db 0.96 μW/cm³ @ 100Db	(Rabaey et al., 2000)
Temperature Variation	10 μW/cm³	(Roundy et al., 2004)
Ambient Radio Frequency	1 μW/cm²	(Yeatman, 2004)
Ambient Light	100 mW/cm² (direct sun) 100 μW/cm² (illuminated office)	Available
Thermoelectric	60 μW/cm²	(Stevens, 1999)
Vibration (using micro generator)	4 μW/cm³ (human motion—Hz) 800 μW/cm³ (machines—kHz)	(Mitcheson et al., 2004)
Vibrations (Piezoelectric)	200 μW/cm³	(Roundy et al., 2002)
Airflow	1 μW/cm²	(Holmes et al., 2004)
Push buttons	50 μJ/N	(Paradiso, Feldmeier, 2001)
Shoe Inserts	330 μW/cm²	(Stamer, 1996) (Shenck, Paradise, 2001)
Hand generators	30 W/kg	(Starner, Paradiso, 2004)
Heel strike	7 W/cm²	(Yaglioglu, 2002) (Shenck, Paradiso, 2001)

In the following sections, literature review of various energy harvesting methods, battery, and ultra capacitor technologies are presented. In the review of literature, different scientific papers are investigated and listed in table 1 according to their power densities. Besides, an implementation of the energy scavenging unit design is conducted and explained as a real life example. This research design is conducted incorporating various disciplines such as mechanical, electrical, and computer engineering. For the purpose of the experimental implementation, a hydraulic door closer is chosen as an ambient energy source. Briefly, the waste mechanical energy from hydraulic door closer occurred when door is opened and closed. By this way waste mechanical will be converted to electrical energy.

Ambient Energy Sources

A broad review of literature of potential energy scavenging methods has been carried out. The results of this literature review are followed by sub topics.

Vibration Energy

Not all working environments have consistent, constant light. For example, machinery-monitoring sensors may not have reliable light but have overflowing vibration energy. Vibration energy harvesters can be either electromechanical or piezoelectric; electromechanical harvesters are more common. Energy extraction from vibrations is based on the movement of a spring mounted mass relative to its support frame (Roundy, Wright, Rabaey, 2003). Mechanical speeding up is produced by vibrations that in turn cause the mass component to move and oscillate causing the damping force that can be converted into electrical energy via an electric field (electrostatic), magnetic field (electromagnetic), or strain on a piezoelectric material. These energy-conversion schemes form harvesting energy from vibrations.

1. Electromagnetic energy harvesting
This technique uses a magnetic field to convert mechanical energy to electrical (Amirtharajah, Chandrakasan, 1998, Kulah, Najafi, 2004). A coil attached to the oscillating mass passed through a magnetic field that is established by a stationary magnet. The coil travels through a varying amount of magnetic flux, inducing a voltage according to Faraday's law. The induced voltage is inherently small and must therefore be increased to viably source energy. Techniques to increase the induced voltage include using a transformer, increasing the number of turns of the coil, and increasing the permanent magnetic field (Torres, Rincon-Mora, 2005). However, each is limited by the size constraints of microchip as well material properties.

2. Piezoelectric energy harvesting
This method similarly alters mechanical energy to electrical by straining a piezoelectric material (Roundy, Wright, 2004, Sodano, Inman, Park, 2004). Strain, or deformation, in a piezoelectric material causes charge separation across the device, producing an electric field and consequently a voltage drop proportional to the stress applied. The oscillating system is typically a cantilever beam structure with a mass at the unattached end of the lever, since it provides higher strain for a given input force (Roundy, Wright, 2004). The voltage produced varies with time and strain, effectively producing an irregular ac signal. Piezoelectric energy conversion produces relatively higher voltage and power density levels than the electromagnetic system.

3. Electrostatic (capacitive) energy harvesting
This method depends on the variable capacitance of vibration dependant varactors (Meninger et al., 2001, Roundy et al., 2002). A varactor, or variable capacitor, is initially charged and, as its plates separate because of vibrations, mechanical energy is transformed into electrical energy. The most striking feature of this method is its IC-compatible nature, given that MEMS variable capacitors are fabricated through relatively mature silicon micro machining techniques. This scheme produces higher and more practical output voltage levels than the electromagnetic method, with moderate power density.

Thermal (Thermoelectric) Energy
Thermal gradients in the environment are directly converted to electrical energy through the Seebeck (thermoelectric) effect (Disalvo, 1999, Rowe, 1999). Temperature changes between opposite segments of a conducting material result in heat flow and consequently charge flow since mobile, high-energy carriers diffuse from high to low concentration regions. Thermopiles consisting of n- and p-type materials electrically joined at the high-temperature junction are therefore constructed, allowing heat flow to carry the dominant charge carriers of each material to the low temperature end, establishing in the process a voltage difference across the base electrodes. The generated voltage and power is relative to the temperature differential and the Seebeck coefficient of the thermoelectric materials. Big thermal gradients are essential to produce practical voltage and power levels. However, temperature differences greater than 10°C are rare in a micro-system, consequently generates low voltage and power levels. Moreover, naturally occurring temperature variations can also provide a means by which energy can be scavenged from the environment with high temperature. Stordeur, Stark, (1997) have demonstrated a thermoelectric micro-device capable of converting 15 μW/cm3 from a 10 °C temperature gradient. While this is promising and, with the improvement of thermoelectrics, could eventually results in more than 15 μW/cm3, situations in which there is a static 10 °C temperature difference within 1 cm3 are very rare.

Light Energy (Solar Energy)
Photovoltaic (PV) cells convert photons from sunlight into electrical energy. Each cell consists of a reverse biased pn+-junction, where light interfaces with the heavily doped and narrow n+-region. Photons are absorbed within the depletion region, generating electron-hole pairs. The built-in electric field of the junction immediately separates each pair, accumulating electrons and holes in the n+- and p-regions, respectively, and establishing in the process an open circuit voltage. With a load connected, accumulated electrons travel through the load and recombine with holes at the p-side, generating a photocurrent that is directly proportional to light intensity and independent of cell voltage. Research demonstrates that photovoltaic cells can generate sufficient power to maintain a micro-system, although at lower power efficiencies than their macro-scale counterparts. A three dimensional diode structure constructed on absorbent silicon helps increase efficiency by significantly increasing the exposed internal surface area of the device (Sun, Kherani, 2005). Overall, photovoltaic energy conversion is a mature IC-compatible technology that offers higher power output levels, when compared with the other energy-harvesting mechanisms. Nevertheless, its power output is strongly dependent on environmental conditions, in other words, varying light intensity.

Acoustic Noise
There is far too small power available from acoustic noise to be of use in the scenario being investigated, except for very rare environments with extremely high noise levels.

Human Power

A large amount of work has been done on the option of scavenging power off the human body for use by wearable electronic devices. The conclusion of studies undertaken at MIT suggests that the most energy rich and most easily exploitable source occurs at the foot during heel strike and in the bending of the ball of the foot. Furthermore, the problem of how to get the energy from a person's foot to other places on the body has not been suitably solved. For an RFID tag or other wireless device worn on the shoe, the piezoelectric shoe inserts offer a good solution. However, the application space for such devices is extremely limited, and as mentioned, not very applicable to some of the low powered devices such as wireless sensor networks. Active human power which require the user to perform a specific power generating motion, are common and may be referred to separately as active human powered systems (Roundy, 2003). Examples include standard flashlights that are powered by squeezing a lever and the free play wind-up radios.

Battery Technologies

The energy necessity for today's portable devices and small scale wireless devices is mostly provided by batteries. As technology scales down, this small proportion is expected to further increase. Also very important is the necessity for proper maintenance of batteries, with the need to either change or recharge them. This is a serious constraint to computing examples like ubiquitous computing or wireless sensor networks, in which there are sometimes dozens or hundreds of small systems with batteries to maintain. Of course, these problems do not hide the benefits of batteries as an energy source. For instance, batteries can be categorized by their energy density, with respect to volume and weight, called volumetric and gravimetric energy density correspondingly. Table 2 shows some typical values of energy densities and self discharge values for commercially available batteries. It is significant noting that these values of energy density are the best options available today. But it differs from application to application or from the system to system.

Table 2: Characteristics of batteries

Battery type	Operating voltage	Vol. energy density Wh/dm^3	Grav. energy density Wh/kg	Self discharge % month	Cycle life number	Charging	Typical cost
Ni-Cd	1.2V	100	30-35	15-20%	300	Simple	1.67
Ni-MH	1.2V	175	50	20%	300	Simple	2.50
Li-ion	3.7V	200	90	5-10%	500	Complex	6.90

Secondary rechargeable batteries are in standard a better choice for ubiquitous or wearable systems because they can be recharged in several ways, in many cases without extracting the battery from the system. Actually, one of the possibilities we deal in this paper to recharge such batteries is to use energy harvested from the environment. In this sense, energy harvesting is not trying to replace batteries, but instead improving some of their disadvantages, especially in relation with the maintenance issues (Ganesan, 2006).

Ultra capacitors

Latest progresses in capacitor technology have led to the development of the ultra (super) capacitors, with a capacitance value of the order of kF. Such remarkably large capacitors, however, present an energy density around 3 Wh/kg, still very away from average battery values. The major advantages of ultra capacitors are the supplied peak power, and the number of cycles. These characteristics make them more oriented to especially automotive applications than to low power electronic devices, where batteries are still the alternative for energy storage.

The capacitors accumulate energy as electrical field by polarizing an electrolytic solution instead of creating it from chemical reactions as in most of the batteries. There are no chemical reactions involved in its energy storage mechanism. This approach is more efficient, and might soon be more economical.

The use of ultra capacitor allows high-speed capacity of charge and discharge (Halber, 2006). Ultra capacitors are half-way between rechargeable batteries and standard capacitors. In fact they can provide extensively high power densities than batteries and standard capacitors. They preserve some favorable characteristics of capacitors, such as long life and short charging time, and their energy density is about 1 order of magnitude higher than standard capacitors (Chapuis, 2006). Moreover, the ultra capacitors are well adjusted to high number of charge and discharge cycles, and are a means of solving durability problems of traditional batteries. Because of their increased lifetimes, short charging times, and high power densities, ultra capacitors could be very attractive as a secondary power supply in place of rechargeable batteries in some wireless sensor node applications.

Hydraulic Door Closer Experiment as an Ambient Energy Source

This section of the paper initiates an energy scavenging technique for low power wireless sensor node and devices with a focus on conversion of mechanical rotation to electrical energy. For this purpose, a hydraulic door closer that is rotated by human power as a potential energy supply is considered. The two stages of hydraulic door closer system operations are: the first phase is the opening phase that is generally activated by human power; the second one is the closing phase that is controlled by a spring and a hydraulic damping mechanism. The waste mechanical energy from hydraulic door closer can be converted into electrical energy using appropriate devices such as generator unit and electrical circuit; to provide energy to low power sensor nodes and similar devices.

In the first stage of the implementation, an appropriate gear set is placed on door closer to increase the speed of the rotation so that it will be possible to provide enough rotation speed for the generator unit. Then a power switching circuit has been designed to manage energy conversion to charge a rechargeable battery. The rechargeable battery will serve as an energy source for the low power device.

Speed Increase Gear Sets

The aim of the gear set in this implementation is to increase the speed of waste rotation from the hydraulic door closer to transfer sufficient speed to a DC motor. This step up for speed is required because, without the increase of speed, the rotation rate from hydraulic door closer will not be sufficient for DC motor as a generator unit. Gear ratios and the number of gear sets are determined by considering the average rotating speed of the door and the rotation required by the generator.

Design of the Circuit

To obtain the consistent power output from the circuit; initially three main issues need to be considered. The generator's output power, the voltage regulation circuit, and the rechargeable battery type. Especially, the design of the circuit should be considered very carefully to increase the system efficiency and reduce power losses.

The circuit board is designed and simulated using SwitcherCAD™ III high performance spice III simulator from linear technology. This program has a big library for the components useful for our needs. The circuit design for our system purpose is detailed below in figure 3 drawn using SwitcherCAD™ III. The circuit board is comprised of a full wave bridge rectifier. After full-wave rectification occurs, the voltage is increased by a DC to DC boost converter. A capacitor (represented by r on the figure 3) is placed between rectifier circuit and DC to DC boost converter circuit as a temporary storage. This capacitor is also allow us to measure voltage, and current after rectification.

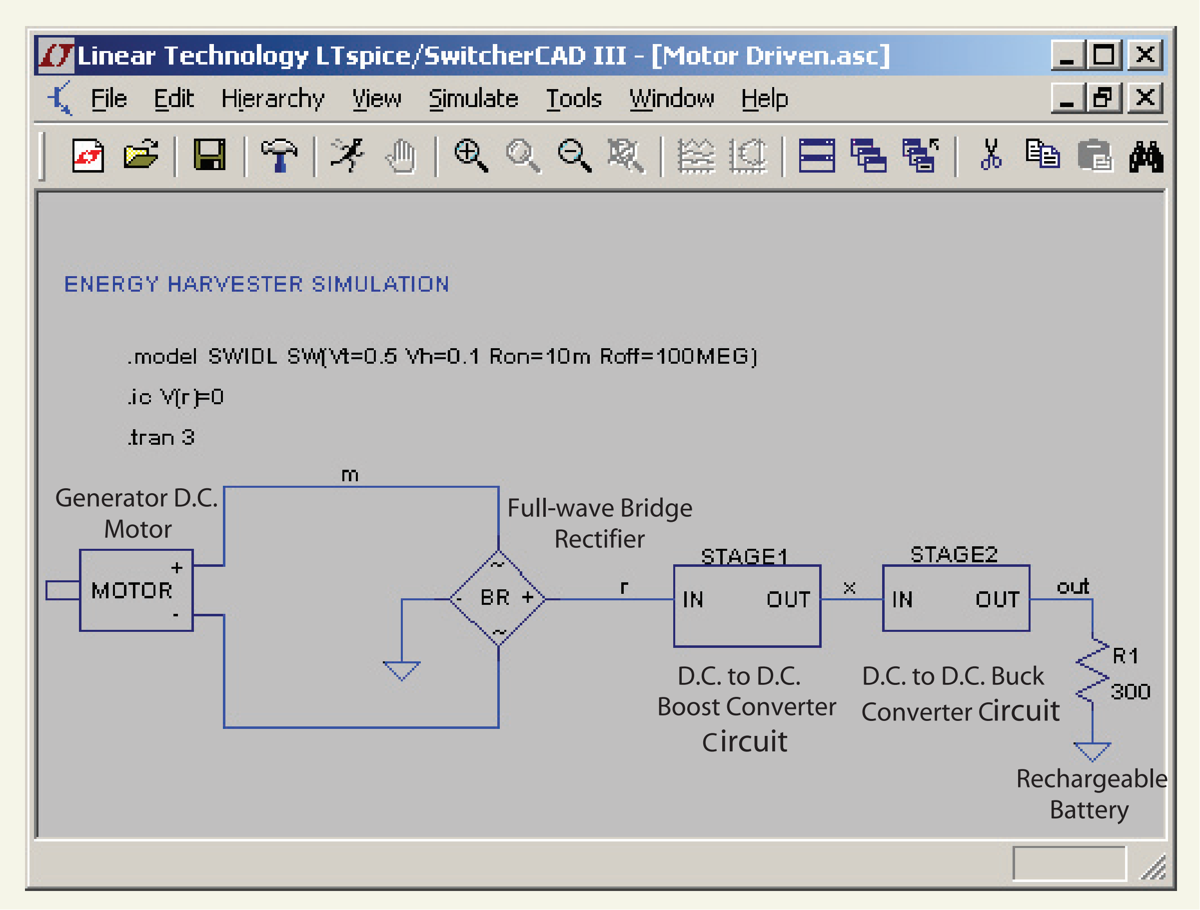

Figure 3: Energy harvester circuit for design and simulation

As a temporary storage device another capacitor is (represented by x on the figure 3) placed to measure gained power after boost converter circuit. Since input voltage is not constant and low, the boost converter is chosen considering this important and challenging point. Consideration of this issue made us decide to select LTC3429 regulator circuit which only needs 0.8V input voltage to start execute its components. In the simulation interface, the values for the circuit components are not indicated. Since the DC motor in this experiment generates electricity up to 4.5V, DC voltage which is V1 was configured to vary from 0V to 5V in the simulation interface. The frequency is required for the circuit trigger is defined as 500Hz. SwitcherCAD™ III software is used to simulate each of the elements on the circuit. By this way, it is possible to confirm voltage or current level any where on the circuit during simulation. The simulation results, including, I_{V1} (input current and duty cycle at V1), I_{Rout} (output current for the load), V_{out} (voltage level after boost converter), are shown in figures 3, 4, and 5 respectively. Figure 3 shows input current from generator unit source before rectification. Figure 4 depicts output current for the load or rechargeable battery. Figure 5 illustrates the output voltage after boost converter which is around 3.6V. Output current and voltages, I_{Rout} and V_{out} are sufficient to recharge a small scale rechargeable battery based on the simulation results.

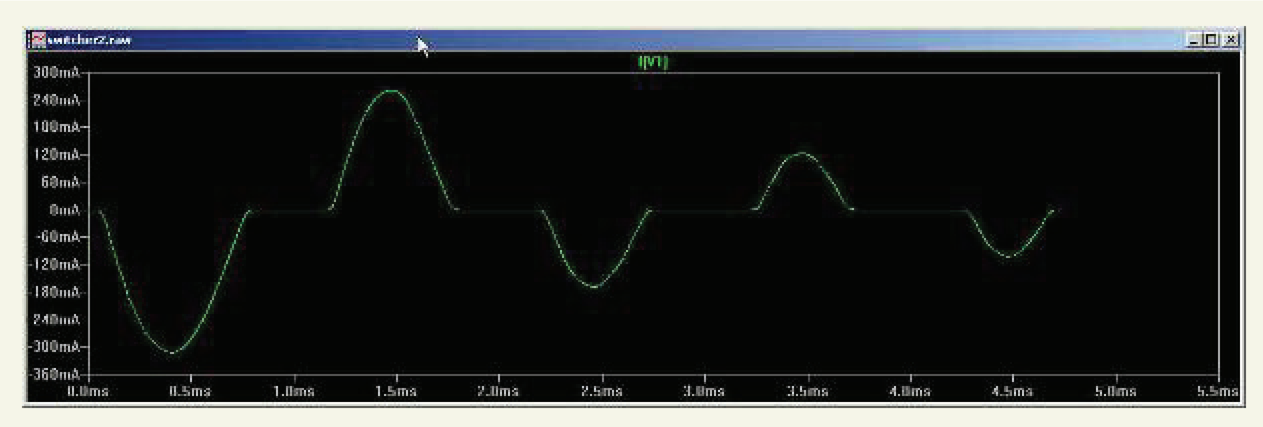

Figure 3: Current I_{V1} derived from generator unit

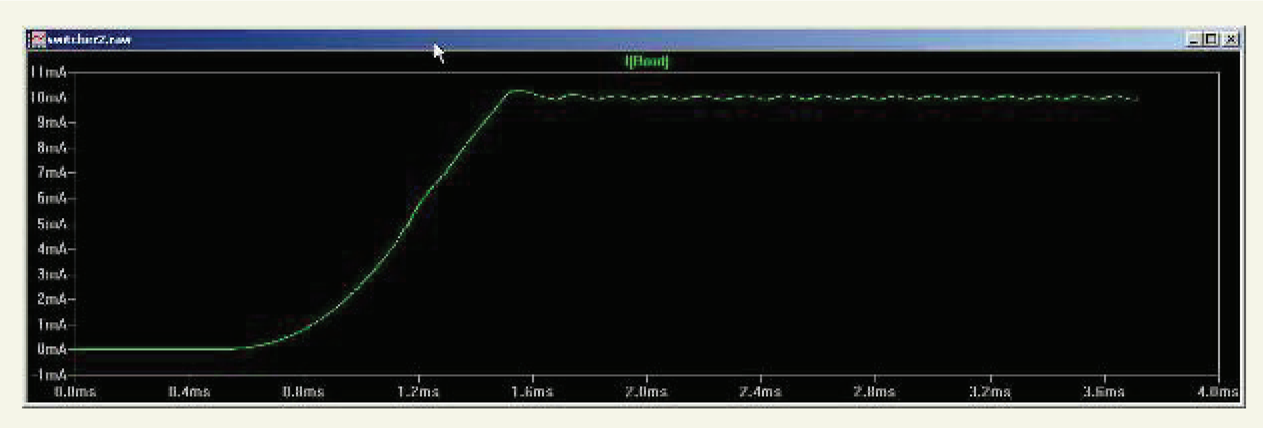

Figure 4: Output current I_{Rout} to the load after DC to DC step up conversion for the load

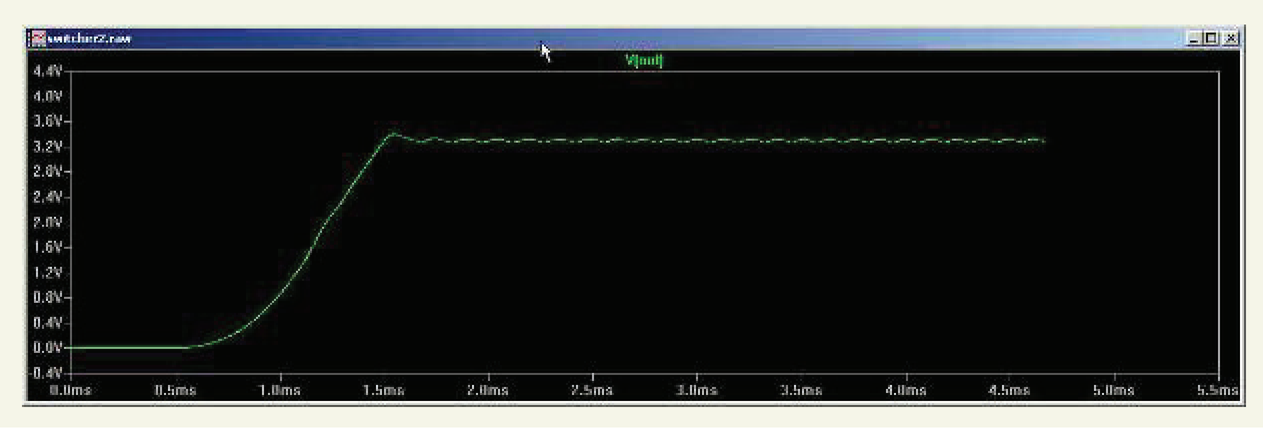

Figure 5: Output voltage V_{out} after DC to DC step up conversion for the load

Experimental Results and Discussions

A picture of the overall experimental system is depicted in figure 6. The actual system is tested using the oscilloscope and digital multimeters. Initially, the output of the gear set is measured in order to test if a maximum 1:400 ratio is occurred. The gear ratio can vary with a change in gear members. The ratio is crucial since DC motor input requires certain spins to generate electricity. The system is tested on the table other than on the door. Gear sets used in this test system are plastic gears. Steel gears were initially ordered but not received on time because of the custom made issues. Since plastic gears are very prone to break anytime hydraulic door closer handle is moved back and fourth very carefully. The connection between gears set's shaft and the door closer's shaft are connected together using custom made special bolts manufactured in our production laboratory. Then hydraulic door closer's handle is moved by hand pretending opening the door. Then the handle is released carefully pretending closing the door without human power. This energy harvesting system may work for busy locations where intensity of people exists such as university campuses, shopping centers, business buildings etc. Once energy generated and stored in the rechargeable, battery then the energy can be used for low power devices such as exit signs around door, theft alarm system, wireless security camera applications, wireless sensor networks, etc. As a future project the system will be tested with steel gear sets mounted on the door mechanism to collect real life data. The experimental results for the tests are given in table 3. In this experiment, the hydraulic door closer handle is moved by hand without any stop for 90 degree. But in real life, the rotation can be stopped at any time due to the human interactions. The gear ratios were sufficient to generate at least 3 volts for generator unit. The results shown in table 3 are average values and can vary around small ranges (+/-0.4V) depending on the door opening/closing speed. But, this does not affect the system operations since capacitors are placed as intermediate storage units. The overall system efficiency may be increased by modifying the elements of the circuit.

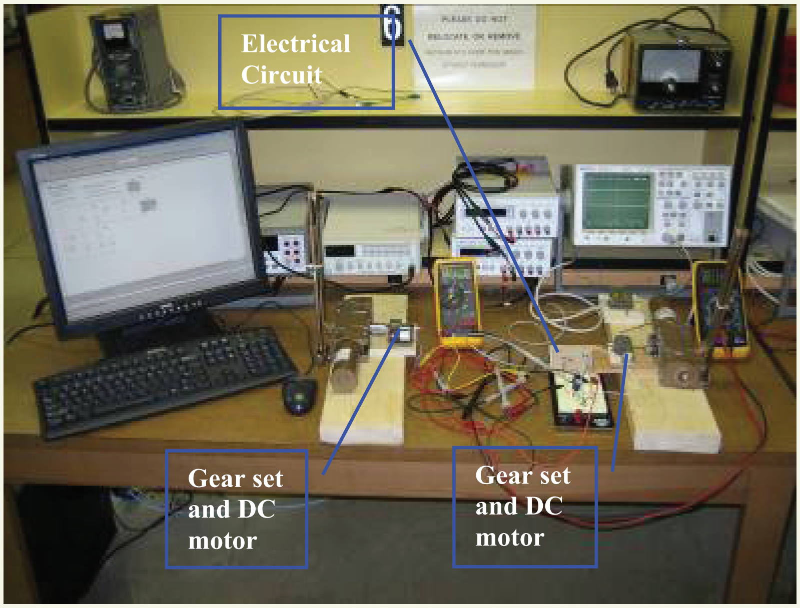

Figure 6: The picture of system in our electrical laboratory during tests

Gear set and DC motor Gear set and DC motor Electrical Circuit Figure 6:The picture of system in our electrical laboratory during tests Battery Type	Nom. Voltage	Nom. Capac. (mAh)	Battery Charge		Battery Initial (V)	Tested Gear Ratios	Torque of type DC Motor	Output Current for the load (I_{Rout})	Output voltage for the load (V_{out})	10 Times	20 Times	30 Times	40 Times	Final V level
			Current (mA)	Time (h)										
NICD	1.2V	110	11	13	0.879	1:344 rpm	FA-130 (1.5-3V)	14mA	1.4V	1.088	1.153	1.179	1.193	1.2 V
NIMH	1.2V	80	8	11	1.031	1:344 rpm	FA-130 (1.5-3V)	14mA	1.4V	1.113	1.148	1.184	1.2	1.2 V
NICD	3.6V	60	6	10	1.791	1:344 rpm	FA-130 (1.5-3V)	15mA	3.8V	1.896	2.775	3.226	3.586	3.6 V
NICD	1.2V	110	11	13	0.651	1:400 rpm	RC- 260 (3-4.5V)	14mA	1.4V	.986	1.110	1.171	1.2	1.2V
NIMH	1.2V	80	8	11	.956	1:400 rpm	RC- 260 (3-4.5V)	14mA	1.4V	1.057	1.114	1.155	1.94	1.2V
NICD	3.6V	60	6	10	1.487	1:400 rpm	RC- 260 (3-4.5V)	15mA	3.8V	1.698	2.454	3.121	3.893	3.6V

Table 3: Test results with different gear ratios and DC motors

- *Battery type*: Types of the rechargeable batteries are used for this experiment.
- *Nominal voltage*: The output (nominal) voltage of the rechargeable battery at full load.
- *Nominal capacity*: The output (nominal) capacity of the rechargeable battery when fully charged.
- *Battery initial voltage*: The rechargeable batteries are discharged using some resistors until some points to make tests.
- *Tested gear ratios*: There were 4 types of gear sets for the test purposes with different gear ratios. The gear sets with 1:344rpm and 1:400 is used for the test.
- *Torque of type DC motor (Generator unit)*: Type of DC motor as a generator unit. These motors came with the gearsets and assembled *Output current for the load*: The output current is occurred after switching circuit to charge the rechargeable battery. It varies according to the speed of gearset.
- *Output voltage for the load*: Load here is the rechargeable battery and this load occurs after boost and buck converters. The output voltage can be changed according to the load capacity.
- *The number of times a door is closed or opened:* 10, 20, 30, 40 times are tested using the gearset.

