ATMAE 2009 Conference Presentation Proposals and Proceedings Papers

Review Process & Statistics for Presentations and Papers

This CD-ROM of the ATMAE 2009 Conference 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 2009 Annual ATMAE Conference, "Emerging and Green Technologies for Today's Economic Challenges," in Louisville, Kentucky, November 10-14, 2009. This CD-ROM includes all of the conference presentation proposals that were accepted through peer-review for presentation and publication (except those withdrawn by the authors), and the Conference Proceedings Papers (that are based on accepted presentations) which were accepted through the peer-referee process.

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

The ATMAE 2009 Conference Presentation Abstracts were subject to a double-blind peer review process. In 2009, the peer-review process led to acceptance of 71% of presentation proposals (182 accepted, and not cancelled or withdrawn, of 257 proposals submitted).

The ATMAE 2009 Conference Graduate Student Research Presentation Abstracts were chosen by a blind-review process led by ATMAE members who are University faculty. Fifteen abstracts were submitted, and four were chosen for presentation, an acceptance rate of 26.6%.

The ATMAE 2009 Conference Proceedings Papers went through a similar process. Authors of accepted conference presentations were invited to submit expanded versions of their presentations and the Conference Papers were chosen after a double-blind peer review process, with panels of at least three reviewers involved in reviewing each submission. Pursuant to ATMAE 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 2009, of 182 accepted conference presentations, 43 were expanded into longer papers and were submitted for the peer-review process. The double-blind peer review process led to acceptance of 44% of the papers submitted, for a total of 19 "ATMAE 2009 Conference Proceedings Papers." These 19 Conference Papers represent 10.4% of the proposals accepted for presentation at the 2009 ATMAE Conference, and only 7.4% of proposals submitted.

Best 2009 ATMAE Conference Proceedings Paper: "Assessing the Impact of Waste on the Value Production Model in Construction" (Construction track), by Mr. John R. Patton, Director of Construction, The Home Depot, and Ph.D. Student, Indiana State University.

COPYRIGHT 2009 ATMAE: The ATMAE 2009 Conference Presentation Abstracts and Proceedings Papers are copyrighted by the Association of Technology, Management, and Applied Engineering. The submission, review and publication process for the 2009 Conference Presentation Abstracts and Proceedings Papers was organized, coordinated and administered by the ATMAE staff at the national office in Ann Arbor, Michigan. If you have questions about the ATMAE 2009 Conference Proceedings, the Annual ATMAE Conference or any of ATMAE's programs, please contact the ATMAE office.

The Association of Technology, Management, and Applied Engineering
3300 Washtenaw Avenue, Suite 220, Ann Arbor, Michigan, 48104
www.ATMAE.org • atmae@atmae.org • 734.677.0720

Acknowledgements

A number of ATMAE members and leaders dedicated their time and expertise to review of the Conference Presentation Proposal Abstracts, Conference Proceedings Papers, and Best Papers for the ATMAE 2009 conference. Without their time and efforts, we could not provide a blind peer-referee process. Our gracious thanks go to all of these dedicated ATMAE members:

Conference Presentation Abstracts: David Batts, Herb Barber, Kevin Berisso, Jessica Buck, Paul Cesarini, Jim Collier, Raj Desai, Mark Doggett, Ahmed ElSawy, John Earshen, Verna Fitzsimmons, Will Fanning, Liping Guo, Mitch Henke, Suzanne Horne, Kevin Howell, Vincent Howell, John Irwin, Mahyar Izadi, Balsy Kasi, Lynda Kenney, James Keyes, Daniel Kirby Dale McDaniel, Tom McDonald, Ugo Mgbike, Mark Miller, Dave Monforton, Arun Nambiar, Sean Nelson, Loren Niemeyer, Leslie Pagliari, Michael Powers, Tom Reeves, Clair Roudebush, Tom Scott, Randy Shaw, Ernie Sheldon, Jeff Short, Ron Spangler, Ravindra Thamma, Cynthia Thompson, Keith Touchet, Ann Trausch, Jeffrey Ulmer, Pao-Chiang Yuan, Ahmad Zargari

Graduate Student Research Presentation Abstracts: Todd Albert, Randy Peters, Marion Schafer

Conference Proceedings Papers: David Batts, Herbert Barber, Kevin Berisso, Raj Desai, Ahmed ElSawy, Verna Fitzsimmons, Allan Gentry, Liping Guo, Vincent Howell, James Jones, Balsy Kasi, James Keyes, Daniel Kirby, Keith Touchet, Terry Leeper, Stan Lightner, Jack Martin, Dale McDaniel, Tom McDonald, Kathryne Newton, Argie Nell Nichols, Leslie Pagliari, Michael Powers, Paul Resetarits, Clair Roudebush, Charles Schwab, Ravindra Thamma, Jeffrey Ulmer, Haoyu Wang, Ron Williams Faruk Yildiz

Best Paper Process: David Hoffa, Lynda Kenney, Ivan Mosley, Sergio Sgro

The ATMAE Staff at Association Management Resources (AMR) manage the submission, review and publication process for the Proceedings CD-ROM. Thanks to Dave Monforton for his administration of the submission process, review process, and preparation of all of the CD-ROM content for publication, and to Keith Bretzius for his design, layout and prepress work for the CD-ROM.

ATMAE
Ann Arbor, Michigan
November 2009

ATMAE
LEAD • INNOVATE • COLLABORATE

The Association of Technology, Management, and Applied Engineering

2009 Conference Preceedings Papers

EMERGING & GREEN TECHNOLOGIES

for Today's Economic Challenges

November 10 - 14, 2009
Hyatt Regency - Louisville, Kentucky

ATMAE LOUISVILLE 2009 NOVEMBER 10-14

Table of Contents - Presentation Abstracts

Administration

Beyond Pasteur's Quadrant: Launching Tomorrow's Leaders by Building the Research Pipeline in Technology, Management, and Applied Engineering ____ 2
Developing a Course Integrating Lean Principles with Green Thinking ____ 10
Employing Clean Energy as a Common Ground for Interdisciplinary Collaborations within a Technology-Driven Institution ____ 15
Leading and Integrating Adjunct Faculty into a Technology Program Team ____ 20

Construction

Assessing the Impact of Waste on the Value Production Model in Construction ____ 25
Selected through peer-review as *"Best ATMAE 2009 Conference Proceedings Paper"*
Incorporating LEED and Green Topics in Construction Management Courses ____ 31

Electricity, Electronics, & Computer Technology

Design a Microcontroller Trainer for Hands-on Distance and on-Campus Classes ____ 37
Exploration of BDI Modeling Applied to Electric Motor Vibration Monitoring and Analysis ____ 47
Including GPS and GPS Tracking in Automatic Identification/RFID Courses ____ 52

Electricity, Electronics, & Computer Technology – *Green Issues*

Energy Harvesting and Storage Techniques from Ambient Energy Sources ____ 57
Power Management of a PV Solar - Savonius Wind Hybrid Powered Illumination System Using the Arduino Microcontroller ____ 64
Wind Power Technologies in the United States: A Technical Comparison between Vertical and Horizontal Axis Wind Turbines ____ 69

Management

Application of Theory of Constraints to Sustainable Manufacturing: A Case Study ____ 77
Can We Make Accounting Relevant Again? Non-Traditional Accounting Systems Can Drive Productivity and Future Prosperity ____ 87
Development of a Quality Management Course for Adult Learners using Backward Design ____ 92
Using Mock Recall Data to Measure Continuous Quality Improvement ____ 97

Manufacturing

Horizontal vs. Vertical Axial Flux Wind Turbine Design and Manufacture ____ 104
Marketing Your Manufacturing/Industrial Technology Program as Clean, Neat and Glamorous ____ 114

Safety

Potential Application of Artificial Neural Network Models for Enhancing the Revised NIOSH Lifting Equation ____ 120

Index of Authors

A
Dr. Mike Asoodeh ____ 64

B
Dr. Gary R. Bertoline ____ 2

C
Dr. William Campbell ____ 120
Dr. Rigoberto Chinchilla ____ 69

D
Dr. Mark Doggett ____ 87

F
Dr. Dennis W. Field ____ 92
Dr. Steven A. Freeman ____ 92
Ms. Mariana Villasana Freites ____ 57

G
Dr. Denise Gravitt, LEED AP ____ 31
Dr. Samuel Guccione ____ 47,52,69

H
Dr. Nathan W. Hartman ____ 2
Dr. Steve Hsiung ____ 37
Dr. Charles R. Hurburgh, Jr. ____ 92,97

I
Dr. John L. Irwin ____ 104

J
Dr. James W. Jones ____ 20
Dr. Nilesh N. Joshi ____ 77

K
Dr. Julia A. Kalish ____ 10

L
Dr. Chad M. Laux ____ 97

M
Dr. Mark R. Miller ____ 114
Dr. Farman A. Moayed, PE ____ 120
Ms. Gretchen A. Mosher ____ 92,97

P
Mr. John R. Patton ____ 25

R
Mr. Glen D. Roberson ____ 15

S
Dr. Marvin I. Sarapin ____ 2
Dr. Douglas J. Schauer ____ 15
Mr. Jim Stratton ____ 47

T
Mr. Joseph Tillman, P.E. ____ 69

W
Mr. David Wekesa Khasenye ____ 64

Y
Dr. Faruk Yildiz ____ 57

Administration

Administration

Beyond Pasteur's Quadrant: Launching Tomorrow's Leaders by Building the Research Pipeline in Technology, Management, and Applied Engineering

Dr. Nathan W. Hartman
Purdue University, 401 N. Grant Street, West Lafayette, IN 47907-2021, 765-496-6104 , nhartman@purdue.edu

Dr. Gary R. Bertoline
Purdue University , 150 Knoy Hall, 401 N. Grant Street , West Lafayette, IN 47907-2021, 765-496-6071, bertoline@purdue.edu

Dr. Marvin I. Sarapin
Purdue University , 401 N. Grant Street, West Lafayette, IN 47907-2021, 765-494-4585 , msarapin@purdue.edu

Introduction

The need to address professional development in higher education is typically geared toward faculty, but the need to prepare undergraduate and graduate students for research in technology disciplines is pressing. Economic uncertainty in the domestic arena and increased global competition will continually have an impact on our society's ability to remain viable and competitive in the global marketplace. An academic research paradigm that accounts for not only traditional strengths, but that also includes more recent ideas towards innovation and entrepreneurship is necessary in this emerging environment. A research methodology that embraces collaboration between technical disciplines, industry, and federal agencies, and an examination of how to manage this environment to glean critical information for decision making is important, particularly for technology programs located in research-intensive universities.

In 2008, the National Association of Industrial Technology Executive Board conducted an extensive study resulting in the membership voting to rename the organization to better reflect the nature of the professional organization for the 21st century. The new name, the Association of Technology, Management, and Applied Engineering, presents many challenges and opportunities for the colleges and universities offering programs related to the association. The renaming has been particularly imperative for programs such as those in the authors' institution because the College of Technology includes a wide array of programs focusing on Technology, Management, and Applied Engineering. The College of Technology offers BS, MS, PhD degrees, and professional development programs focusing on applied and use-inspired research for discovery, engagement, and learning to support the vision and mission of the college.

Developing and articulating a paradigm for how "use-inspired research" in applied technical and managerial programs can define the nature of research in the field of Technology, Management, and Applied Engineering and is important for the identity of our associated disciplines. By doing so, we will better position our programs for making unique contributions to the Academy and society. One critical aspect of making these contributions comes from applied research in university and industry settings. Qualified people must be trained to conduct such work, which typically starts with graduate education. But where do those students come from? Are they currently working in industry, or are they our own undergraduates looking for further education? The answer is often both of those groups, but they may not always be aware of what lies ahead for them in graduate school. They may also have been away from an academic environment long enough to have difficulty adjusting to its own cultural norms, no matter how technical or applied the educational environment. Building the pipeline of undergraduate and graduate students interested in research in the field is critical to the long-term viability of Technology in providing the future leaders in the field.

One University's Strategic Vision

Colleges and universities that offer degree programs in the fields of Technology, Management, and Applied Engineering exist within the mission and vision of their particular institution. The university at which the authors are employed has recently developed the strategic plan "New Synergies." This plan articulates a common vision for the learning, discovery, and engagement mission of the institution based on a foundation of three major elements (see Table 1).

Table 1 – New Synergies

Launching Tomorrow's Leaders	Promote excellence in learning experiences and outcomes, fostering intellectual, professional, and personal development to prepare learners for life and careers in a dynamic, global society.
Discovery With Delivery	Advance the frontiers of knowledge, innovate technologies that address the grand challenges of society to serve humanity, and improve the quality of life around the world.
Meeting Global Challenges	Address the critical needs of society, and catalyze economic development and entrepreneurship consistent with a public research university of the 21st century with global impact.
	Purdue University (2008)

These three elements (Launching tomorrow's leaders; Discovery with delivery; and Meeting global challenges) can be helpful in articulating a vision for much of what we seek to accomplish in the undergraduate and graduate degree programs in Technology, Management, and Applied Engineering. With the proper undergraduate and graduate experiences, our alumni will become tomorrow's leaders. Our programs seek to innovate and apply technologies for the benefit of our economy and society. Knowing that the world is flat (Friedman, 2005), our graduates will need to address the world's grand challenges globally to have successful careers. Employing an integrated research paradigm that draws its vision from the pure research–applied research continuum could be an overarching strategy for the discovery with delivery mission for professionals in Technology, Management, and Applied Engineering fields to reach their full potential in contributing to a better world.

The College of Technology's Strategic Vision

The College of Technology's (2009) recently completed strategic plan was designed to guide its work through 2014. The College goals were developed to complement the New Synergies vision already discussed. A thumbnail view of the College of Technology's strategic vision is as follows.

Overarching Goals

- Build a vibrant community of faculty and student scholars who excel in their disciplines and contribute to the betterment of the college and university through the scholarship of learning, discovery, and engagement.
- Lead an environment that actively promotes strategic collaboration among CoT faculty in all disciplines and at all CoT locations as well as other disciplines across campus and the world.
- Significantly increase financial resources from private philanthropy, corporate investment, and foundations.

Launching Tomorrow's Leaders

- Attract, retain, and graduate quality undergraduate and graduate students prepared to be tomorrow's leaders.
- Promote student success through excellence in curricular programs.
- Increase graduate enrollment in the College of Technology to 15% of the total enrollment.

Discovery with Delivery

- Advance research so that the College of Technology can better enhance economic development, improve societal well-being, and meet global challenges.

Meeting Global Challenges

- Conceive grand challenges and problems facing humankind in areas such as security, energy, and STEM education, and contribute to solutions using global perspectives.
- Create and strengthen relationships with organizations engaged in meeting and affected by global challenges.

Incorporating a research paradigm in a College of Technology context that builds on the unique strengths of its Technology, Management, and Applied Engineering-based programs is important in achieving the vision of this strategic plan. Particularly when our programs coexist on campuses including science programs with well-established missions in discovery, understanding and communication, a broad vision of research and how Technology, Management, and Applied Engineering programs can contribute to the knowledge base and applications of science and technology is paramount.

Historical View of Research

To understand the roles and goals of research in the United States and its institutions of higher education, one would have to begin with the influences of ancient Greek culture. To broadly understand and appreciate the role of research it is recommended that the reader refer to Stokes (1997). Stokes writes that although Greek culture did not have an equivalent for science, they did develop scientific inquiry. They were able to regard the world as a natural system governed by general and discoverable natural causes and to leave the gods out. They believed that natural causes could be explained by rational inquiry.

The other major contribution to our modern view of research was the Greeks' philosophic motive of severing inquiry from use, which was strongly reinforced in Greek civilization by the consignment of the practical arts to people of lesser class, and manual labor increasingly to their slaves. As a result, practical utility was rejected as a legitimate end of natural philosophy, and this became the core belief in the Platonic and Aristotelian systems of thought. Plato's ideal Republic radically separated those engaged in philosophic inquiry from those engaged in the manual arts by assigning a more exalted position to philosophic inquiry. This thought set in motion a tension that remains today between *pure* and *applied* research or research to gain *new knowledge* and research for practical *use*.

The views of the Greek philosophers toward scientific inquiry have been challenged throughout the ages. Challenges started most notably by the Hippocratic physicians of ancient Greece who sought knowledge to improve the practice of medicine. Later, Francis Bacon held the view that techniques were knowledge rather than fruits of knowledge. However, there have also been many more defenders of the linear approach to research who claim that applied or use-based research flows from basic research, including the most influential person in the United States in the mid-twentieth century, Vannevar Bush. After the recognition by our nation's leaders for the important role that research played in World War II, Bush was commissioned by President Roosevelt to submit a report recommending how research should be supported by the Federal government in peacetime. His subsequent report titled *Science, the Endless Frontier*, has as its first canon that basic research is performed without thought of practical ends (Bush, 1945). Its second canon states that basic research is the pacemaker of technological improvement.

Basic vs. Applied Research

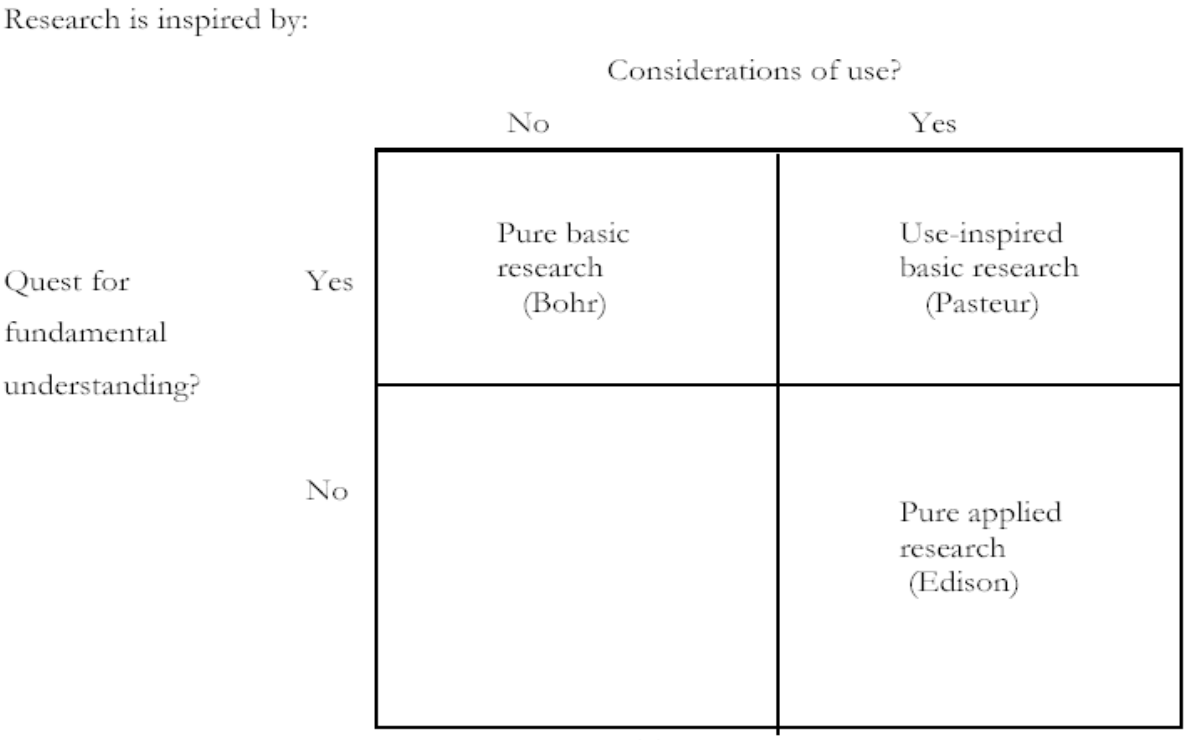
Bush's views continued the tension between basic and applied research in our nation. However, you can find throughout history examples of applied or use-inspired research that actually contributed to our basic understanding of nature. Pasteur is a classic example of a noted scientist who wanted to understand fundamental laws of nature though he was inspired not through his desire to create new knowledge but to solve practical problems related to specific diseases. Pasteur's work in the late 19th century is an example of the rise of a new scientific discipline, microbiology, that was a new branch of inquiry created out of the effort to cure diseases and not only for the quest for fundamental understanding. This is an example of *use-inspired basic research*.
Of course there is much pure research that is undertaken without regard for use or application. A classic example is the work of Niels Bohr's work in physics on the structure of the atom, which can be classified as *pure basic*

research. Research that is the farthest removed from pure basic research is the type that was undertaken by Thomas Edison. Edison's classic work on finding a filament for a light bulb is an example. Edison had no desire to understand the science underlying his discovery during his quest to make a working light bulb. In fact, it was left to other scientists to consider its more fundamental implications for the Edison Effect, which eventually led to a Nobel Prize for Rosenberg and Thompson for discovering the electron. Edison's research can be categorized as *pure applied research*. A great deal of modern research belongs in this category and is extremely sophisticated although narrowly targeted on immediate applied goals.

Pasteur's Quadrant Model of Scientific Research

Stokes advocates that from these three forms of research you can create a model to better understand and explain the goals and roles for various forms of research. Stokes calls his model Pasteur's Quadrant Model of Scientific Research (Figure 1). This model represents the 3 forms of research that are commonly undertaken and described above. The model is a good representation for the types of research but does not depict the interaction that actually occurs when one engages in most research.

Figure 1. Quadrant Model of Scientific Research.



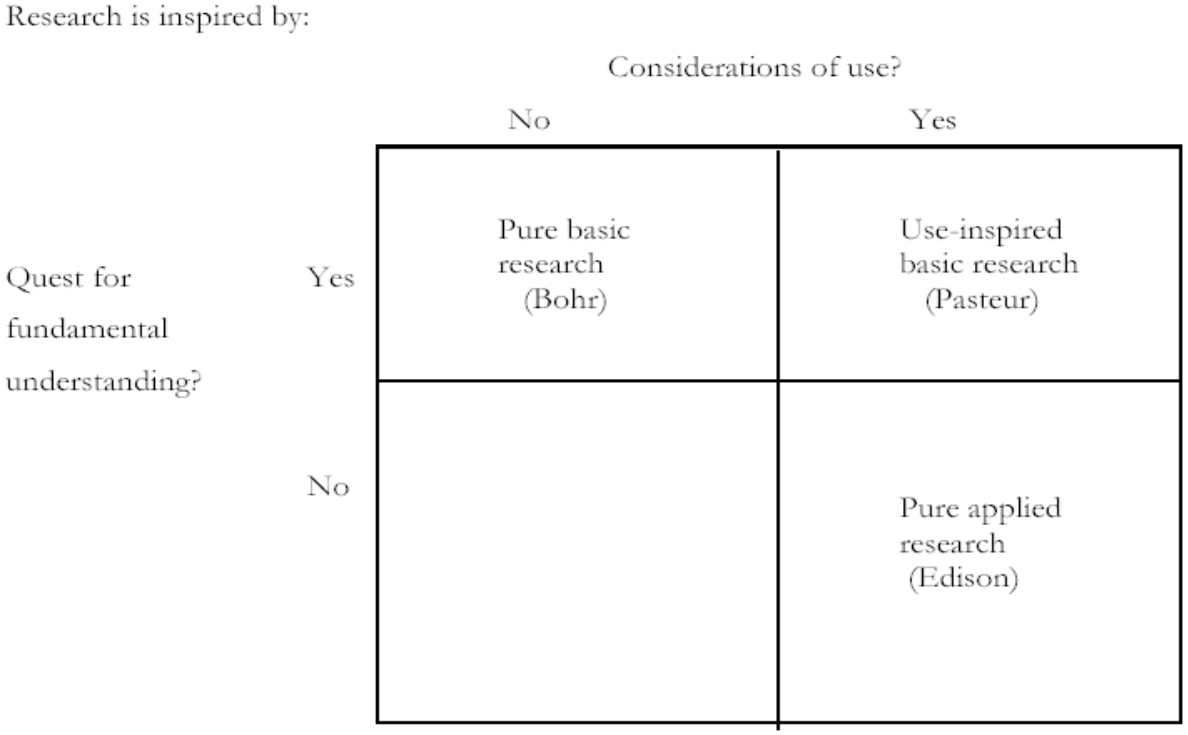
(adapted from *Pasteur's Quadrant: Basic Science and Technological Innovation*, Stokes 1997).