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Graphics

An Innovative Approach Used to Update a Multi-Discipline Engineering Design Graphics Foundation Course Based on Industrial and Academic Needs

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Abstract:

Engineering design graphics courses taught in colleges or universities should provide and equip students preparing for employment with the basic occupational graphics skill competences required by engineering and technology disciplines. Academic institutions should introduce and include topics that cover the newer and more efficient graphics techniques and technologies developed through research by academicians and professional organizations as well as information obtained from experienced engineering design graphics practitioners. This paper presents the systematic approach used at the University of Nebraska at Kearney (UNK), Department of Industrial Technology (ITEC), to update and improve its existing multidiscipline engineering design graphics foundation course.

Twenty engineering design graphics course syllabi, all from programs accredited by either the National Association of Industrial Technology (NAIT) or the Accreditation Board for Engineering and Technology (ABET), were reviewed in this study. A review of the course syllabi identified the 20 most commonly taught engineering design graphics topics. The 20 topics were used to develop a survey instrument subsequently sent to the top 10 employers of ITEC students majoring in Construction Management, Industrial Distribution, and Telecommunications Management. The results obtained from the employer survey were analyzed and used to update the engineering design graphics foundation course at UNK so that engineering design graphics topics taught are kept current and relevant to the needs of industry.

Introduction:

There have been many important developments in the field of engineering design graphics. One of the most significant has been the unprecedented shift from manual drafting to computer-aided design and drafting (CADD) techniques and technology practices by industry over the past three decades. The purpose of this study was to ensure that the current engineering design graphics foundation course being taught at the University of Nebraska at Kearney (UNK), within the Department of Industrial Technology (ITEC), continues to meet the requirements and practices of industry.

Employers of ITEC graduates expect a certain level of engineering design graphics proficiency from new employees and expect educational institutions to adequately prepare students with basic knowledge. The ability of an individual to effectively create and read blueprints is principal to any building contractor, sub-contractor, manufacturer, material supplier, quantities estimator, machinist and many others involved in any project. A comprehensive understanding of working drawings helps control cost in so many ways, and can also be used as the most effective communication tool in today's competitive global market (Neumann, 2006).

Engineering design graphics drafting and drawing standards continue to change as a direct result of trends in manufacturing and construction methodologies as well as accreditation requirements. Some drafting standards are unique to particular fields. For instance, drafting standards in the construction industry may vary considerably from those in automotive or manufacturing areas. In the construction industry, standards may describe how a company may assemble a set of plans; stipulate all the details they want to show on the plans, how they show them, and where they can be found on the set of blueprints. However, there are some drafting standards that are common to most engineering and technology areas of specialization.

In order to eliminate communication ambiguities, it has become imperative that industry engineers, designers, scientists, and technologists come up with methods to standardize the characters of the graphics language (Dygdon et. al., 2003). Most countries have either completely or partially adopted with minor changes the standards established by the ISO Technical Subcommittee 10 (TC 10) (Jensen, Helsel, & Short, 2002).

In the United States, the American Society of Mechanical Engineers (ASME) is the governing body that establishes engineering drafting and design standards through its ASME Y14 committee (ANSI) (Jensen, Helsel, & Short, 2002). The American National Standards Institute (ANSI), working together with the American Society for Engineering Education (ASEE), and the Society of Automotive Engineers (SAE), sponsored and prepared the American National Standard Drafting Manual-Y14 (Dygdon et al., 2003). Members of the ASME Y14 also serve on the ISO TC 10 subcommittee.

The UNK engineering design graphics course, ITEC-120, exposes students to a variety of drafting and design standards established by ASME Y14/ANSI together with other specific professional or trade standards. This helps students appreciate the need for the class and the importance of having a working knowledge of engineering drafting and design standards.
Determining the content in the course presents two challenges. First, what should the basic foundation course contain in order to prepare students going forward into more advanced coursework to be successful? And second, how in-depth should the basic foundation course be and yet be useful to students not planning on advanced coursework? Identification of common course topics is necessary when developing or updating a multi-discipline engineering design graphics foundation course.

Development or improvements of any engineering design graphics curriculum revolves around three major criteria. First, students must have a hands-on experience of drafting techniques, drafting standards and conventions, and a thorough understanding of 2D CADD. Second, the curriculum should expose the students to practical engineering graphics skills and knowledge about how various design components and systems relate and work together on any given project. Doing so will better prepare students for employment. Students are also expected to develop problem solving skills and most importantly, the ability to think, see and create and model 3D visual images in space or on paper from 2D blueprints using the CADD or other forms of media. A finding from a literature review was that instructors believed that most students learn spatial visualization concepts better through parametric modeling technology first before orthographic projection (Carkhuff, 2006). And third, students should be exposed to emerging trends in technical graphics, developments in industrial technologies, and advancement in computer technology (Bradford, Simms, Chip, Ferguson, & Birnberg, 2006).

A number of colleges and universities offer engineering design graphics foundation courses common to all engineering or technical programs. The challenge is how best to identify those common drafting standards/topics common to most engineering and technology disciplines and how they can be taught to develop basic occupational design graphics skill competencies. Once the common drafting standards and topics are identified it is possible to develop a foundation engineering design graphics course that can be taught within multi-disciplined engineering and technology programs.

In the engineering design graphics foundation course taught at UNK, students are introduced to the fundamentals of engineering design graphics and are exposed to different sets of drafting standards used by engineering and technology disciplines before moving to more advanced and specific engineering graphics courses in their areas of specializations. The curriculum at UNK draws from both the National Association of Industrial Technology (NAIT) and the Accreditation Board for Engineering and Technology (ABET) accreditation standards in the development of its engineering design graphics foundation course. To demonstrate a level of professionalism and proficiency, the four industrial technology programs at UNK that utilize the foundation engineering design graphics course are all accredited by NAIT.

Existing Engineering Graphics Foundation Course at UNK:

An engineering design graphics foundation course is required of all ITEC majors within the Department (Aviation Systems Management, Construction Management, Industrial Distribution, and Telecommunications Management). The course seeks to fuse basic and contemporary principles of Computer Aided Drafting and Design together with traditional and newer engineering drawing and modeling concepts for the purpose of solving technical problems. Application of graphics knowledge is one of the main methods of "thinking" that designers use to solve and communicate ideas.

The rationale behind the course, and its main goal, is to assure that upon successfully completing the course, students will have acquired the ability to think and communicate graphically; a skill that promotes the creative use of the computer for technical problem solving. The key student outcomes for the course are shown in Table 1.

1	Interpretation and Use of Blueprint Reading
2	Apply Computer Science Applications
3	Utilize Drafting/Mechanical Drawing
4	Apply personal computer skills
5	Demonstrate technical expertise
6	Comprehend the latest technology
7	Read blueprints and understand geometric tolerancing
8	Apply high technical skills
9	Apply knowledge of drafting and CAD
10	Use appropriate vocabulary
11	Communicate in technical terms
12	Understand and use appropriate product and performance standards
13	Utilize the computer as a tool for daily tasks
14	Distinguish between various computer-based design techniques and systems

Table 1. Student Outcomes

Methodology:

One of the many challenges facing the Department is the need to continuously update the course to current industry practices represented by the four diverse programs. A committee comprising seven faculty members representing the four Department programs, through a series of brainstorming sessions with other departmental faculty, reviewed the existing engineering design graphics foundation course and provided recommendations for its improvement.

The outcome of these sessions was a proposal to conduct a study of various colleges and universities teaching engineering design graphics along with a study of companies that hire department graduates and their requirements. The study involved using information from the existing course together with reviews of course syllabi from different colleges and universities offering similar programs. The goal was to solicit as much information as possible on common course topics and areas taught.

Once a review of course syllabi was completed from colleges and universities and the most important topical areas were identified, a survey instrument was developed and sent to employers who hire or offer internship programs to students in the Department. Information was sought on what employers believe the Department should be teaching based on syllabi topic preferences.

Identified topics that satisfy basic occupational skill competencies preferred by employers as well as contemporary topics offered by other academic institutions serve as the basis for updating the existing multi-discipline engineering design graphics course.

Syllabi Review – Academic Institutions:

Syllabi from 25 colleges and universities offering industrial technology or engineering technology programs were reviewed to determine which engineering design graphics topics/areas were being emphasized and taught. All selected colleges and universities in this study had their programs accredited by NAIT or ABET. A total of 20 key engineering design graphics introductory topics/areas (Table 2) were identified from course syllabi reviews and served as the basis for the survey instrument sent to employers of the Department's students.

1	The Importance of Technical Graphics/Drawing to Industry
2	The Design Process
3	Integrated Design and 2D/3D CADD
4	Manual Drafting and Design (Pen and Paper)
5	Spatial Visualization- 2D/3D Drawings and Interpretation
6	2D/3D Geometry- Point/Line/Area/Volume Concepts & Graphical Illustrations
7	Boolean Operators (addition/subtraction/union of solids)
8	Multi-View Drawings-Orthographic Projections (to include Auxiliary Views)
9	Axonometric (e.g. Isometric)/Perspective/Oblique Drawings
10	Sectional Views
11	Limits, Fits & Geometric Dimensioning and Tolerancing
12	Thread/Fastener/Spring/Gear Graphical Representation/Language
13	Rendering
14	General Dimensions/Text Styles
15	Computer Literacy & File Formats (Basic Hard/Software knowledge as it pertains to CADD/ Graphics)
16	Parametric Modeling (Creation of Intelligent 3D Virtual Solids/Components)
17	Import and Export of CADD Files On-Line, Collaboration, Interoperability
18	Engineering Graphics Document Creation and Management
19	Printing/Plotting
20	Blue Print Reading (Knowledge of Basic Graphical Language: Standards, Symbols & other forms of detailing in compliance with ISO, ANSI, ASME, AIA, CSI, IEEE, ACCE, etc. requirements)

Table 2. Key Engineering Design Graphics Topics

Employer Survey:

The 20 most popular engineering design graphics topics identified through syllabi reviews (Table 2) were used to generate a survey instrument that was sent to the top ten employers in each program area hiring students from each Department program with the exception of Aviation Systems Management program as that program is limited in student numbers as well as in potential employers

Analysis:

Data from all employers was added up in terms of the area of specialization (i.e. Construction Management, Industrial Distribution, and Telecommunication Management) as well as cumulative employer responses on each survey item. This data was compared against data showing the most popular engineering design graphics foundation topics being taught at 25 universities with similar accreditation status as UNK. Topic preferences by employers as well as the colleges and universities were calculated as percentages and the results were used to create the charts provided in the five figures shown in the Appendix.

Figure 1 shows topic preferences by employers, cumulative topic preference responses from the 25 universities and colleges, and cumulative topic preferences from all employers across all program areas. The cumulative employer percentage for each topic was obtained by adding the totals of employer responses regardless of the area of specialization and expressed as a fraction of the total number of employers who took part in the survey.

Figure 1 shows that both employers and colleges and universities selected topics 1, 2, 4, 6, 8, 10, 11, 13, 14, 15, 17 and 20 as being important to be taught. Topics 1, 2, 14, 15 and 20 proved to be the most popular with those subjects surveyed. Topics 2, 5, 7, 9, 12, 16, 18 and 19 showed no preference being given by employers who hire graduates from the UNK Industrial Technology programs. Note that colleges and university preferences, compared to employers, ranked 18 of the 20 topics very high.

Figure 2 shows percentage preferences between employers who hire Construction Management students with the cumulative employers' percentages on each topic. Construction Management employers responded to all 20 items that were on the survey instrument. Response rates on 12 of the 20 items were above 50% (topics 1, 2, 3, 8, 9, 10, 11, 13, 14, 15, 18 and 20).

Figure 3 shows percentage preferences between employers who hire Industrial Distribution students with the cumulative employers' percentages on each topic surveyed. Industrial Distribution employers responded to only 13 of the 20 popular topics taught by most schools. The topics that they preferred taught included topics 1, 2, 4, 6, 8 to15, 17 and 20. Only two of topic preferences (topics 15 and 20) were above the 50% response rate level with most of the topic preference percentages below the 30% mark. This directly affected cumulative employer preference percentages.

Figure 4 shows topic preferences by employers who hire Telecommunication Management graduates in comparison to cumulative employer preferences across all programs requiring the engineering design graphics foundation course. Telecommunication Management employers responded to eighteen of the twenty topics with some variations in preference percentages. Nine of the topic preference percentages were above the cumulative preference percentages. Five topics (1, 2, 15, 17 and 19) thought to be important by employers had preferential percentages above the 50%.

The last group analyzed in the survey involved those topics most colleges and universities surveyed in this study were teaching against cumulative employer preferences. Results show that nine topics (3, 4, 5, 6, 7, 8, 10, 11, and 16) had significantly higher topic preference percentages over cumulative employer preferences. Five topics had close topic preference percentages between the two groups compared (1, 2, 9, 15, 19 and 20).

Findings

Results from the study show that there are topics that need to be emphasized in the multi-discipline engineering design graphics foundation course at UNK. Industrial employers identified twelve engineering design graphics foundation topics that need to be emphasized. These topics include:

- The Importance of Technical Graphics/Drawing to Industry
- The Design Process
- Manual Drafting and Design (Pen and Paper)
- 2D/3D Geometry-Point/Line/Area/Volume Concepts & Graphical Illustrations
- Multi-View Drawings- Orthographic Projections (to include Auxiliary Views)
- Sectional Views
- Limits Fits & Geometrical Dimensioning and Tolerance
- Rendering
- General Dimensions/Text Styles
- Computer Literacy & File Formats (Basic Hardware/Software knowledge as it pertains to CADD/Graphics
- Import and Export CADD Files On-Line, Collaboration, Interoperability
- Blue Print Reading (Knowledge of Basic Graphical Language: Standards, Symbols & other forms of detailing in compliance with ISO, ANSI, ASME, AIA, CSI, IEEE, ACCE, etc. requirements).

College and university preferences showed that in addition to what employers preferred, there are six additional topics that should be emphasized including:

- Integrated Design and 2D/3D CADD
- Manual Drafting and Design (Pen and Paper)
- Spatial Visualization
- Boolean Operations (addition/subtraction/union of solids)
- Sectional Views
- Parametric Modeling (Creation of Intelligent 3D Virtual Solids/Components)

The above results of the study have indicated specific changes to be made to the existing engineering design graphics foundation course. These changes, planned for implementation during the Spring semester of 2008, are currently undergoing final discussion by Department faculty.

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Appendices: Figures 1 – 5

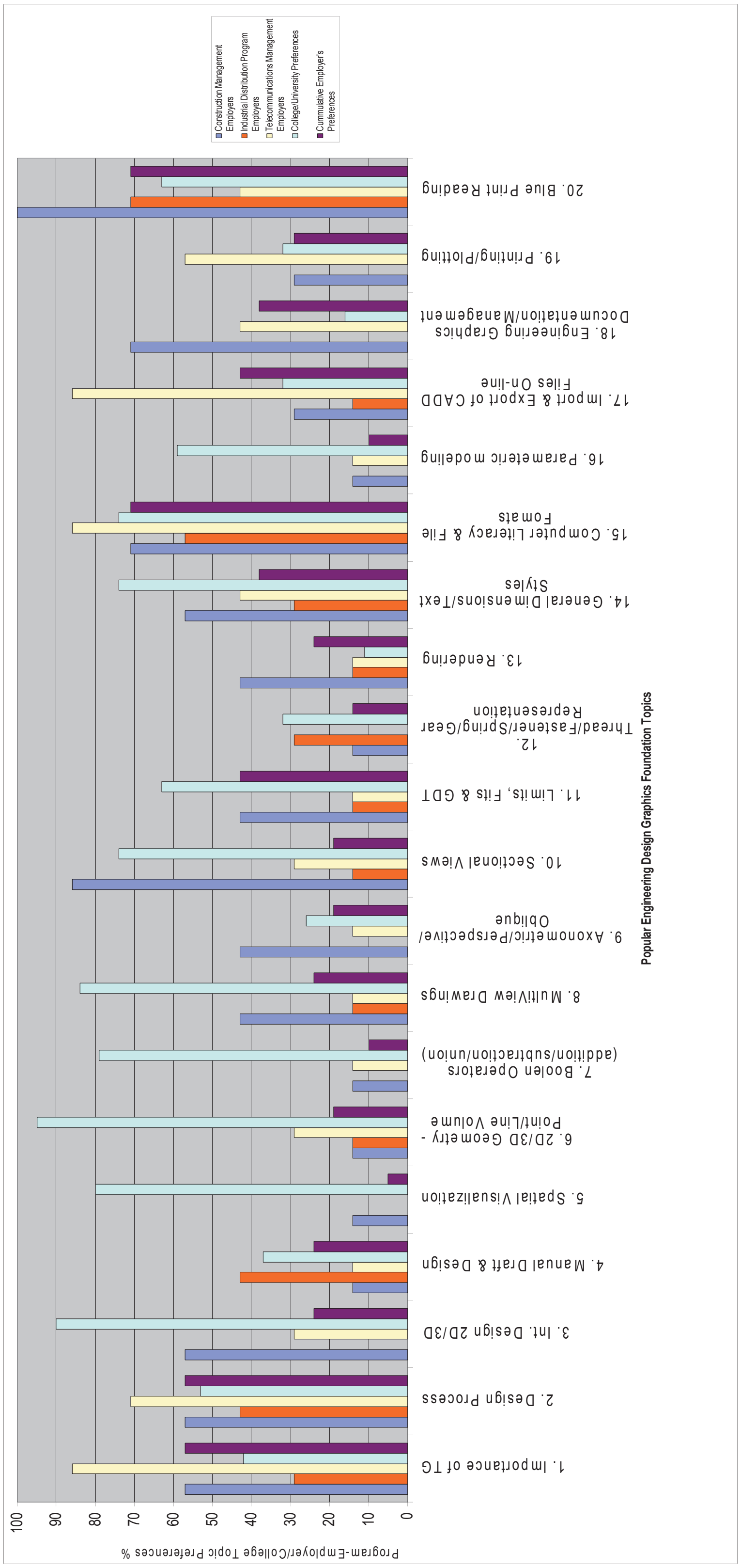

Figure 1. Engineering Design Graphics Foundation Topic preferences by employers who hire Industrial Technology graduates from UNK as well topic preferences by other Colleges and Universities

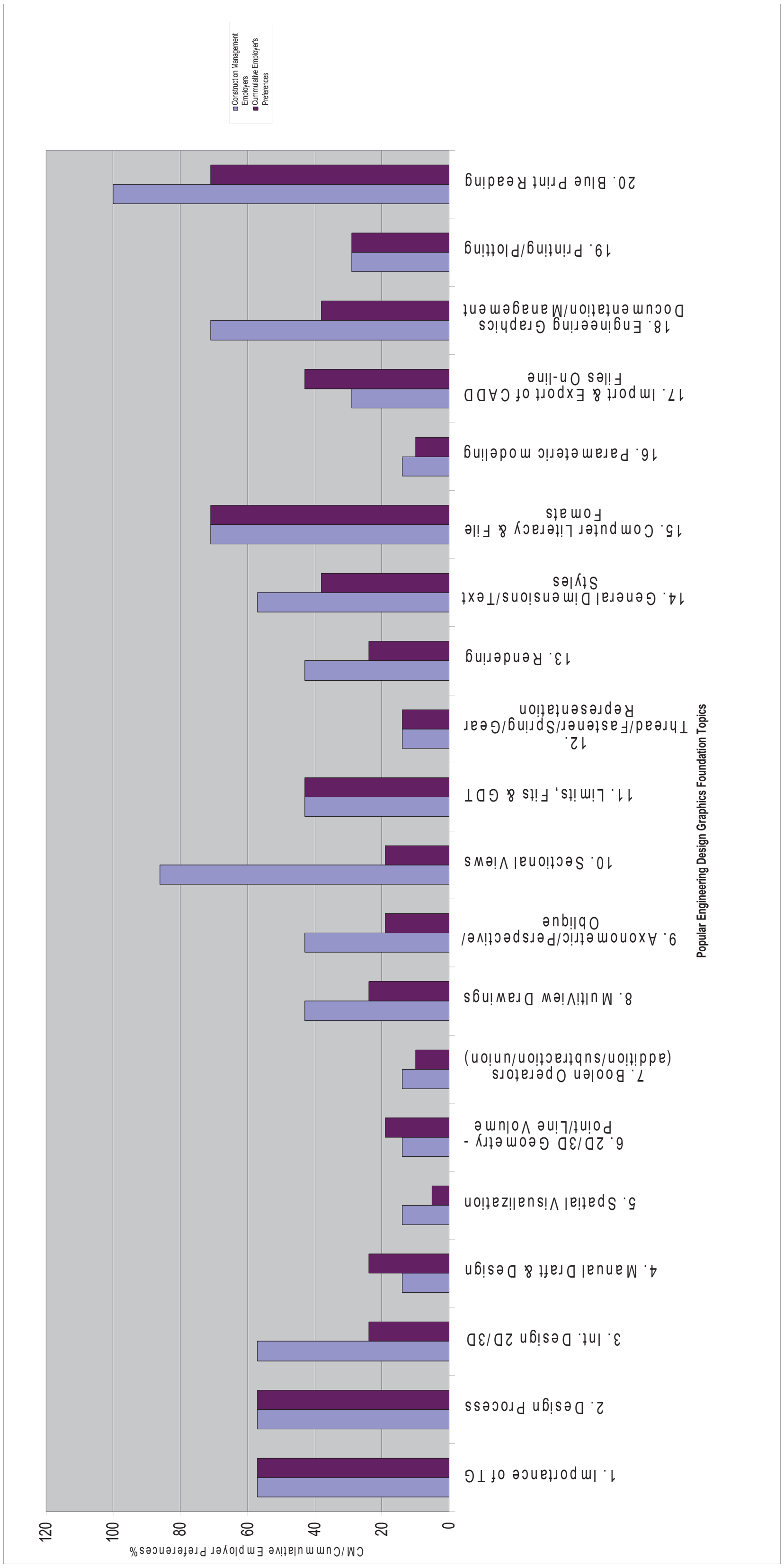

Figure 2. Chart Compares CM Employers' Engineering Design Graphics Topic Preferences with Cumulative Employer Preferences

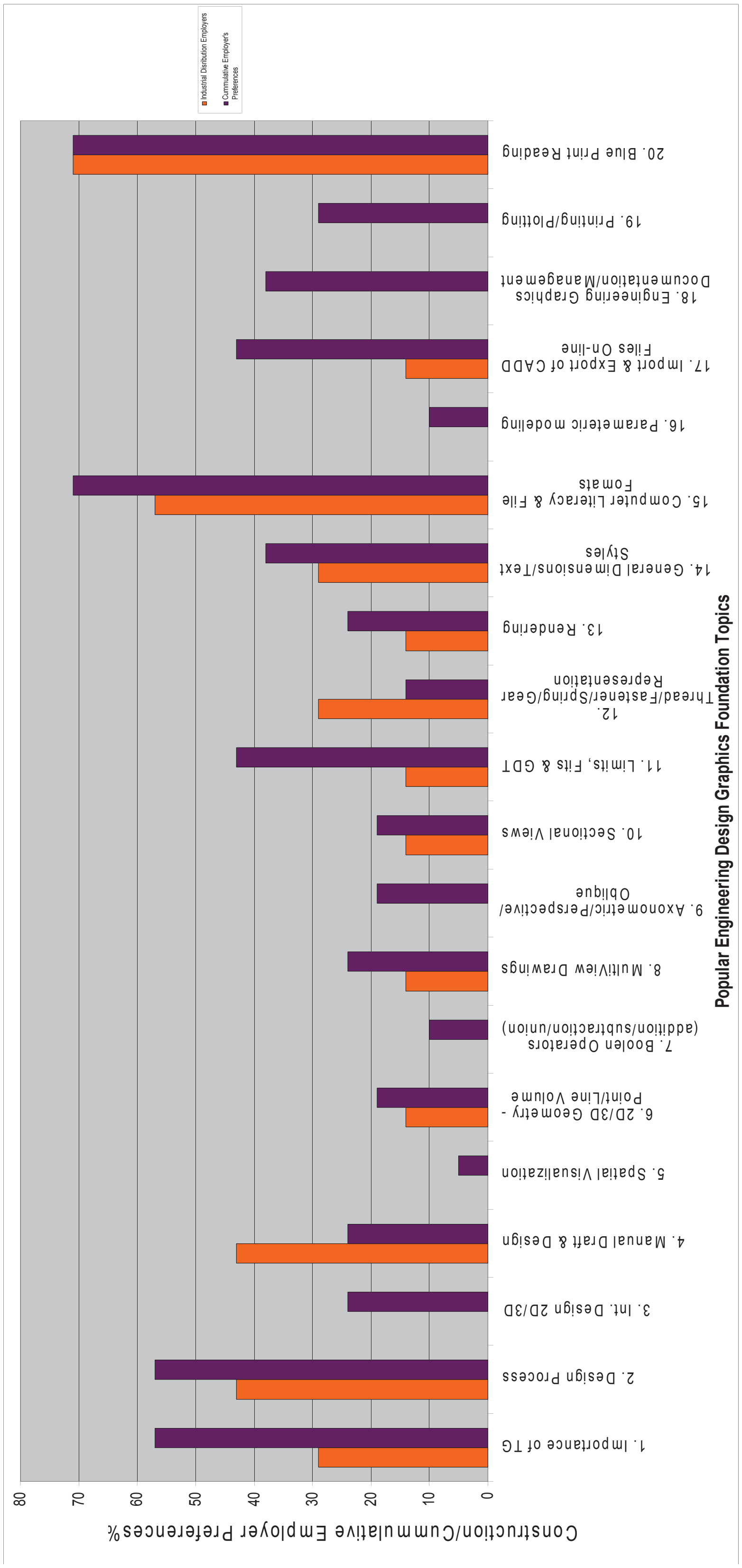

Figure 3. Chart Compares ID Employers' Engineering Design Graphics Topic Preferences with Cumulative Employer Preferences

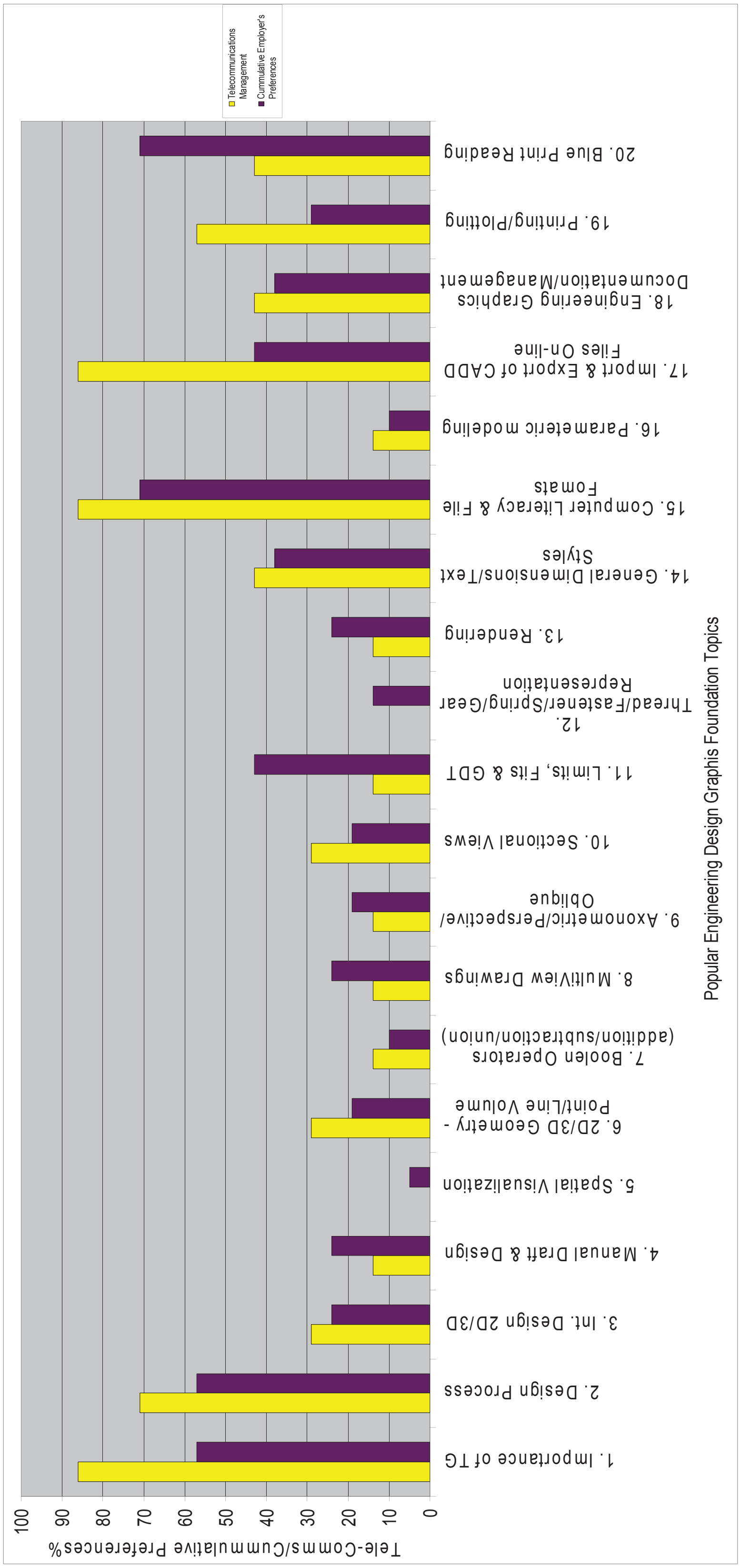

Figure 4. Chart Compares TM Employers' Engineering Design Graphics Topic Preferences with Cumulative Employer Preferences

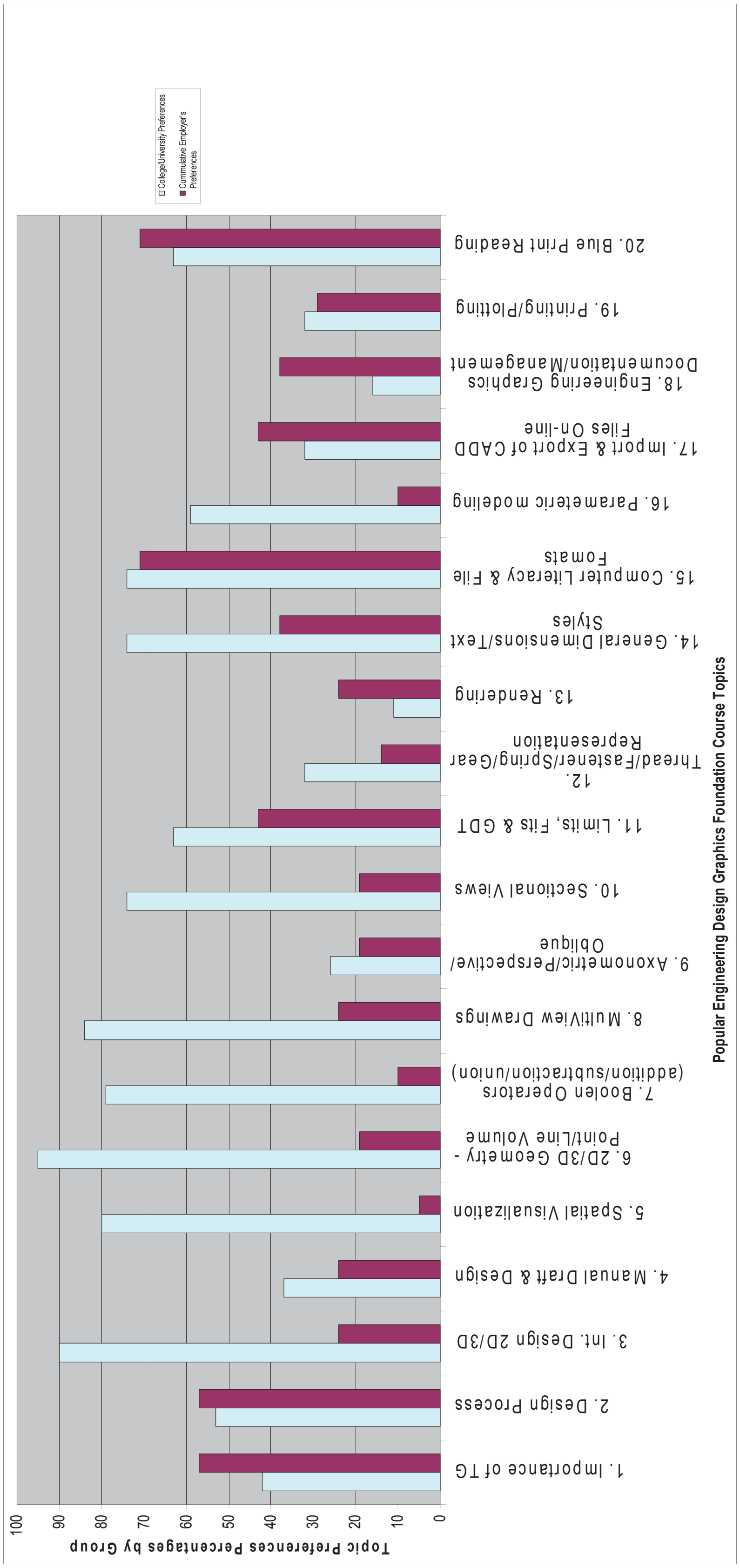

Figure 5. Chart Compares Colleges/Universities with Cumulative Employer Preferences

Management

Ethics Study's Impact on Tomorrow's Industry

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Introduction

Students become involved when discussing cases and scenarios which 1) are related to the industry in which they wish to work, 2) represent situations which they had not considered, 3) are real, and 4) have no simple or obvious answer. Construction management (CM) students in their sophomore year complete a pre and post survey to record changes in their knowledge and attitudes. The post survey was administered after using case studies and class discussions to about professional ethics.

Graduates often have come into contact with situations similar to those discussed in ethics units of classes. Therefore, by contrasting survey data gathered from CM students and from construction industry employees, insight is gained into any changes in attitudes that occurred after real situations were encountered on the job. In addition, the validity of teaching professional ethics using case studies and industry scenarios is examined. Because this is a new, but ongoing study, the authors expect to survey current students after they graduate to track any changes in attitude after they enter the workforce.

Methodology

This survey was administered as a pre/post survey to 61 sophomore students in a construction management class. In addition, the survey was administered to a 69 member control group of freshman and sophomore construction management students from another class, 28 freshman and sophomore manufacturing students, and 38 members of industry. The survey that was administered to industry was identical to the survey administered to current students with the exception of questions used to gather demographic data. Members of industry who participated in the survey included graduates from the department, last semester seniors with construction industry jobs, and people who had no previous contact with the department. Some of the members of industry had been participants in a previous ethical study when they were students.

The survey was administered during the both fall semester of 2006 and spring semester of 2007. The study is ongoing; additional surveys have been administered to members of industry and will be administered to future students.

Constructs

This discussion focuses on four general questions. These questions are about participant's perceptions of ethical behavior and the construction industry and about the participant's attitudes about their own ethics and the construction industry. The constructs for the general questions include the participant's evaluation of: 1) the importance of ethics in the construction industry, 2) the influence of ethical behavior on success in the construction industry, 3) the probability of ethical dilemmas in the construction industry, 4) and the desire for their employer's ethical behavior to match their own.

Other constructs were investigated in the survey, including issues between: 1) contractor and employees, 2) contractor and sub contractor, 3) contractor and employee, 4) contractor and vendor, 5) contractor and public, 6) contractor and owner. These data will be presented in future papers.

Survey Design

The survey began by introducing a scenario in which ethics in the construction industry was the topic of discussion. Survey participants were told that in this scenario, all agreed that ethical actions are important; however, there was much disagreement about the likelihood of individuals engaging in specific activities. The description of the scenario ended with the comment that, from the discussion, it is clear that there many different views of what constitutes ethical behavior in construction. Survey participants were then asked to answer questions about specific events. At the end of the survey, students were asked general questions about ethics, the construction industry, and their opinions.

Method of Data Collection

The survey used Likert scales to categorize data about the participant's attitudes. Data about projected actions in specific events in the survey were collected using a seven category scale, ranging from very unlikely to very likely. The general questions were analyzed using a five category scale, ranging from strongly agree to strongly disagree. This paper deals with the general questions presented at the end of the survey.

Survey Administration and Student Learning (Treatment)

The survey was administered to construction management (CM) students as a pre-test. Students were then given the American Institute of Constructor's Code of Ethics, two different company standards of conduct, and eight case studies from the American Institute of Constructor's (ACI) Program of Ethics (ACI, n.d.). The students were asked to read the case studies and provide a written answer to the questions at the end of each case study.

Students brought their answers to class and participated in a class discussion. These discussions were expanded by real-life examples from the local area, and explanations of some practices central to the case studies. For example, students asked for an explanation of front-end-loading of billing, what it accomplished, questions about cash flow, and why front-end-loading might or might not be ethical. Many discussions included exploration and differentiation of what was ethical and what was legal. A part of the discussion involved a differentiation of legal actions from ethical actions.

Students voted anonymously, indicating what they would do in response to the dilemma presented in each case study. These votes were tallied and posted on the board. Further discussion followed. Students were allowed to submit their papers as they had written them, or to make changes to their answers. After this discussion and submission of papers, the post test was administered.

Data Analysis

Data were recorded using a paper survey, transferred to Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS). For this discussion, frequency statistics were used. Data used here reported "strongly agree" and "agree" together to avoid central tendency bias. Data were treated as ordinal data. For clarity, responses were reduced by combining all agree and all disagree responses into two categories, accept or reject. Neither "agree" nor "disagree" was kept in the analysis. In some instances, this middle category was an important part of the data.

Analysis Results

Results of the analysis are discussed in relation to the four general questions which are central to this discussion. Both the quantitative and qualitative data are included with each question.

First General Question

The first general question was about the importance of ethical behavior. When asked if ethical behavior is important in the construction industry, on the pre-test 67% of the CM students agreed or strongly agreed. In the post test, 50% of these students agreed or strongly agreed that ethical behavior was important in the construction industry. Data collected from senior students and recent graduates working in the construction industry showed 63% agreed or strongly agreed that ethical behavior is important in the construction industry.

This variance in response was investigated by exploring qualitative data collected at the time the post test was administered to construction management students and at the time the survey was administered to senior students and recent graduates. Qualitative data indicated that CM students learned about the need to make ethical decisions in the construction industry. CM students frequently expressed the opinion that the study and discussion had clarified how ethical dilemmas were presented to managers in the construction industry. Students reflected that the study of ethics helped students gain understanding of how ethics can be applied in the industry. Another student acknowledged that studying ethics in the class room allow students to "gain basic knowledge of situations or issues that you may encounter on the job."

CM students indicated they learned, by using case studies, that construction managers had to consider legal issues which might not coincide with the CM student's original ethical response. During the final discussion, the CM students were asked to look at the financial implications of decision making. These conundrums and how the industry worked were already evident to the construction industry employees. A written response from those employed in the construction industry included: "I am answering these questions the way I believe, but our company does not always worry about ethics. They worry about money."

A small group of females who worked in the construction industry were surveyed and saw a much greater importance of ethics to the construction industry: 100% agreed or strongly agreed that ethics were important in industry. No other group, whether owners, managers, laborers, or every male combined, answered this or any other question in the survey in a unanimous manner. The authors of this study plan to investigate this response with an expanded study which will involve more participants.

Second General Question

The second general question investigated participant opinions about success and ethical behavior. The survey asked if success in the construction industry depended on ethical behavior. Although 93% of the CM students agreed or strongly agreed that success depended on ethical behavior in the pre-test, over 97% agreed or strongly agreed that success depended on ethical behavior in the post test. This was similar to over 96% of construction industry employees who agreed or strongly agreed that success in the construction industry depends on ethical behavior.

Qualitative information from students reflected that they had accepted the existence of unethical behavior in the construction industry, as is evidenced in general question one. However, after study and discussion, they became convinced that success in the construction industry was dependent on ethical behavior. Some CM student comments specifically indicated that companies with written codes of ethics, followed by employees and managers, were able to bid and acquire more work because the company was trusted. The construction industry employees wrote that jobs went better if the company was ethical because all of the sub-contractors, suppliers, venders, and inspectors worked more willingly with ethical companies.

Third General Question

The third general question asked the participant's opinion about the probability of encountering ethical dilemmas in the construction industry. Sixty-nine percent of the CM students in the pre-test agreed or strongly agreed that ethical dilemmas would be rare, whereas 77% of the same students agreed or strongly agreed that it would be rare in the post test. Among industry employees, 73% agreed or strongly agreed that ethical dilemmas were rare. Although they did not make up a significant number of the participants, owners and upper lever management agreed or strongly agreed that ethical dilemmas were likely to occur. The authors plan to solicit more participants in this category, thereby allowing further investigation of this subject.

These attitudes were explained by the qualitative data from the CM students which stated that, although ethical situations arose, the construction manager or worker had a solution if the Code of Ethics or company policy was followed; therefore, it was not a dilemma, just somewhere to use the policy.

Qualitative investigation of this question also included comments that "in the business world, I will be faced with many of the same situations. It was neat to get the chance to start thinking about this and hear others opinions of the situations." Other students stated that the lessons helped them learn about dilemmas "that may arise in different business situations, and what is deemed ethically acceptable." One student stated that "I gained an understanding that almost everyone will encounter an ethical dilemma at some point in their career, and that the outcome can influence their future and the future of the company." These comments showed that students accepted that they would be required to make ethical decisions whether they thought of them as dilemmas or not.

Fourth General Question

The fourth general question asked if the participant would only feel comfortable working in a construction environment where the company's ethics matched the participant's personal ethics. In writing about morality and job security, Richard Warren stated that the purpose of a company community includes development of virtuous or ethical behavior and contribution to the common good (Warren, 1996). Survey participants do not seem to agree. Of CM students taking the pretest, slightly over 3% agreed or strongly agreed, but 52% neither agreed nor disagreed. In the post test, none of the CM student participants agreed or strongly agreed, and only 3% said that they neither agreed nor disagreed. However, 97% disagreed or strongly disagreed that they would only be comfortable working in a construction environment where the company's ethics matched their own ethics. The number of participants who disagreed or strongly disagreed with this question was 90% among the members of industry and 86% among the control group.

Qualitative data which related to this question included comments such as "I learned that sometimes you may be asked by your boss to do something that is not ethical. It is up to you to decide whether or not you are going to do it." CM students found that the lessons helped them define their values. One CM student stated "I can now point out easier what is ethical and what is not." This coincides with Jackson and Murphy's findings about construction student perceptions of ethics (Jackson, 1998).

Conclusion

Although over half of CM students and construction industry employees believe that ethical behavior is important in the construction industry, they also believed that success in the construction industry depends on ethical behavior. CM students learned through case studies that ethical dilemmas do occur in the construction industry; however, through exposure to codes of ethics and company policies, they learned that they could have a basis for making good managerial decisions in ethically challenging situations. Perhaps most importantly, CM students learned to believe that they could stay true to their own ethical beliefs even if employed by companies who believed and acted differently.

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A Model for Industry and Education Cooperation in Certification and Training

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Abstract

Representatives from commercial and general aviation, the Federal Aviation Administration (FAA), industry associations, education, and the military convened in a successful effort to finalize industry-based testing standards for the communications and navigation portion of the newly developed National Center for Aircraft Technician Training (NCATT) certification system. This case study describes the NCATT certification system and documents the focus group technique and procedures which were utilized to finalize these particular certifications. The author's participation in this event was a portion of the internship requirement for the PhD in Technology Management at Indiana State University. It is believed that industrial technologists from all fields can utilize the cooperative method presented to develop current and relevant education and training programs.

Introduction

The National Center for Aircraft Technician Training (NCATT) is funded by the National Science Foundation in the interest of improving aviation technician skills, and ultimately, the safety of the nation's air transportation system. NCATT consists of members from industry, government, and education who are working together to achieve these goals and promote aviation maintenance professionalism (NCATT, 2007, p. 1). General aviation and commercial aircraft are generally returned to service by a certified airframe and powerplant mechanic, by virtue of being repaired at a FAA approved repair station. Owners of a Cessna 172, for example, might have their plane's radio replaced at a small hanger by a certified mechanic. On the other hand, FAA Approved Repair Stations, can and do have employees who are trained technicians that are known by the FAA term *repairmen*. Aircraft avionics / electronics technician (repairman) privileges are linked to and fall under the realm of authority approved by the FAA for a given FAA approved repair station. That is, their certification (FAA Repairman's Certificate) is contingent on their employment at the particular repair station.

The current system for certifying airframe and powerplant mechanics was established shortly after World War II and focused on certifying skills required for non-avionic maintenance tasks. It has generally been recognized by industry members that this current system has often been slow to adapt, particularly in rapidly changing fields such as aircraft electronics and avionics. With this in mind, the first task that was undertaken by NCATT was the establishment of an aviation industry recognized certification for aircraft electronics technicians.

The NCATT certification system is a modular one in that additional certifications in a person's particular area of interest can be obtained by passing the Aircraft Electronics Technician preliminary exam. This exam assesses knowledge in areas such as basic electricity, analog and digital circuits, safety, and aviation fundamentals. Unlike the Airframe and Powerplant Certification, which is administered by the FAA, NCATT certifications are designed and developed by and for the aircraft industry. The current certifications and their related skills are identified in Table 1.

The NCATT Organization

The idea of the NCATT certification originated through ongoing discussions between stakeholders from industry, education, and government (W.F. Curtis, personal communication, May 31, 2007). Meetings and conventions of organizations such as the Aircraft Electronics Association (AEA), National Business Aviation Association (NBAA), and the Professional Aircraft Maintenance Association (PAMA), have served as communication vehicles for the interested parties since 1999. In 2005, specific action began with the establishment of the NCATT Executive Advisory Board whose members are listed in Table 2. The board's immediate task was to oversee the development of a new certification system for aircraft electronics technicians, but additional needs were soon identified and appropriate committees were established to establish oversight. These committees are illustrated in Figure 1. As the name implies, the Accreditation and Certification committee will accredit educational providers of aircraft electronics technician courses. Flexibility in a curriculum is considered legitimate as long as the NCATT standards are achieved. Outreach programs are designed to foster interest in aviation maintenance. Organizations such as the Aviation Career Academy and programs such as high school build-a-plane programs are supported by the Outreach Programs committee. The Faculty Development committee partners with members of industry and education to provide skill training for instructors. Local train-the-trainer sessions for example are currently planned at Tarrant County College. The Electronic Media committee is made up of the chairs of all of the other committees and oversees the NCATT website, which serves as a detailed repository for not only information regarding certification, but, as a knowledge base of technical data regarding aircraft electronics. The Standards and Curriculum committee establishes attitude, knowledge, and skill requirements as well as a suggested supporting curriculum and resources which can be adopted by educational institutions. Products of this committee include a study guide, standards and outcome matrix, and the suggested lesson plan.

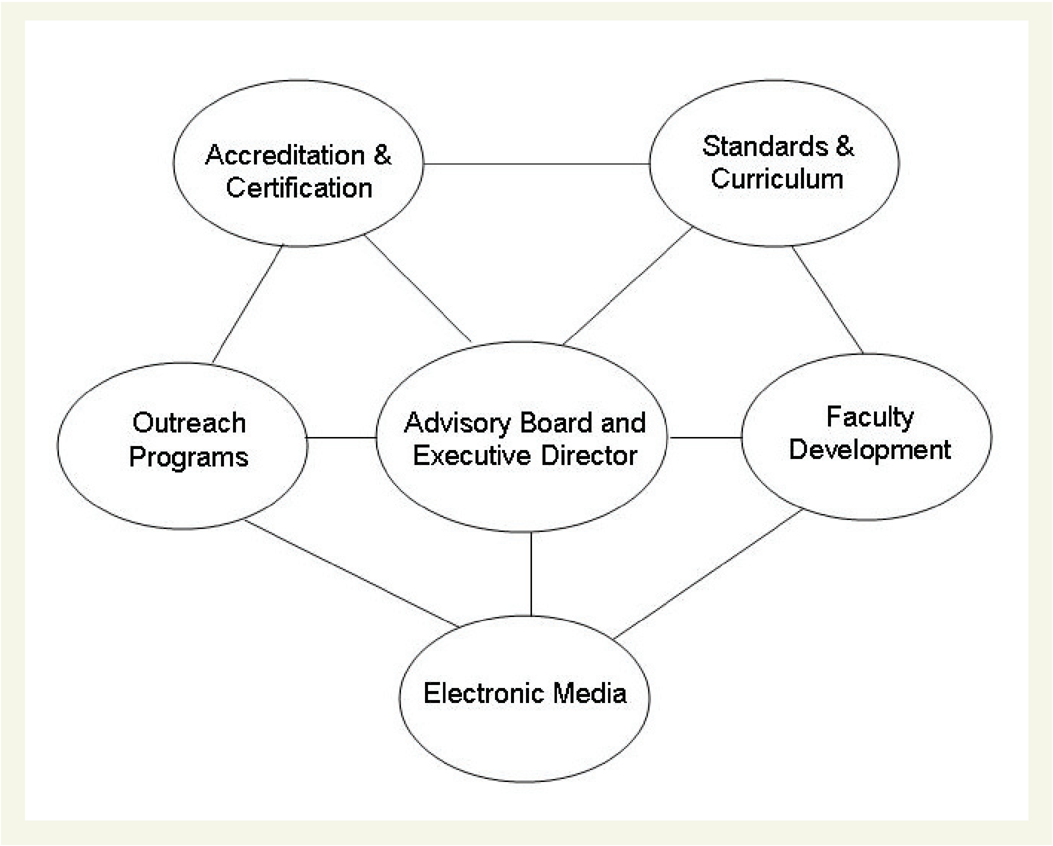
Table 1. Current NCATT Certifications

Certification	Skills
Aircraft Electronics Technician (required for subsequent certifications)	Basic terminology, basic circuits and calculations, resistors, inductors, capacitors, transformers, analog circuits and devices, power supply circuits, filters, wave generation circuits, limiter circuits, digital numbering systems, logic functions, safety practices, materials handling, technical publications, corrosion control, electrostatic devices, wiring, aircraft fundamentals, theory of flight
Communication	High Frequency, Ultra High Frequency, Very High Frequency, satellite communications, VHF data link, Automatic Crew Alert Reporting System, Emergency Locator Transmitter, Cockpit Voice Recorder
Navigation	Global Positioning System (GPS), Instrument Landing System, Variable Omni Range, Distance Measuring Equipment, Inertial Systems, Automatic Direction Finder, Flight Management System, Doppler, Radar Altimeter, Air data systems, Heading systems, Slave compass systems, Heads Up Displays, Loran C
Avionics Systems Installation/Integration	Electrical load analysis, system integration, wiring practices and methods, corrosion control, bonding, sheet metal, forms and documents, soldering
Foreign Object Elimination	Sources of Foreign Object Debris/Damage (FOD), tool and part control procedures, clean-as-you-go
Advanced Digital	Data bus standards, analog to digital converters, digital numbering and logic
Autopilot	Auto throttle, auto land, flight director, Cat I, II, III, Stability Augmentation System, Yaw damp, autopilot, spoilerons, fly-by-wire
Bench	Internal component level repair and troubleshooting
Enhanced Vision	Forward looking infrared, millimeter wave, highway in the sky/synthetic vision, video
In-Flight Entertainment	Audio, video, Internet, displays
Instruments	Analog, digital, liquid quantity indicator, flight data recorder
Power Generation and Distribution	Ac generation, DC generation, stand-by/emergency power, power distribution
Surveillance	Traffic Collision Avoidance System, Terrain Awareness Avoidance System. Air Traffic Control Radar Beacon System, Mode S Transponder, Automatic Dependent Surveillance Broadcast, Traffic Information Service Broadcast
Weather Avoidance	Weather radar, data link weather, lightning detection, predict wind shear
Structural Repair	Metallic, composites, wood And fabric techniques
Weight and Balance	Aircraft weighing, center-of-gravity and moment arm calculations

Table 2. NCATT Executive Advisory Board Membership

Member and Title	Affiliation
M. Adamson, Director of Training and Education	Aircraft Electronics Association
S. Bauer, National Aviation Education Director	Federal Aviation Administration
J. Breeding, Chief, Licensure & Certification	Community College of the Air Force
E. Cotti, Director of Technical Operations	National Business Aircraft Association
D. Howse, Technical Manager	SpaceTEC
K. Farley, Vice President of Manufacturing	S-TEC/A Meggitt Company
S. Gilpin, Lieutenant Commander,	Naval Air Technical Training Center
L. Johns, President	Aviation Technicians Education Council
C. Thomas, Director Training and Development	Mooney Airplane Company, Inc
P. Stewart, Vice President of Operations	Texas Aero Engine Services, Ltd.

Figure 1. The NCATT Organizational Structure



No doubt since NCATT is still a new organization, membership and rules of operation will continue to be revised. However, industry participation and oversight will always remain a mandate. Notably, organization participation on boards and committees is considered to be permanent though individual representatives may change.

More on the Standards and Curriculum Committee

Certification standards development for the system began with an occupational analysis of the aircraft electronics technician. It became apparent that some technicians spent their entire careers specializing in performing installations and upgrades, while others performed bench repairs, or perhaps specialized in maintaining autopilot systems. Thus, the modular structure of the standards and subsequent certifications was formed, enabling students to gain skills in a particular area of interest. Certificate programs such as this have become a popular option for industry workers (Woolsey, Rodchua, and Ulmer, 2006, p. 113). It is believed by NCATT leadership that this modular system will provide an avenue for continuous learning and advancement for aviation technicians as well. It was also evident that even though the Standards and Curriculum committee consisted of seasoned leaders in their respective branch of aviation, they had not necessarily remained current in avionics technology details. With this in mind, focus groups were selected to address specific details of the various standards. A typical focus group session is described in the subsequent section. In addition to the development and review provided by the focus groups and committees, all education and industry partners are afforded the opportunity to review and provide input to the certification standards.

An additional task of the Standards and Curriculum committee is proficiency examination development, which in turn, has been assigned to the Test and Measurement subcommittee, a panel of highly qualified practitioners who can ensure proper technical presentation of questions, grammar, and non-discriminatory language, in addition to being responsible for security of the examination database. Each exam is subject to approval by the Standards and Curriculum committee, and in turn the Executive Advisory Board. Beta testing of examinations has been accomplished at events such as AEA conventions and at the Sheppard Air Force Base Training Center, where volunteers were offered a chance to take the test and earn certification. Every two years, examinations will be assessed for proper technical content and psychometrics. LaserGrade, LP is contracted to provide testing locations and also to assist with psychometrics and test question analysis.

A Typical NCATT Focus Group/Workshop

On March 6th through the 8th of 2006, aviation industry electronics and avionics subject-matter-experts met at a workshop at Tarrant County College in Fort Worth, Texas to establish standards for the AET Communication and Navigation certification. A focus group technique was utilized in this process, witnessed by the author, and is described herein. First, however, some background on the focus group as a research tool is provided below.