Pasteur's Quadrant Model of Scientific Research can be modified to represent the more dynamic nature of research and the interaction that can occur between pure basic research, use-inspired research, and pure applied research. Stokes (1997) proposed such a model and it is represented in Figure 2. This model addressed the clear need to represent the dual, upward path as interactive but semiautonomous. Science often moves from an existing to a higher level of understanding through pure research where technology has little influence. Technology often moves from an existing to an improved capacity by narrowly targeted applied research, or by engineering or design changes on existing technology, or by simple tinkering at the bench, where science has little influence. However, each of the paths is, at times, generally influenced by the other, and this influence can move in either direction, with use-inspired basic research often serving as the connecting role.

A Revised Dynamic Model of Research

The dynamic nature of research is also referred to as *translational research*. The traditional boundaries among basic research and use-oriented research are yielding to a single, continuous, bidirectional spectrum commonly termed translational research. Translational research is the bridge from discovery to delivery and back indicating the interplay between basic, use-inspired, and applied research.

Figure 2. A Revised Dynamic Model of Scientific Research.



(adapted from *Pasteur's Quadrant: Basic Science and Technological Innovation*, Stokes 1997).

The Role of Technology in Research

So what roles in research should faculty and students pursue in the College of Technology? When looking at Pasteur's quadrant or the Revised Dynamic Model and with an understanding for the historical context and definition for each quadrant, it is clear that the faculty and students in Technology should be focused on research that falls within use-inspired basic research (Pasteur) and pure applied research (Edison). This translational research is important, significant, and has great value in our society. This type of research is inspired for a *practical* end, which aligns perfectly with *technology* as a discipline.

Faculty in Technology engaged in Discovery have many opportunities to engage in research which is *use* inspired; that is, with a specific end goal in mind that will solve problems or enhance existing techniques and processes. Faculty in Technology engaged in Discovery have many opportunities to engage in research that is purely *applied* in nature where the specific goal is to apply technology in novel ways to solve problems, extend existing technology, or create new technologies. Technology faculty have the knowledge and professional obligation to pursue use-inspired and pure applied research as leaders in their discipline. All this can be done in a scholarly manner and in many cases following the same rigor and publication standards one would employ when engaged in pure basic research.

Impact of Discovery with Delivery on Technology Programs

Discovery with delivery embodies solving real problems through research that touches people and locations outside the academic environment. It makes use of academic expertise to engage society, especially industry, in addressing its challenges. Given the relative flexibility of the academic environment, there are many ways in which industry can be involved in bringing authentic learning opportunities to students. One of the best ways to accomplish this engagement between academia and society at large is through senior-level capstone courses and graduate-level directed projects for masters degree students.

Undergraduate capstone courses represent a culminating experience for both faculty and students (Boyer, 1998). Students are afforded an opportunity to display all they have learned in their plan of study in the completion of a substantial project work setting. It is meant to expose a broad range of skills and abilities (Paquette, 2005). Faculty also are able to see their students in action and gauge their progress in an environment where they typically serve more as an adviser than as a teacher. Many capstone courses have students work on group projects and they tend to incorporate some form of a service component (Otto & Wood, 1999; Bringle & Hatcher, 1996; Weigert, 1998). As such, these types of courses and projects are an ideal way to begin engaging industry and start building those relationships. In doing so, students learn about managing projects and timelines, adjusting to group differences and managing conflicts with potentially new cultural norms, and the integration of domain expertise with varying levels of technical skills that the group members possess (Byer, 2007).

In the Computer Graphics Technology Department at the authors' university, an applied research model has been employed to capture these ideals. The capstone class actually runs as two courses in parallel: CGT 450 (Professional Practices) and CGT 411 (Contemporary Problems in Applied Computer Graphics). CGT 450 covers topics such as interviews, portfolios, and résumé development, all with a focus on computer graphics disciplines. CGT 411 is a research-based team project course. It is also run in an effort to simulate a corporate environment. Student teams are created with four members in a group. Group members can be "hired" and "fired" on the basis of their performance and weekly rating system. Project specifications are solicited from outside organizations—either industry partners or external organizations on campus. Groups are established by each student bidding on the top three projects he or she would like to work on. Those students who rank a particular project option as their first choice are then pooled to assemble a group. If more than four people choose a particular project as their first choice, the project sponsor is brought in to interview the students along with the faculty course coordinator. Those students not selected move on to their second and third project until they are placed.

The nature of the project and the dynamic nature of the assessment of each group are what make this class effective. Groups are ranked against each other based on meeting project milestones and gaining "press" for their group, which could result from making a poster presentation at a conference, giving a lecture, or substantial project progress in a short period of time or a number of other things. As they receive these weekly assessments, they must always adhere to a basic tenet of the course—how do you know what you have produced is good? Since this is a computer graphics curriculum, the projects tend to have a significant graphics creation process involved with them. But they also have a substantial evaluation component to them. The groups are required to develop a research or evaluation methodology for their project. While not as structurally sound or sophisticated as a Masters thesis or a doctoral dissertation, they are required to form research questions, develop hypotheses as appropriate, select a research design, gather data, analyze it, and draw appropriate conclusions. The nature of the methodology—quantitative or qualitative—is up to the student group members and their faculty sponsor, with the goal being to pick a methodology that is appropriate to the questions being investigated. Each group must pass four substantial milestones: development of a research question, passing a go/no-go presentation (analogous to doctoral preliminary examinations), delivery of a final presentation (analogous to a doctoral defense), and writing of a final report (similar in structure to a dissertation or a journal article). In doing so, the students are able to see first hand each phase of a research project.

This capstone course structure has led to many serendipitous benefits as well. Several CGT student groups have won on-campus entrepreneurial competitions, while others have earned citations from state legislators for their work with non-profit groups and people with special needs to raise awareness of sensitive issues. Still other groups have engaged with industry partners, eventually presenting their results to divisional vice presidents or

traveling internationally to present their findings to the highest corporate officials. All of these experiences not only granted students an opportunity to demonstrate their computer graphics skills, but also reinforced other knowledge and skills that educators desire their students to demonstrate: awareness of others and a social responsibility, effective communications skills to promote an idea, and the ability to engage with external partners in an international setting.

Several of the students who do well in the CGT capstone class often consider (and eventually enroll into) the graduate program within the CGT department. One of the options they have in an MS program is the ability to do a directed project. According to the College of Technology graduate handbook (2007), 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. 12)

As such, this directed project experience serves as a natural lead-in to funneling students with a more applied focus into the graduate program, and it continues to provide an opportunity for applied research that engages industry. The directed project focuses on establishing the significance of the problem, uses a validation mechanism executed in industry terms and conditions, and often produces a tangible deliverable to be shared with the industrial sponsor.

Impacts of Paradigm on Professional Post-Baccalaureate Education

Industry involvement in academic arenas is not new—it has been happening regularly for over fifty years. Academic research has driven industry innovation and vice versa to eventually arrive at our current point where much of the innovation occurring today happens as a result of partnership between industry and academia. By partnering with industry, faculty at all levels can present to students problem scenarios that are not easily contrived in normal academic situations (Reichlmayr, 2006). These are the sorts of problems that require students to engage deeply with the problem, employ active, authentic learning, and build cognitive scaffolding that allows them to assimilate what they have learned (Savin-Baden, 2000). While industry and academic collaboration can revolve around applied research, it is not to say that the relationship does not have its challenges. Misalignment of university and industry calendars, lack of understanding or focus on the part of the partners, and the desire to own all IP makes this situation difficult without a great deal of trust and communication (Swain, 2009). One of the best ways to accomplish industry and academic collaboration is through education. Most schools offer some form of practicum or work-based instruction during their program.

Many schools have turned to professional degree and certificate programs, short courses that have goals of industry outreach, and weekend masters-style programs. These programs typically evolve out of traditional academic programs, but often include course additions that appeal to a specific customer industry segment. For example, the College of Technology at Purdue University has created PROSTAR—The Center for Professional Studies and Applied Research. The goal of this center is to provide an administrative entity for managing professional technical education and to provide a framework to promote applied research (Bertoline & Schuver, 2009).

Summary

This paper presented an academic paradigm for research in Technology, Management, and Applied Engineering for faculty and students at the colleges and universities in the field. It also presented a discussion of use-inspired and pure applied research tied to industry challenges for innovation and entrepreneurship. Academic and industrial partnership in research efforts has been an emerging trend over the last 20 years. To capitalize on such momentum, this model must become more common for technical education in the future. It must engage academic and industrial institutions at all levels in order for Technology, Management, and Applied Engineering to achieve its full potential in contributing to society.

References

Bertoline, G. R. (2009). Applied and use-inspired research for engineering technology: A rationale for defining a research domain. *Proceedings of the 2009 American Society for Engineering Education Annual Conference & Exposition,* Austin, Texas, June 14-17, 2009.

Bertoline, G.R. & Schuver, M.T. (2009). Center for professional studies in engineering technology. *Proceedings of the 2009 American Society for Engineering Education Annual Conference & Exposition,* Austin, Texas, June 14-17, 2009.

Boyer, E. L. (1990). Scholarship reconsidered: Priorities of the professoriate. Princeton, NJ: The Carnegie Foundation for the Advancement of Teaching.

The Boyer Commission on Educating Undergraduates in the Research University. (1998). *Reinventing undergraduate education: A blueprint for America's research universities.* Stony Brook: State University of New York. Retrieved on February 20, 2009 from http://naples.cc.sunysb.edu/Pres/boyer.nsf/

Bringle, R.G. & Hatcher, J.L. (1996, March/April). Implementing service learning in higher education.

Bush, V. (1945). Science: The endless frontier. Washington, DC: United States Government Printing Office.

Byer, R.L. (2007, January). University-industry relations play a key role in technology development.

The College of Technology. (2007). Graduate student handbook. Retrieved July 9, 2009 from http://www.tech.purdue.edu/Graduate/grad_downloads/Grad%20Handbook%20r6-07.pdf

Friedman, T. L. (2005). The world is flat: A brief history of the twenty-first century. Farrar, Straus & Giroux.

Hartman, N., Sarapin, M. and Bertoline, G. (2009). Examining the nature of technology graduate education. Manuscript submitted to *The Journal of Technology Studies: A Publication of Epsilon Pi Tau*. Bowling Green, OH.

Keating, D.A. et al. (2005). Framework for integrating project-based learning, experience and practice in professional graduate education for engineering leaders in industry leading to the professional engineering doctorate and fellow levels. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition,* Portland, Oregon, June 12–15, 2005.

Otto, K. N. & Woo, K.L. (1999, November). Designing the design course sequence. *Mechanical Engineering,* ABI/INFORM Global, 39-42.

Paquette, M.D. (2005). A capstone course in a two-year geomatics program. *Surveying and Land Information Science, 65* (3), 223-226.

Purdue University. (2008). New synergies: Purdue University's strategic plan. Retrieved June 23, 2009 from http://www.purdue.edu/strategic_plan/documents/StrategicPlanBrochure.pdf

Purdue University. (2008). Insight, innovation, impact: The College of Science strategic plan.

Purdue University. (2009). Purdue engineering strategic plan: Extraordinary people, global impact.

Purdue University. (2009). College of Technology strategic plan: Innovation with impact.

Reichlmayr, T.J. (2006). Collaborating with industry—Strategies for an undergraduate software engineering program. *Proceedings of SSEE 2006,* Shanghai, China, May 20, 2006, pp. 13-16.

Sarapin, M., Hartman, N., and Bertoline, G. (2007). Advancing graduate education in a College of Technology context. *2007 Conference Proceedings Papers. National Association of Industrial Technology, 40th Annual Convention*. Panama City Beach, Florida October 23-27, 2007, pp. 2-7.

Savin-Baden, M. (2000). *Problem-based learning in higher education: Untold stories*. Buckingham, UK: The Open University Press.

Stokes, D. E. (1997). *Pasteur's quadrant: Basic science and technological innovation*. Washington DC: Brookings Institution Press.

Swain, C. (2009). Improving academic-industry collaboration for game research and education. *Proceedings of the ICFDG*, Orlando, Florida, April 26-30, 2009, pp. 191-198.

Weigert, K.M. (1998). Academic service learning: Its meaning and relevance**.** *New Directions of Teaching and Learning, 73*, pp. 3-10**.**

Administration

Developing a Course Integrating Lean Principles with Green Thinking

Dr. Julia A. Kalish
Purdue University, 401 N. Grant Street, West Lafayette, IN 47907-2021, 765-496-7708, kalishj@purdue.edu

Introduction

Both industry and academia have been presented with the unprecedented challenge of understanding and promoting more responsible, sustainable, and Greener working environments. Finding ways to integrate "Green" into the existing framework of industry is the key to making this transition a success. Lean Manufacturing has been profitably implemented both alone and in combination with initiative such as Six Sigma Quality. Combining Lean with Green is the next logical step in the growth and development of this robust industrial tool. It can be demonstrated that developing a new course or modifying an existing course to create a Lean/Green Industrial interface will combine Lean Manufacturing values with the philosophy of Green. The focus of this paper is to outline a new course that presents Lean concepts and is augmented with information and examples of how Green and Lean can not only coincide, but how they can actually create a synergistic effect for improvement.

Core Concepts of Lean Principles

Lean philosophy is widely associated with the Toyota Production System and Taiichi Ohno and the term "Lean" was said to be coined by Jim Womack of MIT, (Malloy, 2008). Lean has become a ubiquitous business strategy that works well in many environments which includes not only production systems, but service industries, non-profit agencies, and governmental entities. In order to understand the basic concept of Lean philosophy an understanding of the Five Guiding Principles, the 7 Wastes, and 5-S housekeeping is a must. Any class concerned with the topic of Lean needs to cover these topics in some detail. It is recommended that Lean be introduced first before efforts turn toward introducing Green philosophies.

Five Guiding Philosophies

The foundation of Lean Principles is built around the Five Guiding Philosophies. All other details of Lean can be attached to these five standards of thought. This is why it is important to begin the course with an introduction of the guiding philosophies. "Specifying value" is the first of the five, "identifying steps in the value stream" is next, "making value flow" is the third philosophy, followed by "pull value," and completed by "pursue perfection." When discussing the "specify value" philosophy, Womack and Jones (2003) noted in "Lean Thinking," that "the critical starting point for Lean thinking is value. Value can only be defined by the ultimate customer. And it's only meaningful when expressed in terms of a specific product (a good or a service, and often both at once), which meets the customer's needs at a specific price at a specific time" (p.16).

Once value has been determined, the next step in Lean demands identifying all steps in the value stream by defining and tracking every action taken in creating the product. This does not refer to just the steps in a manufacturing process, but rather incorporates all inputs beginning with the conception of a product or service all the way through delivery to the customer and beyond.

Once value is understood and the value stream has been thoroughly documented, it is paramount to make value "flow." A standard definition of flow is to "move along or out steadily and continuously in a current or stream" (The Oxford, 2009). Even though this definition is not directly tailored to for Lean production, it is still relevant in expressing the goal of Lean. Consideration of batch size, reducing or eliminating inventory, and minimizing unnecessary motion are considered step as well (Womack & Jones, 2003).

The fourth key philosophy is centered on the idea of "pulling" value as opposed to pushing unwanted products or services onto the customer. An easy example of noting the contrast between batch-and-queue, "push" production, and pull production is in the difference between how McDonalds French fries are made as opposed to the Subway sandwich previously mentioned. The French fries' production is founded on the classic batch-and-queue strategy where, based on past experience (sales projection), a batch of fries is made and then kept warm in hopes that someone will order them before they get cold and stale. Subway, on the other hand, does not create any sandwich until a customer indicates exactly what sandwich is desired. There is no waste, no inventory, and each sandwich can be custom-made on the spot (Womack & Jones, 2003).

The final philosophical point in Lean is to pursue perfection. The idea behind it is a simple one; the process of Lean is never complete. As soon as a process is put in place to pull value from the system, it is time once again to specify value. Customers change. Technology changes. The world changes. It would be ridiculous to think that in such a reality a company would ever be done. What "perfection" means changes and shifts constantly. Any course on Lean must start with an understanding of these basic philosophies before moving on to more detailed concepts such as 5-S housekeeping and the 7 wastes.

5-S Housekeeping

After some fundamental training and education concerning what Lean is and why it is important has been conducted, many organizations apply 5-S housekeeping techniques. The five S's, of 5-S housekeeping, loosely translated from Japanese, are; Sort, Straighten, Shine, Standardize, and Sustain (5S, n.d.). Initiating 5-S strategies are concrete and feasible first steps that allow employees to work toward something tangible while seeing immediate results.

Each of the 5 S's facilitates the flow of value by organizing and preparing work spaces and equipment to ultimately meet the needs of the end customer. The first of the 5 S's is "Sort." Sorting necessitates categorizing all items in the workplace as to how often they are used. This can include things as small as paperclips or as large as forklifts. Those items that are never used should be completely removed from the workplace (5S, n.d.; Seddon, 2007). Once sorting has been accomplished, it is possible to "Straighten" what remains. The old adage "a place for everything and everything in its place" applies to the second of the 5 S's. Careful consideration must be given to each item found in the workplace whether it be a tool, manual, or assembly part. Those items deemed to be employed most frequently should be kept closest to the workers and machines that use them whereas items used less frequently should not be allowed to take up prime locations. It is also common, at this step, to create visual control systems such as kanbans, visual scoreboards, or Jidoka lights (5S, n.d.).

With fewer items to consider and with each item assigned to a specific place, the next step is to "Shine" what is left. The Shine step may involve literally shining items, but it may also involve dusting, painting, sweeping, or light maintenance. The Shine step is thoughtfully accomplished before moving on to step four which is Standardize (5S, n.d.; Seddon, 2007).

"Standardizing" involves making the changes necessary to remove old bad habits that exist in the workplace (Sheddon, 2007). This could be accomplished by initiating a scheduled maintenance routine that includes a renewing of Sort, Standardize, and Shine. This step might also involve taking measures to ensure the workstation or cell is performing optimally (5S, n.d.).

Lastly, it is important to sustain the improvements that have been made. Systems must be put in place to preserve the improvements while allowing for future advances. A system of color coding, floor markings, or other visual cues should be used consistently throughout the facility as to minimize misunderstandings from one workspace to the next. It is important to continually go back to Sort and begin the sequence again while attempting to continuously improve the efficiency and organization of every workspace (5S, n.d.).

7 Wastes

Once a student understands the basic philosophy of Lean and the procedures for implementing 5-S, it is important to introduce more specific tools and methods to help eradicate problem areas. The "7 wastes" delineate the most important categories of waste found in many work situations. The 7 wastes are described in various ways using slightly different wording for emphasis but are generally accepted to be: "Overproduction," "Waiting," "Over-Handling," "Unnecessary Inventory," "Unnecessary Motion," "Over-processing," and "Defects." Each of the 7 wastes must be understood and appreciated by students before a more meaningful conversation concerning the expansion of the traditional concepts can be attempted (Page, 2004).

Ohno adds clarity and depth to this list of 7 wastes by defining Overproduction as referring to products that are produced too early or those that were not ordered by a customer. Waiting includes any time employees are idle and not adding value to the product. Over-handling can be any time a product is touched when value is not being added. Unnecessary inventory includes WIP, finished inventory, and unused raw materials. Unnecessary motion can refer to the motion of employees or of equipment. If something or someone is moving but not adding value to the product, it is considered a waste. Over-processing refers to any procedure, engineering, part, or feature that is not desired by the customer. Packaging is just one example of over-processing. Beyond providing basic protection for a product, it serves little or no purpose. Defects are an easily understood form of waste. Any unit or scrape that cannot be sold and does not meet the needs of the customer is the most characteristic type of waste. Understanding these fundamental sources of waste are a necessary starting point before introducing other types of waste that have an environmental twist to them (7 Wastes,. n.d.; Page, 2004).

Core Philosophy of Green Thinking

The second major body of knowledge that students must be introduced to is that of Green thinking or sustainability. This subject area is more challenging to present than Lean as there is a great deal of misinformation, incomplete data, and a lack of consensus with even the most basic of Green concepts. To immerse students in the topic, it is necessary to begin with simple definitions, facts, statistics, and projections. This presents the first challenge of discussing this topic. There are as many definitions of "Green" as there are associations, books, or articles which focus on the subject. These definitions range from concerns dealing narrowly with sustainable energy practices to much broader concerns of energy efficiency, renewable fuels, eradication of pollution, promotion of biodiversity, genetically altered food, and biomemitry (Brown, 2008).

A popular online sustainability dictionary defines Green as, "A common metaphor referring to environmental association based on the shared secondary color of many plants. It is often used to associate products, organizations, political parties, or policies with environmental sensitivity" (The dictionary of, n.d.). This definition is not all inclusive of every faction of Green therefore it must be assumed that processes, ideologies, and practices concerned with the environment can also be defined as "Green."

In presenting Green information to the class, a more creatively assembled array of subtopics is necessary to ensure that the most thorough representation of relevant material is made available. The use of a combination of videos, movies, Internet websites, guest speakers, articles, and books is a good strategy as it is possible to present the most current, varied, and inclusive information available. Topics to cover must include the hazards of dependence on fossil fuel, the potential negative effects of rising global temperatures, fresh water shortages, over population, declining availability of raw materials, and pollution. All of these issues must also be understood in the context of globalization, politics, and economic needs.

Currently, there are a number of sources available that touch on many of these topics and how they interact with one another. A good example includes a short video entitled, "The Story of Stuff" which introduces the concept of the materials economy (extraction, production, distribution, consumption, and disposal), problems found in linear systems, and a number of fascinating facts (Leonard, n.d.). Another example of a potential source of information is the acclaimed documentary narrated by Al Gore: "An Inconvenient Truth." This movie presents an overview of global warming – its causes and implications and shares numerous facts on the issue (David et al., 2006). Given the mixed reception of this film, its presentation would also present the possibility of a class discussion concerning opposing points of view. A very powerful, highly referenced book that is available either in hard copy of as a PDF

download is "Plan B 3.0." This book is written like a well-worded dissertation and is full of statistics, peer-reviewed references, and government reports addressing multiple areas of environmental concern (Brown, 2008). This is just a smattering of potential resources available to educate students concerning issues related to the environment. Only after students have a grasp on the topics of Lean and Green separately can the course move on to exploring the synergistic effects of combining the two.

Potential Synergistic Effects of Lean and Green

The power of this course will come in the exploration of how Lean and Green can create a synergistic effect to transform the business world. The easiest way to structure the final portion of the course is to simply revisit each of the key learnings from the Lean portion of the course and explore how each philosophy, strategy, and tool can be reevaluated and expanded to include Green concerns and expectations.

Once students are sensitized to Green concerns, it becomes apparent that a different set of questions should also be asked when determining what is valuable to the customer. What are the customer's expectations for the recyclability of the product? Does the product create an off-gassing concern? What is the carbon footprint of the product? How many emissions were necessary for the creation of the product? Are Cradle to Cradle engineering concepts being utilized (McDonough & Braungart, 2002)? Every student will need to consider that the answers to questions like these are becoming more relevant to more customers every day. This updated theme of inquiry must be applied to each of the Five Philosophies to ensure that when pursuing perfection, a broader more robust position is taken by the company.

Reconsidering 5-S housekeeping allows for additional advances in the workplace. For example, if Sort is revisited with a new Green twist in mind, it is easy to see that it is not just a matter of sorting out unused items, but there is now a concern of what to do with those items that are not being used. The unused items need to progress through another step – reassign, recycle, or refuse. To simple throw away any item without further analysis can be just another form of waste. Those things that cannot be reassigned could be considered for recycling. Only when reassigning and recycling are not options should an item be thrown away. This strategy can also save money in disposal costs. Following this new line of thinking, students can be challenged to reconsider Straighten, Shine, Standardize, and Sustain using a new Green lens.

As with the review of 5-S and Five Philosophies, the 7 wastes must be reexamined. It should be obvious to students at this juncture that it is appropriate to expand the definition of Waste to include unnecessary use of energy, water, nonrenewable resources, or even clean air. In the same fashion that a value stream is analyzed to identify and remove the seven classic Lean wastes, it is the goal of this course to introduce various environmental and sustainability concerns which are also forms of waste. For example, a process that uses 100 gallons of water to make one widget is probably not adding value to the product as it relates to all that water use. If the process can be changed to eliminate some, most, or even all of those 100 gallons, it is easy to see that waste was removed from the system. The important point is that there is not necessarily one right answer as how to incorporate Lean and Green, but in providing students the tools and opportunities to see business decisions in a new light.
An example of a good exercise that will allow students an opportunity to tie new information to a real life situation is to assign students the problem of reworking the process of laundering clothes using Lean Principles. This exercise should first be assigned following the segment of the class which focuses on Lean. Having just learned about Lean, students will generally focus on considerations such as machine arrangement, load size, removing bottle necks, evaluating the necessity to fold everything, and the like. However, when this same scenario is revisited after the class has been exposed to information focused on environmental concerns, a number of additional changes will be identified. Students will now consider issues such as water usage, energy requirements, toxicity of the detergents used, and how the waste water is being treated before discharge. Many students will begin to notice that what is good for the environment is also good for business. Water usage, energy consumption, and waste disposal, can all potentially cost the company money, as can failed efforts to stay ahead of new environmental standards.

Conclusion

The exciting part of a course like this is that it is not simply the regurgitation of old rules, concepts, and strategies but rather the creating of new ways of thinking. The course will be structured to enable students to generate their own connections and conclusions. Some students will most likely adhere more closely to the philosophies of Lean and will walk away with the ability to lightly sprinkle some environmental concepts over the top of tried and true business methods. Others will be drawn to the environmental urgency described in much of the Green literature and will see Lean as a vehicle from which to advance Green philosophy. Still others will embrace a more hybrid account of the material presented and will see each perspective as equally important and will be prepared to use the information free from either label of Lean or Green but rather seeing it as simply "good business."

References

5S Housekeeping – To Organize the Workplace. (no date). 5S Lean Manufacturing. Retrieved June 2009 from: http://systems2win.com/solutions/5s.htm.

7 Wastes. (no date). Provided by the Manufacturing Advisory Service. Retrieved June 2009 from: http://www.swmas.co.uk/info/index.php/7-Wastes.

Brown, L. R. (2008). *Plan B 3.0.* Earth Policy Institute, New York:W.W. Norton & Company. ISBN 978-0-393-06589-3.

David L., Bender, L., & Burns, S. Z. (producers); Skoll, J. & Guggenheim, D. (executive producers), & Chilcott, L. (co-producer). (2006). *An Inconvenient Truth* [Documentary]. United States: Paramount Classics and Participant Productions present a film directed by Davis Guggenheim, Featuring Al Gore.

Leonard, A. (no date). *Story of Stuff*. Produced by Free Range Studios. Viewed at www.storyofstuff.com on June 28, 2009.

Malloy, J. (2008, Dec). Lean Production. Retrieved June 2009 from: http://searchcio.techtarget.com/sDefinition/0,,sid182_gci810519,00.html

McDonough, W. & Braungart, M. (2002). *Cradle to Cradle*. North Point Press, Farrar, Staus, and Giroux, New York. ISBN:13: 978-0-86547-587-8.

Page, J. (2004). Implementing Lean Manufacturing Techniques: Making Your System Lean and Living With It. An Automotive Design and Production book, Hanser Gardner Publications. Implementing Lean Man tech p 137-138

Seddon, J. (2007, June). Watch Out for the Tool Heads. Retrieved June 2009 from: http://www.superfactory.com/articles/featured/2007/0706-seddon-tool-heads.html.

The dictionary of sustainability management. (no date). *Green.* Retrieved June 2009 from http://www.sustainabilitydictionary.com/g/Green.php.

The Oxford Pocket Dictionary of Current English (2009) *Flow.* Retrieved July 09, 2009 from Encyclopedia.com: http://www.encyclopedia.com/doc/1O999-flow.html

Womack & Jones (2003). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation (Rev ed.).* New York: Simon & Schuster, Free Press. ISBN: 13:9780743249270.

Administration

Employing Clean Energy as a Common Ground for Interdisciplinary Collaborations within a Technology-Driven Institution

Dr. Douglas J. Schauer
Ivy Tech Community College, School of Applied Science and Engineering Technology, Lafayette, IN 47905, 765-269-5295, dschauer1@ivytech.edu

Mr. Glen D. Roberson
Ivy Tech Community College, Schools of Applied Science and Engineering Technology and Technology, Lafayette, IN 47905, 765-269-5229, groberso@ivytech.edu

Introduction

The merit of interdisciplinary collaborations has been well-recognized as a means of solving new challenges in many sectors (Amey & Brown, 2004). As such, one may expect that a broad exposure to related disciplines beyond one's own area of study would facilitate such collaborations upon entry into the workforce. Modeling these types of interactions in the community college classroom can be a challenge due to the limited contact time that instructors have with students as well as a typical student's desire to avoid extraneous classes. By including collaboration within the curriculum, students can gain a better understanding of how their skill sets will intersect with those of co-workers from other disciplines in a given environment. Furthermore, with careful consideration, only moderate modification of the core curriculum can result in cross-disciplinary education without the necessity for extra courses or loss of core material.

At our institution, faculty members are forming cross-disciplinary partnerships by building portions of their curriculum on a common theme: clean energy. Similar partnerships have been formed at other institutions (Koester, Eflin, & Vann, 2006; Mitchell, 2000). Clean energy provides a unique opportunity to bring together disciplines that typically do not overlap in an academic setting. Currently, the Chemical Technology, Automotive Technology, and HVAC programs have established practical projects that introduce students to clean energy and its application. For instance, Chemical Technology students producing biodiesel are working closely with students in the Automotive and HVAC departments in order to more fully understand the effects of fuel quality on end use.

Background

Biodiesel fuel is a substitute for petroleum-derived diesel fuel (petrodiesel) that is produced by a chemical reaction on fats that are either animal- or vegetable-based. The benefits of biodiesel over petrodiesel are economical, ideological and practical. In terms of economics, biodiesel blends can be less expensive than petrodiesel (Clean Cities Alternative Fuel Price Report, 2007). Of great importance to the environment is the fact that biodiesel adds significantly less carbon dioxide to the atmosphere as compared to petrodiesel. The carbon in biodiesel is derived from plant matter that sequesters carbon dioxide from the atmosphere. The carbon dioxide generated from combustion of the biodiesel is then, in turn, sequestered by other plant matter to produce more biodiesel feedstock. For this reason, biodiesel is said to be *carbon neutral*, not withstanding carbon emissions from production (Johnston & Holloway, 2007). In addition, biodiesel has better lubricating characteristics than the new low-sulfur mandated diesel now being sold at the pump (Wadumesthrige, Ara, Salley, & Ng, 2009). The direct result of this is longer engine life and enhanced performance.

Due to the reasons listed above, there has been considerable interest generated in biodiesel. This interest has translated into an increase in home-production of biodiesel, as well as an increase in industrially-produced biodiesel. Both scenarios require that adequate training be provided for those who will be involved in biodiesel production, whether producing tens of gallons in their garage, or millions of gallons in an industrial production facility. Our campus has begun providing this training through its Chemical Technology program as part of a cross-

disciplinary endeavor. Recognizing that biodiesel production begins with feedstock and ends with combustion, current efforts have focused on forming collaborations among programs in the Schools of Applied Science / Engineering Technology and Technology that reflect the partnerships that are forged in the industrial production of biodiesel. As such, students involved in this project will experience a broader view of biodiesel production than can be conveyed within their respective programs. For this reason, faculty in the Automotive Technology, Chemical Technology, and HVAC programs have begun working together to provide their students with biodiesel training that goes beyond the traditional borders of their disciplines. This collaboration will fully include the Sustainable Energy, Agriculture, and Biotechnology programs as it continues to grow.

Project Overview

The biodiesel project was informally initiated upon communication between faculty in the Automotive Technology and Chemical Technology programs. The early initiative allowed students in the Chemical Technology program to produce biodiesel fuel that was consumed by vehicles in the Automotive Technology program. The project was set in motion by a devoted group of Chemical Technology students who, with the support of their instructor, wanted to learn about biodiesel production. Starting with a small-scale production, the instructor noted the enthusiasm that the students displayed for a project that had such clear practical application. It was also noted that the students were very inquisitive about how their homemade fuel would be consumed and how it would perform in comparison to its petroleum-based counterpart. Furthermore, students in the Automotive Technology program expressed a strong interest in the production of biodiesel, despite having no previous chemical training. These observations revealed that students would be likely to connect to the cross-disciplinary nature of biodiesel production. More importantly, biodiesel production would serve as a platform for providing students with a well-rounded education that includes disciplines that are intimately related, but rarely integrated academically. The vision of the biodiesel project can be broken down into four progressive phases (Table 1):

Table 1 - *Outline of the Biodiesel Project*

	Phase I (Induction)	Phase II (Development)	Phase III (Implementation)	Phase IV (Closed Loop)
Faculty Inclusion	CHMT, AUTC	Phase I + HVAC	Phase II + SUST, AGRI	Phase III + BIOT
Curriculum Development	Develop pilot experiments	Carry out pilot experiments with select students	Scale up pilot experiments to include in curricula	Expand into ethanol production
Community Involvement	Odyssey Day and AFV Day	Phase I + student poster session	Phase II + Biofuel Class	Phase III + Biodiesel Trailer display
Service Learning	None	Testing waste fryer grease	Biodiesel Quality Testing	Workshops and Summer Camps
Equipment	Biodiesel Reactor	Diesel Engines, Furnace, Dyno, Emissions Testing	ASTM Test Equipment, Seed Press	Course Materials
College Service	None	None	Produce biodiesel to be used in tractors on campus farm	Use biodiesel to fuel a generator that powers a building on campus

Note. Those objectives in shaded boxes have been achieved at time of publication. CHMT = Chemical Technology, AUTC = Automotive Technology, HVAC = Heating, Ventilation, and Air Conditioning Technology, SUST = Sustainable Energy Technology, AGRI = Agriculture Technology, BIOT = Biotechnology.

Induction

The first phase of the biodiesel project has been named the *induction phase*. This phase served as an opportunity for the core faculty (Automotive and Chemical Technology) to become familiar with biodiesel fuel. The two programs were careful to initially focus their research on understanding the aspects of biodiesel that directly impacted their particular discipline. For the Automotive Program, this involved learning about the fuel efficiency of biodiesel as well as its effects on a modern diesel engine. It was necessary that the faculty be familiar with key concepts such as cold-weather performance, fuel blends, and emissions profiles. Naturally, the initial focus for the Chemical Technology program was placed squarely on the chemical process involved in biodiesel production. It was requisite that the collaborators from this department simply be able to produce biodiesel fuel on a small scale. During this phase of the project, several major objectives were met:

- Faculty from the Automotive and Chemical Technology programs were able to successfully integrate expertise from their respective disciplines to produce a common body of knowledge concerning biodiesel production and consumption.
- Chemical Technology faculty, along with a select group of students, successfully generated biodiesel fuel from waste fryer grease that was donated by a local restaurant.
- Automotive Technology faculty, along with a select group of students, established the viability of biodiesel fuel produced by the Chemical Technology students by combusting it in both a large and small diesel engine.

During this time, a biodiesel reactor was purchased to allow for a scale-up of biodiesel production in order to produce quantities that were amenable to utilization by the Automotive Technology program in their courses. Furthermore, this reactor served as centerpiece in community outreach programs that displayed the biodiesel project. The purpose of these programs was to educate the public about the work being done at the college, as well as imparting information about biodiesel production.

Development

The second phase of the biodiesel project is considered the *development phase*. During this phase, it was imperative that the knowledge obtained in Phase I be developed into models for inclusion into pre-existing curricula. While there was clearly opportunity for fusing the biodiesel project with the curricula in place for both Automotive Technology and Chemical Technology, general community interest indicated that the HVAC program should be integrated into the biodiesel project as well since members of the community were also interested in utilizing biodiesel as a fuel in residential furnaces. Furthermore, because there is a growing market for biodiesel furnaces, it was deemed appropriate that HVAC technicians gain some exposure to biodiesel, should they encounter it in their careers at some point. During Phase II, the following key objectives were met:

- The Chemical Technology program developed a service learning lab module whereby waste fryer grease from local home-biodiesel producers is quality-tested.
- Chemical Technology students successfully scaled-up the biodiesel production process to generate 20 gallons of biodiesel per batch.
- The Automotive Technology program successfully procured diesel vehicles for testing the horsepower and torque output of biodiesel vs. diesel fuel. Select students in the program began gathering data to create a model for curriculum development. This data is being measured on a dynamometer.
- The Automotive Technology program purchased engine stands and outfitted them with diesel engines for continuous run experiments along with other performance testing.
- The HVAC program began developing pilot experiments with select students to create a model for further development. This work was done with a pre-existing furnace in the HVAC laboratory.
- Students currently involved in the biodiesel project have agreed to present posters at local community outreach events.

Implementation and Closed-Loop:

Phase III of the biodiesel project has been named the *implementation phase*. This phase of the project is devoted, as the name suggests, to implementing the technology developed in the first two phases by fully infusing the project in current curricula. This is being done in two different ways. First, the Sustainable Energy program will create a biofuels course that will provide both traditional students and members of the community with an opportunity to gain meaningful in-depth knowledge about the production of biofuels. This course will focus

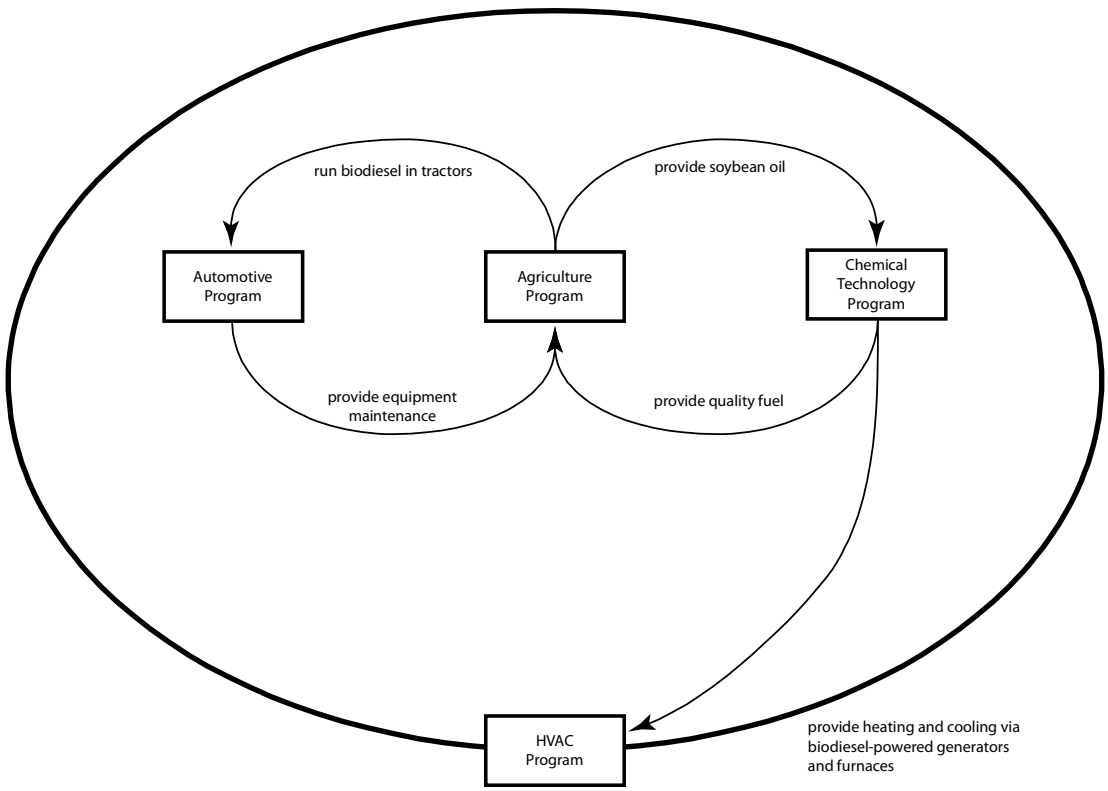
primarily on biodiesel and ethanol production and is slated to run for the first time in Fall 2009. Biodiesel projects are also being integrated into the curriculum of the Automotive Technology, Chemical Technology, and HVAC programs by modifying current lab courses to include modules that examine biodiesel usage. The goal is not to add extra course material, but rather to use existing experiments as a vehicle for comparing the performance of biodiesel to petrodiesel. Cross-disciplinary information will be included in lab handouts. In addition, pre- and post-tests have been developed to gauge the students knowledge of biofuels before and after the lab module. This data will be used to gauge the depth of knowledge retained by the students.

The focus of the Chemical Technology program will shift to quality testing of the biodiesel being produced to ensure that it is of ASTM quality. This is necessary because a poor batch of biodiesel could potentially lead to failures in the experiments being carried out within other programs.

At this stage of the project, a considerable amount of effort will be focused on creating a *closed-loop system* (Phase IV, Figure 1) at our institution. This means that inclusion of the Agriculture program will supply the project with an independent source of soy bean oil for producing biodiesel. The Agriculture program has purchased a diesel-powered tractor that will be used to cultivate the fields on our campus farm. In the near future, the tractor will run on ASTM-quality biodiesel and be maintained by diesel mechanics trained in the Automotive Technology program. Simultaneously, the Chemical Technology program will be providing the HVAC program with ASTM-quality biodiesel that will be burned in a furnace to heat a campus building. In addition, the biodiesel fuel will also be used to fuel a Caterpillar Generator Set that will provide cooling for said building. It is envisioned that the building being powered on biodiesel house those programs involved in the project.

Future collaborations will involve utilizing the expertise of the Biotechnology program to explore ethanol production through fermentation as a means of supplementing the biodiesel project. At the same time, the Sustainable Energy program will be exploring cellulosic feedstock as a source of ethanol. Short courses and

Figure 1. Illustration of a closed-loop system, whereby the biodiesel feedstock is produced on-campus, with the resulting biodiesel fuel being consumed on-campus as well.



workshops will be developed to educate local producers of biodiesel about good production techniques, along with legal and ethical considerations. Summer camps will be developed to educate middle school and high school students about biofuel production as well.

The project will culminate with the development of a biodiesel display vehicle. This display vehicle will consist of an electric-powered vehicle that is charged by a biodiesel-fueled generator. The generator will rest on a trailer that carries a full biodiesel display and will be transported to campuses within the community college system as well as fairs throughout the state of Indiana.

Conclusion

Biodiesel production provides students from a wide variety of academic backgrounds with an opportunity to gain cross-disciplinary exposure to an industrially relevant process. This exposure is intended to prepare students for the modern workplace environment whereby collaborative efforts are often invoked to address challenges. Thus far, the faculty at our institution has made significant strides toward implementing strategies to include this collaborative model in their respective curricula. Future plans will not only better prepare our students for entry into the workforce, but also educate the local community about alternative fuel production.

References

Amey, M. J., & Brown, D. F. (2004). *Breaking out of the Box.* North Carolina: Information Age Publishing.

(2007). *Clean Cities Alternative Fuel Price Report.* Washington, D.C.: U.S. Department of Energy.

Johnston, M., & Holloway, T. (2007). A Global Comparison of National Biodiesel Production Potentials. *Environmental Science and Technology* , 7967-7973.

Kocak, M. S., Ileri, E., & Utlu, Z. (2007). Experimental Study of Emission Parameters of Biodiesel Fuels Obtained from Canola, Hazelnut, and Waste Cooking Oils. *Energy and Fuels* , 3622-3626.

Koester, R. J., Eflin, J., & Vann, J. (2006). Greening of the campus: a whole-systems approach. *Journal of Cleaner Production* , 769-779.

Mitchell, R. (2000). Fuel you curriculum. *The Science Teacher* , 30.

Wadumesthrige, K., Ara, M., Salley, S. O., & Ng, K. Y. (2009). Investigation of Lubricity Characteristics of Biodiesel in Petroleum and Sythetic Fuel. *Energy & Fuels* , 2229-2234.

Administration

Leading and Integrating Adjunct Faculty into a Technology Program Team

Dr. James W. Jones
Ball State University, Applied Technology 207D, Muncie, IN 47306, 765-285-1433, jwjones@bsu.edu

Abstract

Administrative leadership in modern technology programs presents many challenges, from faculty and budget issues to enrollment trends and campus politics. Among these challenges are leading and integrating adjunct faculty members, who are becoming more prevalent in many programs. These instructors, often virtually invisible as a result of their part-time and typically evening schedules, present unique opportunities to contribute to and enhance the technology program if they are made a part of the instructional team. Although the use of adjunct faculty is on the rise, little research and information is available to help guide program administrators in the hiring, leading, managing, and developing of these valuable team members. The use of adjunct faculty is often a last-minute reaction to cover a course rather than a strategic, planned application of a specialist from outside the institution. Drawing from university and industry experience, this paper helps administrators lead these valuable faculty members and integrate them into their instructional teams, from the pre-hiring and hiring processes through their training, development, and integration.

Introduction

Administrators of programs that are comprised of similar academic disciplines and programs, as is typical at most colleges and universities, face a seemingly ever-growing list of challenges. In these academic units, "faculty are organized in disciplinary departments clustered in colleges that purportedly represent reasonable pathways for how scholarship should be produced and how students should be educated" (Rich, 2006, p. 43). However, these challenges are amplified in a department comprised of diverse programs. This situation is common in community colleges, where "various disciplines are often combined, more for administrative convenience such as numerical party, rather than for cohesiveness" (McArthur, 2002, p. 1). It can also be found at other institutions, sometimes as a "catch-all" department for programs and disciplines that do not readily fit elsewhere, as is common in many industrial technology programs nationwide. For example, at one public Midwestern university, the Department of Technology has disparate programs and majors including manufacturing engineering technology, graphic arts management, career and technical education, construction management, process improvement/Six Sigma, and computer technology.

Administrative leadership is further complicated in all programs where contract and adjunct faculty continue to grow larger as percentages of the faculty in relation to tenure-line faculty (Altback, 2005). Loyalty of faculty, administration, and institution are being questioned, with the administrator being squeezed in the vice by virtue of his or her position.