Overview of Focus Groups

A focus group is a qualitative research technique which enables the use of group interaction to produce data which would be less accessible without the interaction of a group (Morgan, 1997, p.2). This collective interaction of the group produces ideas and responses which are greater than those which could be achieved through individual interviews (Threlfall, 1999, p. 102). Most of the literature identifies sociologist Robert Merton as the originator of the modern focus group, initially using the technique to collect audience reactions to radio programs in 1941 (Chappelow, 2004, p. 23). The rise in the number of female television newscasters in the 1980's is attributed to the use of the technique by consultants to verify audience acceptance of female news anchors (Allen, 2003, p. 154). Today, focus groups are widely used, and perhaps misused at times, in marketing, communications, and political science studies, as well as in public health and sociological research (Morgan, 1996, p. 132). Moreover, the technique is often used in conjunction with interview and survey methods. The main advantage of the focus group technique over participant observations and interviews is that large amounts of interaction can be observed over a limited period of time (Morgan, 1997, p. 8). Morgan goes on to note how studies have shown that focus groups, when compared to surveys, produce more in-depth information regarding the topic at hand than surveys. Interviews, on the other hand, actually tend to produce more ideas than focus groups, though not necessarily better ones. Logistical issues and personal schedules for instance can make the focus group a more logical choice. Such is the case with participants in the NCATT organization.

Social and marketing research endeavors often use focus group techniques to collect data on how groups of people think or feel about a particular topic, gain insight into why certain opinions are held, improve the planning and design of new programs and provide a method of evaluating existing programs. Focus groups cannot however be used to provide valid information about individuals, information regarding how things have changed over time, and data that can be generalized to other groups of people (Marczak and Sewell, n.d.). It is important to note that the idea of focus groups is to take advantage of the information which is generated by the group, not individuals. This is where the role of moderator or group facilitator becomes critical, especially in terms of providing clear explanations of the purpose of the group, helping people feel at ease, and facilitating interaction between group members (Gibbs, 1997).

Navigation/Communication Focus Group

The twenty member focus group met at Tarrant County College for three full days with the task at hand of validating the standards and standards levels that were initially developed by the Standards and Curriculum committee, and refined in turn, by a previous focus group. Members and their affiliations are listed in Table 3. Throughout the event, three facilitators took turns guiding the group through the various activities, which began with a review of NCATT's mission and vision, recent milestones, and a review of standards level definitions and validation, the main purpose of the event.

Table 3. Focus Group Membership

Member Name	Affiliation
C. Bartosek	American Airlines
B. Gremler	American Airlines
B. Carpenter	Carpenter Avionics
M. Stagg	Dallas Avionics
A. Peterson	Delta Airlines
T. Yanus	Embry-Riddle Aeronautical University
P. Kwaak	FAA
R. Jackson	Federal Express
T. Psenak	Field Tech Avionics
P. Novacek	Sun Flight Publishing
G. Steele	Meggit/S-TEC
R. Hestilow	NCATT
F. Curtis	NCATT
R. Ochs	Spirit Avionics
M. Shriver	Tarrant County College
C. Tays	Texas Aviation Services
MSgt. W. Ferguson	U.S. Air Force
TSgt. C. Weiland	U.S. Air Force
AEC C. Doherty	U.S. Navy
ATC S. Lopez	U.S. Navy

At the current session, as with other sessions, standards level definitions were assigned for each of the components and sub-components of the certifications. For example, recall from Table 1 that a skill requirement of the Navigation certification was GPS. Training knowledge requirements within the GPS component are; purpose and characteristics, theory of operation, system integration, operational checkout, component replacement, and troubleshooting. Each of these knowledge requirements were assigned an alphanumeric score based on a system which is similar to the Air Force's AFH 36-2235 level of learning objective verb rating system. The alphanumeric numbering system which was utilized is illustrated in Table 4 and the final score sheet for the Navigation certification is illustrated in Table 5. The value in the scoring system is that proper attention can be paid to particular skill sets in course development. During this process, missing skill categories were identified, added, and rated. Members were given an opportunity to score each skill on their own, then debate each score as a group until a final score was agreed upon.

With the analysis and scoring of the certification standards skill level complete, the event concluded by giving members the chance to be the first AET certification (the basic test) examinees. Most, but not all, attendees passed this 60 question examination, perhaps giving an indication of its difficulty.

*Table 4. Standard's Level Definitions**

Level	Scale Value	Definition
Task Performance Levels	1	IS EXTREMELY LIMITED. Can do simple parts of the task. Needs to be told or shown how to do most of the task.
	2	IS PARTIALLY PROFICIENT. Can do most parts of the task. Need help only on the hardest parts.
	3	IS COMPETENT. Can do all parts of the task. Needs only a spot check of completed work.
	4	IS HIGHLY PROFICIENT. Can do the complete task quickly and accurately. Can tell or show others how to do the task.
Task Knowledge Levels	a	KNOWS NOMENCLATURE. Can name parts, tools, and simple facts about the task.
	b	KNOWS PROCEDURES. Can determine step-by-step procedures for doing the task.
	c	KNOWS OPERATING PRINCIPLES. Can identify why and when the task must be done and why each step is needed.
	d	KNOWS ADVANCE THEORY. Can predict, isolate, and resolve problems about the task.
Subject Knowledge Levels	A	KNOWS FACTS. Can identify basic facts and terms about the subject.
	B	KNOWS PRINCIPLE. Can identify relationship of basic facts and state general principles about the subject.
	C	KNOWS ANALYSIS. Can analyze facts and principles and draws conclusions about the subject.
	D	KNOWS EVALUATION. Can evaluate conditions and make proper decisions about the subject.

(* A task knowledge scale value may be used alone or with a task performance scale value to define a level of knowledge for a specific task (Example: b or 1b could be used). A subject knowledge scale value is used alone to define a level of knowledge for a subject not directly related to any specific task, or for a subject common to several tasks. These skill levels are currently in use by the Air Force.)

Table 5. Excerpt from Final Navigation System Standards Level Definition Sheet

Navigation System Skill	**Score**
Principles	
Earth Coordinate System	B
Great Circle Navigation	B
Navigate	2b
Global Positioning System	
Purpose and Characteristics	B
Theory of Operation	B
System Tie-In/Integration	A
Perform Operational Checks	2b
Remove and Install Line Replaceable Units	2b
Isolate Malfunctions	2b
Doppler	
Purpose and Characteristics	A
Theory of Operation	A
System Tie-In/Integration	A
Perform Operational Checks	2b
Remove and Install Line Replaceable Units	2b
Isolate Malfunctions	2b
Radar Altimeter	
Purpose and Characteristics	B
Theory of Operation	B
System Tie-In/Integration	A
Perform Operational Checks	2b
Remove and Install Line Replaceable Units	2b
Isolate Malfunctions	2b

Lessons Learned

Critical to the success of the NCATT organization to date has been the obtainment of buy-in and support from the top management of over 200 industry partners (W.F. Curtis and R. Hestilow , personal communication, June 14, 2007). Armed with the support of company presidents and high-ranking military officers, for example, the staffing of committees and the attendance at meetings and workshops has been greatly facilitated.

As with an activity involving more than one person, facilitators who are leading focus groups often encounter problems with group dynamics. One person may tend to dominate a discussion and may need to be reminded that the output will be the result of a team effort. The group itself, however, often takes care of such issues. The modular design of the certification system itself is seen as an advantage in limiting excessive argument and debate over what should or should not be included in a standard. That is, a member of the military may not consider In-Flight Entertainment to be worthy of inclusion in the system of standards while an airline members sees it as critical. Modularity helps focus the discussions.

Lack of prompt attendance at such events can be problematic in that time is wasted getting late arrivals up to speed on events. Finally, the larger a group tends to be, the harder it is to capture specific technical details which are developed. NCATT has implemented the use of audio recording to facilitate data collection.

Summary and Conclusion

When considering training and certification programs for industry, it is imperative that users be involved from the start in a concurrent and integrated fashion in order to provide a product that is current and relevant. The NCATT organization has included involvement and input from over 200 different aviation-industry entities, including the U.S. Military, the Federal Aviation Administration, airlines, component suppliers, and education in developing procedures, processes and products (NCATT, 2007, p. 2). The focus group technique has been found to be a valid research tool and method for helping accomplish such cooperation.

To date, over 200 individuals have obtained the basic AET certification and the number is continuing to grow exponentially. The Air Force and Navy are gearing training around the certification curriculum and are providing testing opportunities for enlisted personnel. The certification is viewed as an opportunity for recruiting and retention (NCATT, 2007, p. 6). Furthermore, certain companies will soon require NCATT certifications as a condition of employment. This new certification should provide a more skilled workforce and a safer aviation system. For further information regarding the NCATT organization and its progress, please visit the NCATT website at http://www.ncatt.org/.

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Restrooms: An Unusual Place to Find Cost Savings

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Abstract

Global competition has continued to squeeze American manufacturing. Much research and work has been done in terms of cost reduction and improved manufacturing processes, including outsourcing. The challenge for management is where to look for additional cost savings. Sometimes, a creative approach is necessary to find in this case almost $250,000 opportunities. This paper explores one company's resourceful look at cost savings in an area that is rarely considered and was indirectly affected by changes in manufacturing.

Introduction

The Midwest has many factories that were designed and constructed in the late 1940's and 1950's. Many of these facilities have fallen empty or were replaced as the era of the Rustbelt emerged in the 1960's. However, some facilities have sustained production over the years. This continuous use has required various upgrades in order to continue to produce products and stay competitive. This project took place at one such facility.

The facility began production line manufacturing operations in 1957. The facility was originally designed to house about 6000 employees, primarily men and has about 2.5 million square feet under roof. The plant sits on almost 175-acres.

Over the years, improvements were made to the production line. These changes made for many reasons including integration of new technology, changes in the product, and better management of resources (cost cutting). More recently methodologies such as lean and six-sigma have resulted in even more reductions in time, material, and labor. As an example of the results related to these aggregated changes over the years, the original lines which required 12 people to operate now only needs two people to produce the same product at a higher rate.

Purpose of the Project

As a result of the many changes, the number of employees has been reduced from 6000 in the 1950's to about 1800 currently. Significant cost savings have been realized, but not enough. Management, the union, and employees are struggling to find ways to keep this old plant open. That means finding ways to reduce costs in order to make this old facility competitive with new, modern plants. A question came up in conversation. "What did we forget to look at? It became clear that specific units and operations had been scrutinized for cost savings, but no one had intentionally looked at the entire system.

This idea led to many more discussion about what it takes to maintain and support the current system. One idea that came up during brainstorming was a bit unconventional. Perhaps not as many restrooms were needed. After the laughter subsided, the question led to a more serious discussion. It was determined that currently, the facility had restroom facilities allocated for a much larger work force and gender different than currently employed. Striving toward lean manufacturing it was determined that there was a need to consolidate the restrooms and utilize man power elsewhere and that resources would be allocated to examine the restroom question. A maintenance manager took on the task.

Methodology

Since many people would be affected and the union would have to agree, a serious evaluation would be necessary for any changes to be agreed to and made. The following steps were required:

1. Review union contract to ensure compliance
2. Review any regulatory requirements for compliance
3. Perform restroom audit to determine usage
4. Use plat map of locations to determine redundant facility locations

5. Use the local contract to determine management's responsibilities for washroom janitorial services and any language addressing restroom locations
6. Management agrees on the proposed recommendations
7. Management presents union leadership with the final proposal
8. Management and union agree on what changes will happen during the planned facility shut down
9. Management redirects displaced janitors to vacant janitorial jobs

Contract Parameters

Over the years, various union contract negotiations have included issues of restrooms and cleanliness:

- Management acknowledges its obligation and responsibility to maintain the cleanliness of rest rooms and rest areas. Rest rooms will be cleaned each operating shift including floor mopping and cleaning of the urinals, toilets, and wash basins. Rest areas on the manufacturing floor will be cleaned on each operating shift and mopped twice weekly.
- Management is agreeable to steam cleaning of restrooms and the shower facility on a bi-weekly basis.
- Management recognizes that rest rooms and rest areas must be maintained at an acceptable level of cleanliness and sanitation. The number of janitors assigned to perform these tasks for the rest rooms and rest areas on the manufacturing floor on a full time basis will be at least three (3) per manufacturing shift at operating levels exceeding 1700 hourly employees.

There are currently 1,797 people working in the plant, 25 in the job bank, and 121 on temporary separation. If all personnel returned to work the total number would be 1,943. Management had agreed in the contract to keep at least three janitors on a full time basis to service the restrooms and rest areas when the facility exceeds 1,700 hourly employees. The breakdown of personnel by gender is 1608 males and 308 females.

Regulatory Parameters

The standard for the local city requires the following for restrooms: Compliance with the 2003 International Plumbing Code for Industry. The standards are from section 403, titled Minimum Plumping Facilities. In table 403.1 the requirements are shown for toilets and urinals. The requirements for an industrial complex are:

- Minimum of one urinal per 100 men
- Minimum of one toilet per 100 men
- Minimum of one toilet per 100 women

The code does **not** specify any given distance one person must travel to reach a restroom, nor does it specify any maximum time one can travel to a restroom. It is left to local discretion and common sense on the distances and time it will take for an individual to reach a restroom.

Feasibility

The only foreseen problems will be the local union. The leadership will not want to have a man-power reduction in the janitorial department. Additionally, the union would have to deal with their membership complaints about the inconvenience of having to walk farther to use the lavatory or using another lavatory than the one they have become accustomed to. This latter issue was not considered originally and only became apparent as workers voiced a preference of one lavatory over another. In a few cases, people were willing to walk almost twice as far to use a lavatory than to use the one closer but requiring them to walk up one flight of stairs.

Audit

The information from the Restroom Audit Figure 1 shows the restroom utilization. The numbers are generated during audits conducted on first shift. The audits are conducted hourly and include utilization during break and lunch times. This chart is meant to show the under-utilized restrooms which are to be considered for consolidation

Benefits and Recommendations

There are currently a total of 149 toilets and 67 urinals breaking down to 46 for women and 103 for men. This number of available facilities can accommodate up to 4,600 women per shift and 10,300 men per shift. The urinals will support 6,700 men per shift. However, there are less than 2,000 people working in plant.

The plan to shut down various restrooms will leave the facility with 36 toilets for women, and 47 toilets and 42 urinals for men. The plant capacity could be up to 3,600 women per shift and 4,200 men per shift based n current building code requirements.

The restroom closings will save approximately 10.5 man-hours per shift of janitorial services. This does not include the chemicals, equipment, supplies nor the secondary labor involved. There will be an additional savings on overtime. The three displaced janitors will be reassigned to cover open jobs. The open jobs were created when factory janitors retired.

The factory janitor rate is $24.98 an hour. The coverage would generate three janitors from third, one from second and two from first shift. The cost breakdown is $4,758.87 a week, $19,035.48 a month or $247,461.24 a year.

Another cost savings would be the steam cleaning of the restrooms on the weekends. The one maintenance laborer and janitor would not be needed to address the restrooms due to a 23% reduction of restroom area to clean. Maintenance Laborers rate 25.57 an hour without premiums. The total cost for the steam cleaning on Saturdays only is, $333.63 a week, $1,334.52 Monthly and $17,348.76 annually. Contractually there is still the need to steam clean all of the restrooms and the shower facilities bi weekly. The current total of wash rooms and shower facilities is 31. After the reconfiguration occurs there will be a total of 20 full restrooms and 4 half restrooms.

The secondary labor would be the crib attendant getting supplies, trash man removing waste, jitney repairman to service the equipment.

Results

- 23% consolidation of restrooms less maintenance
- Elimination of Saturday restroom steam cleaning. Due to time available to perform steam cleaning during week. Estimated savings, $333.00 a week, $1,334.00 a month or $17,350.00 a year contractually bi weekly per restroom.
- Cost savings of three eliminated janitor jobs
- Ability to fill vacant janitor jobs with out increasing department personnel
- Cost savings on float material and equipment
- Cost savings on overtime generated by filling vacant jobs currently covered with overtime. Estimated savings $4,759.00 a week, $19,000 a month or $247,450.00 a year.

The manpower cost savings would be $5,092.32 a week, $20,369.28 a month and $264,800.60 a year!

Conclusion

As a result of this project and the effectiveness of management/union negotiations, the project will be implemented. This project was considered successful by all parties involved. Additionally, other support areas are now being evaluated. What started out as a joke or appeared to be a negligible issue, turned out to yield significant cost savings upon closer exploration.

Figure 1: Utilization audit of restrooms

	1st	2nd	3rd	4th	5th	6th	7th	8th
Men								
E17	1	0	2	1	0	1	1	0
Location Men 1	1	0	1	0	1	1	0	0
Location Men 2	0	0	0	0	1	0	0	0
Location Men 3	3	1	3	1	0	5	2	2
Location Men 4	2	1	3	0	0	4	1	2
Location Men 5	1	0	0	0	1	0	0	2
Location Men 6	0	1	0	0	0	0	0	0
Location Men 7	0	0	0	1	0	1	0	0
Location Men 8	0	0	0	0	0	0	0	0
Location Men 9	1	1	0	0	1	1	0	0
Location Men 10	1	1	0	0	0	1	0	1
Location Men 11	1	2	2	1	1	2	0	1
Location Men 12	0	0	0	0	0	0	0	0
Location Men 13	0	0	0	0	0	0	0	0
Women								
Loc Women 1	0	0	0	0	0	1	0	0
Loc Women 2	0	3	0	0	1	1	0	0
Loc Women 3	2	2	3	1	6	5	3	5
Loc Women 4	0	0	0	0	0	0	0	0
Loc Women 5	2	3	0	0	1	1	0	0
Loc Women 6	0	1	1	0	0	0	0	0

Manufacturing

Educating the Manufacturing Technologist: Current Trends and Gaps in Curricula *(Best NAIT 2007 Convention Paper)*

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(Note: A Committee of the NAIT Executive Board selected this paper as the "Best NAIT 2007 Convention Paper" from the 25 Convention Papers which were accepted after peer-review.)

Introduction

Graduates of Industrial Management and Manufacturing Technology Programs are constantly challenged to meet the demands of a rapidly changing business and technological environment. Changing and emerging technologies along with the ever-increasing competition brought by globalization have altered and added to the required skills of the manufacturing professional. To meet the expectations of employers, graduates must draw on a broad range of knowledge that often requires a blend of management and technical abilities. This skill set tends to change with the evolving competitive pressures of the industrial environment. In order to prepare students for the expectations placed upon them as they enter their profession, educators must identify current knowledge requirements and trends in industry. This paper reports the results of an industry survey relating to career opportunities and needed skills for manufacturing professionals. Based on survey results, recommendations are made for curricular improvements at the college level.

Background

As globalization accelerated over the past decade, numerous manufacturing jobs left the United States for cheaper labor markets in developing areas such as China and the Pacific Rim. As those jobs left, some were replaced by positions in smaller start-up companies. Those smaller organizations along with the remaining traditional manufacturers face strong global competition as they strive to survive and grow.

Although fewer people are working in manufacturing in the United States, this sector still accounts for about 22-25% of the gross domestic product as it has for the past 50 years. (Shinn, 2004). The remaining manufacturing professionals such as manufacturing technologists and manufacturing engineers play an increasingly important role in improving the efficiency and competitiveness of the company. Manufacturing professionals in the United States are increasingly asked to perform new and different tasks. It is no longer acceptable to only understand the technical components of the operation. A broader understanding of the overall business environment, competitive forces, and trends is necessary in order to properly apply technical knowledge (Sinn, 2004).

Various continuous improvement tools are widely used in industry today as a means for meeting the additional expectations placed on manufacturing professionals. Lean and Six Sigma methodologies are prominent examples of these tools which strive to eliminate waste, improve quality and reduce production time. Implementing these types of programs can improve value for the customer while increasing profits for the company (Summers 2007). According to one recent survey conducted by Industry Week and the Manufacturing Performance Institute, 40% of manufacturers have implemented some form of lean manufacturing program. Another 12% have implemented a combination of Lean and Six Sigma (Katz 2007). Some companies considering outsourcing have found that they can stay competitive and meet financial goals by implementing lean concepts while remaining in the United States. Small-to-mid sized companies in particular may be better off implementing lean concepts rather than migrating offshore (Langer, 2007).

Rapidly changing technology is also a factor in educating the manufacturing professional. New high-tech industries are developing and expanding as a result of advances in material science, health care, and electronics. Microtechnologies and nanotechnologies typify the trend toward converging technologies where several disciplines such as material science, biology, chemistry, engineering, and physics are all critical in the development and manufacture of a product (Kalpakjian and Schmid, 2006). These new and developing industries require the same process improvement and efficiency skills as traditional manufacturing organizations. Examples of products currently being developed around the convergence of disciplines include microsensors for healthcare testing, automation applications using intelligent software, and high-performance materials using carbon nanotubes (McCann, 2006). These new industries and technologies bring expectations and challenges to skilled professionals that must be addressed by both continuing education and traditional college degrees. Plaza (2004) proposed developing some core college technology courses around a topic involving several disciplines and instructors. This integrative approach could be particularly helpful at the introductory or capstone level in demonstrating the importance and application of the convergence of technology. Continuing education may also play an important role in updating the working professional on new technologies and applications.

Advances in software and internet applications can play an important role in the success of a manufacturing organization. Software to support lean concepts that required a major investment in the past is now available incrementally in much more affordable packages. Internet-enabled software is also now available in specialized segments allowing cash strapped companies to purchase only what they presently need as they begin to implement a lean or continuous improvement program (Peake 2003). Knowledge of these tools along with the training and skills needed to use them can provide companies with a significant competitive edge.

Educational Needs of Manufacturing Professionals

To better understand the current and future educational requirements for manufacturing technology programs, a survey was administered to a wide range of manufacturing professionals working in a variety of manufacturing and process-related industries in the United States. The survey was e-mailed to approximately 6000 individuals, with 261 responding. The addresses were supplied by the Society of Manufacturing Engineers (SME) and were selected from a database that consisted of both members and participants in SME events. This database generally represents manufacturing professionals who often have a technical component associated with their jobs.

The survey initially addressed the role of the respondents by asking them to identify their current job function. Table 1 summarizes this data.

Table 1. Job Function Data From Survey

What best describes your job function?	
Engineer	64.0%
Management	21.1%
Technologist/Technician	5.0%
Foreman/Group Leader/Supervisor	3.1%
Not listed	2.3%
Owner/CEO/Executive	1.9%
Machinist/Machine operator/Other Skilled Trades	1.5%
Other	0.8%

This information indicates that most of the respondents are placed in an engineering role while only 5% consider themselves technologists. At first glance this seems to indicate that manufacturing professionals with a technology education have a very limited presence in industry. However, a closer look at the data reveals a much different conclusion. Participants were also asked to list their highest level of education: 27% indicated either a two or four year technology related degree and 26% indicated a 4-year engineering degree. Only 5% of participants responded as being in technologist positions, indicating that most of the respondents with technology degrees have actually been working in engineering related positions. The data also indicates that the pool of manufacturing professionals is roughly made up of equal numbers of engineering and technology educated individuals. This clearly reflects the major contribution and position of technology educated graduates.

The survey also asked participants what technologies they were currently required to use. Lean process improvement tools, CAD/CAM, flexible manufacturing, integrated manufacturing systems, Six Sigma and automation were the top answers. These skills all relate to better efficiency and process improvement and have been utilized in industry for some time. Technology and engineering students are typically exposed to CAD and automation topics, but often see less exposure to soft skills such as lean concepts and Six Sigma methods. These process improvement skills are often taught through employee training initiatives on the job or through seminars and special classes. The survey reports that lean process improvement tools are the most commonly required skill in today's industrial environment.

The survey addressed the issue of future trends. Participants were asked to indicate the tools and technologies they believed would increase in importance in the future. Again, lean process improvement tools led the responses. Six Sigma, integrated manufacturing, sensor technology, flexible manufacturing and CAD were also prominent answers. The results for this question are shown in Table 2.

Table 2. Tools and Technologies Expected to Increase Over the Next 10 Years

In your opinion, which technologies do you see increasing in importance over the next ten years?	
Lean Process Improvement Tools	10.6%
Six Sigma	8.6%
Integrated Manufacturing Systems	8.5%
Sensor Technology, Vision Systems, etc.	8.5%
Flexible Manufacturing Systems	8.4%
CAD, CAE, CAPP, or CAM	8.2%
Advanced Inspection Technologies	7.4%
Automated Material Handling	7.1%
Expert Systems, Artificial Intelligence	7.1%
Simulation	6.7%
Laser Applications	6.4%
Design of Experiments	5.1%
Composite Materials	4.0%
Other	3.3%

Continuing Education Needs

Recognizing that the rate of change in technical knowledge is significant and that manufacturing professionals often need to update their education after they have entered their careers, the survey also sought to gain information with regard to continuing education. The participants were asked to identify areas of training or continuing education that are important in today's industrial environment and what areas are expected to be important over the next ten years. The results for this question are listed in Table 3.

Table 3. Continuing Education Requirements

What areas of continuing education or training are important to the manufacturing professional in today's environment and over the next 10 years?	Today	10 yrs.
Lean Manufacturing	15.4%	16.2%
New Processes or Technologies	15.2%	16.6%
CAD or Modeling	12.2%	10.9%
Six Sigma	12.0%	11.7%
Statistical Analysis	10.4%	9.6%
New Materials	9.9%	11.4%
Quality Management	9.4%	9.7%
Leadership or Supervision	9.1%	8.5%
Facilitator/Train the Trainer	6.5%	6.4%

The data indicate that lean manufacturing concepts are a major factor in continuing education now and are expected to also be important in the future. Process and efficiency improvement efforts typically include a variety of tools including lean manufacturing, Six Sigma, and statistical analysis. Summing these three results from the survey reveals that about 38% identify process and efficiency improvement methods as an important area for continuing education both now and 10 years into the future. New technologies and materials also rank high in this survey question: 15.2% of respondents indicate new processes and technologies and 9.9% indicate new materials as currently important areas for continuing education. The survey also indicates a slight upward trend in these areas as they relate to continuing education over the next 10 years.

Topics where employees lack exposure or depth of knowledge even after their formal education can be addressed through continuing education. Some areas requiring additional training may have developed after individuals finished college such as new materials, new methods, and continuous improvement tools including lean manufacturing and Six Sigma. In these situations employers may develop an in-house training mechanism or send employees to specialized training elsewhere. Another possibility is to fund additional formal education such as completing a two- or four-year degree or even completing a degree on-line. Training and assisting with formal education are expensive activities for employers. They are willing to absorb these expenses realizing that an even bigger reward will be realized through improved performance and efficiency. Continuing education activities are a major factor now and are expected to remain so in the future. The survey addresses this issue by asking how much time employers should devote to training manufacturing professionals over the next ten years. The response to this question is summarized in Table 4.

Table 4. Quantity of Training Required Over the Next 10 Years

In your opinion, over the next 10 years, the amount of time devoted to training for a manufacturing engineer/technologists will:	
Increase dramatically	15.7%
Increase somewhat	36.0%
Stay about the same	33.3%
Decrease somewhat	8.4%
Decrease dramatically	4.6%

The survey indicates that about 52% of respondents predict that time spent on continuing education will increase over the next 10 years and only 13% predict it will decrease. This result demonstrates the emphasis companies place on continuing education now and the expectation that it will continue into the future.

Conclusions

More than ever, the rapidly changing global manufacturing environment places demands on manufacturing professionals. Advances in technology and ever-increasing competition require expertise in business, efficiency, and technology. With a significant number of manufacturing professionals being supplied by two- and four-year technology programs, these institutions play a significant role in educating future industry leaders to meet the challenges of modern industry.

The survey described in this paper identifies critical skills and knowledge needed by manufacturing professionals. Lean process improvement tools and Six Sigma methods top the list as major areas of importance both now and in the future. Based on this information, technology programs should emphasize these topics wherever possible in their curricula. Production management and quality courses often include components of these continuous improvement methods; however, additional and more in-depth coverage should be considered. Based on the level of interest shown concerning these topics, perhaps an additional course or courses should be offered that focus primarily on continuous improvement and efficiency methods.