Nontenure and adjunct faculty are employed in greater numbers than ever before in departments of many types, including industrial technology. Fagen-Wilen, Springer, Ambrosino, and White (2006) relate that the number of nontenure faculty has tripled in the past 15 years in the field of social work, and that about 40% of all academic positions are now part-time. While this brings about new challenges for modern administrators that were not faced by his or her predecessors, this is actually part of larger employment tendencies. Over the next 10 years, temporary employment nationwide is expected to increase threefold, a growth rate more than 30% higher than employment overall (Temporary Employment, 2007, p. 16). This is an employment trend that is being grappled with in many fields and sectors.

Technology administrators are faced with leading and integrating these adjunct instructors into the program team. Often, adjunct faculty members teach part-time in evenings or weekends, making them "invisible" to both program and administration, and they are sometimes given "second class" status when thought of at all. However, with the patterns of increased adjunct use, coupled with some approaches adopted from other organizations, these faculty can be turned from afterthought to strengths as they are brought into the program's faculty team.

Pre-Hiring and Hiring Processes

When bringing on any new member of the team, leadership by the program administrator must be evinced from the inception of the process. For new faculty members, this usually starts in the pre-hiring and hiring processes, from the identification of the need through to the first day of class.

Financial considerations are often part of the equation when deciding to hire nontenure track and/or adjunct faculty, and in fact are cited as the *primary* consideration in many instances (Fagen-Wilen, Springer, Ambrosino, and White, 2006, p.41). While the program administrator may face financial constraints, careful consideration must be given to each position. Business has found that a key point of this process is to "determine the scope of the job" before it is filled (Miller, 2004, p. 28), and it follows that this should be the primary concern of a technology program administrator.

Coming from an industry perspective, Radeloff (1995) reinforces the primacy of the job analysis, and suggests that contract workers may best fit into roles that require specialized knowledge:

> When you are considering using contract labor, you should also carefully evaluate the tasks that the person will perform. You should identify the core competencies the worker must have. Contract workers fit best into project driven areas that make best use of their highly specialized skills. When you focus on using the contract employee for specialty areas, you can more readily deliver high quality work that leverages their competencies. (¶ 7)

Similarly, a technology program administrator may consider using adjunct faculty most effectively in positions where the tenure track faculty do not have a particular expertise, rather than simply for courses that no one else wants to teach.

Although leadership in the technology may seem obviously necessary at this early stage, in practice it has not been the case. One adjunct faculty member who has taught at three different institutions, found that:

- academic departments often put forth very little effort to recruit adjunct faculty members
- the screening process for selecting adjunct faculty members often is informal and less than thorough, and
- academic departments often do little to acculturate adjunct faculty members to the department. (Recruiting, 2006, p. 7)

Gadbury and Burnstad (2005) recommend that both part-time and full-time instructors have similar qualifications, particularly since "hiring an adjunct is not necessarily a short-term staffing solution" (p. 1). Just as the program administrator leverages his or her leadership in the hiring process of tenure track faculty, the same leadership principles apply with regard to nontenure and adjunct faculty. Radeloff (1995) echoes this position from a managerial perspective:

> As the work force shifts to include more contract employees, managers will need to rethink the staffing and hiring criteria. Today, managers should not hire contract labor just to fill a slot with a capable person. They must also consider the attitudes and work ethic of the people they employ. The supervisor needs to secure contract employees who will fit with their organizational culture. (¶ 14)

While the administrator can certainly influence faculty after hiring, a good initial match between the candidate and the position expedites the new member into the faculty team.

If the faculty that actually teach students are considered the backbone of the university, then it should be evident that the recruitment of quality faculty, tenure or adjunct, is an area that demands close attention by the program administrator. The process of selecting the "proper" mix of tenure, contract, and adjunct faculty is not always made at the program or departmental level, yet it is the responsibility of the program administrator to at least weigh in and - if necessary - fight for what is in the best interests of the department's students and faculty. This might be the sphere of influence where an administrator's leadership will have the longest lasting effects. Rich (2006) states:

> Many universities grew dramatically in the 1960s and 1970s. How faculty hired then are replaced will determine the structure of universities for many future decades. What types and mix of faculty will be hired (tenure track, nontenure track, full time or part time, junior or senior rank)?....Each decision represents millions of dollars of investment, not only in the compensation for the faculty members but in the infrastructure required to support their work. Most important, these decisions set the foundations for what the university can contribute and achieve for decades. (p. 43).

The program administrator is in a unique position to influence faculty as the come on board and insure the right "fit" in both the program and department. Beyond the mere job description, early involvement can see if a faculty candidate will be a positive match for the program's culture – or where the administrator thinks that the culture should be heading. For example, the hiring process may be the leverage point to promoting diversity in a department. James Anderson, the vice president and associate provost for institutional assessment and diversity at Texas A&M University at College station, concurs:

> The department head has to be involved in talking about the changing culture in an academic department, and diversity has to become a critical part of that discussion….Sometimes [departments] have a historical definition, and sometimes that definition needs to change slightly….I think a department head or a department chair becomes very prominent in [discussing different perspectives] during department meetings, in educating a search committee as to what kinds of critical questions they need to examine. (The Diverse Department, 2004, p. 3)

While the leadership and involvement of the program administrator in the hiring process might make take more time and resources, the payoff will be worthwhile. Similarly, Miller (2004) professes that:

> You may…decide to spend more time in the recruiting process, ensuring that new hires possess not just the requisite technical skills but also a work ethic and attitude that is compatible with that of the organization. This would probably increase initial recruiting costs, but by improving retention rates would dramatically reduce the overall turnover expense. (p. 28)

The technology program faculty team is becoming more and more dependent on nontenure and adjunct faculty members. Unlike the stereotypical department of aged and tenured professors, department faculty are now more likely to be an eclectic mix of tenured, tenure track, nontenure, and adjunct faculty. The program administrator can be most influential during the hiring process, including deciding the best mix of positions and candidates. While the stereotype of a homogenous, tenured departmental faculty might persist, new leadership approaches should be considered with the variety of employment categories.

Post-Hiring: Bringing Adjuncts into the Team

While early involvement in the hiring process may help the technology administrator lead contract faculty, the practice and the challenges do not end there. Contract and adjunct faculty has a host of specialized challenges, including feelings of dislocation and disconnectedness (Allen, 2006), invisibility (Fagen-Wilen, Springer, Ambrosino, and White, 2006) and belonging (Recruiting, 2006). However, most of the recommendations for leading these faculty center on treating them as valued team members; in other words, much like leading other faculty.

Orientation is one way of treating contract and adjunct faculty members as valued team members. A solid orientation, including expectations, procedures, and the department vision, will help set the new instructor on track, regardless of employment type (Gadberry and Burnstad, 2005; Recruiting, 2006). A mentor, whether full-time or part-time, is another winning approach for the new teammate, and some have suggested that a permanent adjunct liaison be appointed for adjunct faculty (Fagen-Wilen, Springer, Ambrosino, and White, 2006) Besides getting off to a new start, offering adjunct faculty professional development opportunities helps to improve their pedagogical practice while building loyalty. However, department heads should be aware that many professional development opportunities do not fit into the schedules of adjunct faculty. Some institutions have developed specialized programs for adjuncts to meet these specialized needs (Gadberry and Burnstad, 2005) and others recommend providing compensation for involvement (Recruiting, 2006). Involvement in committees, social functions, graduations, and other events should be highly encouraged for *all* faculty.

Contract faculty have been known to be resistant to change, as related by Allen: "When the receiver is an adjunct faculty member … 'change' can be a four-letter word" (2006, p. 3). Allen proposes that trying the same approach as for your tenured faculty is not likely to have the desired effect: "Communicating with them as though they are full-time faculty on a tenure track is an exercise in disappointment: yours" (p. 3). Allen suggests good listening skills are critical, as is effective communication, particularly face-to-face. Get to know the adjunct faculty member, just as with any team member. Additionally, celebrate adjunct faculty's achievements and instill pride, remembering that peer approval is a powerful motivator.

By remembering and respecting that the *entire* department must be included in order to effect change, not just those that show up in the office every day during normal work hours, the chair will be able lead the way to the shared vision of success.

Conclusion

Technology program administrators face a multitude of challenges today, including properly utilizing adjunct faculty members. By adopting best practices from both academia and industry in pre-hiring and hiring, including financial considerations, scope of position, expertise needed, qualifications, and initial "fit," help to ensure the proper candidate is selected and hired. Afterwards, thorough orientation, mentorship, development, and communication help to integrate the adjunct faculty into the program team.

References

Allen, S. (2006, January). Communicating change to adjuncts. *Academic Leader, 22*(1), 3.

Altbach, P. G. (2005). Harsh realities: The professoriate faces a new century. In Altbach, P. G., Berdahl, R. O., & Gumport, P. J. (Eds.), *American education in the twenty-first century: Social, political, and economic challenges* (pp. –314). Baltimore: Johns Hopkins University Press.

The diverse department: An interview with James Anderson. (2004, January). *Academic Leader, 20*(1), 3-7.

Fagan-Wilen, R., Springer, D., Ambrosino, B., & White, B. (2006, February). The support of adjunct faculty: An academic imperative. *Social Work Education, 25,* 39-51.

Gadberry, J., & Burnstad, H. (2005, July) Integrating adjuncts into the community through professional development, support. *Academic Leader, 21*(7), p1-6.

McArthur, R. C. (2002, Winter). Democratic leadership and faculty empowerment at the community college: A theoretical model for the department chair. *Community College Review, 30,* p. 1-10. Retrieved July 5, 2007 from http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=9168093&site=ehost-live

Miller, D. A. (2004, March/April). Management: A human resources potpourri. *Commercial Law Bulletin, 19*(2), 28-30.

Radeloff, R. (1995, March). The supervisory challenge of the contemporary employee. *Supervision, 56*, p. 9-12. Retrieved July 5, 2007 from http://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=9503152939&site=ehost-live

Recruiting, developing, retaining adjuncts. (2006, July). *Academic Leader, 22*(7), 7-8.

Rich. D. (2006, Summer). Academic leadership and the restructuring of higher education. *New Directions for Higher Education, 134*, 37-48.

Temporary employment to triple. (2007, April). T+D, Apr2007, Vol. 61 Issue 4, p. 16.

Construction

Construction

Assessing the Impact of Waste on the Value Production Model in Construction

Selected through peer-review as *"Best ATMAE 2009 Conference Proceedings Paper"*

Mr. John R. Patton
Director of Construction – The Home Depot, Indiana State University, Terre Haute, IN 47809, 610-653-7370, john_patton@homedepot.com

Abstract
This paper will introduce and develop the value production model (VPM). This model discusses how value is generated to the client throughout the construction process. In conjunction with the development of this model, waste and value loss will be examined for their distinctive and disparate relationships to the value generation process.

Introduction
The concepts of waste and value have emerged as two of the most important considerations in assessing the relative health of a construction project, program or industry. However implied, value and waste do not necessarily have reciprocal relationships. Waste in the construction process does not always move in the opposite direction as construction value. In other words if there is more value, that doesn't mean there is necessarily less waste; or conversely if there is more waste, that should not imply that there is less value. In fact, it is possible that the client's expected value can be achieved in spite of pervasive waste, or that a lean construction company can fail to provide the client's expected value.

Various process control methods have been introduced over the last fifty years with the shared goal of driving waste out of the production process. The prevention, appraisal, failure (PAF) model (Feigenbaum, 1991), Motorola's six sigma (Barney, 2002), total quality management (TQM) by Taguchi (Martinez-Lorente, 1998), Toyota Production System (TPS) (Ohno, 1988), are all examples of process control models which assist the producers in lowering costs and increasing profit margins through waste elimination. But do these now famous process control methods increase value? Is it possible for a lean company to produce a product with diminished value? Conversely, is it possible for a wasteful company to achieve the client's 'expected value'?

Shewhart's (1931) was one of the first to develop the concept that production transformations generate value for the consumer. Contemporarily, Shewhart's production quality models have been successfully introduced and expanded by Koskela & Vrijhoef, (2001) and Bertelsen & Koskela (2002) into the transformation, flow and value (TFV) model for the construction industry. Bertelsen and Koskela (2002) describe how construction generates value for the customer: "a series of processes; forming a workflow drawing on transformations delivered by the trade contractors under a contractual arrangement with the client – either direct or through a GC."

Specifically, the transformation, flow, value (TFV) model of construction production defines value as the fulfillment of the client's requirements (Koskela & Vrijhoef, 2001; Crosby, 1979). Therefore we can suggest that the transformations in and of themselves hold no value – in spite of the costs incurred to turn inputs into outputs. Only when the transformations fulfill the client requirements do they represent an achieved value (Koskela, 2000).

The Value Production Model (VPM)
The value production model (VPM) is introduced and constructed below. The building blocks of this model start with how the client derives his expected value (EV). Various strategies for achieving the client's expected value will be examined. Below, consideration is given to the subject of how trade-offs impact the expected value (EV), including the expectation, or assumption of embedded waste. At the time of the procurement decision, the client

may wish to trade-off certain components in order to secure the best available value (BAV). The client clearly understands that the BAV is not lowest cost to achieve the client's requirements, but it simply represents the best available value given the delivery environment at the time of bid letting. During the execution phases of construction, value loss (VL) may degrade the best available value below the client's EV. If value loss does cause the BAV to be delivered at a value less than the client's EV, then this is referred to as the actual achieved value (AAV). The variance between the specified condition (EV) and the achieved condition (AAV) is value loss (VL). Finally, the theoretical best value (TBV) is discussed as the lowest cost possible to achieve the client's EV. Table 1 summarizes the main building blocks of the VPM.

Table 1 Value Production Model

Term	Definition	Relationship	Principal Concern
CR	Customer Requirements, represents the conforming work that a producer must exert to achieve the customer requirements.	CR = EV	Producer
EV	EV is the client's expected value from the purchased construction services. This is represented by the client's plans, specifications, addendum and other contract documents.	EV = CR	Customer
BAV	Best available value. This is the best value available to the customer at the time of purchasing decision. It is not the best theoretical value and trade-offs are necessary at the time of contracting. The BAV usually implies waste embedded in the producer's work.	BAV = CR + W	Producer
AAV	Actual Achieved Value (AAV) is the value that is finally delivered as the end product. The BAV has been diminished by value loss to the AAV. The customer is usually not aware of this diminishment because the VL is mostly represented by latent defects.	BAV * VL = AAV Therefore AAV ≠ □EV	Customer
VL	Value Loss (VL) represents the variance between the BAV and the AAV. It represents defects that are undiscovered and un-corrected during construction, and linger through the delivery phase to latency. It is represented as the sum of all defective construction tasks divided by the value of the contract, and is expressed as a number between zero and one.	BAV * VL = AAV	Customer
W	Waste (W) is a conforming work task that took more labor and/or material cost than originally expected. Rework is an example of Waste. This impacts the producer's cost and profit potential, but restores value to the client.	BAV = CR +W	Producer
TBV	Theoretical Best Value is defined as the lowest possible costs to achieve the client's EV, or the CR.	TBV = EV; where W = 0	Both

Expected Value & Best Available Value

In manufacturing a tremendous amount of effort and resources are routinely dedicated to the identification, development and achievement of client requirements (Shen, et al 2000). In construction, however, the client's requirements are usually very well defined through the specifications, plans, general conditions and other contract documents which are delivered to the producer through a bid-letting process. The construction producers then, have only to worry about conforming to well-defined client requirements in order to fulfill their contractual obligations. The final component of this model states that only the customer can define the concept of value (Womack & Jones, 1996; Pennanen et al., 2004; Drucker, 1989). Therefore if a construction client defines his value through his contract documents, then these descriptions become the client's 'expected value'. These task specifications within the contract documents become the value that the client expects to receive.
Here we introduce our first value concept. The expected value (EV) of a construction project is the value represented by the client's requirements -- expressed through the contract documents (Dos Santos, et al, 2004). The client exchanges a financial obligation to secure a professional service commitment to meet those explicit

requirements. If we annotate the producer's work to conform to the client requirements as 'CR', then:

$$CR = EV \qquad (1)$$

The typical procurement model in construction is to bid out or negotiate based on the client's requirements as communicated through the construction documents. The producer submits his bid after thoroughly reviewing the customer requirements and estimating a cost to achieve them. At this point the producer's bid proposal is constructed from an in-depth review of the bid documents (client requirements) and represents the producer's cost to conform to those requirements.

It is important to understand that the client's expected value (EV) may not equal the theoretical best value (defined as the lowest cost to achieve the client requirements). In fact, implied within the client's EV is the expectation that various trade-offs may occur which will impede the theoretical best value (TBV). The client may expect to trade off higher contract cost for risk transfer, exclusive contractor qualification, faster response during a weather disaster, greater reliability, embedded waste, etc. If the client feels their best value at the time of the procurement decision is to commit to the contract, given the trade-offs or embedded waste, then the client's expected value is equal to the best available value (BAV) at that time. In a sense, the client acknowledges the possibility of waste and feels that at the time of the procurement decision, the best available value is to commit to the contractual relationship. Here we would then show:

$$EV = BAV \qquad (2)$$

Aoieong et al., (2002) touched on the central theme of this dynamic when he described the prime contractor's disinterest in the recurring waste and inefficiencies associated with the sub-contractors. According to Aoieong, et al., (2002):

> From the general contractor's point of view, most contractors interviewed indicated that they were not enthusiastic about obtaining facts on quality costs. This is simply because most of the projects are [sub] contracted out, and only the final 'product' and not the process is their concern.

Clearly in this case the prime contractor was the 'client' and the 'sub-contractors' were the producers. Here the prime contractor states clearly what we have assumed in our model, that all the rework and quality costs encountered by the producer are immaterial if the final product meets the expected value (EV). The client (the prime contractor in this case) understands that the contract cost may include waste and that this may be acceptable based on various trade-off decisions. For example the client's favorite contractor may have notoriously higher costs because of higher waste and lower efficiency. Yet the client may still seek to contract with this contractor because in the end, the contractor can satisfy the client's EV.

Aoieong et al., (2002) understood that the prime contractor is the client in his survey, and is purchasing a set of value expectations, and is not overly concerned with how this value is met. The expected value may be achieved even though the producer (sub-contractor) encounters recurring waste and inefficiencies in his operation. Despite the waste and inefficiencies, the work can still conform to the 'end product' or BAV = EV, given that BAV = W + CR.

Waste or Value Loss?

Unfortunately, the literature review suggests that the expected value (EV) is rarely achieved. In the construction industry, indictments of pervasive waste, lack of quality, increased legal disputes, fraud etc., are common place. Hart (1994) claims that more than 25% of the costs can be cut from most constructed facilities and Latham (1994) agrees, but estimates the total impact of waste at 30%. 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% if it were to survive as a competitive UK operation. Arbulu and Tommelein (2002) state that waste is "omnipresent" in the construction process. Perhaps most descriptive is Schonberger's (1990) 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 from the site to go from the site to get something forgotten) are normal,

everyday events for the average company."

Waste reduction efforts and quality control initiatives focus predominantly on the producer (Chitla, Abdelhamid, 2003). Yet the construction buyer is the contract party that receives and defines value (Womack, Jones 1996). If production quality control (waste reduction) methods do not assist the producer in conforming to the client's specifications, then they may exert no influence in generating value for the client. So while these process control methods may assist the producer in maximizing profit and minimizing costs, these efforts could have little impact on delivered value. Producers may expend millions on rework, or waste, but in the end if their work conforms to the client requirements, then the EV will have been achieved. Perhaps it will cost the client more, but if the client is satisfied with his contract delivery method the expected value (EV) terms can still be satisfied. Clearly, waste is not value loss.

The pessimistic view of construction above assesses construction defects during the trade transformations which are identified and subsequently corrected through rework. Existing literature does not assess the existence – much less the magnitude – of diminishments that are not discovered, and not restored throughout the various phases of the development process. If a portion of these quality problems or defects are not corrected through normal quality assurance or quality control (QAQC) methods, then these un-restored defects persist to degrade the client's expected value of the construction product. These un-discovered and uncorrected defects are value loss.
In Abdul Rahman's (1997) article about quality in the UK construction industry, he reported on a survey regarding the Cost of Quality (COQ). One question asked where the costs of recorded quality failures are borne. One respondent, listed as No. 16 – a QA manager with a contracting firm – stated the following:

> Site management will record the failure of others, and it's the unrecorded [failures] that holds the key.

Indeed this statement by the QA manager is a principle indicator of a potentially broader gap in the construction industry's assessment of latent defects. Throughout the extensive literature review, capturing the costs of unrecorded or unreported failures has been largely ignored. Part of the problem is the scope of the issue. It is difficult to assess the magnitude of unreported construction defects specifically because they are undiscovered --- no one has recorded them.

We can now add these new concepts to our value production model. As previously shown, value loss occurs when there is any variance between the specified condition (EV) and the achieved condition (AAV). Value loss is expressed as a fraction from zero to one based on the sum of the costs to correct all degraded tasks divided by the amount of the construction services contract. Best available value (BAV) is degraded by the value loss (VL) factor to become actual achieved value (AAV):

$$(BAV) \times VL = AAV \qquad (3)$$

$$\text{Given } BAV = W + CR \qquad (4)$$

(*CR = work to conform to customer requirements*)

If the client's or the producer's QA/QC programs managed to detect and correct defects during the execution phases of construction, then value would be restored and there would be no variance between expected value (EV) and actual achieved value, regardless of the producer's rework – or waste – to achieve it. However, because value loss is realized by defects that are undiscovered and therefore uncorrected during the various execution phases, the client is usually unaware of the diminished value. Unless these latent defects manifest themselves through a catastrophic failure (bridge collapse, etc.), the client may not be aware of reduced value of the facility. For example if the plans call for rigid galvanized steel (RGS) piping to be installed in a classified area of a building, but the plumber installs schedule 80 PVC then the client receives a diminished value for his facility. The client paid for the more expensive RGS piping but received instead schedule 80 PVC. Therefore the contract terms changed but client was not able to participate in this *ad hoc* re-negotiation. So the best available value is degraded by value loss to become the 'actual achieved value'. There is a change in contract terms at this point without

participation from the client. VL degrades the best available value (BAV) to a level below the client's expected value (EV). The actual achieved value (AAV) is not equal to the client's expected value because the client never agreed to the value loss attenuations. We show this as:

$$(BAV) \times VL = AAV; \text{ (from equation 3 above)}$$

$$\text{Where: } AAV \neq EV \qquad (5)$$

For municipalities, government agencies, industries, companies, and corporations that purchase large amounts of construction value during a given year, the lost value, or diminished value of the asset means that they have wasted portions of their capital expenditures on value loss. In 2000 for example, the U.S. construction industry let contracts for a total of $US990B (Bogdan, 2000). We can see that even marginal value loss of three to five percent would represent huge losses to the industry.

Best Theoretical Value

We have endeavored to show that waste may have no impact on the producer's ability to achieve the client's expected value. However, undeniably waste impacts value on a macro or industry wide scale. The higher the level of waste in the producer community, the higher costs clients must pay for the service. As a portion of each service contract is attributed to pay for waste, we can see that higher construction costs are the result of higher waste levels. This is the condition represented by the pessimistic views of the Construction Industry as shared by Hart (1994), Latham (1994) and Schonberg (1990). Ultimately, theoretical best value exists when production is delivered at the lowest possible price to achieve the customer requirements. Therefore we would see:

$$TBV = CR; \text{ assuming } W = 0 \qquad (6)$$

Conclusion

The introduction of the value concepts within the value production model demonstrates the distinct impact relationships between waste, value loss, and value generation. Lean methods will ultimately drive costs down on a macro level as more producers adopt lean methods. Although a client may choose to use the 'best available value' (BAV) producer at the time of the procurement decision in order to secure his 'expected value' (EV), this is only an expedient strategy. The best available value (BAV) implies that there may be wasteful activities which will drive up the cost of the contract. The BAV will be degraded by sub-optimally executed work tasks that linger, undiscovered and uncorrected through the delivery phase of the project. These diminished work tasks will represent value loss to the contract terms, and result in an actual achieved value (AAV) less than the EV.

Ultimately we can see that a contractor who has waste embedded in his processes can still achieve the client's EV as long as all defects are discovered and corrected. This may result in lots of QC and lots of rework (both are waste), but ultimately the value to the client is restored. Conversely, a lean contractor who conducts the majority of his work only once may install degraded work that is not discovered or corrected during construction (the schedule 80 PVC for RGS piping, for example). This would result in a variance between the EV and AAV, described as value loss.

References

Abdul-Rahman, H. (1997). Some observations on the issues of quality cost in construction. *International Journal of Quality and Reliability Management, 14*(5), 464-481.

Aoieong, R. T., Tang, S. L., & Ahmed, S. M. (2002). A process approach in measuring quality costs of construction projects: model development. *Construction Management and Economics, 20,* 179-192.

Arbulu, R.J. and Tommelein, I.D. (2002). *"Value Stream Analysis of Construction Supply Chains: Case Study on Pipe Support Used in Power Plants."* Companion paper to appear in *Proc. IGLC-10*, Gramado, Brazil.

Barney, M. (2002). Motorola's 2nd Generation. *American Society for Quality*. May, 2002, pp.13-16.

Bertelsen, S., & Koskela, L. (2002). Managing the three aspects of production in construction. In *10th annual conference in the International Group for Lean Construction.* Symposium conducted at the meeting of the Gramado, Brazil, Aug. 2002.

Bogdan, C., & Doolos, C.M., Dept. of the Army. (2000, May). Industrial College of the Armed Forces. *Industries Studies Report – 2000: chap. Construction.* Retrieved March 4, 2006, from http://wwwndu.edu/icaf/industry/2000/construction/construction.htm
Chitla, V. K., & Abdelhamid, T. S. (2003). "Comparing Process Improvement Initiatives Based On Percent Plan Complete And Labor Utilization Factors". *Proceedings of the 11th Annual Conference for Lean Construction*, 22-24 July 2003,Blacksburg, Virginia, 118-131.
Crosby, P (1979). *Quality is Free*. New York: McGraw-Hill.
Dos Santos, A., Kistmann, Virgina B., & Fischer, S. (2004). Assessing total value requirements on low income houses in Brazil. *Annual Conference of International Group for Lean Construction Technology.* Symposium conducted at the meeting of the Bristol, UK.
Drucker, P. F. (1989), *The New Realities*, Harper Business, New York.
Feigenbaum, A. V. (1991). *Total Quality Control.* New York, NY: McGraw Hill.
Hart, R.D. (1994*). Quality Handbook for the Architectural, Engineering, and Construction Community;* ASQ Press.
Koskela, L. (2000). *An exploration into a production theory and its application to construction*. VTT Publications 408. VTT, Espoo.
Koskela, L., & Vrijhoef, R. (2001). Is the current theory of construction a hindrance to innovation? *Building Research and Information, 29*(3), 197-207.
Latham, M. (1994). Constructing the Team. *Final Report on Joint Review of Procurement and Contractual Arrangements in the UK Construction Industry*, HMSO, London, UK.
Martinez-Lorente, A.R., Dewhurst, F., & Dale, B.G. (1998). Total quality management: origins and the evolution of the term. *The TQM Magazine*, 1998 10/5, pp. 378-386.
Ohno, T. (1988). *Toyota Production System – Beyond Large-Scale Production*. Productivity, Inc., New York.
Pennanen, A., Whelton, M., & Ballard, G. (2004). A theory of workplace planning: general principles and management steering model. *Proc.127th Annual Conf. of the Int. Group for Lean Constr.* Copenhagen, DK, 3-5 August, 2004.
Schonberger, R. J., 1990. *Building a chain of customers*. The Free Press, New York p 349.
Shen X.X., Tan K.C., & Xie M. (2000). *An integrated approach to innovative product development using Kano's model and QFD.* European Journal of Innovation Management, 3/2 pp. 91-99.
Shewhart, W.A. (1931). *Economic control of quality of manufactured product*. Van Nostrand, New York, p. 501
Womack, J. P., & Jones, D. T. (1996). *Lean thinking: Banish waste and create wealth in your corporation*. Simon & Schuster, New York.

Construction

Incorporating LEED and Green Topics in Construction Management Courses

Dr. Denise Gravitt, LEED AP
Western Kentucky University, 1906 College Heights Blvd #51066, Bowling Green, KY 42101-1066, 270-745-2176, denise.gravitt@wku.edu

Introduction

Department of Energy stimulus funds for energy projects, federal and state construction project requirements, passage of climate and energy bills, utilities offering rebates and incentive programs for customers saving energy are all recent news topics collected and listed on green building Web pages such as www.buildinggreen.com. All of these indicate the large potential for green and sustainable construction opportunities now and in the near future. However, green and sustainable construction information has been around for over fifteen years. The website for Sustainable Sources (http://sustainablesources.com) was on the World Wide Web in June of 1995, but the construction industry did not totally accept green and sustainable construction as something that was not a passing trend until 2008. One particular article in Engineering News Record clearly states the current industry attitude on green and sustainable construction:

> "If in previous years green design was a burgeoning trend, 2008 is the year when industry has finally bought into it on a broad scale. In the manufacturing sector, the clamor for green facilities has sparked a hill-fledged design revolution as owners increasingly look to sustainability as the panacea for skyrocketing energy costs. Existing factories and plants are being retrofitted to be more energy efficient, and sustainable design is now standard on new projects of almost every kind. Leveraging the broad-based push in industry to reduce energy consumption, many design firms are active in a growing market for energy assessment services. Even with a 5% to 10% increase in upfront costs typically expected for a project striving for LEED certification, manufacturers are increasingly willing to invest for the long-term energy-saving benefits, designers report. Manufacturers also are rushing to meet growing demand for green materials and components, such as solar panels, fuel cells and other new sources of energy (Nicholson, 2008)."

Articles in other journals related to specialty contractors and residential construction agree. According to Vrolijk (2008), in 2005 Green building comprised $10 billion of the commercial and residential construction market, but is expected to increase to $60 billion by 2010. Forecasts for the heating, ventilating and air conditioning (HVAC) industry in 2018 see the industry being expected to be leaders in green building and/or sustainable practices (Skaer, 2008).

Authors such as Kibert and Todd have written about the need for sustainable construction practices since 1993 and how the industry could evolve, but materials for courses, especially text books on green and sustainable materials and practices, weren't readily available until recently. College text books are now available on topics such as green and sustainable building construction, as well as materials for sustainable sites from publishers such as Wiley & Sons. Now that the construction industry has finally accepted green and sustainable construction practices and projects, it is up to construction educators to provide graduates with the knowledge to support industry needs. While these topics can be covered in single courses on green and sustainable construction along with the LEED rating system, materials and information for these topics can also be included into many courses in a typical construction management program curriculum.

This paper will first explain LEED principles and outline the 2009 LEED rating system for new construction. Second, basic categories and definitions for green and sustainable construction will be introduced. Finally, the paper will suggest ways that these topics can be incorporated into a construction management curriculum.

LEED Overview

The U.S. Green Building Council (USGBC) was created in 1993 and is a consensus based nonprofit organization geared to providing leadership for building. According to the USGBC, buildings in the United States account for "72% of electricity consumption, 39% of energy use, 38% of all carbon dioxide (CO_2) emissions, 40% of raw materials use, 30% of waste output (136 million tons annually), and 14% of potable water consumption" (www.usgbc.org, 2008). The LEED green building certification system provides third-party verification that projects are designed and built using strategies for energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, and resource management. The systems developed by the USGBC provide building owners and operators ways to identify and implement practical and measurable green building design, construction, operations and maintenance solutions. LEED certifications are applicable for all building types, commercial and residential, and apply throughout the building lifecycle: design and construction, operations, maintenance, tenant fitout, and significant retrofit (www.usgbc.org, 2008).

In June 2009, the revised LEED certification systems became effective. The revised certifications titles are Homes, Neighborhood Development (in pilot), Commercial Interiors, Core and Shell, New Construction, Schools, Healthcare and Retail, and Existing Buildings Operations and Maintenance. Thus, a variety of LEED topics can be covered in any basic construction program, as well as those that have concentrations in residential, commercial, industrial construction.

The most general guide for all construction management programs is the Green Building Design and Construction LEED reference manual (2009 edition). It is applicable for the design, construction and major renovations of commercial and institutional buildings including core and shell and K-12 school projects. This guide replaces the LEED manual for New Construction and Major Renovation version 2.2 (third edition 2007, reference guide).
LEED rating systems are organized into five environmental categories that may have prerequisites, and multiple credits that allow projects to earn points towards a certification level. Project certification levels are as follows: Certified (40-49 points), Silver (50-59 points), Gold (60-79 points), and Platinum (over 80 points).
The LEED categories cover Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, and Indoor Environmental Quality. An additional category, Innovation in Design, allows for exemplary performance in some credits, but may also address areas not covered in other categories or credits. One credit is given for having a LEED Accredited professional on the Project Team. A new category in the 2009 LEED criteria, called regional bonus points, acknowledges the importance of local conditions in determining the best or most appropriate design aspects for the project and the construction practices.

Each category is broken down into possible prerequisites and credits that may have multiple components, but vary per type of project: New Construction, Schools, or Core and Shell. The USGBC 2009 New Construction LEED requirements are shown in Table 1.

Green and Sustainable Construction

Before addressing how LEED topics can be addressed as components of green and/or sustainable construction, a basic understanding must be achieved as to what is green and what is sustainable. According to Wilson (2006), green products are those made with salvaged, recycled, or agricultural waste content, but also where those materials came from is important to determining whether something is green. A summarized green criteria list, most of which are addressed in the Material and Resources section of LEED, follows:

1. Products made with salvaged, recycled, or agricultural waste content: Salvaged products; products with post-consumer recycled content; products with pre-consumer recycled content; products made from agricultural waste material.
2. Products that conserve natural resources: Products that reduce material use; products with exceptional durability or low maintenance; certified wood products; rapidly renewable products.
3. Products that avoid toxic or other emissions: Natural or minimally processed products; alternatives to ozone-depleting; alternatives to hazardous products; products that reduce or eliminate pesticide; products that reduce stormwater; products that reduce impacts from construction or demolition; products that reduce pollution or waste from operations.

Table 1. 2009 LEED New Construction Categories and Credits

Sustainable Sites (SS):
Prerequisite 1- Construction Activity Prevention
Prerequisite 2- Environmental Site Assessment
Credit 1- Site Selection
Credit 2- Development Density and Community Connectivity
Credit 3- Brownfield Redevelopment
Credit 4- Alternative Transportation
  4.1- Transportation Access
  4.2- Bicycle Storage and Changing Rooms
  4.3- Emitting and Fuel-Efficient Vehicles
  4.4- Parking Capacity
Credit 5- Site Development
  5.1- Protect or Restore Habitat
  5.2- Maximize Open Space
Credit 6- Stormwater Design
  6.1- Quantity Control
  6.2- Quality Control
Credit 7- Heat Island Effect
  7.1- Nonroof
  7.2- Roof
Credit 8- Light Pollution Reduction

Water Efficiency (WE):
Prerequisite 1- Water Use Reduction (20%)
Credit 1- Water Efficient Landscaping
Credit 2- Innovative Wastewater Technologies
Credit 3- Water Use Reduction (30, 35 or 40%)

Energy and Atmosphere (EA):
Prerequisite 1- Fundamental Commissioning of Building Energy Systems
Prerequisite 2- Minimum Energy Performance
Prerequisite 3- Fundamental Refrigerant Management
Credit 1- Optimize Energy Performance
Credit 2- On-site Renewable Energy
Credit 3- Enhance Commissioning
Credit 4- Enhanced Refrigerant Management
Credit 5- Measurement and Verification
Credit 6- Green Power

Materials and Resources (MR):
Prerequisite 1- Storage and Collection of Recyclables
Credit 1- Building Reuse
  1.1- Maintain Existing Walls, Floors, and Roof
  1.2- Maintain Interior Nonstructural Elements
Credit 2- Construction Waste Management
Credit 3- Materials Reuse
Credit 4- Recycled Content
Credit 5- Regional Materials
Credit 6- Rapidly Renewable Materials
Credit 7- Certified Wood

Indoor Environmental Quality (IEQ):
Prerequisite 1- Minimum Indoor Air Quality Performance
Prerequisite 2- Environmental Tobacco Smoke (ETS) Control
Prerequisite 2- Minimum Acoustical Performance
Credit 1- Outdoor Air Delivery Monitoring
Credit 2- Increased Ventilation
Credit 3- Construction Indoor Air Quality Management Plan
  3.1- During Construction
  3.2- Before Occupancy
Credit 4- Low-Emitting Materials
  4.1- Adhesives and Sealants
  4.2- Paints and Coatings
  4.3- Flooring Systems
  4.4- Composite Wood and Agrifiber Products
Credit 5- Indoor Chemical and Pollutant Source Control
Credit 6- Controllability of Systems
  6.1- Lighting
  6.2- Thermal Comfort
Credit 7- Thermal Comfort
  7.1- Design
  7.2- Verification
Credit 8- Daylight and Views

  8.1- Daylight
  8.2- Views

Regional Priority (RP): Applicable to projects registered for 2009 LEED certification
Credit 1- Regional Priority
  USGBC lists for each state per zip code can be found at
  http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1984

4. Products that save energy or water: Building components that reduce heating and cooling; equipment that conserves and manages energy; renewable energy and fuel cell equipment; fixtures and equipment that conserve water.
5. Products that contribute to a safe, healthy built environment: Products that do not release significant pollutants into the building; products that block the introduction, development, or spread of indoor; products that remove indoor pollutants; products that warn occupants of health hazards in the building; products that improve light quality; products that help control lighting; products that enhance community well-being (Wilson, 2006).

Although many people use the terms green and sustainable interchangeably, sustainable may differ from green. To be sustainable, a product or practice must not use more resources to make the product or conduct a practice than that product or practice can save. Thus, currently some green products, such as solar panels, may not be sustainable if they require more energy or resources for panel production than they can recoup in their life cycle (Kibert, 2005). The first commonly accepted definition of sustainable development was written in the UN Report of the World Commission on Environment and Development titled Our Common Future (also known as the Brundtland Report) from The United Nations World Commission on Environment and Development (WCED) (1987). This document defines sustainable development as development that meets people's current needs but does not compromise the ability of the future generations to meet their needs.

Construction Program Curriculum

The easiest way to include discussion of green and sustainable construction as well as how the LEED system impacts the construction industry would be a single course that incorporates all of these topics. However, typical construction programs contain courses in surveying, site development, and soils where discussions of LEED credits concerning site selection, building orientation, Brownfield redevelopment, and availability of transportation and utilities could be appropriate. Construction methods and materials would be appropriate courses for discussion on green and sustainable materials selections, and issues for obtaining local or regional materials as suggested for incorporation for LEED credits.

Mechanical and plumbing systems, electrical systems, energy and lighting, and design of structures courses would be appropriate for discussion of energy efficient systems, controls for occupant comfort, day lighting, fenestration and ventilation issues, as well as building orientation related to seasonal passive solar gains. Structural design courses could address the engineering challenges of reusing existing structures. Alternative energy pros and cons including geothermal, wind, and solar among others would be appropriate for discussion in these courses as well. Soils courses would be appropriate for talking about geothermal heating and cooling, storm water and erosion control, and soil and water contaminant issues that may occur during the redevelopment of urban sites. Economics, estimating, and scheduling courses could address cost and schedule issues dealing with obtaining green and sustainable materials, obtaining local materials and suppliers, and shipping/delivery/storage issues. This information could be pertinent depending on project locations and availability of roads and utilities, parking and storage facilities.

Construction documentation, management and/or administration courses could address the documentation requirements of LEED certification processes, and the organizational and team building issues involved with these types of construction projects. Because registration of LEED projects is done on the Internet, and this system requires many written documents for each credit submission, emphasis on basic computer and written communications skills should also be included in construction programs.

Summary

The number of LEED certified and/or green and sustainable construction projects are going to increase in the future compared to the number of projects today. This area of construction is no longer considered a passing fad, but an important part of the construction industry as a whole. The positive benefits from green and sustainable construction products and practices for the environment, owners, and occupants will continue to drive the need for construction graduates to have knowledge of these topics in addition to the LEED certification process. Inclusion of these topics can be done in single course, but may also be spread among existing courses in a construction program curriculum.

One suggested text book for a single course on sustainable and green construction that also incorporates discussion of the LEED system is *Sustainable Construction: Green Building Design and Delivery* by Kibert (2008).

References

Kibert, C. Ed. (1999). *Reshaping the built environment: Ecology, ethics and economics*. Island Press: Washington, DC.

Kibert, C. (2008). *Sustainable construction: Green building design and delivery,* 2nd ed. John Wiley & Sons, Inc.: Hoboken, NJ.

Nicholson, T. (2008, Jun 23). Green building goes mainstream as manufacturers seek to cut costs. *ENR, 260*, 21; p. 48.

Skaer, M. (2008, Oct. 20). The industry 10 years from now. *Air Conditioning, Heating & Refrigeration News, 235*, 8, pp. 1-3.

Todd, N., & Todd, J. (1993). *From eco-cities to living machines*. North Atlantic Book, Berkeley, CA.

Todd, N. (2005). *A safe and sustainable world: The promise of ecological design*. Island Press: Washington, DC.

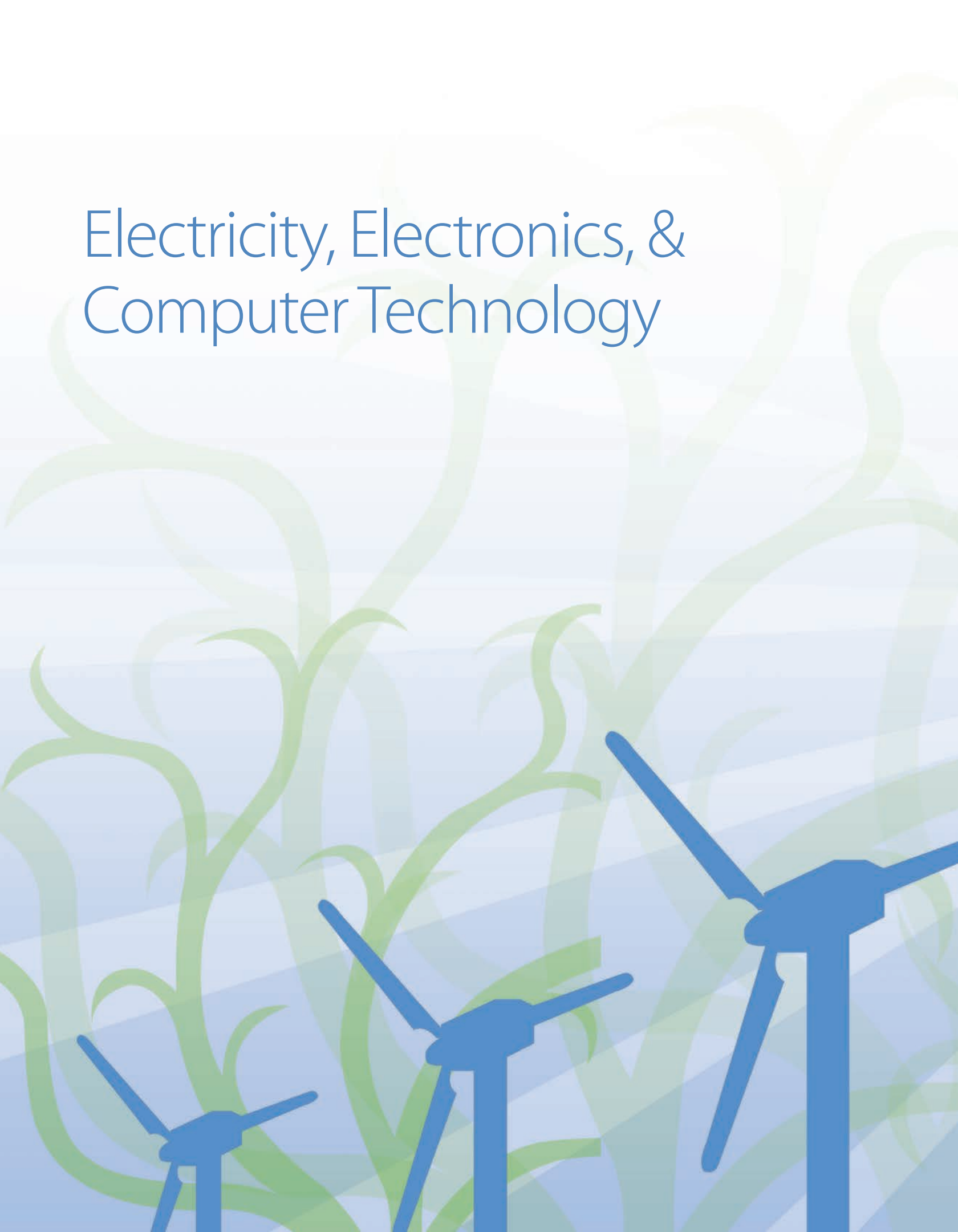
UN Report of the World Commission on Environment and Development: Our Common Future (1987) retrieved 7/12/2009 at http://www.un-documents.net/wced-ocf.htm

USGBC (2009). LEED *Reference guide for Green building design and construction.* U.S. Green Building Council: Washington, D. C.

Vrolijk, J. (2008, Jul). Green and growing: Sustainable building insurance methods are still under construction. *American Agent & Broker*. *80*, 7; p. 34.

Wilson, A. (2006). Building materials: What makes a product green? *Environmental Building News*, retrieved 7/12/2009 at http://www.buildinggreen.com/auth/article.cfm?fileName=090101a.xml

Electricity, Electronics, & Computer Technology



Design a Microcontroller Trainer for Hands-on Distance and on-Campus Classes

Dr. Steve Hsiung
Old Dominion University, Department of Engineering Technology, 214 Kaufman Hall, Norfolk, VA 23529, (757)683-4606, shsiung@odu.edu

Abstract
The purpose of this project is to design a low cost microcontroller trainer affordable ($130) for student to keep and in an attempt to improve student learning, eliminate the institution budget limitation on lab equipment, and overcome obstacles in teaching digital, microprocessor/microcontroller related courses that are delivered through distance learning and on-campus formats. Using this trainer and curriculum provides opportunities to students in rural and urban areas to learn current technology concepts and become prepared to qualify for high-tech jobs. The training system hardware and software is undergoing testing/evaluation and part of those evaluations are presented. The curriculum package and presentation of how to use the trainer system will be addressed.