New processes and materials were also indicated as a major concern both now and over the next 10 years. Including these topics in technology curricula is critical in preparing manufacturing professionals to enter the workplace. Adding an emerging technologies component to traditional manufacturing materials and processes courses could help instill this knowledge. Based on the trend toward converging technologies, creating a multidisciplinary capstone course that includes several areas such as technology, physics, materials, and biology may prove beneficial.

Continuing education will also play an important role in preparing manufacturing professionals for the changing demands of industry. Lean manufacturing, new processes or technologies, CAD, and Six Sigma topped the list as needed areas for continuing education. Technology programs can help meet this need by offering completion degrees, and certificate programs that emphasize these skills. In addition, internet courses that address continuous improvement and new technologies can be a critical resource for those working full-time and unable to attend live courses.

A significant number of manufacturing professionals are being supplied by two- and four-year technology programs. These institutions play a key role in preparing manufacturing professionals for current and future challenges. By adjusting the curricula to further emphasize continuous improvement skills and new technologies, these programs will provide a major resource for competing in the global manufacturing economy.

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Gauge R&R: An Effective Methodology for Determining the Adequacy of a New Measurement System for Micron-level Metrology

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Introduction

To compete in a global marketplace, manufacturers are increasingly turning to advanced manufacturing techniques to increase productivity and gain a competitive advantage. This trend requires management to be able to make decisions based on proper quantitative analysis of data. In the manufacturing process, control of variation with an increasingly high degree of precision demands an improved degree of measurement effectiveness. Measurement Systems Analysis (MSA) is a collection of statistical methods (which includes the Gauge Repeatability and Reproducibility study) for the analysis of measurement system capability (Automotive Industry Action Group [AIAG], 2002; Smith, McCrary, & Callahan, 2007).

Accumold , a highly specialized, high-tech manufacturer of injection molded lead-frame and small- and micro-scale plastic parts, has realized a need for an improved measurement system as a result of customer demands for ever-smaller part features with increasingly tight tolerances. Specifically, Accumold must meet a new customer demand for a critical-to-function feature of a difference of 10 ± 2 microns (394 ± 79 millionths of an inch) between two adjacent step heights. This particular customer also demanded that a Gauge Repeatability and Reproducibility study be performed and the result of the accompanying precision to tolerance ratio (P/T) exhibit less than 30% error, per standard MSA techniques (AIAG, 2002; Smith, McCrary, & Callahan, 2007).

For illustration's sake, let us first consider the requirement of 10 ± 2 μm. The thickness of a human hair is approximately 90 μm; therefore, not only is this specification asking Accumold to injection mold features into plastic parts which are 1/9th the thickness of a human hair, they are also demanding that Accumold maintain total tolerance on that feature equivalent to the thickness of one sliver of a human hair which has been split along its length 22 times!

Review of Literature

Measurement Systems Analysis

Deming once stated that knowledge of variation was one of the most powerful tools a company could apply in the quest for improvement (Joiner & Gaudard, 1990). Because variation is inherent in a process and is unpredictable, strategies to minimize variation are common in manufacturing (McGhee, 1985; MacKay & Steiner, 1997). Understanding the individual components of process variation (measurement system variation, in particular) is critical to this process because the reduction of process variation requires the ability to discriminate between process variation and measurement variation (Ishikawa, 1982; Juran, 1990; Persijn & Nuland, 1996). Measurement Systems Analysis (MSA) is based on the philosophy that measurement error masks true process capability; therefore, it is performed prior to any process improvement activities in order to quantify and minimize the measurement error (Harry & Lawson, 1992). Indeed, popular quality improvement programs such as Six Sigma utilize managing for measurement as a major analysis activity (Antony, Kumar, & Tiwari, 2005; Goffnett, 2004; Harry & Lawson, 1992; Horel, 1998; Hu, Barth, & Sears 2005; Pan, 2006). Whereas Balano's (1994) survey of quality professionals determined that containing measurement variation was the primary responsibility of quality managers in the manufacturing environment, there appears to be a gap between the knowledge and practice of measurement studies and the actual deployment of measurement improvement techniques in organizations with formal quality management programs (Smith, McCrary, & Callahan, 2007).

AIAG (2002, p. 5) describes a measurement system as "a collection of instruments or gauges, standards, operations, methods, fixtures, software, personnel, environment, and assumptions used to quantify a unit of measure or the complete process used to obtain measurements". MSA quantifies measurement error through the examination of multiple sources of variation in a process, including the variation resulting from the measurement system, from the operators, and from the parts themselves (AIAG, 2002, 2005). The components of measurement system variation include bias, stability, repeatability, and reproducibility, where bias is the difference between a measurement and a reference value; stability quantifies a change in bias over time; repeatability is the variation of measurements due to instrument error (also known as precision); and reproducibility is the variability resulting from external sources such as operators and their unique techniques, setups, and environmental fluctuations over time (AIAG 2002; Engel & De Vries, 1997; Smith, McCrary, & Callahan, 2007). A Gauge Repeatability & Reproducibility (GR&R) study estimates the repeatability and reproducibility components of measurement system variation with the primary objective of assessing whether the gauge is appropriate for the intended application (AIAG, 2002; Burdick, Park, & Montgomery, 2005). Assessing the suitability of the examined measurement systems using the GR&R study was the primary goal of this paper.

Gauge Repeatability & Reproducibility

GR&R is a well-covered topic in the literature (AIAG, 2002; Burdick, Borror, & Montgomery, 2003; Dolezal, Burdick, & Birch, 1998; Goffnet, 2004; Montgomery & Runger, 1993a, 1993b; Pan, 2004, 2006; Persijn & Nuland, 1996; Smith, McCrary, & Callahan, 2007; Vardeman & Job, 1999). Though a detailed description of GR&R is beyond the scope of this paper, a brief review of the application is appropriate.

Repeatability $\left(\hat{\sigma}_{repeatability}\right)$ can be determined by measuring a part several times, effectively quantifying the variability in a measurement system resulting from the gauge itself (AIAG, 2002; Smith, McCrary, & Callahan, 2007; Pan, 2006). This can also be thought of as "within operator" variability (Smith, McCrary, & Callahan, 2007).

Reproducibility $\left(\hat{\sigma}_{reproducibility}\right.$ is determined from the variability created by several operators measuring a part several times each, effectively quantifying the variation in a measurement system resulting from the operators of the gauge and environmental factors such as time (AIAG, 2002; Burdick et. al, 2003; Pan, 2006; Tsai, 1989). This can also be thought of as "between operator" variation (Smith, McCrary, & Callahan, 2007; Pan, 2004).

"Total Gauge R&R" ($\hat{\sigma}_{R\&R}$) is the estimate of the combined estimated variation from repeatability and reproducibility (AIAG, 2002).

Total measurement system variation is the sum of the variation of Total Gauge R&R ($\hat{\sigma}^2_{R\&R}$) with part-to-part variation ($\hat{\sigma}^2_{part}$) : the variability of the individual pieces) (AIAG, 2002; Pan 2006).

Statement of the Problem

As a result of customer demands for ever-smaller injection molded plastic part features with increasingly tight tolerances, Accumold(r)'s pre-study metrology capabilities had been exceeded, creating the need for a more capable measurement system.

Purposes

This study served two purposes: first, to identify a new measurement system capable of providing Accumold with three axes of repeatable, reliable, automatable measurements of precision, injection molded plastic parts with engineering tolerances as tight as ± 2 µm; and second, to illustrate the practicality of the GR&R study as a decision making tool for Industrial Technology students and practitioners.

Methodology

The main statistical analysis tool utilized in this study, to determine the suitability of a measurement system for measuring micro-scale features on injection molded plastic parts with engineering tolerances as tight as ± 2 µm, was the ANOVA-based GR&R study as provided by the "Gage R&R study (crossed)" module in Minitab release 13.32 (2000).

Ten parts, three operators, and three trials are typical study designs for both ANOVA and average and range methods (AIAG 2002), but Burdick et al. (2005) state that traditional designs are not sufficient to discriminate between good and bad parts and recommend a minimum of six operators. Pan (2004) states that the total number of measurements should be determined first based upon cost and subsequently, by determining the combination of operator and replicates. Time constraints mandated smaller studies involving fewer operators than recommended by Burdick et al. (2005) for the tests discussed here.

Precision to tolerance ratio or P/T ratio (also known as Gauge Capability Ratio, study variance to tolerance ratio, et al.) compares the precision of the measurement system to the total tolerance on the dimension in question (Minitab performs this computation and places the result in the "Total Gage R&R" row under the "% Tolerance" column). It can be used to determine the suitability of a measurement system for the application (Minitab, 2000; Pan, 2006). According to AIAG (2002), if the P/T is under 10%, the measurement system is acceptable; if between 10% and 30%, a measurement system "may be acceptable based upon the importance of application" and the associated expenses (p. 77); and if over 30%, the measurement system is considered unacceptable.

Based on expected customer demands, Accumold was requiring an ANOVA-based GR&R study with a resulting P/T less than 30% and a minimum of two distinct categories (see Findings section) in order to consider a measurement system suitable for purchase. Provided by Minitab (2000) and recommended by AIAG (2002), the "number of distinct categories" (also known as classification ratio), is computed by dividing $\hat{\sigma}_{part}$ by $\hat{\sigma}_{R\&R}$, multiplying by 1.41, and rounding down to the nearest whole number (AIAG, 2002; Wheeler & Lyday, 1989). AIAG (2002) states that if the measurement system resolves less than two distinct categories, the data is all noise – the system is of no value; two distinct categories divide the data into high and low groups, essentially reducing the variable data to attribute data; and the measurement system is adequate if the number of distinct categories is greater than or equal to five (AIAG, 2002, p. 117).

Four measurement systems from three vendors were deemed potential candidates for satisfying Accumold(r)'s requirements and were tested. Two of the tested systems were immediately discarded from the pool of possible candidates after failing to meet the minimum specifications of this study, leaving the two multi-sensor systems discussed hereafter as possibilities.

Multi-sensor Measurement Systems
The Multi-sensor systems were essentially live video microscopes with three powered axes, zoom lens, and available laser, white light confocal, and contact measurement probes. The laser probe was used for the critical Z-axis measurements and X-Y plane measurements (the width between two through-holes) were gathered with the camera system.

Two separate GR&R studies were conducted on two different multi-sensor base platforms, both using the identical laser probe (the design of the probe allows for its removal and installation on any machine equipped for its use) – these will be called "Multi-sensor A" and "Multi-sensor B". The two base systems use the same software and differ in terms of appearance and degree of precision (the second system is more accurate and repeatable than the first according to sales literature), but they were functionally identical. This is discussed in full detail in the Findings section.

Findings

Multi-sensor A
This test was conducted using 10 parts, two operators, and two trials (40 measurements in total – an abbreviated design due to time constraints). The P/T for this study was 14.65%, less than half of the 30% maximum (see Table 1); however, the system was only able to resolve one distinct category, which is to be interpreted as the system having no value for measuring these parts – but was this the really the case? The sample used for this test was comprised of 10 parts gathered at one time from a single cavity of a four cavity mold; since Accumold is confident in the repeatability of their processes (for example, the lead author measured a 20-piece, random sample of a different product taken from a single lot with the customer-supplied gauge pin measurement system and found zero variation in the feature at the micron scale), it was possible that these parts were actually too similar for the system to differentiate between them.

Table 1. Gage R&R for Multi-sensor A, Z-height

Source	StdDev (SD)	Study Var (5.15*SD)	% Study Var (%SV)	P/T (SV/Toler)
Total Gage R&R	1.14E-04	5.86E-04	88.75	14.65
Repeatability	7.44E-05	3.83E-04	58	9.57
Reproducibility	8.61E-05	4.44E-04	67.18	11.09
Operator[a]	0.00E+00	0.00E+00	0	0
Operator*Part	8.61E-05	4.44E-04	67.18	11.09
Part-To-Part	5.91E-05	3.04E-04	46.08	7.61
Total Variation	1.28E-04	6.60E-04	100	16.51

Number of Distinct Categories = 1

[a]The metrology software completely eliminated variation due to the three operators.

Multi-sensor B

To clear up the ambiguity of the first Multi-sensor test, Accumold gathered a second sample comprised of 10 parts gathered from each of the four mold cavities across three months of production "retains" to capture a potentially broader range of the process variability (AIAG, 2002; Burdick et al., 2003; Pan, 2004, 2006) and conducted a second GR&R study with the typical study design (10 parts, three operators, and three trials – 90 measurements in total). After much discussion, it was also decided that two of the 10 parts would come from a prior revision of the mold where the nominal difference between step heights was 14 μm; the justification for this was that their inclusion in the sample would provide upfront certainty that there were indeed two distinct categories of parts; therefore, another result of one distinct category could be accepted as accurate and the system could be deemed unsuitable. Since it was also determined (based on sales literature) that the Multi-sensor A system was a step down from the current video measurement system capabilities, the manufacturer's highest-performing base system (again, with the same laser probe) was used.

The results of the second test of the step height feature (see Table 2) revealed a P/T of 10.47% (approximately 4% lower [a 29% improvement] than Multi-sensor A). The majority of this difference is most likely attributable to the larger data set since both systems used the identical laser probe. Seventy-four distinct categories were resolved, which can be interpreted as highly capable of differentiating parts from each other, and is the result of having $\hat{\sigma}_{part}$ two orders of magnitude larger than $\hat{\sigma}_{R\&R}$. Since AIAG (2002) states that a measurement system must resolve only five distinct categories to be considered acceptable, these results indicate that this system is suitable for use in measuring this critical feature.

Table 2. Gage R&R for Multi-sensor B, Z-height (full sample)

Source	StdDev (SD)	Study Var (5.15*SD)	% Study Var (%SV)	P/T (SV/Toler)
Total Gage R&R	8.13E-05	4.19E-04	1.91	**10.47**
Repeatability	5.95E-05	3.06E-04	1.39	7.66
Reproducibility	5.55E-05	2.86E-04	1.3	7.14
Operator[a]	0.00E+00	0.00E+00	0	0
Operator*Part	5.55E-05	2.86E-04	1.3	7.14
Part-To-Part	4.27E-03	2.20E-02	99.98	549.51
Total Variation	4.27E-03	2.20E-02	100	549.61

Number of Distinct Categories = 74

[a]The metrology software completely eliminated variation due to the three operators.

Since there was some doubt concerning the validity of including two intentionally different parts in the sample, they were removed from the model and the analysis was repeated on the remaining eight parts from the same mold revision (see Table 3). The P/T increased slightly to 11.40%, which is likely attributable to the smaller sample. Twelve distinct categories were resolved – while this is certainly a much smaller value than when using the full sample, it is still more than double the AIAG-specified value of five.

Table 3. Gage R&R for Multi-sensor B, Z-height (adjusted sample)

Source	StdDev (SD)	Study Var (5.15*SD)	% Study Var (%SV)	P/T (SV/Toler)
Total Gage R&R	8.86E-05	4.56E-04	12.01	**11.4**
Repeatability	6.34E-05	3.27E-04	8.6	8.17
Reproducibility	6.18E-05	3.18E-04	8.38	7.96
Operator[a]	0.00E+00	0.00E+00	0	0
Operator*Part	6.18E-05	3.18E-04	8.38	7.96
Part-To-Part	7.32E-04	3.77E-03	99.28	94.25
Total Variation	7.37E-04	3.80E-03	100	94.94

Number of Distinct Categories = 12

[a]The metrology software completely eliminated variation due to the three operators.

For the width between the centers of the through-holes on either end of the part (again, measured using the camera system – not the laser probe) for all 10 parts, the P/T was revealed to be 24.89% (marginally below the 30% maximum) and 16 distinct categories were resolved (see Table 4). With the two "old revision" parts discarded, the P/T increased slightly to 26.31% and the number of distinct categories decreased slightly to 12 (refer to Table 5). Although these results are approaching the cutoff mark at 30%, Accumold believes that these values will improve with additional testing and options (the test system was not equipped with the high-resolution, monochromatic optics, which Accumold intends to purchase).

Table 4. Gage R&R for Multi-sensor B, Width (full sample)

Source	StdDev (SD)	Study Var (5.15*SD)	% Study Var (%SV)	P/T (SV/Toler)
Total Gage R&R	1.93E-04	9.96E-04	8.93	**24.89**
Repeatability	1.52E-04	7.82E-04	7.02	19.55
Reproducibility	1.20E-04	6.16E-04	5.53	15.41
Operator	6.49E-05	3.34E-04	3	8.35
Operator*Part	1.01E-04	5.18E-04	4.64	12.94
Part-To-Part	2.16E-03	1.11E-02	99.6	277.59
Total Variation	2.16E-03	1.11E-02	100	278.71

Number of Distinct Categories = 16

Table 5. Gage R&R for Multi-sensor B, Width (adjusted sample)

Source	StdDev (SD)	Study Var (5.15*SD)	% Study Var (%SV)	P/T (SV/Toler)
Total Gage R&R	2.04E-04	1.05E-03	11.38	**26.31**
Repeatability	1.60E-04	8.25E-04	8.93	20.63
Reproducibility	1.27E-04	6.53E-04	7.06	16.33
Operator	8.60E-05	4.43E-04	4.79	11.08
Operator*Part	9.32E-05	4.80E-04	5.19	12
Part-To-Part	1.78E-03	9.19E-03	99.35	229.66
Total Variation	1.80E-03	9.25E-03	100	231.16

Number of Distinct Categories = 12

Implications

The outcomes of this study have direct implications for Accumold and more general implications for the field of Industrial Technology. The immediate implications of this research are the improved measurement capabilities for Accumold(r). The results of this research have successfully identified a new measurement system that will allow Accumold to ensure measurement validity on injection molded plastic part features with engineering tolerances as tight as ± 2 μm.

In broader terms, this research demonstrates the practicality of the GR&R study as a decision-making tool; in this instance, to aid management in making a sound decision in the purchase of a new measurement system with a prescribed degree of precision. This statistical tool can be applied to any measurement system from the most advanced multi-sensor system to the simplest measuring stick. It can be used to establish a baseline of precision of a given process's measurement system, or to quantify a suspected inadequacy in a measurement system so that the process of identifying a new measurement procedure or system can begin.

Recommendations and Discussion

The practitioners' knowledge of the appropriate MSA techniques allowed Accumold to learn about the appropriateness of several highly technical measurement systems for their unique needs in a novel, scientific way. Callahan, Amos, and Strong (2004) indicated the importance of industrial technology professionals possessing knowledge and skills in metrology and MSA techniques, and this paper corroborates that assertion – as the complexity of manufacturing processes continues to grow, individuals who can solve problems and make decisions based on quantitative methods such as MSA will become increasingly valuable to such organizations as the metrological demands of their customers change (Smith, McCrary, & Callahan, 2007).

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Manufacturing Engineer-Manufacturing Technologist, Is There a Difference?

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Introduction and Background

In the world of manufacturing, adopting reliable and appropriate technologies, continuously improving manufacturing practices, and exceeding the competition in both quality and cost, has become the essential to survival. Leading this challenge is the Manufacturing Engineer. Over the past several years, both schools of engineering and technology have developed facilities and curriculum to prepare individuals to meet this challenge. Professional organizations such as the Society of Manufacturing Engineers have noticed from their membership rosters that both Manufacturing Engineers (ME: those educated in an engineering school) and Manufacturing Technologists (MT: those educated in a technology school) often have similar responsibilities, utilize the same technologies, and carry the same title in the workplace.

Purpose of Research

Because of these similarities, this research team became interested in answering the question: ME or MT, is there a difference? To this end the following objectives were established:

1. Determine and analyze the demographics of project participants,
2. Compare and contrast the roles and responsibilities,
3. Compare and contrast the desired technologies utilized,
4. Develop implications for future curriculum revisions decisions.

Review of the Literature

A review of the literature reveals that the above question and objectives are similar to those that have been discussed by others. Murray (1990) considered the demographics of U.S. engineers by noting the decreased number of engineering degrees granted. He suggested that one solution was to increase the use of technologists when job responsibilities overlapped with engineers. Underlying this suggestion is the question of what is the difference between technologist and engineer. Traditionally, engineers are expected to have more interaction with customers than is expected of technologists (Sessions, 1991). However, what might have been traditional roles assigned to either the engineer or technologist is now being reconsidered. Singh (1995) suggested that engineers should champion advanced technology. Nambisan (2005) challenged U.S. technologists to develop mind-sets capable of producing future innovation. The above papers indicate that roles, responsibilities, and technological needs often overlap among engineers and technologists. This overlap has future curricular implications. Dowling (2006) described an education program that enabled technologists to use their workplace experience to become professional engineers. Analysis of the data in this paper indicates that both engineering and technology schools should evaluate curricular content to assure that students are skilled in the technologies that will be needed in the workplace.

Research Methodology

The research project was conducted utilizing an online survey tool. The Society of Manufacturing Engineers provided the e-mail addresses and dispersion service. Approximately 6000 e-mail invitations were distributed. The addresses selected for the survey were picked at random from a larger data base composed of both members of the society and any individual who had registered to attend SME sponsored events, such as trade shows and workshops. The survey resulted in 261 participants or approximately a 4.5% response rate.

The actual survey had 30 total questions including those to determine participant demographics and those focused on roles, responsibilities, and desired technologies. In the survey there was an attempt to distinguish between the ME and MT. The following is an excerpt from the questionnaire.

"…please consider a ME to be anyone responsible for the design of the manufacturing process. This person utilizes the theoretical body of knowledge and core principles of engineering. Please consider a MT to be anyone working in the operation and improvement of the manufacturing process. This person applies the technology based on rules and directions derived from the core principles of engineering."

Data Analysis and Research Findings

Participant Demographics

Researchers have deemed it necessary to determine certain demographic information of the participants. They have included the educational level and emphasis area, time of service in a manufacturing related job, age of the participant, and size of the company.

Participant Education	Percent
4-year (Bachelor's) engineering	25.7
2-year with technical focus	17.6
4-year (Bachelor's) manufacturing technology focus	9.6
Advanced degree manufacturing	9.2
Advanced degree other	9.2
Advanced degree applied engineering focus	7.3
Other formal training	6.9
4-year (Bachelor's) industrial technology focus	6.1
4-year (Bachelor's) other	4.6
No technical school or college training	2.3
Advanced degree theoretical engineering	1.5

Table 1. Participant Education

Relative to education level and emphasis area, Table 1 provides a summary of data analyzed. Of particular interest is that approximately 34.5% of the respondents had an engineering-focused educational background, 42.5% had a technology or manufacturing-focused educational background, and the remaining 23% had an unrelated educational background.

In addition to educational levels, researchers have been interested in participant age and years of experience within the manufacturing community. Over 83% of participants reported greater than 10 years experience in manufacturing, with 56% of those in the 20 or more years of service category. In addition, 71.4% of participants were 40+ years old. Obviously, the participant group collectively represents a group of individuals that, by both age and experience, are in a unique position to provide knowledgeable input into the question raised by the survey.

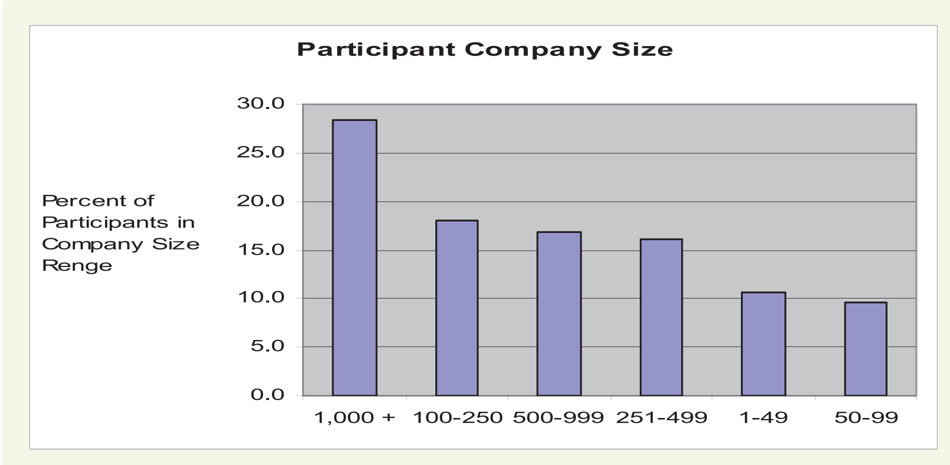

Figure 1. Participant Company Size

Researchers have been also interested in the types and sizes of companies the participant group represented. Results of data analysis on company size are presented in Figure 1. While companies with 1000 employees or greater represents 28.4% of the participant group, there is still a reasonable distribution of participants in the various size ranges present in the survey. Results on the type of company are presented in Figure 2. Aerospace/aircraft tops the list by company type at 19.5% of participants; fabricated metal products and automotive/truck, other manufacturing is at 16.9% and 15.7%, respectively, thus making up 52.1% of the participant group. Although not an exhaustive list of company types, the data does suggest that participants represent a broad range of industries.

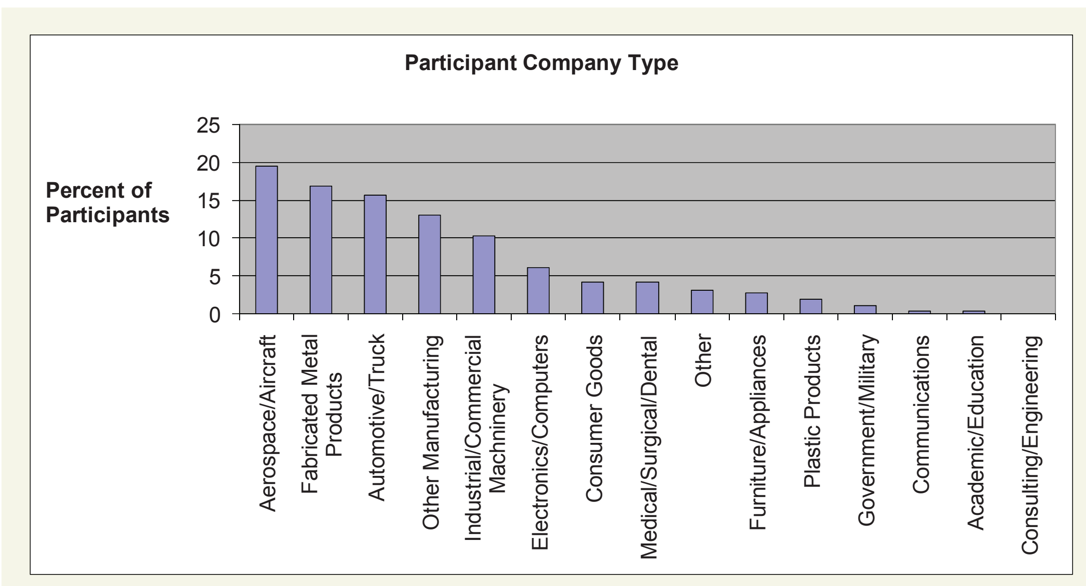

Figure 2. Participant Company Type

Perhaps one answer to the question, "Is there a difference?" is revealed by what job function this educationally diverse group reports. While only 34.5% of the participants report an engineering-based education, 64% report engineering as their job function. Of the remaining participants, 21.1% report management as their job function. The survey broadly defined management as operations, materials, purchasing, supply chain or quality. Therefore, it appears that the difference is not solely based on formal education, but that it strongly relies on the individual's job function.

Roles and Responsibilities

Recall that 42.5% of the participants report that their educational background was technology-based. Findings from this project suggest that only 5% of those individuals see their current job function as a technologist, and 64% report a job function of engineer. It appears from the following analysis on roles and responsibilities that this demographic finding probably had the greatest influence on the following survey results:

In your opinion, choose the most important areas where a ME/MT would be regularly involved and responsible	Average of 2 groups	ME	MT	Diff
Troubleshooting production problems	10.7%	8.6%	12.9%	-4.3%
Developing manufacing methods, processes and systems	9.7%	9.3%	10.1%	-0.8%
Facilitating process improvement methodoligies on the factory floor (Lean, TPS, Six Sigma, Etc.)	9.0%	8.0%	10.0%	-2.0%
Researching new methods/processes for improving future manufacturing performance.	7.7%	8.4%	7.1%	1.2%
Selecting or designing equipment and tooling for manufacturing	7.6%	8.3%	6.9%	1.3%
Factory floor layout and design	7.6%	7.7%	7.5%	0.2%
N/C; CNC machine programming	6.7%	4.9%	8.5%	-3.5%
Quality assurance/quality control	5.9%	5.4%	6.4%	-1.0%
Interfacing with vendors/purchasing	5.6%	6.2%	5.0%	1.2%
Maintaining equipment and facilities	5.2%	3.8%	6.6%	-2.9%
Education and training	4.7%	4.7%	4.6%	0.1%
Preparing capital spending plans and business-case justifications.	4.3%	6.1%	2.4%	3.7%
Designing new products and product features	3.4%	4.4%	2.4%	1.9%
Financial analysis	2.7%	4.0%	1.3%	2.6%
Supervising production operations	2.6%	2.4%	2.8%	-0.4%
Interfacing directly with customers	2.5%	3.2%	1.7%	1.5%
Production scheduling/inventory control	2.1%	1.7%	2.4%	-0.7%
Supervise professional staff	1.9%	2.8%	1.0%	1.8%
Other	0.3%	0.3%	0.2%	0.1%

Table 2. Roles and Responsibilities

In an attempt to answer the question: ME or MT, is there a difference? ; the research team has focused on a better understanding of the participant's roles and responsibilities. Researchers have been especially interested in discovering those activities that the ME and/or the MT would be regularly involved and specifically, to compare and contrast these activities as were participated in by the two groups. Table 2 presents both a summary of questions and the data analysis that resulted. Participants were allowed to select multiple activities, and thus the information for each question in Table 2 represents the percent of total responses. Based on an average between the ME and MT; trouble shooting, developing new manufacturing methods, and facilitating process improvement methodologies on the shop floor rank highest in importance; while supervising professional staff, production scheduling and control, and interfacing with the customer rank lowest. Now, giving consideration to the objective of compare and contrast, it is surprising that across the 19 different activity choices, respondents show an average difference of only 1.7%, with only 6 of the 19 being greater than 2%. Although differences are minimal, the ME is more likely than the MT to prepare capital spending plans, complete financial analysis, and design new products and product features. On the other hand, the MT is more likely to trouble shoot production problems, do N/C or CNC machine programming, and maintain facilities and equipment.

Desired Skills and Technologies

Similar to roles and responsibilities, researchers have sought information relative to the technologies deemed important for use by the ME and MT. Table 3 provides the question presented, the various choices, and results of data analysis. Of those technologies listed in the survey, respondents rank lean process improvement tools, CAD, CAE, CAPP or Cam, and flexible manufacturing systems highest; while bio-tech, manufacturing in space, and composite materials rank lowest.

Even a smaller difference between ME and MT is noticed. Overall, a 0.8% difference is reported, and unlike the roles and responsibility data, 15 of the 15 technologies listed are within a 2% difference between ME and MT. The ME is more likely to use design of experiments, composite materials, and simulation than the MT. The MT is more likely to use lean process improvement tools, sensory technology, and flexible manufacturing systems.

In your opinion, what technologies are ME/MT required to use in today's environment?	Average of 2 groups	ME	MT	Diff
Lean Process Improvement Tools	10.7%	9.9%	11.5%	-1.6%
CAD, CAE, CAPP, or CAM	10.4%	10.1%	10.8%	-0.7%
Flexible manufacturing systems	9.4%	9.0%	9.9%	-0.9%
Integrated manufacturing systems	9.1%	9.1%	9.1%	0.0%
Six Sigma	8.6%	8.5%	8.7%	-0.2%
Sensor technology, such as machine vision, adaptive control, and voice recognition	8.1%	7.4%	8.7%	-1.4%
Automated material handling	8.0%	7.8%	8.2%	-0.4%
Advanced inspection technologies, including on-machine inspection and clean room technology	7.7%	7.6%	7.8%	-0.2%
Laser applications, including welding/soldering, heat-treating and inspection	6.7%	7.0%	6.5%	0.5%
Design of Experiments	6.2%	6.9%	5.4%	1.4%
Simulation	5.6%	6.0%	5.2%	0.8%
Expert systems, artificial intelligence and networking	4.6%	4.9%	4.3%	0.6%
Composite materials	3.0%	3.7%	2.3%	1.5%
Manufacturing in space	1.0%	1.2%	0.7%	0.4%
Bio-technology	0.6%	0.8%	0.4%	0.4%
None of the above.	0.2%	0.1%	0.4%	-0.3%

Table 3. Desired Technologies

Curricular Implications

Going back to the "desired technologies data," notice that lean process improvement tools rank highest for the MT, with CAD, CAE, CAPP, or Cam ranking second, and integrated manufacturing systems ranking third. It is however important to recognize that of the sixteen choices participants could choose from, eleven are in a fairly tight range between 5% and 12%. It is interesting to observe that the same technologies that rank in the top three for MT are also ranked in the top three for ME. The only difference is that the order of the first two is reversed for the ME making CAD, CAE, CAPP or CAM their highest priority.

It is also important to consider the job functions reported by this participant group as additional input into curricular implications. Ranking highest, based on the average of ME and MT, are troubleshooting production problems, developing manufacturing methods, processes and systems, and facilitating process improvement methodologies on the shop floor. While not being ranked as high, functions such as preparing capital spending plans, business case justifications, education and training, and interfacing with both customers and suppliers are still important.

While this research project has not investigated curricular content in schools of engineering and technology to discover potential gaps, this data does provide information relevant to such an effort.

Conclusions and Recommendations

Is There a Difference?

Based on the data analysis provided through this project there appears to be limited differences in what both the ME and MT see as their job function. In addition, technologies utilized are quite similar between the ME and MT. These similarities indicate there is effectively no difference between the ME and MT. This observation can be partly attributed to the fact that over 83% of the participants had ten or more years of experience. Typically, the ME and MT work closely together to achieve the same goals. It is reasonable to expect that over time they learn from each other and share job functions and technologies.

Curricular Implications

This project provides insight into both technologies needed and typical job functions for both the ME and the MT. Schools of engineering and technology should evaluate curricular content to-ensure that students are provided practical skill-based instruction in the desired technologies and prepared to handle the typical job functions explored in this project. To that end, the analysis of the data through ranking of the percent of responses can serve to develop a priority list. For example from Table 3 above, the technologies that were most required by the participants are lean process improvement tools. Obviously, both schools of engineering and technology should place these tools high on their curricular priorities. On the other hand, care must be taken not to eliminate a technology based on its ranking by the participants. From the same table, "Bio-technology" is least required by the participants. However, as indicated in Figure 2, only about 4 % of the participants are from the medical industry; thus this could account for the low ranking.

This research team recognizes that there is a need for further research to quantify the gap that exists between a typical engineering and technology school and the information provided here.

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Reducing Warranty Related Costs by Direct Part Markings of Automotive Parts

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Abtract

This paper describes a project completed at an automobile parts manufacturing facility that deals with the traceability of a part throughout the part's life. The project investigated various Direct Part Marking (DPM) methods for tracing information related to the part. Various DPM methods were tested by exposing the markings to different environmental conditions to ascertain the durability of such markings. Sample products were marked using a rolling stamp, mechanical dot peening, and laser etching, and then subjected to thermal and salt fog exposure. The samples were examined after testing, and all three methods tested had an acceptable readability level. This project also looked at the cost benefits of part traceability that could be captured during quality sorting and warranty return activities. Return on Investment (ROI) was calculated and found to be acceptable to the part manufacturer, thus justifying the DPM for traceability to the current production lines. A single quality or warranty containment event was found to have an immediate ROI through reduced sorting times and fewer parts replaced due to accurate part traceability. Adding part traceability would also reduce future costs, as more customers are developing warranty cost sharing programs.

Introduction

The three automakers, Ford, GM and Daimler-Chrysler, have begun to include warranty cost sharing programs in the service contracts with their suppliers to reduce their cost burden. This will encourage suppliers to improve the quality of their products without increasing their prices. The Federal Government is also getting involved in monitoring vehicle warranty and has implemented the Transportation Recall Enhancement, Accountability and Documentation (TREAD) Act, which was created after the Ford-Firestone tire recall (Albright, 2005). The TREAD Act requires that auto makers periodically provide information from "customer satisfaction campaigns, consumer advisories, recalls, or other activity involving the repair or replacement of motor vehicles or items of motor vehicle equipment" (Transportation Recall, 2000, sec.3.b.3.A.ii).

Companies that supply components to the motor vehicle industry needs to have a permanent marking system to help identify, at a minimum, the specific part number and build date. Some of these products can be easily marked with ink systems that will still be legible at the end of the product's useful life. Others, like exhaust components, require a more permanent method of part marking to withstand the temperature extremes and environmental exposure of today's motor vehicles. Without an engineering standard for part traceability, Company will not be able to identify the products involved in quality quarantines or in warranty campaigns.

The purpose of this project was to initiate and develop a traceability standard for the automotive exhaust components. The objective was to provide traceability for exhaust components and assemblies from the time they are produced until the end of the product's intended lifetime. The main issues for traceability that were investigated in this project included minimum traceability requirements, Direct Part Marking (DPM) application, DPM durability,

Literature Review

Direct Part Marking (DPM) is generally described as "markings applied directly to the surface of a part using intrusive or non-intrusive identification techniques" (ISO/IEC WD24720, 2004, p. 1). Intrusive methods typically alter the surface of the part being marked by removing, displacing or coloring the parent material. Non-intrusive methods typically add material to the surface of the part by adding ink, liquid metal or other media. Either method can provide a means for permanent identification, depending on the material to be marked and the environment in which the part will be exposed.

Marking considerations and benefits

Keifer, quality analyst at Giddings & Lewis, noted that adding the component supplier information on the part helps them "know instantly who made the part and can usually contact the vendor to quickly remedy the quality problem" (Chase, 1999, p.53). Begneaud, the founder of Begneaud Manufacturing, has noticed a "shift to direct marking throughout the automotive industry, especially with suppliers to GM Powertrain and Ford Powertrain divisions" ("Scanning the horizon," 2005, p. 1). Not all the benefits of lifetime part traceability can easily be stated in exact dollars. Albright (2004) states that "General Motors estimated that the cost savings and cost avoidance from Direct Part Marking could be $200 million to $300 million per assembly plant, but there won't be any savings at all without leveraging that traceability across the supply chain" (p. 23). Pryor Marking Technologies believes that part traceability is a high profile issue, "particularly for safety critical and high value parts, permanent Direct Part Marking, can significantly reduce the value of scrap and rework, deter counterfeiting, reduce bogus warranty claims and, in the event of a part failure, aid the analysis of the cause of failure and the identification of other parts that may be susceptible to same failure mode" ("Direct Part Marking", 2002).

John Deere achieved 100% traceability of key components through Direct Part Marking, which allowed them to quickly locate suspect parts, reduce warranty costs and have faster, more accurate evaluation of customer issues ("John Deere Engine Works," 2005). Cummins Engine Company has also implemented a traceability system on their engine blocks that provides seamless traceability of the blocks from the beginning of the transfer line to the final assembly line while recording build information along the way. This information is stored in a database that provides valuable documentation for addressing future issues relative to quality, process or warranty. ("Cummins Engine," 2005).

Marking environment

The engine exhaust components must retain their full functionality for the duration of the vehicle warranty period, which can last up to eight years or 80,000 miles. These components are made from various types of stainless steels. These materials are designed to "stain less", but will corrode when exposed to certain environmental factors, like road salt. The corrosion makes it difficult to retrieve any build information located on the surface of the components. Some vehicles, like pick-up trucks, are often used at construction sites, farms, parks, trails and boat docks that can cause the entire exhaust system to become covered with thick layers of mud, sand and grass. These parts often have to be sand blasted or cleaned with a high-pressure wash system before any information can be retrieved from the exterior of the part. A robust part marking method must be employed to ensure part traceability.

Procedure

This project focuses on the ability to cost effectively produce a durable, human readable string of characters on an exhaust component. The method for direct part marking, surface contour and component design are some of the key variables for this project. First, the various customer minimum requirements were determined by polling the three customer-focused product-engineering groups (six manufacturing engineering managers) at the Company. The identified characters were, auto manufacturer's logo, part number, vendor identification, Julian date code, and the manufacturing facility identifier. The last identifier helps educe the time necessary to develop a corrective action plan in the event of a quality or warranty issue for components built in multiple locations.

The existing processes used for marking of exhaust components were identified by polling the six engineering managers at the six locations in North America. The results are listed in Table 2.

Current DPM method	Application	ArvinMeritor Facility					
		Columbus	Taylor	Spartanburg	Concord	Dexter	Carretera
Dot peen	Converter, pipe	X	X	X		X	X
Paper Label	Mufflers, converters, pipe				X	X	X
Roll Stamp	Pipe	X	X			X	
Press Stamp	Converter, pipe	X	X	X		X	
Emboss	Mufflers	N/A	N/A	X	N/A	X	X

Table 1. List of current DPM methods, applications and their respective facilities

The embossing method is only used in muffler production facilities. Facilities that do not produce mufflers are indicated with an "N/A". Embossing uses a hydraulic or mechanical force press to create impressions on flat sheet metal by sandwiching it between two hardened steel dies: one with a shaped cavity and one with raised characters. The information is changed by replacing individual sets of dies. An example of a part marked in this method is shown in Figure 1.

Figure 1. Example of part with emboss

The roll stamp method uses two pneumatic cylinders: one to apply a downward force on a wheel type stamp while the other pushes the tube out of the machine. This combination of forces causing the stamp to roll and imprint the information along the axis of the cylindrical tube while it is supported on the inside of the tube with another rolling contoured wheel. This method uses a fixed part number and requires the date code information to be updated by changing pie shaped inserts in the stamp. Any part number change would also require a different stamp. An example of this marking is shown in Figure 2.

Figure 2. Example of a roll stamped part

The dot peen method is a mechanical system with computer that controls two positioning motors and a pneumatically driven pin to create impressions in the surface of the part to form the tracing characters. Changes to any part of the marking could be made by altering the program. The date code is automatically updated by the computer's internal clock (Figure 3).

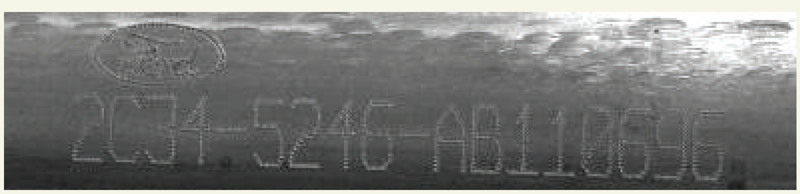

Figure 3. Example of a part with mechanical dot peen marking

Laser engraving uses high power lasers to remove material from the surface of the part through vaporization. Marks produced by this method do not discolor the part surface and would be similar to the existing stamping process as the contrast for reading the markings are created by the irregularity made in the surface finish. The readability of this type of direct part marking is dependent on the depth of the groove produced. The material being marked greatly affects the depth and may require higher power laser systems and longer cycle times to produce an acceptable mark. This would greatly affect the implementation costs and feasibility of this marking type. This marking method was included in this study and samples were obtained from Telesis Industrial Identification/ Traceability Equipment Company.

Each DPM method chosen was used on three samples from each of the following exhaust system components with a common material type of 409 stainless steel: tubing (50.8mm O.D.) and stamped converter. The samples of the existing DPM methods were obtained from the available production equipment or a local equipment vendor. The alternative DPM samples were obtained from equipment vendors. Each sample was marked in the as-produced condition with no additional surface preparation allowed.

Each sample was then subjected to one thermal cycle from room temperature to 590-600°C for 30 minutes in a muffle furnace using 2-4 PSI air circulation. This thermal cycle is the standard Company test for exhaust components to determine the heat resistance of a part mark for traceability. The samples were then subjected to corrosion testing per ASTM B 117 neutral salt fog testing, which is the industry standard for corrosion testing of stainless steel products. The test parameters were as follows:

- Salt spray solution concentration of 5% (NaCl) and specific gravity 1.030
- 48 hours exposure time
- Cabinet temperature of 97° F
- Tower temperature 120° F (atomizing temperature)

Samples were obtained to determine the readability (through visual inspections) of the markings after corrosion and thermal exposure testing. The DPM methods tested were roll stamping, mechanical dot peening and laser etching. The samples were examined three times, 1) prior to testing, 2) after thermal cycling, and 3) after corrosion testing. The readability of the marking methods were rated as excellent, good or poor based on the following criteria

- Excellent – easily read at any angle with low light
- Good – easily read looking directly at the markings in normal light
- Poor – readable but requiring close examination under a direct light source

Results and Discussions

The purpose of this study was to provide a recommendation for a traceability standard for exhaust components of an automobile. The results from the visual inspections are listed in Table 3 and photographs of samples from each examination are shown in Figure A1 through A9.

DPM Method	Readability (Excellent, good, poor)		
	Before testing	After thermal cycle	After salt fog
Pin Stamp/dot peen	good	good	good
Roll/Press Stamp	good	good	good
Laser engraving	excellent	excellent	excellent

Table 2. Readability results

Cost Justification

The cost of each DPM method was based on cost estimates from vendors. The results are listed in Table 4. The total cost for implementation would be approximately $79,000.

DPM method	Application	Cost Estimate	Additional Lines	Total Cost
Dot Peen	Pipes, converters	$10,000	4	$40,000
Roll Stamp	Pipes	$3,000	13	$39,000
Laser Etch	Pipes, converters	$50,000	-	$0
TOTAL	-	-	17	$79,000

Table 3. Cost estimates per production line for adding DPM

The estimated savings from DPM was minimal, as most of the assemblies produced at this facility require a self-adhesive paper barcode label with date information to be affixed to the part.

The time spent for tracing the part build information for (warranty return) components was estimated from polling the warranty, product and manufacturing engineering groups through e-mail, telephone and face-to-face communication. The following number of responses was obtained from each engineering group: warranty (3), product (4), and manufacturing (3). The polling activity was informal as no official tracking occurs during this type of activity. The estimates indicated that a minimum of eight hours was needed by the three groups for tracing part build information when it was not marked on the returned part. This time included the communication time necessary between each group, and the time to determine the approximate number of parts to be included in the warranty investigation. The annual savings were calculated to be $3,987 and are detailed in Table 5.

Event description	Hourly Rate	Hours	Cost per event	Average events/year	Annual cost	Estimated savings	Annual savings
Quality sorts	$53.75	4	$215	12	$2,580	15%	$387
Warranty investigation	$100	8	$800	6	$4,800	75%	$3,600
Total					$7,380		$3,987

Table 4. Cost estimates gathered from the polling activities

The polling of the product engineering groups also provided information about a quality issue from 1999 that involved sorting of exhaust systems on vehicles at a holding lot for the Ford Motor Company. The front muffler contained a tube that had become dislodged during the assembly process at Company, and was not discovered until there was a problem encountered at the Ford assembly plant. The dislodged tube on some of the vehicles blocked the flow of exhaust through the muffler and caused the cars to have reduced power or to stall completely. Company was able to determine the time of the exhaust assembly process and identified the specific build period. The build date information was stamped on the exhaust system. This date code on the part helped reduce the on-vehicle sorting time at one of the auto manufacturer's plant by approximately 25%. The sorting activity involved six Company employees and ten UAW employees working ten-hour shifts over a weekend. Vehicles were driven over an inspection pit to check the date on the exhaust assembly and to determine if it fell within the known build period. If the exhaust was built during this period, the exhaust was disconnected and a lighted fiber-optic scope was guided through the inlet pipe of the assembly and into the front muffler where the suspect tube could be examined to determine if it had become dislodged. Vehicles with dislodged tubes were identified and the exhaust was scheduled for replacement in the customer's rework garage. The time necessary to complete the inspection of the inside of the muffler averaged approximately 15 minutes per vehicle. The sorting time was reduced due to Direct Part Marking, as only 75% of the vehicles built during the quarantine period needed inspection of the muffler. The resulting savings from DPM for this one time event were approximately $3,306, which paid for the roll stamp machine used to apply the date code to the exhaust assembly (see Table 5).

Cost description	Hourly Rate	Man-Hours	Cost	Estimated savings	Event savings
ArvinMeritor labor	$54	60	$3,225	25%	$806
UAW labor	$100	100	$10,000	25%	$2,500
Total					$3,306

Table 5. Estimated cost for the on-vehicle sort

Summary and Conclusions

The purpose of this study was to develop a standard for tracing exhaust components through the assembly process and the exhaust's intended lifetime. In this study, a detailed analysis was completed to determine the minimum traceability information needed as well as the process used to mark the part.

Based on laboratory testing of the rolling stamp, dot peen and laser etch applications; all three methods yielded a legible string of characters. The laser etch method provided the best clarity of characters, but is cost prohibitive and would likely be used infrequently. The dot peen method provided good clarity with a better cost, but should be utilized only when the application requires. The rolling stamp method provided good clarity at the lowest cost, but was restricted to applications where a straight section of pipe can be marked.

The cost justification for this project showed that a single event cost avoidance estimate based on an incident from 1999 and involved the on-vehicle sorting of exhaust assemblies at a customer facility. The cost avoided by having traceability to the build date was approximately $3,306.00, which provided an immediate ROI for the rolling stamp process used to mark the assemblies.

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Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act of 2000, 49 U.S.C.A. § 30166.

Figures

Figure A1. Converter samples before testing

Figure A2. Close-up view of dot peen (top) and laser etch (bottom) before testing

FigureA3. Pipe samples before testing

Figure A4. Close-up view of dot peen marking

Figure A5. Close-up view of roll stamp (top) and laser etch (bottom)

Figure A6. Pipe laser etch (top) and dot peen (bottom) after thermal cycle

Figure A7. Converter laser etch (left) and dot peen (right) after salt fog exposure

Figure A8. Converter dot peen (top) and laser etch (bottom) after thermal cycle

Figure A9. Pipe laser etch (top) and dot peen (bottom) after salt fog exposure

Research

Hardware Implementation of FIR Neural Net for Time Series Data Prediction

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Abstract

In this paper we present hardware implementation of a finite impulse response (FIR) neural network for time series data prediction. To this end a complete implementation framework is discussed. The final FIR neural net topology was obtained through simulations on synthetically generated time series data. This FIR neural net had one input node, two hidden layers of ten nodes each and one output node. The complete hardware design was modeled in very high-speed integrated circuit hardware description language (VHDL) and functionality testing was done using ModelSIM. The design was then mapped on to XILINX 4000 series field programmable gate arrays (FPGAs). The complete design needed five XILINX 4000 FPGAs for hardware mapping. The implemented FIR neural network can be operated at 4.54 MHz.

Introduction and Problem Background

Many data processing problems can be mapped to the problem of predicting future values based on the recent past. This problem of time series prediction has applications in such areas as telecommunications, financial world, and industrial processes (Widrow, Rumelhart & Lehr, 1994). We can state the goal of time series prediction as follows: find a function $f: \Re^N \rightarrow \Re$ to obtain an estimate of *x* at time $t + d$, so that:

$$x(t+d) = f(x(t), x(t-1), \ldots x(t-N-+1))$$

$$x(t+d) = f(y(t)),$$

where *y(t)* is the *N*-ary vector of lagged x values. Normally d will be one, so that f will be forecasting the next value of x.

Artificial neural networks (ANNs) are general function approximators that have been applied in pattern recognition, classification, and process control (Widrow, Rumelhart & Lehr, 1994; Haykin, 1994). Recently, they are being used in the areas of prediction, where regression and other related statistical techniques have traditionally been used (Clermont, 2005; Bisht, Gupta, Pal & Chakraborty, 2005). One class of ANNs is the feedforward networks, which has one or more hidden layers of neurons, also referred to as hidden units (Haykin, 1994). The nonlinearities of the hidden units allow the network to extract higher-order statistics and are particularly valuable when the size of the input layer is large.

The architectural graph of Figure 1 illustrates the layout of a multilayer feedforward neural network. For brevity, the network in Figure 1 is referred to as a 4-3-3-4 network in that it has 4 source nodes, 2 hidden layers of 3 hidden neurons, and 4 output neurons.

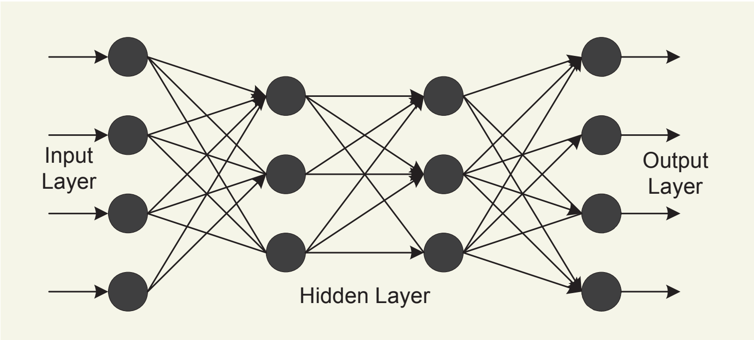

Figure 1: Fully connected feedforward network

The standard neural network method of performing time series prediction is to approximate the function f in neural network architecture, using a set of *N*-tuples as input and a single output as the target value of the network. This method is often called the sliding window techniques as the *N*-tuples input slides over the training set. Figure 2 shows the basic architecture of a sliding window method for time series prediction.

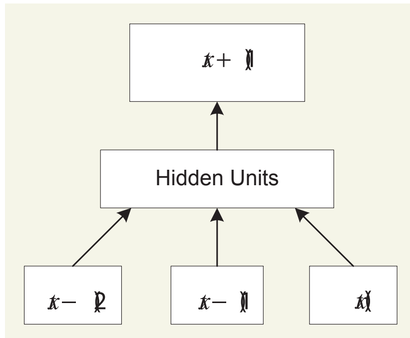

Figure 2: Sliding window based time series predictor

Such architecture can be either implemented in software or hardware. Software solutions are comparatively slower as large numbers of computations are involved. Several researchers have adopted hardware implementation with great success (Botros & Abdul, 1993; Ulrich, 2002). These hardware implementations facilitate the use of network in real-time applications. Recently, reconfigurable hardware solutions in the form of FPGAs offer high performance with the ability to be electrically reprogrammed to perform changes in design and algorithm (Zhu & Gunther, 1999; Porrmann, Witkowski, Kalte, & Ruckert, 2002). The work presented in this paper focuses on FPGA implementation of FIR neural network for time series data prediction.

The first step will involve simulation of complete network and the training algorithm (temporal backpropagation) using Matrix Laboratory (MATLAB). The outcome of MATLAB simulation is the design parameters, such as number of hidden units, number of hidden layers, number of FIR taps per synapse, and FIR coefficients. This information is later used for hardware implementation. The rest of the paper consists of several sections. Section II presents FIR neural net model. Section III presents the implementation framework. In section IV we discuss the hardware block of FIR neural net architecture in detail. Section V presents the simulation and FPGA synthesis results on benchmark time series data. Finally relevant conclusion is presented.

FIR Neural Network

In a FIR neural network each neuron is extended to be able to process temporal features by replacing each synaptic weight by a finite impulse response filter (Haykin, 1994; Wan, 1993). A general structure of a FIR neuron is shown in Figure 3 with corresponding time delay neural network representation of FIR network in Figure 4.

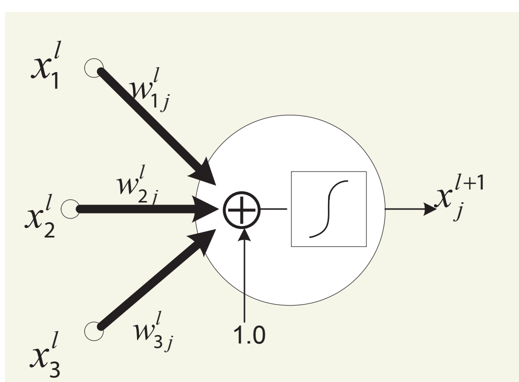

Figure 3: FIR neuron model

An FIR networks input layer consists of FIR filters feeding the data into neurons in hidden layer. Similar to conventional feedforward networks, an FIR network may have one or several hidden layers. The output layer consists of neurons that receive their inputs from previous hidden layer. The network in Figure 4 consists of three layers with a single output neuron and two neurons in hidden layer. As seen all the connections are delayed (time processed) before passing on to neurons in the next layer.