Introduction
Microcontrollers have become ubiquitous helpers in our daily lives. They are compact, single-purpose computers running embedded application software that are widely utilized in modern electrical devices and systems to control operations, such as temperature settings of ovens, remote control of television sets, or extended features of cell phones. Now automobile mechanics must work with microcontrollers to control fuel mixtures and ignition timing. Because microcontrollers are so important to our high-tech world, demand is high for workers trained to design, maintain, and embed them into products. But many people who want the training cannot take time away from work or families to enroll in engineering and/or technology programs on university campuses.
Digital electronics and microprocessors/microcontrollers are a major component of the high-tech world and important subjects in Electrical, Electronic and Computer Technology (EECT) and related curricula. To educate students in these fields and accommodate the growing need for distance learning, the methods of delivering these educational materials must be changed. Studies show the obstacles in delivering hands-on education in distance learning environments (Michael, 2001), but all issues can be resolved with modified instructional strategies. Currently, most of the solutions to laboratory related courses in distance learning are to use computer simulations and sometimes Internet virtual labs, which have fundamental difficulties in solving this issue (Bernard, 2004). For example, circuit design, testing, implementation, debugging, and performance checking can not be covered by pure use of software simulations and virtual laboratories (Michael, 2001; Gohale, 2007). In addition, the cost of doing all the learning exercises and experimentation is another issue for instructors and students.

The design and implementation of a microcontroller training system for hands-on distance learning projects can provide opportunities to students in rural and urban areas to learn current technology concepts and become prepared to qualify for high-tech jobs. Following is a description of a microcontroller training system including hardware and software designs, and their implementation using distance learning instruction.

The Needs of a Hands-on Microcontroller Training Platform
According to Gokhale's (2004) findings, the effective integration of computer simulations into lecture-lab activities enhances the understanding and performance of students. From the findings of Michael[1], the use of computer simulations to enhance product creativity was not supported. To simply apply computer simulations in distance learning classes will not be effective to support students' understanding. There must be an association with hands-on experiments or laboratory activities to achieve the maximum learning results, a key in understanding engineering concepts.

There are courses that can easily fit into the distance learning format. But there are also curricula that have fundamental difficulties in offering the course material on-line. The most common problems are the courses that require hands-on laboratory experimentations/exercises and their associated high costs, such as those offered in the Engineering and Technology areas. The implementations of virtual labs in which students can remotely log onto and control the laboratory equipment to do the needed exercises via the Internet will solve some of the learning difficulties but they have limitations. Especially, when considering tests, experiments on real circuits and software designs, trouble shooting, and debugging in the microcontroller control related material, it is a major obstacle to students in understanding the concepts in remote locations. Without letting students actually build the circuits and test their designed software on real hardware set-ups, it is very difficult to visualize the course instructional materials. Without a common training system platform, it has been increasingly difficult for teachers to guide and assist students in trouble shooting their circuits/systems and give them proper suggestions or answers to their problems in a remote environment. On the average, this significantly increases the time required to assist students performing laboratory work on-line when compared to students taking the course on campus. Distance learning students spend more time in understanding the course materials, since they can only obtain help from teachers via Internet postings, chats, or e-mail discussions.

The cost of learning microprocessor/microcontroller applications is another major issue for implementing distance learning programs, because students usually need to purchase parts and equipment themselves to meet the course requirements. This significantly increases the cost of the hands-on courses; oftentimes these financial burdens force potential students to have second thoughts in selecting the major. Converting the course to computer simulation will reduce these costs, but the authors consider hands-on experiences to be vital to the success of microprocessor related laboratory courses. The project idea is to make the training system with associated instructional modules available to students to buy in place of a textbook and parts list for purchasing through a bookstore or vender arrangement.

There is currently a wide variety of PIC programmers and in-circuit emulators (ICE) available on the market. The Easy PIC development tool made by MidroElektronika (2006) (an East European company) uses the PIC16877, which has inputs, outputs, keys, a LCD, and LED display for $149.00. The PIC TUTOR made by AMS (2006) (a British company) has a keypad, LEDs, and a LCD display for $340.00. The MR1-MC-05 PIC Emulator made by MCPros (2006) (a US company) is a full ICE (when the POD and adaptor modules are added) and costs from $1,200.00 to $2,400.00. The BASIC Stamp made by Parallax Inc. (BASIC, 2006) provides software and hardware in various module configurations for microcontroller applications in a BASIC programming environment. The cost of the individual module is attractive and within a range from $30.00 to $100.00. Implementing all the needed laboratory exercises and projects requires different modules from the BASIC Stamp and the total price becomes unaffordable to most distance learning courses. Micorchip (2006), the manufacturer of PIC microcontrollers, has development systems ranging from $199.00 to $2,560.00. These systems are all designed for professional applications, debugging, and simulation. Most of their applications are single purpose and of limited educational value for classroom and laboratory exercises which require multiple functions for various learning experiences. They were not developed based on academic needs and especially are not suitable for a distance learning environment.

Based on the research of the available training systems, it proves they are either too expensive to the distance learning student to own or the design focuses are not suitable for distance learning applications. The microcontroller training platform described here is designed to address these active hands-on distance learning problems and associated cost issues. Use of this training platform, with a mix of internet-based real time audio, video, e-mail, chat, conference meeting, and individual consultation software can, make the distanced students' learning experience equivalent to that of their on-campus counterparts.

Project Objectives, Curriculum, and Hardware Design

The research team transformed their ideas for this learning system into project objectives. These included:

1. **Training System Development:** Design and develop the hardware and software for a training system board that uses PIC medium family members, such as PIC16F84A (2004), PIC16F88 (2004), and PIC16F877A (2004), for two-year and four-year institutions in the areas of digital, microprocessor/microcontroller, automation control, and senior project courses to directly resolve the

problems of cost and learning from a distance.

2. **High and Low Level Programming Languages:** This system will serve as a common platform for high and low level software programming design, hardware circuit trouble shooting, evaluation, and final project control.
3. **Hardware Modules and Components:** The training system will be designed with many basic modules such as power supply, input/output switches, keypad, interrupt inputs, LED outputs, LCD display, serial interface, parallel interface, PC communication interface, high power motor driver, sensing, etc. It also will have the flexibility to accept advanced module connections for future expansions.

Due to the differences in program design and institution mission, an extensive information exchange was used to help the team members to reach consensuses on curriculum modules. After many discussions and exchanges of experiences between the design team members, a common list of instructional topics was developed. The design team members elected the following units to develop the course curriculum modules that can be integrated into various courses:

Session #	Content
0.	**Microcontroller Technology:** A Brief History of Microprocessor Development, Differences between Microcontrollers and Microprocessors, Microcontroller Applications, Microprocessor Architectures, Memory Types, Microcontroller Packaging/Appearance, PIC16F84A, PIC16F88, and PIC16F877A Memories
1.	**Gates, Number Systems & PIC Environment:** Different Number Systems, Number System Conversions, Logic Gates, Logic Arithmetic (Add & Subtract), Header File and Source Codes, The Environment and Software Operations, and Header File and Source Codes
2.	**PIC Instructions in Assembly Language Programming:** Assembly Language Format, PIC Instruction Sets and Registers, 16F84A, 16F88, and 16F877A Internal Blocks and DRAM Distributions, C, Z, and DC Flags in STATUS Register, Setting and Clearing Bits, Logic and Math Operations, and Addressing Modes
3.	**I/O Interface:** PIC Embedded System Designs, Use of Internal Oscillator and External Resonator, Ports Configuration, I/O Port Interface, DIP Switches Inputs, LED Controls, and 7-Segment Interface
4.	**Assembly Language Software Designs:** Programming Controls, Flowcharts, Counters, Loops, Time Delays, Subroutines, DRAM Memory Banks, and PRAM Memory Pages
5.	**The Uses of WDT:** CONFIG Register Configuration, Watch Dog (WDT) Configuration, Controls, and Applications
6.	**The Uses of IRQs:** Source of Interrupts, Flags and Enable Setup, Interrupts Handler, IRQ Configuration, Polling vs. IRQ, IRQ Service Routines, Prioritize IRQ Services, and Multitask Applications
7.	**Parallel Data Communication:** Parallel Interface, Data Transmission Protocol, Long and Short Table Lookup Implementations, and LCD Module Interface
8.	**3*4 or 4*4 Matrix Keypad:** Software Debounce Designs, Key Decoding Designs, Matrix Keypad Interface Designs, Interface Software Design, and Testing and Verification
9.	**Stepper Motors:** Unipolar and Bipolar Stepper Motors, Stepper Motors Interface, H-Bridge, Driver, Speed, and Direction Designs/Controls
10.	**DC Motors:** H Bridges Controls, DC Motors Interface, Driver, Speed, and Direction Designs/Controls, and PWM Controls

PIC Training System Hardware and Software

After finalizing the session topics, work began on the hardware design. The initial goal was to design a hardware circuit that will both enable PIC microcontroller programming and provide limited debugging functions. Information required to develop the PIC microcontroller programming of the PIC flash and EEPROM memories was obtained from the Microchip web site. Designs of the PC parallel/printer port hardware and software used to program the PIC microcontroller flash and EEPROM memory are widely available on the internet, and these were modified for use in this project by the design team members (PIC16F8X, 2003). However, due to the limited availability of PC parallel ports on newer computers (particularly laptop computers), it was determined that a USB programming port would also be needed. Nevertheless, available software in the public domain using a USB port is limited, mainly because hardware designs vary and the accompanying software differs for each design. This posed a challenge to the project team.

To provide limited debugging functions on a PIC processor, an understanding of the "Background Debugger Control" and the "On-Chip Debugger" specifications is essential. But, there is lack of sufficient documentation of these materials (On-Chip, 2001). After consultation with Microchip Inc., it was found that full documentation of the debugger routines is usually not available to the general public and is only shared with Microchip's affiliated third party tool development companies. Following extensive research, trial and error, and additional consultation with Microchip design engineers, it was their suggestion that the best approach would be to use the available Microchip public domain software.

It was decided that Microchip's "PICKT2" hardware and software architecture would be followed for the design of this development system (PICKIT2, 2007). In implementing this scheme, the system would be designed around the "PICKT2" USB communication criteria, thereby using a dedicated PIC18F2550.

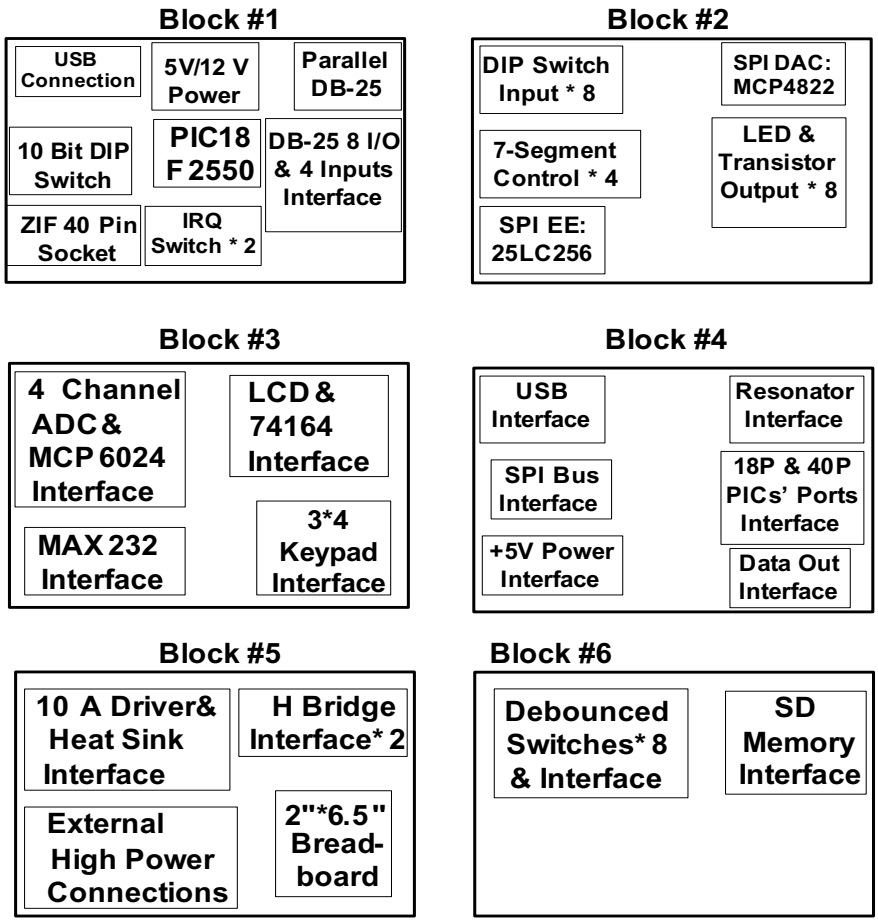
To be able to better communicate with the project team members and to create clear and effective documentation, hardware blocks were used to initiate different design ideas. The hardware block design is also aimed toward better links in fulfilling the needs of the curriculum sessions listed earlier. The core circuit design, shown in Block #1 of Figure 1, was tested and verified with the "PICKIT2" software. The USB port uses "PICKIT2" software and the DB25 parallel port uses "ICPROG" software (ICPROG, 2007). Additionally, the DB25 parallel port can also be used for high level language programming controls in C or C++ running Microsoft Visual Studio (Hsiung, 2006). After three revisions of the hardware functional blocks that were mutually agreeable to the participating colleges, a final circuit design was completed. Figure 1 shows a block diagram representing the training system hardware.

Printed Circuit Board (PCB) Implementation

Based on the bill of materials from the designed circuits (Eagle, 2004), there are a total of 205 electronic components/parts needed on the PCB. The goal is to make a PCB that has to be less than a standard page size of 8.5"*11" format for easy transportation. When implementing the designed circuits into a desirable fit in a PCB, there are several factors that need to be considered:

1. All the parts should be used in a through-hole format; any surface mount component will make the assembly and trouble shooting very difficult.
2. Even if footprints and prices for the surface mount parts are lower, they do not justify the difficulty in replacing and updating the training system in the future.
3. Not all the available parts' footprints for the PCB layout software can be perfectly matched with the parts from available venders, so making customized footprints is necessary.
4. Different adjustments on the parts' footprints are a critical design process.
5. To better meet budget constraints, an adjustment on parts' footprints with available parts should work coherently during the PCB layout designs.
6. A four-layer PCB is preferable because of ease of layout, but the PCB manufacturing cost has forced the design to be a double sided board.

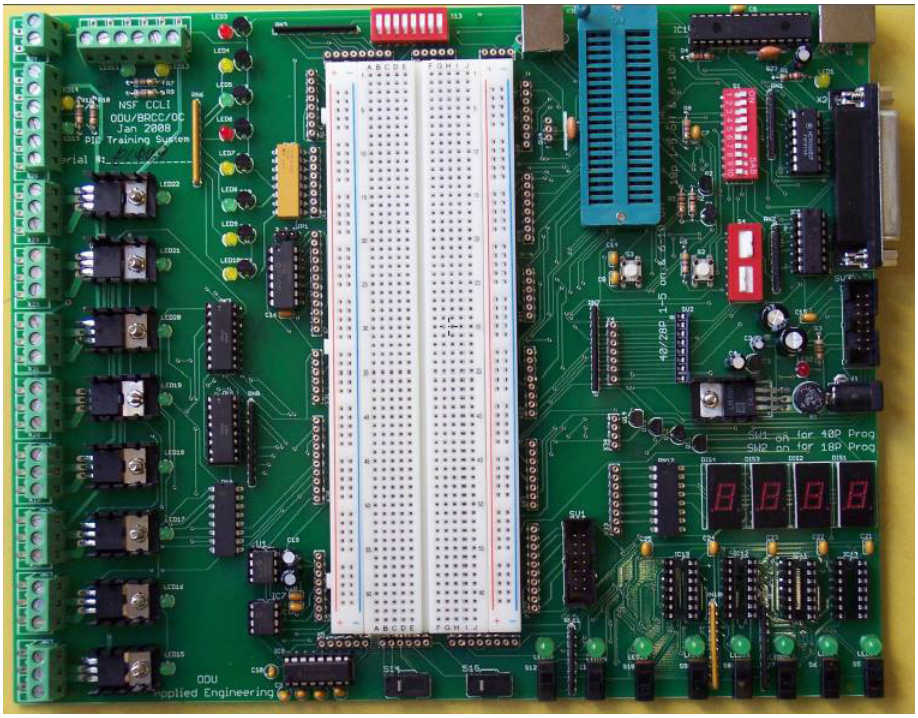
Figure 1. PIC Microcontroller Training System PCB Function Blocks



7. The size of the training PCB can only shrink to its absolute minimum of 8"*10" to host a total of 205 electronic components. This makes the routing a very challenging task. The auto route function performed by the software will not be able to do the job. Several trials and manual routes are the solution to meet the goal.
8. High power and low power sections of the circuits should be separated.
9. The routing traces of the high power signal should be wider in order to carry higher current.
10. High frequency components, such as the USB, resonators, and SPI bus lines, should be placed as close as possible to their communication partners.
11. All the interface connectors should be placed around the 2.2"*6.5" breadboard for easy access in building interfaces.
12. All the low power, USB, DB25, and ribbon cable connections are placed at one side of the PCB and all the high power connectors for motor controls are placed on the other side. These arrangements are designed for user friendliness and easy access in performing laboratory experiments.

After applying these PCB design considerations, a final assembled PCB for this PIC training system is presented in Photo 1.

Photo 1. The Assembled PIC Training System



Training System Workshop Evaluations

This newly designed training system had been introduced through two workshops: one was on June 22, 2008 at ASEE Annual Conference in Pittsburgh, PA and the other was on November 21, 2008 at NAIT Annual Convention in Nashville, TN. The assessments from both workshop attendees were very positive and won all agree and majority strongly agreed support of the academic application in on-campus and distance learning microprocessor/ microcontroller related courses. ASEE08 workshop assessment results are shown in Table 1 and Figure 2. NAIT08 workshop evaluations are presented in Table 2 and Figure 3.

Table 1. *ASEE 08 Workshop Evaluation Summary*

#	**Question** ***5 = Strongly Agree … 1 = Strongly Disagree***	**Rating** 5	4	3	2	1	Mean N	
1	Do you think the interface connectors' layout is sufficient for this training system?	9	6				15	4.60 Strongly Agree
2	Does this training system design fit your program needs?	3	7	4			14	3.93 Agree
3	Does this training system meet your current lab exercise needs?	3	6	4		1	14	3.71 Agree
4	Does this training system provide sufficient options in peripheral circuits' for different interface exercises?	8	6	1			15	4.47 Agree
5	Does the price of $130 justify this training system cost?	9	6				15	4.60 Strongly Agree
6	Does this training system software provide sufficient options for your lab exercises?	4	10				14	4.29 Agree
7	Do you think a wireless RF module is necessary for this training system?	5	3	3			14	4.00 Agree
8	Do you think a wireless IF module is necessary for this training system?	4	4	4			12	4.00 Agree

#	Question *5 = Strongly Agree … 1 = Strongly Disagree*	Rating 5	4	3	2	1	Mean N	
9	Do you feel the curriculum package is sufficient to cover your uP/ uC courses?	3	7	4			14	3.93 Agree
10	Do you think you would like to adapt this training system for your face to face campus courses?		9	2	2		13	3.54 Agree
11	Do you think you would like to adapt this training system for your distance learning courses?		4	4	1		9	3.33 Uncertain
12	Does this workshop assist you in the lab courses preparation and implementation?	8	3	3			14	4.36 Agree
13	Is this workshop useful to your academic needs?	5	7	3			15	4.13 Agree
Overall Workshop Assessment		**9**	**4**	**1**			**14**	**4.27 Agree**

Comments:
-Not enough time to understand the potential of the system. System seems well designed and provides detailed documentation.
-Great work so far; could use a user-centered design revision so other institutions could use it without developer's knowledge.
-Need to find an appropriate textbook to parallel the system.
-Excellent workshop and excellent project.
-It is very comprehensive and informative for my future use with digital control of electric machinery.
-Excellent workshop. Hands-on is important tool to learn better.
-Need to be able to reprogram without taking out wires.
-The training board has some connecting bugs with the software. Sometimes it can connect; sometimes it cannot.

Figure 2. *ASEE08 Workshop Evaluation Chart*

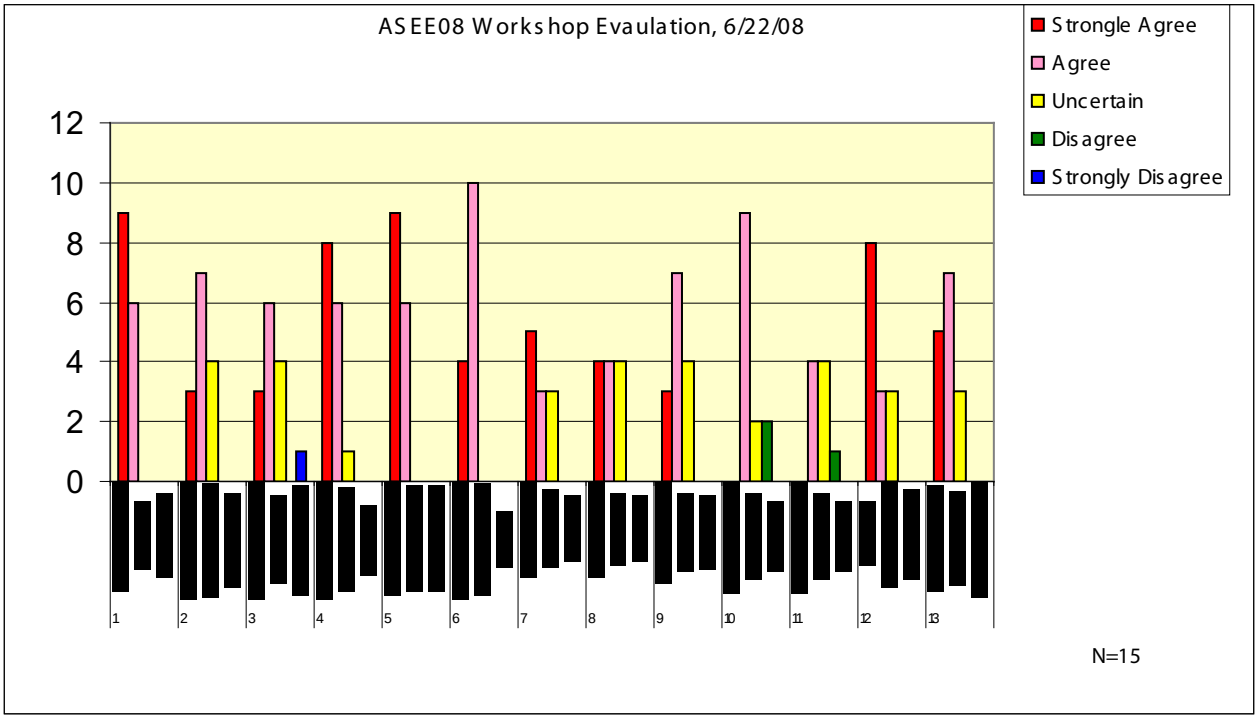
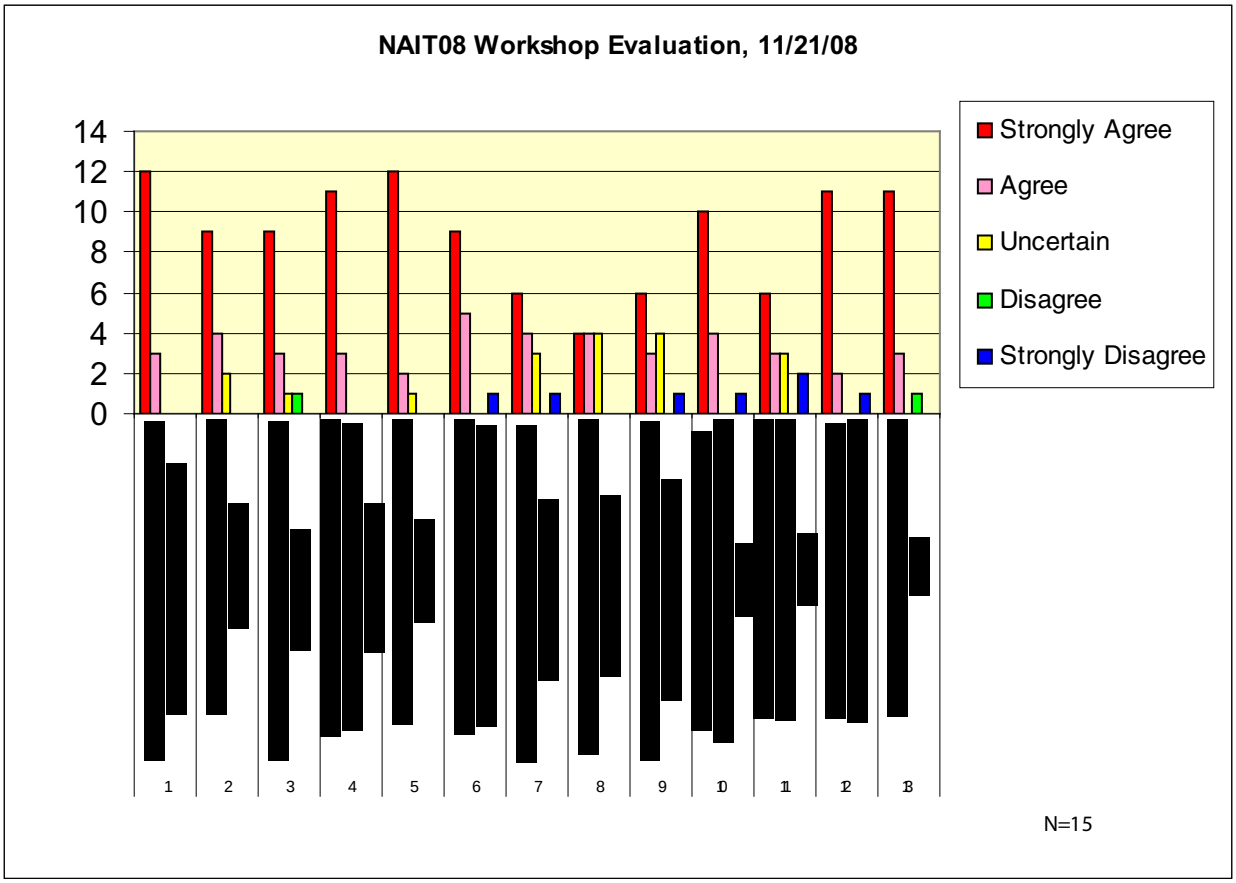


Table 2. *NAIT 08 Workshop Evaluation Summary*

#	Question *5 = Strongly Agree … 1 = Strongly Disagree*	Rating 5	4	3	2	1	Mean N	
1	Do you think the interface connectors' layout is sufficient for this training system?	12	3				15	4.80 Strongly Agree
2	Does this training system design fit your program needs?	9	4	2			15	4.47 Agree
3	Does this training system meet your current lab exercise needs?	9	3	1	1		14	4.13 Agree
4	Does this training system provide sufficient options in peripheral circuits' for different interface exercises?	11	3				14	4.79 Strongly Agree
5	Does the price of $130 justify this training system cost?	12	2	1			15	4.73 Strongly Agree
6	Does this training system software provide sufficient options for your lab exercises?	9	5			1	15	4.40 Agree
7	Do you think a wireless RF module is necessary for this training system?	6	4	3		1	14	4.00 Agree
8	Do you think a wireless IF module is necessary for this training system?	4	4	4			12	4.00 Agree
9	Do you feel the curriculum package is sufficient to cover your uP/uC courses?	6	3	4		1	14	3.93 Agree
10	Do you think you would like to adapt this training system for your face to face campus courses?	10	4			1	15	4.47 Agree
11	Do you think you would like to adapt this training system for your distance learning courses?	6	3	3		2	14	3.79 Agree
12	Does this workshop assist you in the lab courses preparation and implementation?	11	2			1	14	4.57 Strongly Agree
13	Is this workshop useful to your academic needs?	11	3		1		15	4.60 Strongly Agree
Overall Workshop Assessment		**7**	**1**				**8**	**4.88 Strongly Agree**

Comments:
-Excellent presentation and this workshop has been of excellent value to me.
-Good hardware lab design.
-Not use distance learning and like to have direct contact with students.
-This type course is not current offered, these question are difficult to answer with no prior knowledge.
-This workshop is ideal for those involved in training future electrical engineering & product designers.
-Add some coding in .ASM would be have been helpful.
-Would like to talk you about implementing this item in possible package/kit format.
-Excellent and outstanding workshop: containing high academic values on pedagogic, training, & course curriculum.

Figure 3. *NAIT08 Workshop Evaluation Chart*



Conclusions and Suggestions

In addition to the goals of this project, several additional results were achieved. First, this has been a rewarding educational experience for the research team members. Team members have realized the vast amount of work required to develop new training hardware, software, and accompanying instructional support materials. It was a challenging learning experience for everyone on the design team.

Also there are current demands for this type of training system. This was determined through conversations with faculty during conference meetings. The team has learned that there is a common concern of the obstacle in implementing hands-on distance learning – a lack of a good teaching platform that is effective and affordable.

Since the beginning of this project in April 2007, several groups of students at BRCC and ODU were involved in organizing electronic components, assembling PCBs, evaluating and testing assembled PCBs, testing circuits, and completing surveys for evaluating the effectiveness of this training system. Responses were positive during their learning experiences while assisting with this project.

The other issue for this project was the budget; there was always a lack of funds to get the project completed. Spending more time and paying attention to details enabled the research team meet the optimal goals without jeopardizing the quality of the project. The final cost for this training system board was set to be approximately $100, but the current bill of material calls (Eagle, 2004) for a total expense of $124.19, not including assembly cost. This would have increased the budget by over 25%. However, by increasing the search for components and negotiating volume purchases, it is expected that the bill of material cost can be lowered by 15%-20%. Using the

students' help (with pay) in PCB fabrication can lower the cost of assembling the system, and at the same time teach students manufacturing processes, quality control, and trouble shooting skills. It also provides students with practical training experience for their future employment. These approaches bring the $100/training system board closer to a reality.

The prime goal was to make affordable technology-related course materials, activities, hardware, and software available to students who do not have access to on-campus college and university laboratory equipment in microcontroller related training that is required for many high-tech careers. This project produced microcontroller prototype hardware and software and instructional materials needed to support the active distance delivery of several microprocessor related courses. Without allowing students to actually build circuits and test their designed software programs on real hardware set-ups using a common platform, it is very hard for them to understand the course content through distance learning programs.

As this project evolves, individual laboratory activities are also being developed to reinforce student learning and skill development in programming concepts as well as provide a platform for individual student research and development after course completion. The expected outcomes will be better trained/educated students who will qualify for positions in the technical knowledge-based workforce.

References

25A256/45LC256 Data Sheet. (2007). Microchip Technology Inc. DS21822F. http://www.microchip.com/.

AMS (2006). Burning Software Corporation, PIC Training & Development System. Retrieved March 20, 2006, from http://www.burnningsoftware.co.uk/pricelst.htm

BASIC (2006). BASIC Stamp, Parallax Inc. Retrieved February 25, 2006, from http://www.parallax.com/index.asp

Bernard, R.M., Abrami, P.C., Lou, U., Borokhovski, E., Wade, A.W., L. et al. (2004). How does distance education compare with classroom instruction? A meta-analysis of the empirical literature. *Review of Educational Research*. 74(3), 379-439.

Eagle. (2004). Easy Applicable Graphical Layout Editor, 2nd Edition, Cadsoft Inc.

Gokhale, A. (2007). Effectiveness of computer simulation for enhancing higher order thinking. *Journal of Industrial Teacher Education*. 33(4), 36-46.

Hsiung, S. & Ward, D. (2006). Design Software and Hardware for PC I/O Control. *Journal of Engineering Technology*. Spring, 16-24.

ICPROG. (2007). Available: http://www.ic-prog.com/index1.htm, December, 2007.

MAX232-MAX249 Data Sheet. (2006). Maxim Integrated Products. http:///www.maxim-c.com/.

MCP4821/MCP4822 Data Sheet. (2005). Microchip Technology Inc. DS21953A. http://www.microchip.com/.

MCPro (2006). Microcontroller Pros Corporation, Microchip PIC Emulator PICE-MC. Retrieved April 25, 2006, from http://www.microcontrollershop.com/product_info.php?cPath=21_65&products_id=208

Michael, K. (2001) "The effect of a computer simulation activity versus a hands-on activity on product creativity in technology education". (2001). *Journal of Technology Education*. 13(1), 31-43.

Microchip (2006). Technology Inc., Development Tools. Retrieved April 30, 2006, from http://www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=81

MikroElektronika (2006). Development Tools. Retrieved April 23, 2006, from http://www.mikroelektronika.co.yu/english/product/tools/etools.htm

On-Chip Debugger Specification. (2001). Microchip Technology Inc., DS51242A.

PIC16F84A Data Sheet. (2004). Microchip Technology Inc. http://www.microchip.com/.

PIC16F88 Data Sheet. (2004). Microchip Technology Inc. http://www.microchip.com/.

PIC16F877A Data Sheet. (2004). Microchip Technology Inc. http://www.microchip.com/.

PIC16F87/88 Flash Memory Programming Specification. (2002). Microchip Technology Inc., DS39607B.

PIC16F87X EEPROM Memory Programming Specification. (2003). Microchip Technology Inc., DS39025F.

PIC16F8X EEPROM Memory Programming Specification. (2003). Microchip Technology Inc., DS30262E.7.

PICKIT2. (2007). Available: http://www.microchip.com/pickit2, December, 2007.

Exploration of BDI Modeling Applied to Electric Motor Vibration Monitoring and Analysis

Dr. Samuel Guccione
Eastern Illinois University, School of Technology, Charleston, IL 61920, 217-581-7259, saguccione@eiu.edu

Mr. Jim Stratton
Eastern Illinois University, School of Technology, Charleston, IL 61920, 217-232-2127, jastratton@eiu.edu

Introduction

Vibration is one of the main causes of failure in electric motors used in production, manufacturing, and other processes. When a motor fails, the cost of repair or replacement as well as the cost of downtime can be extraordinarily high. In addition, Pintelon and Puyvelde (1997) identify that performance reporting for maintenance has an impact on production and operation such as capacity, quality, costs, environmental issues and employee safety.

Proprietary monitoring, reporting, and analysis systems are available but they can be extremely cost prohibitive. The goal of this project was to demonstrate that a Belief-Desire-Intention (BDI) methodology (Rao and Georgeff, April, 1995) could be included in a motor vibration monitoring and control system using existing or readily available industrial control and monitoring hardware and software. Further, the goal also included an exploration to determine if it would effectively monitor, control, and make decisions based upon real time collection of motor vibration data.

BDI is an intelligent agent oriented model that uses human like reasoning's of belief, desire, and intention to provide data to a decision making process for a problem. This agent architecture will hopefully facilitate department conflict resolution and facilitate coordination between different departments (Campos and Prakash, 5-7 July, 2005; Campos and Prakash, May 17-19, 2006) as well as perform high-level management and control tasks (Rao and Georgeff, 1995).

Jo, Chen, and Choi (March 14-17, 2004) describe belief, desire, and intention in the following computational terms. Belief is "the value of a variable, a relational database, or symbolic expressions". Desire is a desired end goal which is "the value of a variable, a record structure, or symbolic expression". Intention is "a set of executing threads in a process that achieve the desired goals".

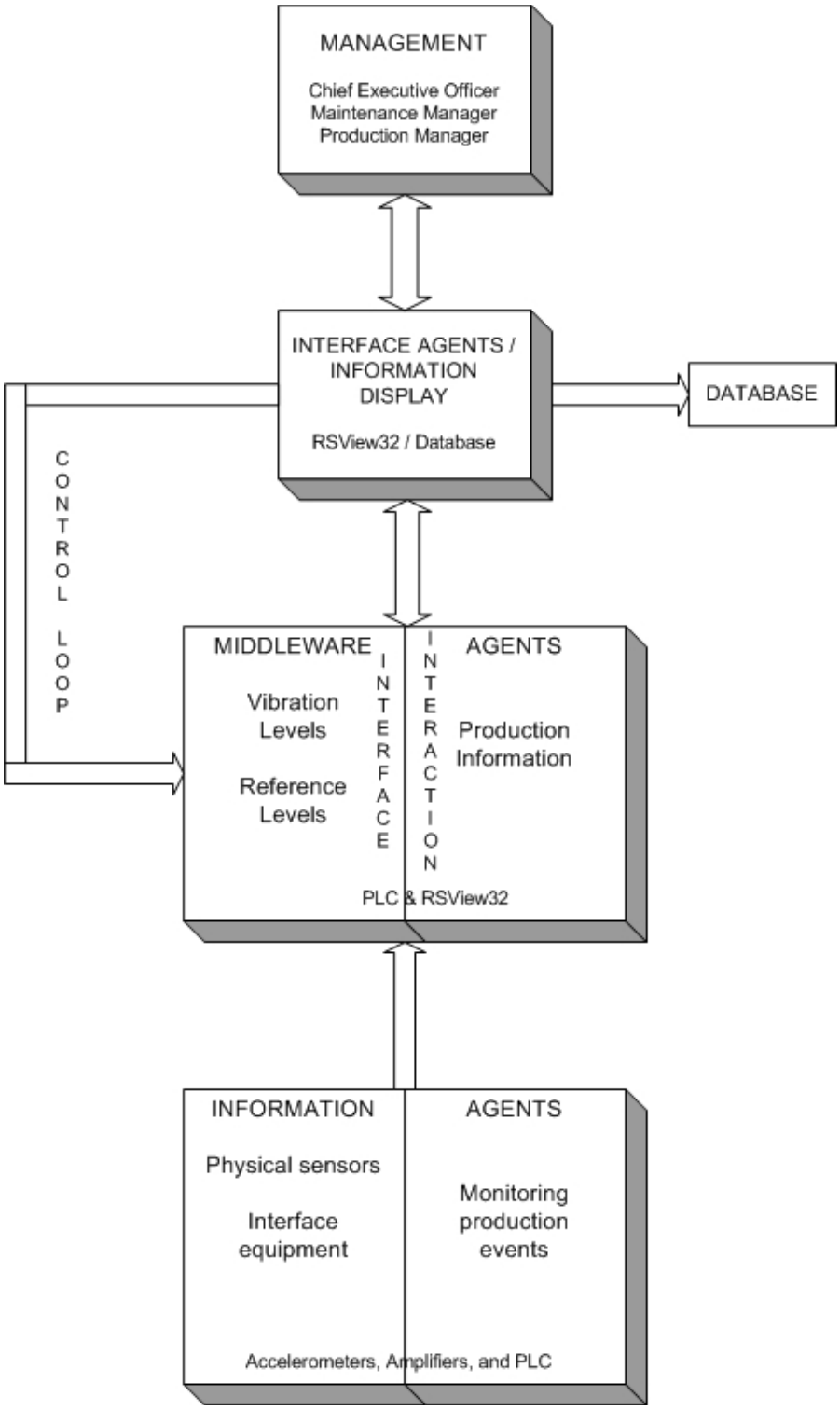
Campos and Prakash (5-7 July, 2005) describe a possible BDI methodology they propose to be used in a plant that uses vibration monitoring. The proposed system uses a multi-tier multi-agent architecture to gather and store data in a database along with information about the production operation which is processed by an expert like system method. A system user then interacts with the agents to review decision values from the expert system for confirmation or over-ride.

This undergraduate research project involved exploring a BDI type model with an intelligent agent like system could be implemented in a Supervisory Control and Data Acquisition (SCADA) system without using specialized large amounts of coding with programming languages (Java, VB, C, etc) not commonly used by maintenance, production, or manufacturing personnel. The monitoring system included a programmable logic controller (PLC) coupled to human machine interface (HMI) software with a database. The monitoring system collects vibration data that is displayed graphically in real time and collected in a database. BDI modeling was applied to the data to present an expert system like process that assists in helping the decision making process for specific vibration levels in real time.

BDI Model

Figure 1 shows a plan of the BDI model created for the vibration monitoring system described herein. This model follows the general outline as proposed by Campos and Prakash (5-7 July, 2005) with specific information about the actual agents used. Parts of several blocks were only partially implemented in this project due to lack of time.

Figure 1. *BDI Model*



The Information Agents measure and collect the new vibration data entering into the system from the outside world as well as the production data, such as, "number of units produced" by the production machine in which the motor resides. Monitored production data was collected as part of this project which focused only on the vibration measurement and display aspect.

The Middleware Agents perform different operations on the new information such as comparing measured vibration level with recommended criterion level for the motor size. There are several vibration criterion standards available. For this project, the VDI 2056 German standard (Norton and Karczub, 2003, page 539) was chosen based upon the work of Campos and Prakash (5-7 July, 2005). Production information was not entered in this project due to lack of time.

The Interface Agent(s)/Information Display facilitate user interaction with the system. It captures data from the Middleware Agent(s) into a database. The database can be accessed to review data, to analyze it, and for other uses. In addition, the Information Display part of this agent provides a real time display of the actual vibration velocity, a graphic display of the severity of the vibration, and other control choices. Note that this agent is connected in a feedback loop to the Middleware Agent to introduce some control of the motor through both automated and manual control of the PLC.

The top Management block is the user interface to the Interface Agent(s)/Information Display so that human input can be included in the model. The manual control identified above can override an automated control or create a special input based upon production data. This was partially implemented in this project.

Description of Vibration Measuring System

The actual vibration was measured on a single-phase motor speed controlled with a variac. Single axis accelerometers interfaced through an instrumentation amplifiers connect to a Micrologix 1100 PLC analog input collected the vibration data. A PLC program was written to convert the acceleration values into the standard rms vibration velocity units of mm/sec.

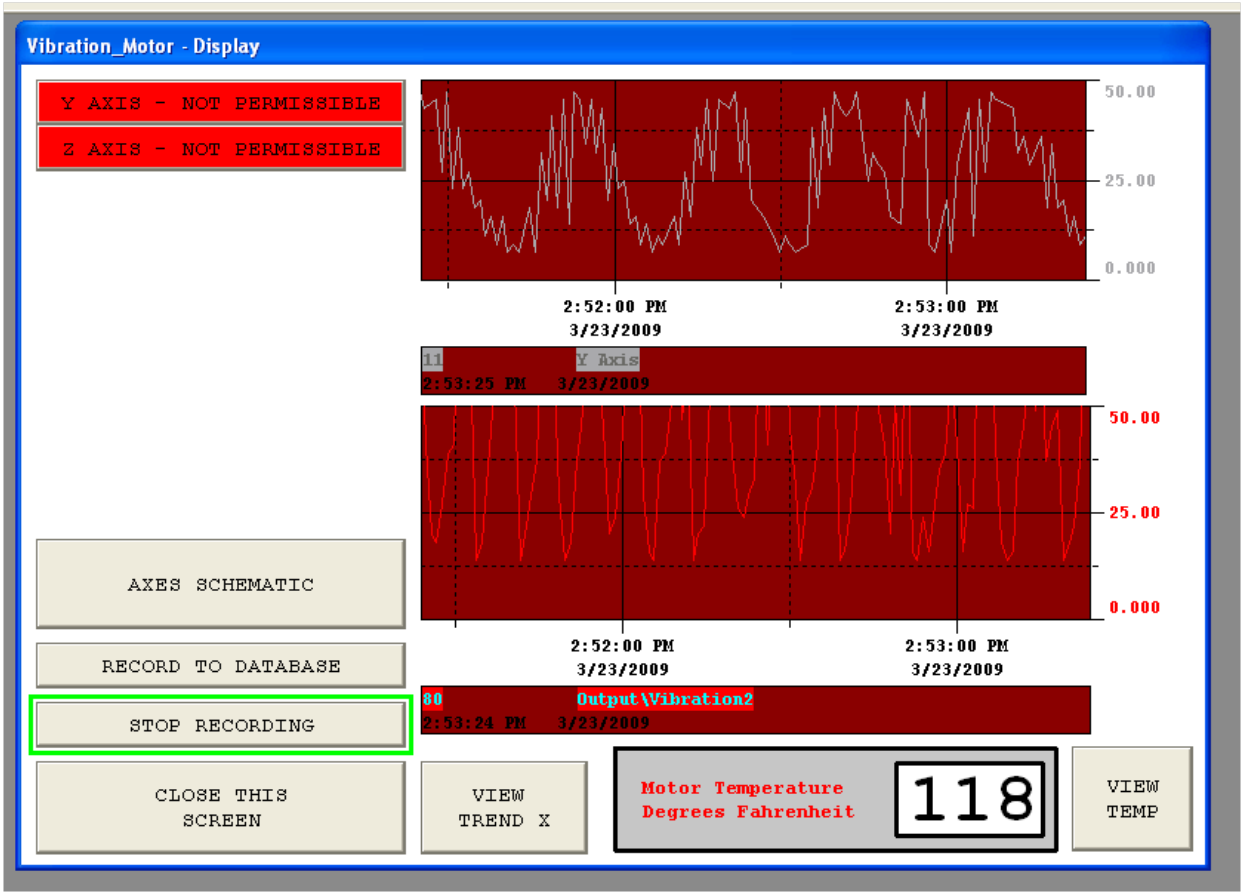
The RSView32 human machine interface industrial transaction software is the Middleware and Information Display/Interface Agents. Using the standard programming available in RSView, the following display screen was created as shown in Figure 2.

The two graphic displays show a real time display of two vibration velocity levels. Two accelerometers were used in this project to measure two axes. A third axis of vibration was not available because of equipment limitations. The VDI 2056 vibration criterion chart is broken down into the following four levels of severity of vibration: 1) Good, 2) Allowable, 3) Just Tolerable, and 4) Not Permissible. The two small graphic displays on the upper left side of the screen are level indicators for the severity. They are colored coded so that a Not Permissible level is red as in the figure. This type of display gives machine operators a visible means to alert management that a potential vibration problem is occurring. These level indicators can also be programmed to send alerts to the maintenance department manager for example which can cause a management decision to take a specific action.

The AXES SCHEMATIC button displays the axes of measurement of the accelerometers relative to the motor. The VIEW TREND X button is used to review past vibration data contained in the database. Motor temperature is an example of other data that could be collected and displayed besides vibration.

One way to prolong the life of a motor experiencing significant vibration is to reduce the applied voltage to some lower value. The lower voltage slows the motor rotational velocity down which in turn reduces the vibration level. So programming the Middleware Agent(s) to have a decision point such as Not Permissible level could be set to automatically reduce the applied voltage to the motor which in turn would reduce the motor rotational velocity which correspondingly would reduce the vibration to the next criterion level below. Other capabilities including manual overrides can be relatively easily added through RSView programming.

Figure 2. *RSView32 Display of Vibration Data and Production Process Control*



Future Work

The BDI model constructed for this project has basically two data input values. The vibration monitoring and control data input was explored as described here. The other data input involving monitoring production levels and introducing production information through the Middleware Agent will be explored next. Further, including input to the BDI software model by management (top block in Figure 1) as well as the BDI model sending information with expert system like decisions to management can enhance collaboration between machine operators through management. The collaboration provides the opportunity of more efficient machine operation, lower costs, longer motor life, etc.