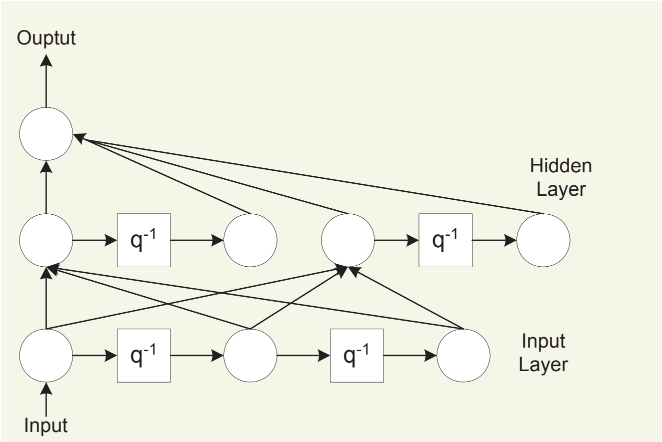

Figure 4: A time delay neural representation of FIR neural net

In effect, the network is unable to learn temporal features that are longer than its filter lengths summed together. Consequently, selection of the lengths of FIR filters is quite critical in achieving good prediction performance.

A Hardware Implementation Framework for FIR Neural Net

When implemented in hardware, neural networks can take full advantage of their inherent parallelism and run orders of magnitude faster than software simulations (Botros & Abdul, 1993; Beiu, 1996). The implementation is divided into two parts. The first part is off-chip. This consists of software implementations of FIR neural net and of the temporal backpropagation learning algorithm (Rafael, Francisco, Antonio, & Joaquín, 2000). The simulation program reads a time series data file, with the network configuration supplied by the user. The outputs of off-chip learning are filter coefficients and the best possible FIR neural network topology (number of hidden layers, number of hidden units, number of filter taps) for the input times series.

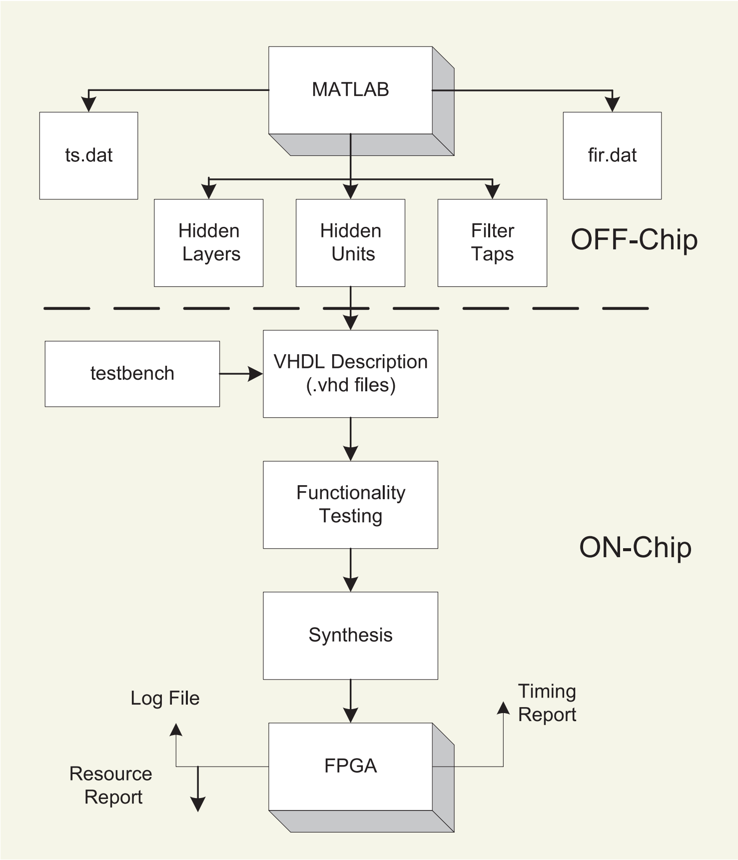

Figure 5: A complete implementation framework for FIR neural net

Equipped with these values we can proceed to the on-chip, i.e. hardware implementation, part. The hardware implementation involves modeling each computation module in VHDL. These modules were tested for functionality using ModelSIM. All the modules are then integrated to form the complete design. The final step is to run the design description through a synthesizing tool, which generates textual representation of the entire design. This textual representation, which is in form of a bit stream, is subsequently downloaded on to the FPGA.

Building Blocks of FIR Neural Net

The basic computing modules used in the FIR neural net design are addition, multiplication, delay, and twos complement. Such circuits as the adder tree, multiplier-accumulator unit, and the FIR filter can be designed using these basic modules. In this work, we combine the area efficiency of a corresponding bit-serial architecture with the time efficiency of bit-parallel architecture into a single area-efficient and time-efficient digit-serial architecture (Hartley & Parhi, 1995). In the digit-serial approach, data words are divided into digits, having a digit size *N*, which are processed in one clock cycle. Architectures based on the digit-serial approach may offer the best overall solution considering the tradeoffs between speed, efficient area utilization, throughput, I/O pin limitations and power consumption. The digit-serial approach also leads to regular layout and the possibility of building a pipeline with it.

Digit-Serial Adder

A basic element in a digit-serial arithmetic implementation is the digit-serial adder, as shown in Figure 6. The two operands, *A* and *B*, are fed one digit at a time into the digit-serial adder. The addition is done *N* bits at a time, with the carry rippling from one full adder to the next. The carryout from the digit-serial adder is fed back in to the first full adder during the next clock cycle, when the next digits of the inputs have arrived.

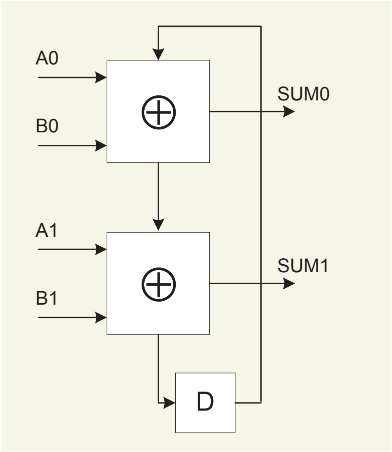

Figure 6: A digit-serial adder module

Digit-Serial Multiplier

Multipliers are used in multiplying weights values to the incoming times series data. The simplest way is add-shift multiplication. The *N*-bit operands for multiplication are stored in two registers and multiplied with each other in *N* steps. The digit-serial multiplier basic module and multiplier structure with *N* are shown in Figure 7 and Figure 8, respectively.

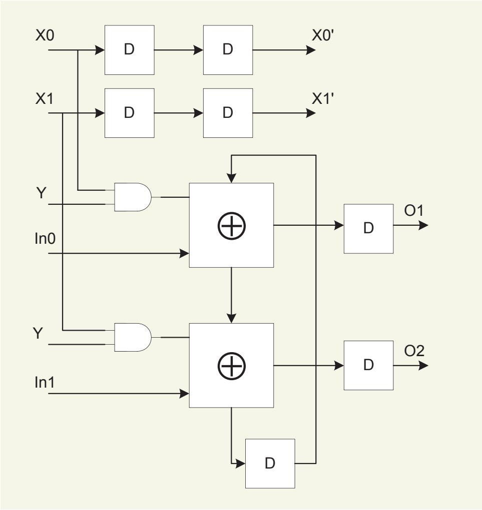

Figure 7: Digit-serial multiplier module

A 2-input AND gate generates each partial product. Each digit-serial multiplier modules (DSMM) can be connected in a systolic array fashion to implement a very fine-grained pipeline. The bits of the multiplier are supplied one digit at a time, starting with the least significant digit, while the bits of the multiplicand are supplied as a parallel word. Each partial product is shifted and then added to the previous partial products.

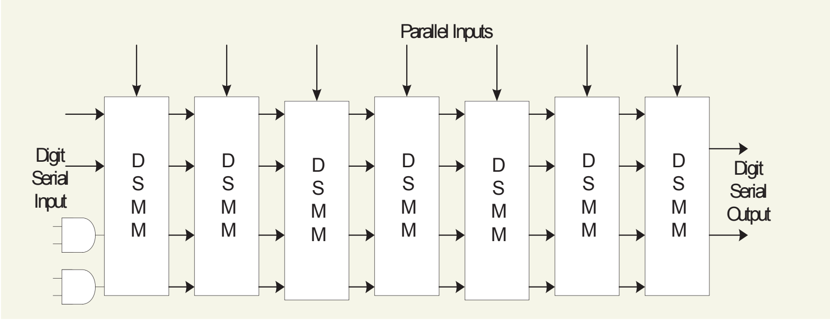

Figure 8: Digit-serial pipelined multiplier

In order to increase the throughput of the digit-serial multiplier, the architecture is highly pipelined. Pipelining is done in order to limit the critical path propagation delays between registers. In the example shown, the pipelining limits the propagation to a 2-bit adder in the digit-serial multiplier with $N=2$.

Multiplier-Accumulator Unit

In multiply-accumulate operation the synaptic filter coefficients (weights) are multiplied with time series data values and the results are accumulated. Figure 9 shows the pipelined structure of multiply-accumulate unit.

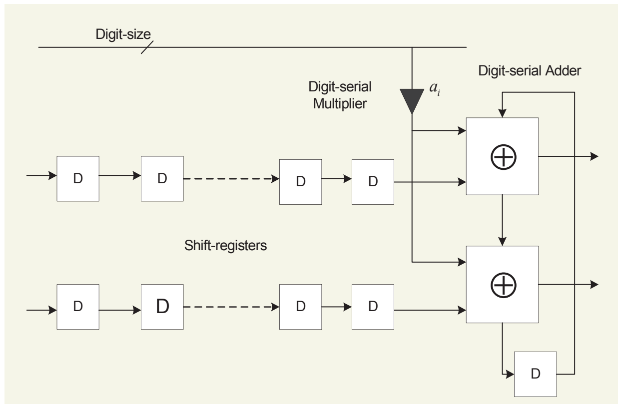

Figure 9: Multiply-Accumulate Unit

Digit-Serial FIR Filter Design

In the case of a FIR neural net, a finite impulse response filter replaces the synaptic weights in the network. An FIR filter can be easily implemented using just three digital hardware elements, a unit delay (a latch), a multiplier, and an adder. The unit delay simply updates its output once per sample period, using the value of the input as its new output value. In the convolution sum,

$$y(n) = \sum_{m=0}^{M} h(m)x(n-m) \qquad (3)$$

Notice that at each n we need access to the $M + 1$ samples $x(n),\ x(n-1),\ x(n-2),\ \ldots\ x(n-M)$

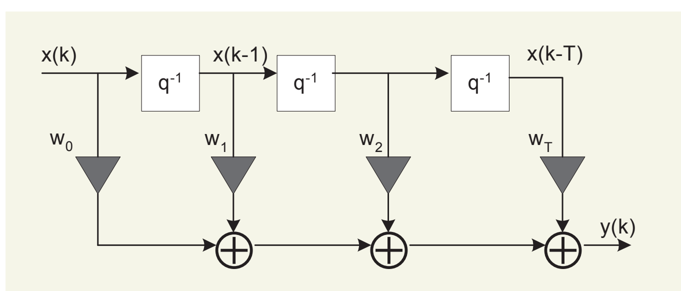

Figure 10: Tapped delay line implementation of FIR filter

The Architecture of a Neuron

The most important part of a neuron is the multiplier, which performs high-speed pipelined multiplication of synaptic signals with weights. An 8-bit data format is chosen for synaptic signals as well as for the weights. As seen in Figure 11 each neuron has a local coefficient read only memory (ROM) that stores as many values as there are connections (filter taps) to the previous layer.

An eighteen-bit accumulator is used to add three signals from the pipeline with the neuron's bias value, which is stored in an own register. The output of the register is buffered before passing on to sigmoid generator. A register holds the neuron's computing result until it is to write the value to a shared output bus. All neurons of a layer use the same bus to address the sigmoid generator. The sigmoid function is programmed as lookup table that is downloaded with the bitstream during FPGA mapping.

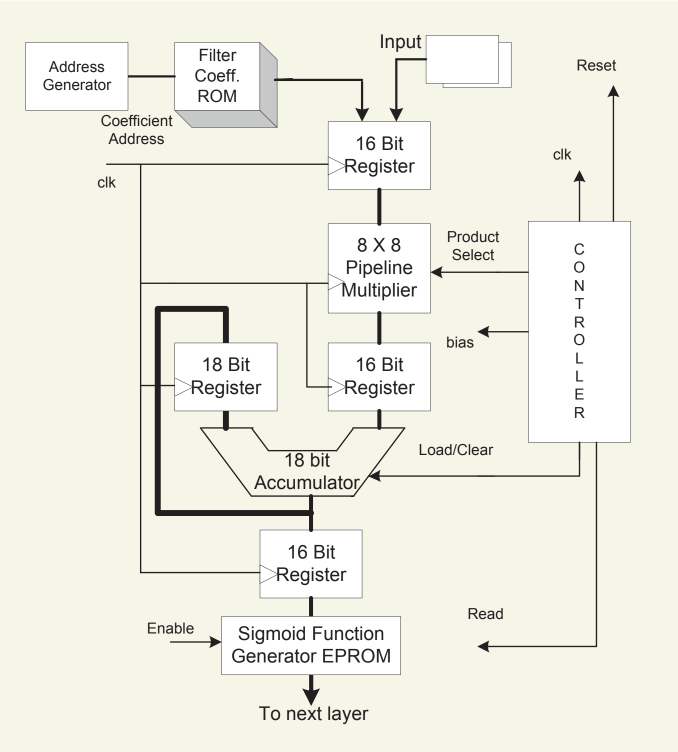

Figure 11: Architecture of neuron with its input and output signals

In Figure 11, the controller generates a proper sequence of signals to control the timing for nodes in each layer. It generates addresses for the coefficient ROM and controls the time of multiplication, accumulation, using the output bus and preloading the bias. The controller is modified according to how many neurons want to use the common bus. In a layered feedforward network, not all the neurons have to be connected together; rather, data are passed from one layer to the next. Every neuron has its multiplier, and all neurons may receive one data word in parallel, feed it to a multiplier pipeline, accumulate the multiplication results and write them to the common bus leading to the next layer one after each other.

Simulation Experiments and FPGA Synthesis

The simulation of FIR net was performed using MATLAB. The time series data sets used for the experiments are the benchmark sets of load in electrical net (Time series 1) and fluctuations in a far-infrared laser (Time series 2). Table 1 shows the number of data samples used to train networks and to test network generalization ability for each time series. Training data starts from the beginning of the series and test data starts from the end for the training data.

Table 1: Training and test data set sizes

Time Series	1	2	3
Training Set	1500	1000	5000
Test Set	500	1000	5000

The simulation was done with a FIR neural network that has two hidden layer and one nonlinear output neuron. These simulation results provide the optimized values for different hardware building blocks needed for implementation. Different combinations of prediction order and number of neurons in hidden layer were tried in effort to find the configuration that would model the data most effectively. The temporal backpropagation algorithm was implemented in MATLAB. Normalized mean square error (NMSE) was used as performance measure. In Eq. 4, σ^2 is the variance of the desired outputs d_i and N is the number of patterns.

$$NMSE = \frac{1}{N\sigma^2} \sum_{i=1}^{N} (x_i - d_i)^2 \qquad (4)$$

Table 2, shows the architecture that gave lowest NMSE for test data for each time series. For FIR networks the lengths of the FIR filters are also shown. The final implemented architecture was based on topology obtained for synthetically generated time series (Time series 3). The final architecture is a 1:10:10:1 fully connected feedforward network with the topological description shown in Table 3.

Table 2: Training and test set errors for selected time series data set.

Time Series	Tap length	Neurons in hidden layer	NMSE for training set	NMSE for test set
Load in electrical net	25-5-5	8	0.0518	0.1612
Fluctuations in a far-infrared laser	25-5-4	10	0.3542	0.3562
Numerically generated series	20-5-4	15	0.5435	0.5983

Table 3: Topology of the final FIR Neural Net

Topology	# of taps per synapse	Train. set error	Test set error
1:10:10:1	20:4:4	0.5683	0.5838

The complete VHDL description of the final topology was synthesized on to FPGA using the XILINX synthesis tool (XILINX, 1996). The tool performs routing and placement for the design layout. FPGAs are configured by setting each of their programmable elements (i.e. logic cells, routing network and I/O cells) to a desired state. These are programmed via programmable switches (PSM).

We used the XILINX XC4000 series FPGAs for implementation. The architecture XC4000 series FPGA is as shown in Figure 12. It consists of an array of programmable function units called Configurable Logic Blocks (CLBs), linked by programmable interconnect resources. The internal signal lines interface to the package through programmable Input/Output Blocks (IOBs).

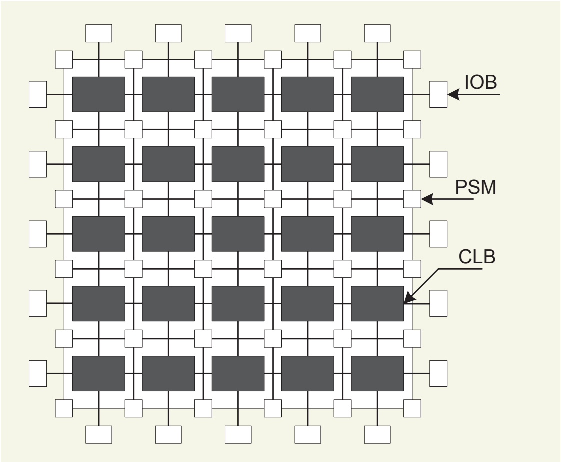

Figure 12: XILINX XC4000 series architecture.

The XC4000 series FPGA used for the implementation has 576 CLBs in form of a 24 x 24 matrix. In addition to this it has 1,536 flip-flops and 192 IOBs. Each CLB consists of function generators, flip-flops, SRAM, and fast carry logic for addition. The resource utilization of the entire design on XC4000 series boards is summarized in Table 4.

Resources	Used
Configurable Logic Blocks	2204
Input/Output Blocks	182
Flip-flops or Latches	3862

Table 4: Resource utilization for FIR neural network

The maximum critical path delay was reported as 220nsec. Thus, FIR neural net chip can operate at 4.54MHz.

Conclusion

Time series prediction has applications in various areas of science and engineering. Due to their inherent capabilities, neural networks have been used for time series prediction. One such variation of neural network design is an FIR neural net, which gives dynamic connectivity to the network and facilitates temporal processing.

This work investigated FIR neural net design and its hardware implementation for time series prediction. The network incorporates finite impulse response filters to model the processes of signal propagation in the synapses. To demonstrate potential applications, three different times series data sets were selected. One of the data set, synthetically generated, was used to obtain the final FIR neural network topology for hardware implementation.

In order to implement FIR neural net on to FPGA, a complete design framework was proposed. The training algorithm was implemented off-chip using MATLAB simulation program.

On-chip or hardware implementation procedure was in compliance with the FPGA design flow. The complete VHDL description was synthesized on to XILINX 4000 series FPGA using XILINX synthesizing tool (XST). The synthesis tool also reported the amount of device utilization and maximum critical path delay. Reconfigurability and adaptability are the main features of the hardware. For a new application, only the filter coefficient and biases need to be reconfigured on the CLBs without changing the basic design. We can expand the design by just adding more nodes with the same configuration. The implementation of entire network needed five XILINX FPGA chips and can be operated at maximum frequency of 4.54 MHz.

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Safety

The Effects of Behavior-based Safety Techniques on Safe Behaviors: A Case Study Highlighting Advantages and Drawbacks

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Abstract

American industry has begun to implement safety and health initiatives based on applied behavioral research. Collectively, these types of initiatives are often referred to as Behavior-based Safety (BBS) programs. This increase in the number of BBS programs has peaked the interest of industrial leadership and also raised concerns. An applied industry study was designed to determine the effect of changes in targeted safe behavior, initiated through a Behavior-based Safety (BBS) Program. The methodology involved a multiple-baseline study across two groups incorporating several months of baseline and post-intervention measurement. Behavior was measured using work-sampling techniques. The intervention consisted of training and graphical feedback. The subjects included employees at two manufacturing and assembly facilities. The results of this applied industry study indicate that a BBS Program has a significant effect on targeted safe behavior.

Introduction

The economic and moral cost of workplace injuries may provide motivation for employers to try new and different techniques for improving workplace safety. Over the last couple of decades implementation of "Behavior-Based Safety Programs" has become widespread among industry with varying degrees of success. There are numerous examples of effective behavior-based safety programs employing various strategies (Krause, Seymour, and Sloat, 1999; Sulzer-Azaroff and Austin, 2000). Others are more critical of behavior-based safety programs and identify several limitations (Hopkins, 2006). Behavior-based safety means different things to different people. For that reason, among others, it is practically important to continue examining the usefulness of implementation of behavior-based safety techniques. Additional studies help industry management understand the benefits of implementing behavior-based safety techniques. In other words, actions speak louder than words. The purpose of this project was, in part, to conduct an evaluative study reaffirming and demonstrating the effects of behavior-based safety techniques on targeted safe behaviors. In general, behavior-based safety programs are a systematic approach to promoting behavior supportive of injury prevention (Sulzer-Azaroff and Austin, 2000). Although behavior-based safety programs may be relatively recent, the underlying principles are not. Behavior-based safety programs vary in design but all are based on the fundamental principles of applied behavioral research. Komaki, Barwick, and Scott (1978) provided one of the first examples of the application of applied behavioral research to workplace safety. Komaki et al., (1978) identified and defined critical safety behaviors for two departments in a food manufacturing facility. These targeted behaviors were observed over a 25-week period. The study included an intervention consisting of training with participatory goal setting and graphical and verbal feedback. The performance of targeted behaviors in two different departments increased from 70% and 78% to 96% and 99%, respectively. Numerous other studies support the basic process used by Komaki showing an increase in targeted behaviors after identifying critical behaviors and providing feedback based on worker performance.

This study systematically applied the fundamental behavior-based safety techniques used in the studies described above. Specifically, the techniques of pinpointing critical behaviors, developing precise definitions, collecting and measuring observable data using an observational checklist, and implementation of training, participatory goal setting, and both graphical and verbal feedback as an intervention package to increase targeted behaviors, were to be evaluated. The reaffirmation and demonstrated generality of these fundamental techniques is important to provide continued evidence of the value of focused effort on improving worker safe behavior. This paper may also be used as a guideline for organizations considering the implementation of Behavior-based safety techniques and programs.

Project Implementation

The experimental design for this evaluative study was a multiple-baseline design across four groups. This multiple-baseline design demonstrates the effect of an intervention by showing behavior variation with the introduction of the intervention at different points in time for each group. The purpose of this staggered implementation is to introduce a level of experimental control (Robson,

Shannon, Goldenhar, and Hale, 2001). After baseline behavior has stabilized, the intervention is applied to the first group while the baseline measurement is continued for the remaining groups. Using this overlapping approach, the intervention is applied to all groups. The objective is to demonstrate similar behavior variation after the introduction of the intervention.
In this study a combination of run charts and statistical process control charts were used to present and analyze the data. Targeted behaviors were plotted over time (weekly) using a run chart for each of the four groups. Each run chart includes two distinct phases, baseline and intervention. Statistical process control charting techniques were used to analyze the data to determine whether or not significant changes in the targeted behaviors occurred following the intervention as evident by special cause variation. The behavioral observations were interpreted as "in control" when all variation was random and between the statistical limits and therefore, a result of common causes. The behavioral observations were determined to be "out of control" when variation was a result of special causes.

Setting and Participants

The setting for this study involved two different manufacturing facilities in the southeast United States. Two different departments were selected from each of the manufacturing facilities providing four different groups. The first facility is a light manufacturing and assembly operation. The two departments selected from this facility have similar processes. Both departments utilize basic machining and assembly operations. Differences between the departments pertain only to product configuration. The participants included all 40 fulltime employees of Department R and all 26 fulltime employees of Department TW. The facility had a compliance-based safety program focused on meeting workplace safety and environmental regulations. The facility has developed and implemented programs and training required by regulation. At the beginning of the study the facility's OSHA Total Case Incident Rate (TCIR) was 22.2, with a total workers' compensation claim cost of $94,065 for the preceding 12 months. In addition, the facility maintained a first-aid logbook recording minor "non-recordable" injuries such as small lacerations and foreign objects in eye. In the 12 months prior to this study there were 86 first-aid cases recorded.

The second facility is also a light manufacturing and assembly operation producing a different product than the first facility. The two departments selected from this facility again have similar processes centered around slightly different product lines. The participants included all 71 fulltime employees of Department 1 and all 47 fulltime employees of Department 3. Like facility one this second facility's safety efforts were entirely focused on meeting workplace safety and environmental regulations. All employees had received required regulatory safety training. At the beginning of the study the second facility's OSHA Total Case Incident Rate (TCIR) was 18.4. Unfortunately, this facility did not record first-aid injuries. Their recordkeeping only involved the required OSHA 300 log. Facility Two management was unwilling to provide workers' compensation information, stating privacy concerns.

Identification and Definitions of Critical Behaviors

The study began with pinpointing behaviors that would have the greatest impact on overall workplace safety. These targeted behaviors were identified by examining past injury and accident records and interviewing management and departmental supervisors. Approximately twelve unique target behaviors were identified for each of the four different departments. Examples of targeted behaviors include the proper use of eye and hearing protection, proper use of box cutters, work aisle housekeeping, and team lifting heavy objects.

After determining the critical behaviors, precise definitions were developed. These precise definitions aided in the collection (observation) of data. A unique critical behavior checklist was developed for each of the departments. This checklist consisted of an abbreviated definition of each target behavior and included two additional columns labeled "Safe" and "At Risk".

Data Collection Procedures

The study involved the collection of a total of 50 weeks of observational data. Baseline observations using the developed critical behavior checklists were collected at random starting times on a daily basis in all four departments. Observers alternated routes and starting points each day when collecting observations. Each data collection tour took less than 30 minutes for each of the two facilities. Observations were collected 4 to 5 days per week (Monday through Friday) with only one observation session per day. Prior to the start of data collection a short meeting was held informing departmental supervisors that safety observations would be collected. The departmental supervisors were asked to inform their employees that safety data would be collected over a period of time with the intention of improving workplace safety. This explanation included the fact that individual data would not be collected; that the data collected is reported solely on the department as a whole.

The observers visited each workstation and instantaneously recorded the workers' behavior. Each employee was observed only long enough to make a determination of whether one or more of the targeted behaviors were present and if the performance of the behaviors were "Safe" or "At Risk". Collected data were used to calculate a weekly "percent of activities performed safely" score.

Percentage of Activities Performed Safely = (Total Number of Safe Behaviors Observed ÷ Total Number of Behaviors Observed)

Intervention

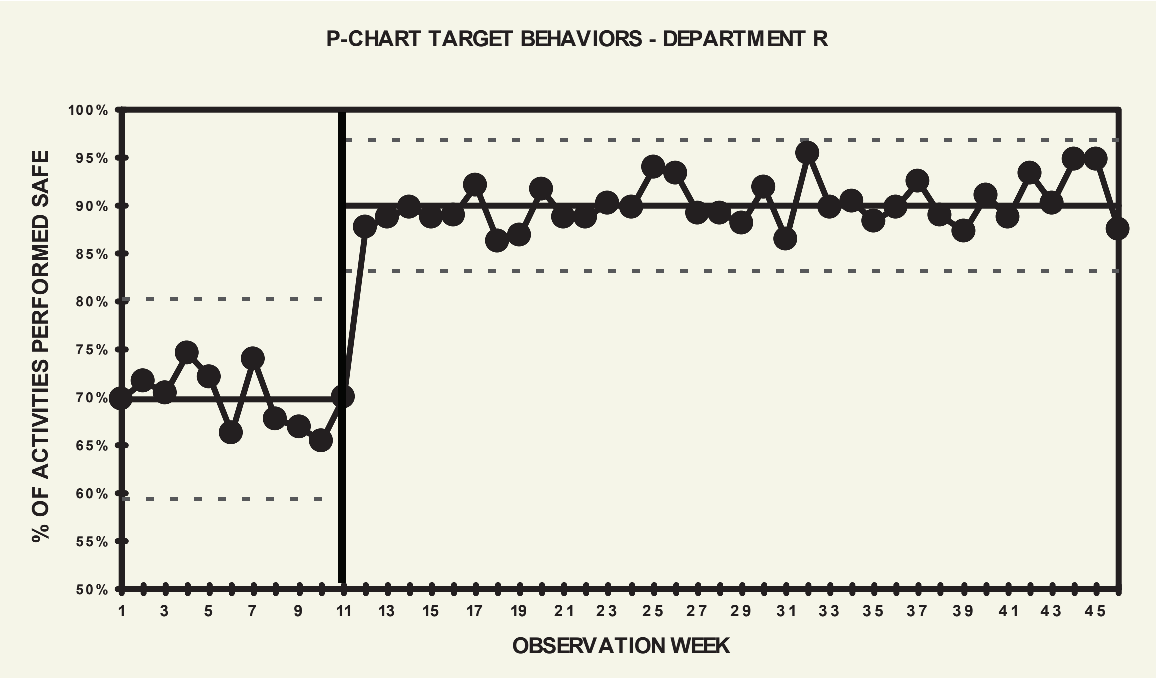
After establishing stable and substantial baseline data an intervention package of training, participatory goal setting, and graphical and verbal feedback was implemented in an effort to increase targeted behaviors. The one-time training session lasted approximately one hour for each of the four departments. The training session consisted of an explanation and a combination of pictures depicting the "safe" and "at-risk" performance of each targeted behavior. The training pictures were taken at each of the facilities using actual workers demonstrating each of targeted safe behaviors. The pictures showing "at-risk" or unsafe behaviors were carefully "staged" using actual workers from the corresponding facility. During the training session employees were shown a graph with their department's baseline performance and were encouraged to increase their performance. The layout and components of the graph were explained in detail and employee questions were answered.

The training session concluded with discussing a goal for increased performance. Collectively and with guidance, the employees of each department agreed upon a performance goal. These goals remained constant throughout the study. The employees of Department R and Department TW both agreed on 85% as a reasonable and attainable goal. The employees of Department 1 agreed on 70% for their goal and Department 3 decided on a 75% goal.

After the intervention training, observations continued with the addition of weekly feedback to the employees. Each week a short session was held explaining the preceding week's performance and encouraging improvement. The weekly graph was placed on the department's bulletin board. Following the multiple-baseline design, the intervention was staggered for each of the four groups.

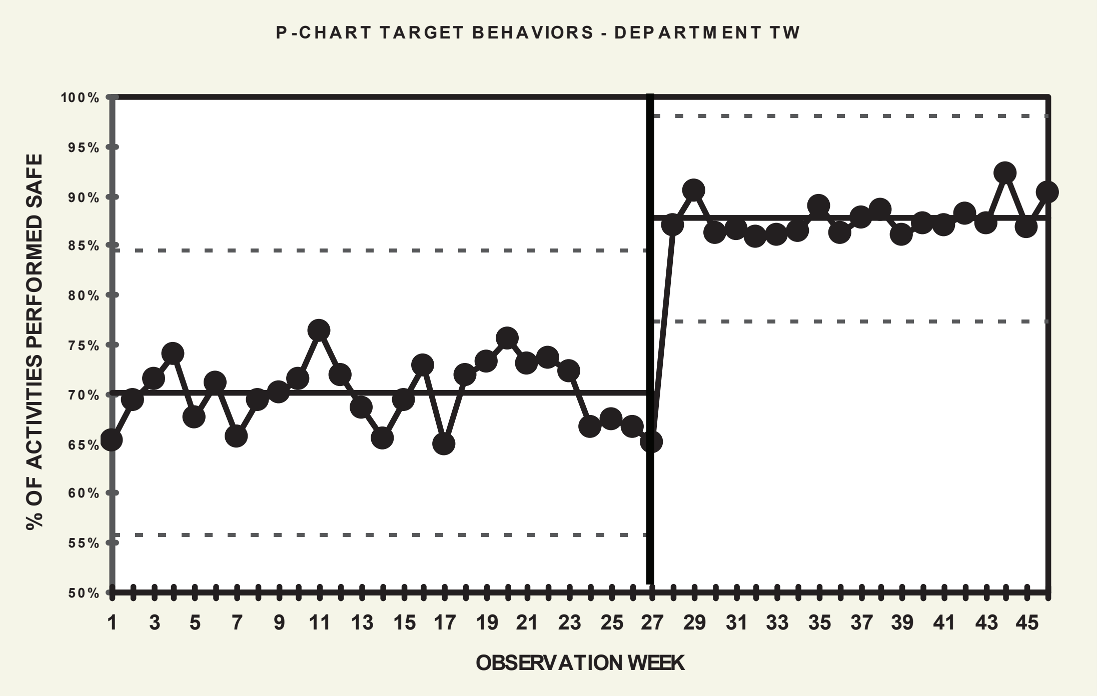
Results

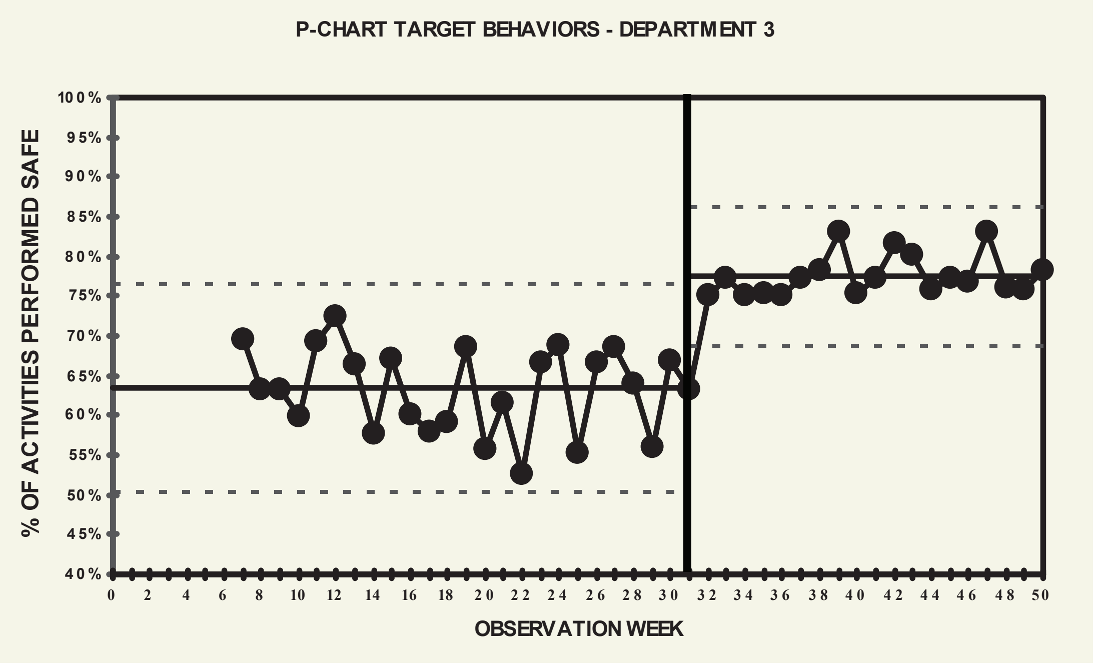
The results of the observational data collected on the targeted behaviors over the 50-week period are shown in four graphs, one per group. Each of the graphs consists of a run chart and the associated control limits for each individual department. Baseline "percent of activities performed safely" of targeted behaviors averaged 69.8% in Department R, 70.2% for Department TW, 63.5% for Department 3, and 57.1% for Department 1. The vertical line in each graph indicates the implementation of the intervention package.

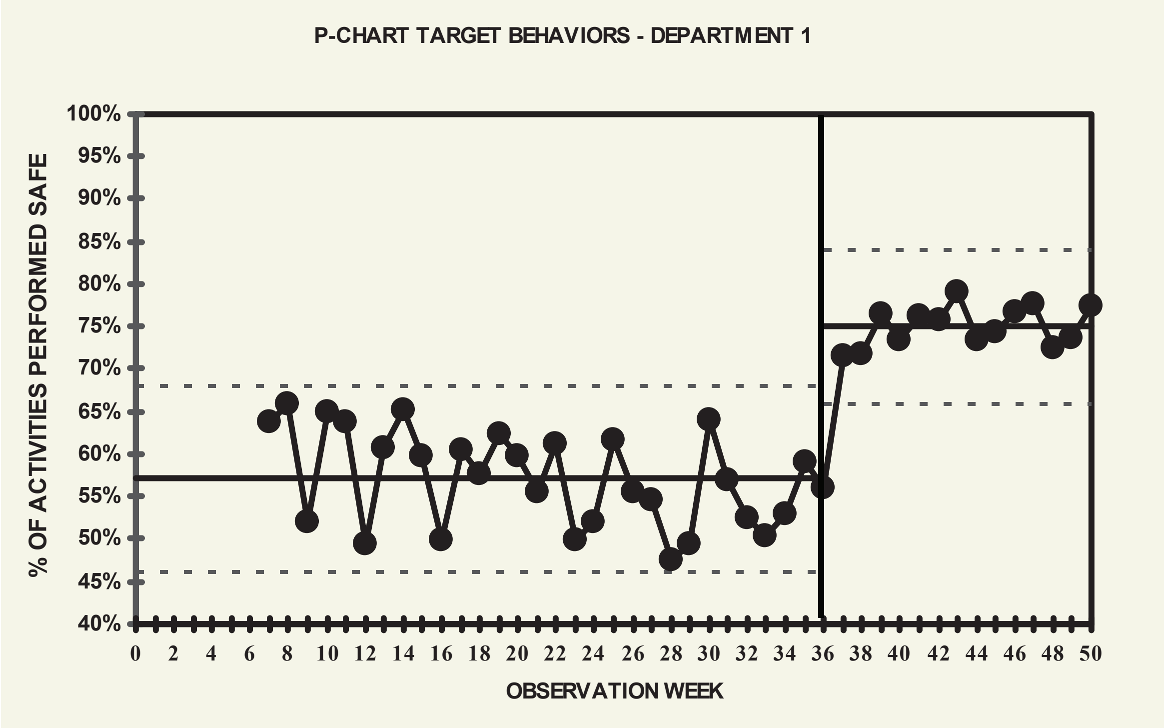


The intervention was first conducted in Department R of Facility One resulting in a substantial increase in the performance of the targeted behaviors. Within the first week of the intervention phase, Department R had surpassed their goal of 85%. The average "percent of activities performed safely" of targeted behaviors during the intervention phase for Department R was 90.0%, an increase of 20.2 percentage points over the baseline average. The lowest weekly score during the intervention phase was considerably higher than the highest baseline weekly score for Department R. All other groups maintained baseline levels during the introduction of the intervention package to Department R including Department TW, which is in Facility One.

Similar increases in average "percent of activities performed safety" were noted in the other three groups after the introduction of the intervention. Department TW's average weekly score during the intervention phase was 87.7%, a 17.5 percentage point increase over their average baseline score. The two groups from Facility Two average intervention phase scores were 77.6% for Department 3 and 75.0% for Department 1, an increase over average baseline performance of 14.1 and 17.9 percentage points respectively.







Based on control limits all four groups were in statistical process control during the baseline phase indicating a stable process. Immediately after the intervention, in all four groups, the "percent of activities performed safely" score was above the upper control limit indicating the occurrence of a "special cause" variation. As a result of this non-random variation within the process, the control limits were adjusted. This increased level of targeted safe behavior performance continued throughout the duration of the study.

Discussion

The results of this evaluative study reaffirm the benefits of behavior-based safety techniques on targeted behaviors. Targeted behaviors increased significantly and were maintained throughout the intervention phase in all four groups. This study confirms the effects of positive reinforcement in the form of feedback on targeted behavior performance and the use of training and participatory goal setting as intervention procedures. The use of statistical process control techniques indicate that the process was "in control" during both the baseline and intervention phases of all four groups. The observed variation of targeted behaviors within each phase is random and naturally occurring indicating the process is working as well as it possibly can without process changes.

This study and the corresponding increased performance of targeted safe behaviors also had an impact on incidents and injuries at the two facilities. The Total Case Incident Rate (TCIR) of "recordable" injuries for Facility One was 22.2 at the beginning of the study. At the end of the study the annualized TCIR for Facility One was cut by more than 50% to 10.6. The annualized workers' compensation cost for Facility One was reduced to a total of $22,030, a cost savings of $72,035 over the year prior to the study. The number of first-aid cases were reduced as well. In the year prior to this study there were 86 reported first-aid cases at Facility One. During the year of this study there were 25 reported cases of first-aid treatment, a 70% reduction. In fact, during the study the human resource clerk maintaining the first-aid case logbook reported a problem to the plant manager. She told the plant manager that there must be "something going on" because of the noticeable drop in employees requiring treatment. The management of Facility One maintained this program of behavior-based safety techniques and has started making plans for expansion to other corporate facilities.

Facility Two experienced a similar impact on incidents and injuries. Facility Two had a TCIR of 18.4 at the beginning of the study. This measure of "recordable" injuries was reduced to 12.8 for the year. Again, this TCIR covered the entire facility. During the study employees informally expressed a noticeable increase in general safety at the facility and, in particular, an increase in management involvement with safety concerns. Regrettably, Facility Two management was unwilling to provide information on workers' compensation cost citing privacy concerns. Likewise, it is unfortunate that Facility Two did not collect and maintain information on first-aid level injuries. It is likely that had this additional information been available a similar improvement would have been observed providing management with additional evidence of success.

Conclusion

The purpose of this study was to systematically apply the fundamental behavior-based safety techniques of pinpointing critical behaviors, developing precise definitions, collecting and measuring observational data using an observational checklist, and implementation of training, participatory goal setting, and both graphical and verbal feedback as an intervention package to increase targeted behaviors. The results reaffirm the effectiveness and demonstrate the generality of these fundamental techniques. This study provides continued evidence of the value of focused effort on improving worker safe behavior.

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Ensuring the Safety and Health of Employees in Global Industries Using Lean Systems

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Abstract

The paper will provide ideas for the elimination or reduction of safety and health hazards, using concepts derived from Lean manufacturing systems. Parallelisms between safety considerations and Lean systems will be explored, and recommendations for improving workplace safety will be provided. It will also help explain how companies stand to benefit by emphasizing safety in their global manufacturing facilities, an aspect that is usually overlooked.

Introduction

Safety refers to the control and elimination of recognized hazards to attain an acceptable level of risk (Occupational safety terms and concepts, n.d.). It concerns the minimization of exposure to hazards. Workplace safety deals primarily with the reduction or elimination of recognized safety hazards in environments where products or services are rendered. Workplace safety encompasses aspects as varied as employee engagement, safety programs, and safety inspections for workplace hazards, hazard identification and training.

Lean is a management philosophy that focuses on reducing waste in order to improve overall customer value (Wader, 2002). Lean recognizes seven types of waste: transportation requiring unnecessary movement of materials, motion requiring unnecessary movement of workers, inventory for stocking excess work in progress at various stages, waiting time of workers or of equipment, overproduction, processing or reprocessing, and defective products requiring rework or repair.

Safety should be a point of paramount significance for companies worldwide. The assessment of current safety conditions is a logical starting point while determining what changes in existing safety policies might be needed. The necessary measures to correct or to improve the safety of all employees can then be applied. New methodologies have been introduced in both the service and manufacturing industries in the past two decades, including Lean manufacturing. Lean has been found to have a series of important attributes that if applied correctly can significantly help alleviate safety issues.

The orchestration of Lean and any safety initiative requires that all the principles and tools of Lean systems be understood. These tools are meant to complement each other and to be compatible with the majority of other manufacturing and administrative systems. Lean methodologies have been deployed and closely scrutinized by companies and organizations worldwide. Adoption of Lean contributes to increased productivity, decrease inventory stock by as much as 90%, decrease costs, reduce delivery time of products and reduce errors and waste.

Global companies have also noticed that there are some other benefits that can be derived from the philosophy behind Lean. One very interesting advantage that comes along with it is the fact that safety at the workplace can be dramatically improved through its deployment. In this paper, the principles and tools of Lean manufacturing which can be used to strengthen safety programs will be examined.

Safety and health correspondence to Lean

The focus of Lean is the removal of waste, thereby enhancing quality, productivity and reducing costs. Several global companies and organizations, including those in the public sector, are moving from traditional management systems to Lean manufacturing. Doing so enables the delivery of products and services to become more efficient, with these being provided to end users without having to increase personnel, equipment, space or inventory.

Lean can be linked to employee safety and health by taking the following key steps:

- Becoming involved
- Identifying the connections between unsafe practices and waste
- Incorporating safety and health studies into the company's Lean processes
- Asking questions

When it comes to safety and health, the employees or safety consultants involved in the effort should familiarize themselves with Lean methodologies. They will also have to learn the terminology, the 'language' which is associated with Lean. The value of safety can be emphasized in terms of productivity to top management. Doing so will make it likely that their suggestions and recommendations regarding safety will be adopted.

Safety and health hazards can be recognized in terms of Lean by examining the seven different types of waste.

- Excessive product movement increases exposure to material handling systems and industrial truck injuries. Inefficient work flow and additional processing steps increase overexertion.
- Eliminate inefficient steps such as avoidable reaching, twisting and manual material handling tasks. Reaching over the head for a tool instead of having it within normal reaching distance is considered to be a wasteful and hazardous motion.
- Excess inventory as the result of large production or long cycle time processes impedes movement, increases the risk of trip hazards and distractions, and creates blind spots for pedestrians and fork lifts.
- Delays and time wasted due to poorly designed material flow systems can also impact employees by decreasing their motivation and by increasing the risk of falls and overexertion as workers rush to catch up with materials. Task design must be such that tasks will not overload employees physically or mentally, and they should never be so slow-paced that they start causing distraction, boredom or lack of motivation in employees.
- Overproduction indicates that workers may be working faster than necessary. They could increase the risks of repetitive strain injuries.
- In the absence of clear requirements additional unnecessary procedures may be added causing operator strain. Also, the equipment needed for reworking parts should be designed to meet safety specifications. Reworking often involves non-standard fixtures, equipment and operations. It may require the worker to performing unnecessary lifting or equipment adjustments that can cause injuries.
- Defect prevention requires less work and involves fewer injury exposures than defect discovery and repair. High levels of defects could also be an indication of poor housekeeping or bad lighting. Such conditions may create eye strain or cause the worker to be distracted.

Whenever safety problems are discovered, they should be explained or described through the use of visuals in a manner that will get employees' attention. Production processes must be analyzed from an ergonomic perspective, and the root causes of injuries must also be found. Ergonomic design principles could be applied to reduce or eliminate the source of these injuries.

Asking questions to employees about existing plant set-ups, working conditions or safety incidents may be the best way to discover the root causes of safety and health issues. Questions that combine Lean and safety concepts might include the following:

- Is your process less efficient due to repetitive bending or reaching?
- Slip and fall injuries are being caused by poor housekeeping or excessive material handling?
- Has Total Productive Maintenance handled all the machine guarding initiatives that needed to be addressed?
- Were there mechanical issues that compromised safety and created bottlenecks in the production processes?

Table1 illustrates the correspondence between the Safety and Health concerns within an organization, with similar ones from a Lean Manufacturing perspective.

Integrating Lean Concepts with Health and Safety

For many, Lean is just a set of Toyota Production System tools that assist in the identification and steady elimination of waste or 'muda', quality is improved, production time and costs are reduced. An often overlooked fact is that Lean can also help eliminate or reduce safety and health hazards. The tools of Lean include 'Kaizen' or continuous process improvement, the '5 why's' or the practice asking why the problem occurred in order to get to the root cause of the problem, and 'Poka-Yoke' or mistake-proofing. These can also be applied to aspects dealing with the safety and health of employees in the workplace.

Cost reduction can also be achieved by eliminating or reducing accidents and injuries of employees. By applying the principle of perfect, first-time quality or the quest for zero defects, safety and health hazards can be revealed, and they can be resolved at the source. The waste minimization principle also helps eliminate all activities that do not add value to a process. Let's suppose that we have a crew of roof framers, setting roof trusses on the top floor of a house. If these roof framers have a good set of best work practices in place, activities that may be redundant or repetitive can be eliminated. This will leave only those tasks which allow for a smoother work flow. By eliminating repetitive or ineffective tasks, the exposure time to potential hazards involved in roof framing for the house can be reduced and safety improved.

Safety and Health	**Lean Manufacturing**
Was the product made free from injuries?	Is the product or service defect free?
Are the safety resources available on demand?	Can the product be provided on demand?
Can safe work practices be applied to any new job or task? Are they a part of every job?	Can the service be rendered immediately?
Are safety and health extensively involved in order to produce a product without injuries or uncontrolled hazards?	Can the product be produced without any waste?
Is the work environment physically and emotionally safe?	Is the work environment able to meet the needs of internal and external customers?
Are safety and health considered in every activity and decision that is made?	Can the service be delivered one request at a time?
What recognized, hazardous conditions are present on the job? Can a worker get hurt?	How is the product or service rendered?
How does one know if one's job is being done safely?	How does one know if one's job is being done the right way?
How does someone know if a service they provided was free from recognized hazards or injuries?	How does someone know if the service they are providing is free from defects?
If an employee has a safety concern, does this person know who to contact?	If a worker has a problem, does this person know who to contact?

Table 1 Parallelism of Safety and Health with Lean Manufacturing

Continuous improvement means that companies are constantly looking for ways to better their operations, processes or end-products. If work procedures are improved, and workers understand well what they mean, then the root cause of near misses or actual accidents can be better understood, and corrective actions can be expedited as well. Maintaining long, lasting relationships with other companies or organizations, private or public, will be easier through mutual collaboration and the reduction in mishaps, injuries or fatalities. This will no doubt be reflected in the quality of the end-product, increased productivity or good reputation of the company.

Another principle of Lean that can be applied to safety and health is automation. If an abnormal situation arises, then the process must be stopped. A near miss is a very clear indication that there exists a situation that is presenting discrepancies. An unsafe action or condition may be present, and it must be corrected. Lean also relies upon visual controls. In safety and health management, this principle has to do with signage, photographs or pictograms. If suitable pictures are used to depict, for instance, how to lock-out and tag-out an injection molding machine, equipment startups following maintenance activities could be made much safer. Employees in charge of this procedure will be reminded of all the steps they need to take in order to eliminate these and similar safety issues. Better product quality can also mean more safety for the end-user. When Lean is used in a company it eliminates low-value, inefficient activities from various process. Thus by adopting Lean the reputation and safety of a company's product can soar worldwide.

Impact of Globalization on health and safety

On occasion, multi-national companies may act irresponsibly, as is the case of chemical companies that still make DDT in developing countries. The result of these and similar decisions is ecological and social damage to the region. Migrating industries or companies with operations offshore generally require conformance to environmental and occupational health and safety standards of the host country. Consequently, worker fatality rates are much higher in newly industrialized countries than in the developed nations. Workplace injuries occur in developing countries at rates which were common in developed nations during the early years of the Industrial Revolution. In this regard, the Industrial Revolution is taking place all over again, but with much larger populations of workers and in many more countries. Eliminating and reducing the exposure of employees to hazardous working conditions means fewer accidents.

Developing countries seldom have enforceable occupational and environmental regulations. They are concerned with overwhelming problems of unemployment, malnutrition and infectious diseases, often to the exclusion of environmental hazards. Newly industrialized countries are eager for the financial benefits that foreign companies and foreign investors bring them. But with those benefits come social and ecological problems.

The positive economic and social results of industrial activity in developing nations are often accompanied by serious environmental degradation. The major cities of developing nations are now reeling with the impact of air pollution, the absence of sewage treatment and water purification, the growing quantities of hazardous waste buried in or left on the soil or dumped into rivers or the oceans. In many of the world's countries, there are no environmental regulations or, if they exist at all, there is little or no enforcement. The workforce of developing nations is accustomed to working in small industry settings. Generally, the smaller the industry, the higher the rate of workplace injury and illness, and these workplaces are characterized by unsafe buildings and other structures, old machinery, poor ventilation, and noise. Moreover, workers in such companies may not have access to safety equipment, training, and skills. Protective clothing, respirators, gloves, hearing protectors and safety glasses are seldom available. The companies are often inaccessible to inspections by government health and safety enforcement agencies. In many instances, they operate as an "underground industry" of companies not even registered with the government for tax purposes.

Lean is focused on getting the right things to the right people/equipment and to the right place at the right time in the right quantity, in order to achieve perfect work flow, even while minimizing waste and maintaining flexibility. In addition, Lean is focused nowadays on mentoring processes or what is known globally as 'Lean Sensei'. The philosophy behind Lean Sensei says that companies should be encouraged to seek third party unbiased advice and coaching from other companies, organizations or teams. Occupational safety and health can also be viewed as Lean Sensei. Companies with global operations can still seek for advice with regard to work practices and safety and health standards, especially if those standards are non-existent in the country where operations are currently being done.

Poor arrangement of the workplace results in wasted motion or effort. Reduction of this is a major focus of Kaizen. Other types of waste include: 'muda' or non-value added work, 'muri' or overburden and 'mura' or unevenness. Muri applied to occupational safety would be all the unreasonable work that management imposes on workers due to poor organization. Carrying heavy weights, moving things around and doing dangerous tasks is essentially pushing a person beyond their natural limits, which could result in serious, permanent injuries or fatal accidents.

Unreasonable work or poor organization is almost always a cause of variation. That is, the worker, when pushed beyond her limits, tends to move away from best work practices and starts working with no pattern, creating thus potential unsafe conditions in the workplace. Muri focuses on preparation and planning of a process or what can be avoided proactively by design. Bad planning in safety could lead to disastrous consequences. Mura focuses on the implementation and elimination of deviations at the operational level instead. If safety plans are carried out with a lot of deficiencies or variations, workers will start creating their own way of doing their work, and these fluctuations could lead to injuries or accidents. Muda is discovered after the process is in place and is dealt with reactively. Overproduction can exert a great deal of physical and mental stress on workers, and fatigue and weariness could cause distraction and serious accidents. Excessive motion is also a waste or muda. People moving or walking more than is required to perform their job could slip and fall, for example. Over processing due to poor tool or product design and the effort involved in fixing defects could expose an employee to crushing or limb amputations when working with power presses.

In North America, unfortunately, most Lean practitioners focus on the tools and methodologies of Lean versus the philosophy and culture of it. Behind occupational safety and health, there is also a philosophy that should be understood, no matter where the company might stand globally. The primary goal of occupational safety and health is the reduction of illnesses, injuries and deaths in order to improve the well-being of workers.

Conclusion

Lean and safety both demand change and improvement. Through the elimination of waste, Lean can ensure that employees worldwide work in a safe environment by reducing overexertion, stress levels, repetitive motion, excessive transportation, inventory and waiting time. Safe work practices must be developed and set up by employees in conjunction with the work area that presents safety issues. The problems and their solution must be understood instead of overreacting. Safety and health can be incorporated into Lean when production systems are simplified, space is maintained through the tools of Lean, and when visual charts, graphs and information are displayed and understood. This will make the organization a safer, more productive place of work. Companies that operate worldwide must understand the importance of global occupational health, and they must be aware that their operations might be contributing to the import of safety hazards into poor countries. Multinational corporations are the most powerful political institutions of our time, and they have the resources to influence local and overseas governments. Therefore, people in developing countries must make demands for governments to ratify global enforcement of OSH (Occupational Safety and Health) standards through the international labor organization and OSH conventions.

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