Conclusion

Motor vibration monitoring is crucial in any industrial setting. When a motor stops running, a significant amount money is potentially being lost. A motor vibration monitoring system based upon BDI modeling and readily available hardware and software found in production, manufacturing, and related processes is demonstrated in this project. Implementing a monitoring system as described here with proper decision making can payback time and money to the operation of a process. The project will be continued to add the production and management aspect which should enhance the production process with increased efficiency of operation by reducing down time as a result of motor vibration and reduced costs by the real time monitoring and control to reduce vibration.

References

Campos, Jamie and Prakash, Om (July 5-7, 2005). Agent Architecture for Efficient Decision Making in a Plant Practising Vibration Monitoring, IBIMA 2005 Conference, Lisbon, Portugal.

Campos, Janie and Prakash, Om. (May 17-19, 2006). Information and Communication Technologies in Condition Monitoring and Maintenance, INCOM 2006: 12th IFAC/IFIP/IFORS/IEEE/IMS Symposium, Saint-Etienne, France.

Jo, Chang-Hyan, Chen, Guobin, and Choi, James. (March 14-17, 2004). A New Approach to the BDI Agent-Based Modeling, SAC 2004, Nicosia, Cyprus.

Norton, Michael Peter and Karczub, Denis G. (2003). Fundamentals of noise and vibration analysis for engineers, Cambridge University Press, UK, page 539.

Pintelon, Liliane and Puyvelde, Frank Van. (1997). Maintenance Performance Reporting Systems: Some Experiences, Journal of Quality in Maintenance Engineering, Vol. 3, No. 1, pages 4-15.

Rao, Anand S. and Georgeff, Michael P. (April, 1995). BDI Agents: From Theory to Practice. First International Conference on Multi-Agent Systems, pages 312-219.

Including GPS and GPS Tracking in Automatic Identification/RFID Courses

Dr. Samuel Guccione
Eastern Illinois University, Charleston, IL 61920, 217-581-7259, saguccione@eiu.edu

Introduction

Tracking assets with GPS (global positioning system) technology is an integral part of supply chain tracking but there is little about how to teach it and what equipment could be used to give students real world or near real world experiences. Guccione and Marjanovic (November 17-19, 2008) suggest how this topic can be included in an Automatic Identification or RFID course. They identified that there is little about potential texts and virtually nothing about suggested teaching methods. Further, there is little readily available and clearly identified information about how to teach GPS tracking and what equipment would be reasonable for schools to purchases. In addition, research into this technology at the undergraduate and graduate level could be possible with the appropriate choice of equipment even with a limited budget.

AutoID books do not usually include GPS tracking as a topic even though it is becoming an integral part of the supply chain and automatic identification in general. In addition, commercial GPS tracking equipment is expensive and the tracking system may not be open to general public use. These make it hard to include hands on GPS tracking in AutoID courses.

Teaching GPS tracking is different than other AutoID technology. Being able to create tracking systems and knowing how they are used is another important area for students to know. Since GPS tracking involves a GIS (geographical information system) type display typically involving a map, helping students to be aware of how to use this type of GIS is used is an important topic area.

This paper describes how to include GPS tracking in an Automatic Identification or RFID course. Included will be suggested reading materials, media presentation methods, and other information. A suggested list of equipment for teaching a series of lab activities on the topic areas identified will be given. Ideas about how to use the equipment for undergraduate and potential graduate research will be discussed as well.

Introducing GPS and GPS tracking

It is easy to introduce GPS and GPS tracking to a course due to the ubiquity of the uses of GPS receivers in automobiles, boats, airplanes, and even strapped to cows (George, 2003). Showing students the various uses of GPS devices would be beneficial by having them work with actual GPS receivers. Since receivers are very low cost today, 10 receivers would be adequate for a class of 20 students. Begin with introducing the students to how to operate and use the GPS receiver to having them find a specific GPS location. One neat activity is to have students find a local GPS benchmark. http://www.geocaching.com/mark/ is a good web site to start learning about them. Guccione (Sep, 2005) describes a number of GPS activities that can help students learn various capabilities of GPS receivers.

Introducing GPS tracking can be almost as easy due to Amateur Radio Service experimenters (also called ham operators) who have developed their own world-wide GPS tracking system that tracks vehicles, hurricanes, satellites, and does much more. The system is called Automatic Position Reporting System (APRS) developed by Robert Bruninga (APRS: Automatic Packet Reporting System, July 9, 2009). This is a free access network to transmit GPS data by any licensed ham operator but not to the general public. As long as there is at least one person with a ham license controlling the radio transmitters, it can be used for teaching purposes.

Teaching Topics and Materials

Guccione and Marjanovic (October 17-19, 2008) suggest possible topics, study topics, labs and other materials in teaching GPS tracking as shown Table 1. Labs and activities are representative of possible areas.

Table 1. Outline of GPS Tracking Concepts

GPS Tracking 5 Weeks	Study Topics: Automatic Identification Systems (AIS) Automatic Vehicle Location (AVL) Automatic Position or Packet Reporting System (APRS) Geographical Information System (GIS) Global Positioning System (GPS) Real Time Locating Systems (RTLS) Vehicle Tracking System (VTS) Teaching Resources: Web Sites APRS PowerPoint's	Example Activities and Labs: Explore using a GPS receiver for position location. Create a GPS tracking base station setup using APRS software. Explore using a one-way tracker with GPS attached. Explore using a two-way tracker with GPS attached. Explore using a two-way tracker with messaging system and GPS attached. Explore other types of tracking systems Evaluation(s): Concept and Terminology test

The list of GPS tracking technology in Study Topics provides a basis to search for web sites that can become teaching materials. In addition, Youtube.com has a very large number of GPS and GPS tracking videos, many of which would be useful to use as demonstrations in class. The Internet is also a source of teaching materials in PowerPoint form. Besides labs and activities, a concept and terminology test is used for evaluations of learning. The APRS: Automatic Packet Reporting System (July 9, 2009) web site has several APRS PowerPoint presentations that describe GPS tracking from a practical standpoint.

Equipment needed for lab activities

APRS uses digital technology through packet radio. Location data from a GPS receiver is converted to a packet of bits to a RF (radio frequency) modem which transformed them into a stream of sound pulses. These sound pulses are then sent through the microphone input of a VHF (very high frequency) FM (frequency modulated) high powered wireless radio transceiver (transmitter and receiver). The packet sounds are received by a FM receiver which sends the sound pulses to the RF modem. The modem transforms the packet sounds back into a digital bit stream. The bit stream is processed and displayed on GIS type map based software with database called APRS. APRS can be used to teach GPS tracking since commercial vehicle tracking uses very similar types of software, equipment, and tracking network. The main differences exist in the frequency of operation of the wireless radio transmitters and receivers.

Since high powered wireless radio transmitters are used in APRS, a Federal Communication Commission (FCC) Amateur Radio Service license is required. Study guides are available from the ARRL (American Radio Relay League), the national organization for Amateur Radio (ARRL, July 10, 2009). License testing, consisting of only a written test on radio communication, rules and regulations, are administered periodically by local ham radio groups. The license cost is minimal and would be relatively easy to study for and pass for technology or engineering students and faculty.

Ham radio operators have included the Internet in their APRS operations. They have connected the wireless radio packet signals into special servers called IGates. APRS is now a world-wide GPS tracking system. Ham operators have created a finder program, called APRS FindU that anyone can use. A project for students would be to explore the APRS FindU Online Finder Database (May 28, 2008).

The Internet connection also includes SATGates which connect packet signals originating to and from satellites and the International Space Station (ISS).

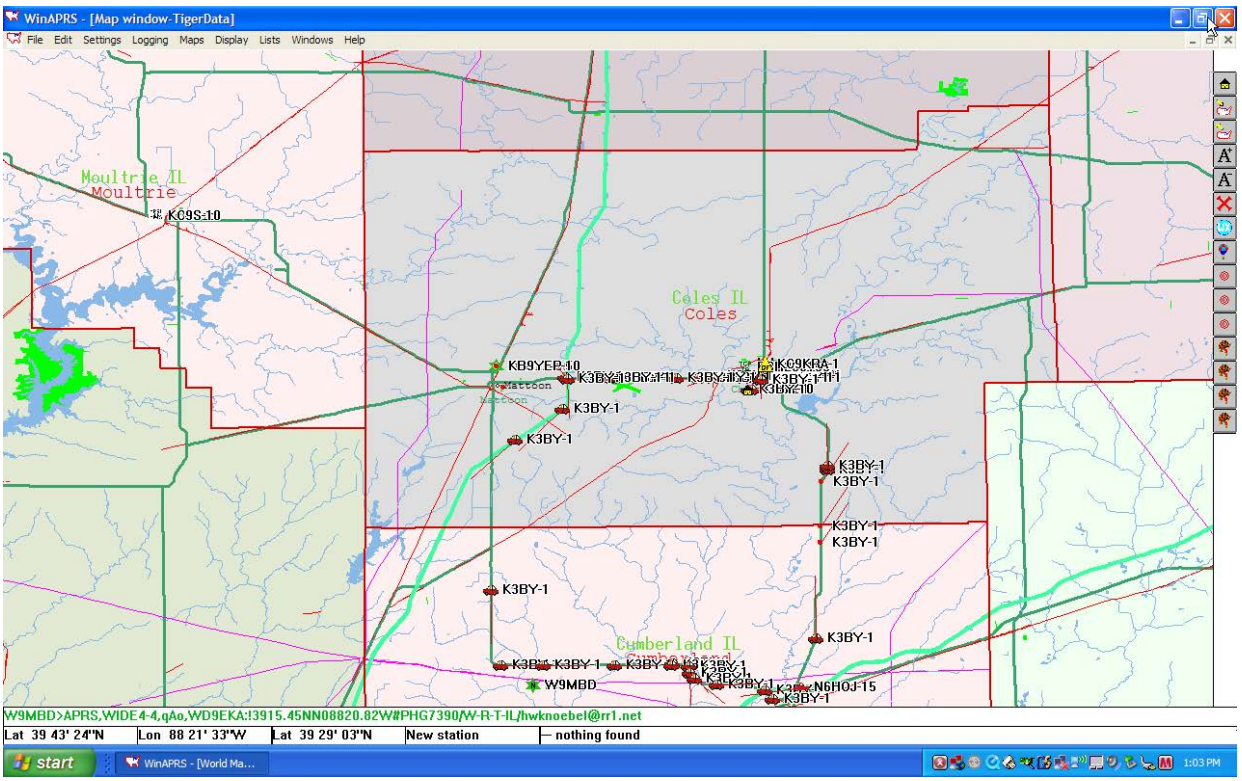
The specific equipment needed to implement an APRS base station setup is a Ham Radio VHF FM wireless mobile transceiver and DC power supply, a VHF antenna, a radio modem called a TNC (terminal node controller), a version of APRS software, and a host computer. A GPS receiver is not needed for the base station. Since it is not moving, the GPS latitude and longitude of the base station location can be manually entered into the APRS software. The vehicle to be tracked requires a GPS tracking installation. This setup can make use of a special ham radio VHF FM APRS ready handheld data radio. An inexpensive GPS receiver with RS232 serial data output capability is needed to be connected to the data radio to create position locations as the vehicle moves. The data radio is a self contained unit with a built in RF modem and APRS like control software.

A standard VHF FM radio can also be used if a small radio modem and GPS receiver is attached. A VHF antenna can be attached to the vehicle then connected to either type of radio to increase the range.

Commercial installations will need a wireless data network to be able to track vehicles beyond a local (10 to 20 miles) area. Cell phone technology as well as certain satellite technology is available for commercial use. Both of these technologies operate on different frequencies but the operational characteristics are the same as using APRS on VHF. In addition, commercial networks are not free access. There is a rental or use fee.

There are a number of APRS software packages available (APRS: Automatic Packet Reporting System, July 9, 2009). Some are free. They are available for both Microsoft Windows and Linux operating systems. Figure 1 below displays the GPS track of Guccione's personal vehicle (K3BY-1) during a test drive loop of about 40 miles.

Figure 1: *Example GPS Track in APRS Software*



APRS software has many other capabilities besides tracking an object and plotting it on a map. For example, messaging from base to vehicle and vice a versa or even vehicle to vehicle is incorporated. Another is a database that holds lists of objects and their characteristics.

Setting up and learning the characteristics of a vehicle tracking system would be a first activity for students. A second one could be to have students learn how to access and use the Internet connection to APRS (APRS Internet Service, May 25, 2008) and the online finder database (APRS FindU Online Finder Database, May 25, 2008). Another activity could be to explore setting up a complete tracking system for a product that integrates all aspects of APRS GPS tracking with that of RFID tracking.

A reminder that an Amateur Radio Service FCC license would be required to operate the ham radio equipment identified here. The person(s) controlling the radio(s) must have a valid license which is relatively easy to obtain. The license process is to pass a basic test on radio technology, rules and regulations. Having students and teaching faculty study for the license would be an obvious activity as part of teaching GPS tracking.

Research uses of equipment

One major research area that would be of interest today is the integration of APRS information into an enterprise resource planning type of system. This would require research to determine how this could be implemented. Creating some type of interface software including a web connection would be in keeping with the types of needs that are becoming important in today's enterprise operation.

Summary

The ideas identified in this paper provide practical information about how to introduce GPS tracking into an Automatic Identification or RFID course with equipment and study materials, possible lab activities, and research possibilities.

References

ARRL (American Radio Relay League). Retrieved on July 10, 2009 from http://www.arrl.com.

APRS: Automatic Packet Reporting System. Retrieved on July 9, 2009 from http://www.aprs.org.

APRS FindU Online Finder Database. Retrieved on May 25, 2008 from http://www.findu.com/.

APRS Internet Service. Retrieved on May 25, 2008 from http://www.aprs-is.net/.

George, Mel. (2003). Cows in Space, Sierra Foothill Research & Extension Center, University of California, Davis, Retrieved on July 10, 2009 from http://repositories.cdlib.org/cgi/viewcontent.cfi?article=1001&context=anrrec/sfrec

Guccione, Sam. (Sep, 2005). Where in the World? GPS Project for the Technology Class, Tech Directions, v65, no. 2, pp 16-19.

Guccione, Sam and Marjanovic, Uros. (October 17-19, 2008). Automatic Identification/RFID Course and Equipment for Teaching and Research, Proceedings of the 2008 IJAC-IJME International Conference, ISBN 978-1-60643-379-9, Nashville, TN.

Electricity, Electronics, & Computer Technology - *Energy Issues*

Energy Harvesting and Storage Techniques from Ambient Energy Sources

Dr. Faruk Yildiz
Sam Houston State University, Industrial Technology, Huntsville, TX 77341, 936-294-3774, fxy001@shsu.edu

Ms. Mariana Villasana Freites
Sam Houston State University, Industrial Technology, Huntsville, TX 77341, 512- 784-3219, mxf012@shsu.edu

Abstract
The students from different disciplines such as construction technology, design development, industrial technology/management and electronics examined the effectiveness of ambient energy as a source of power after extensive literature review. Energy harvesting, conversion, and storage systems were also extensively investigated from most recent research works and summarized. This study gathered students from a variety of technology disciplines by merging their knowledge in this broad literature review.

Introduction
Ambient energy harvesting is also known as energy scavenging or power harvesting and is the process where energy is obtained from the environment. There are several techniques and sources available for energy scavenging: solar and wind powers, ocean waves, piezoelectricity, thermoelectricity, and physical motions. For example, some systems convert random motions including ocean waves into useful electrical energy to be used by oceanographic monitoring wireless sensor nodes for autonomous surveillance. Ambient energy sources are classified as energy reservoirs, power distribution methods, or power scavenging methods, which may enable portable or wireless systems to be completely battery independent and self sustaining. Additionally, chemical and biological sources and radiation can be also considered as ambient energy sources. The most common ambient energy sources listed below are part of this research and they were investigated by an extended literature review.

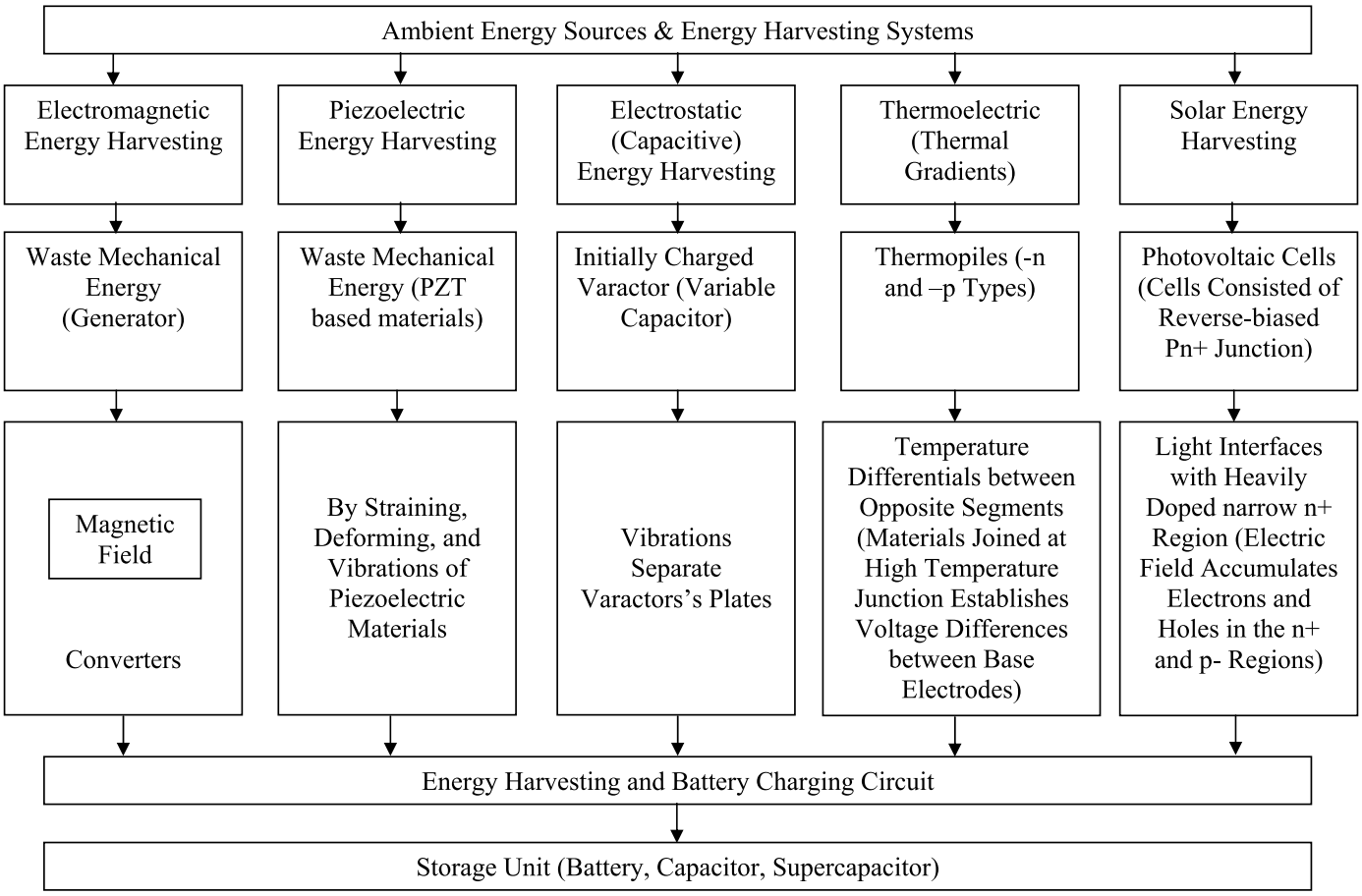
- Human Body: Heat variations on the body, walking, and running.
- Natural Energy: Wind, water flow, ocean waves, and solar energy.
- Mechanical Energy: Vibrations, mechanical stress, strain and, waste rotations.
- Thermal Energy: Waste heat energy variations from furnaces, heaters, and friction sources.
- Light Energy: Indoor room light and outdoor sunlight energy.
- Electromagnetic Energy: Inductors, coils, and transformers.

Conventional electronics devices were designed to be powered with batteries as required, but did not allow scavenging of ambient energy as a power source. In contrast, development in portable/wireless technology and other electronic components are constantly reducing the power and energy needed by many applications. If energy requirements of electronic components decline reasonably, then ambient energy scavenging and conversion could become a viable source of power for many applications. Recently, researchers have performed several studies in low power alternative energy sources that could provide small amounts of electricity to low-power electronic devices. These studies were focused to investigate and obtain power from different energy sources, such as vibration, light, sound, airflow, heat, waste mechanical energy and temperature variations. In order to harvest and convert ambient energy into usable electrical energy an energy harvesting system should be developed according to nature of the ambient energy source. Figure 1 shows a block diagram of ambient energy harvesting systems. The literature review summarizes research efforts performed by a variety of research attempts both academically and industrially. The research efforts are employed by the aforementioned sources to explore the general practicability and achievable performance of devices that extract power from ambient energy sources. A broad review of the literature of potential energy scavenging methods has been carried out by the authors.

Mechanical Energy Harvesting

An example of electric power generation using rotational movement is the self powered, battery-less, cordless wheel computer mouse cited by Mikami, Tetsuro, Masahiko, Hiroko (2005). The system is called Soc and is designed as an ultra low power wireless interface for short range data communication as a wireless battery-less mouse. The system was uniquely designed to capture rotational movements by the help of the mouse ball to generate and harvest electric power. The electric generator is powered through exploiting rolling energy by dragging the mouse. The system was uniquely designed to capture rotational movements by the help of the mouse ball to generate and harvest electric power.

Figure 1. *Ambient Energy Systems*



The electric generator is powered through exploiting rolling energy by dragging the mouse. The energy harvesting system was intended to power the electronic system of a mouse device such as the ultra low power RF transmitter and microcontroller. The experimental results of the study showed that the mouse only needed 2.2mW energy to operate. The total energy captured using an energy harvesting system was bigger than 3mW, which was enough for the wireless mouse operations in a one meter transmit range.

Indoor operating environments may have reliable and constant mechanical vibration sources for ambient energy scavenging. For example, indoor machinery sensors may have plentiful mechanical vibration energy which can be monitored and used reliably. Vibration energy harvesting devices can be either electromechanical or piezoelectric. Electromechanical harvesting devices, however, are more commonly researched and used. Roundy, Wright, and Rabaey (2003) reported that energy withdrawal from vibrations could be based on the movement of a spring mounted mass relative to its support frame. Mechanical acceleration is produced by vibrations that in turn cause

the mass component to move and oscillate. This relative dislocation causes opposing frictional and damping forces to be applied against the mass, thereby reducing and eventually extinguishing the oscillations. The damping force energy can be converted into electrical energy via an electric field (electrostatic), magnetic field (electromagnetic), or strain on a piezoelectric material.

Thermal (Thermoelectric) Energy

Thermal gradients in the environment are directly converted to electrical energy through the Seebeck (thermoelectric) effect as reported by Disalvo (1999); and 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. They allow heat flow to carry the dominant charge carriers of each material to the low temperature end by 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. Large thermal gradients are essential to produce practical voltage and power levels (Roundy, Wright, & Rabaey, 2004). However, temperature differences greater than 10°C are rare in a micro-system, consequently such systems generate 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 and Stark (1997) have demonstrated a thermoelectric micro-device which is capable of converting 15 $\mu W/cm^3$ from 10 °C temperature gradients. While this is promising and, with the improvement of thermoelectric research, could eventually result in more than 15 $\mu W/cm^3$, situations in which there is a static 10 °C temperature difference within 1 cm^3 are, however, very rare and assumes no losses in the conversion of power to electricity.

Light Energy (Solar Energy)

A photovoltaic cell has the capability of converting light energy into electrical energy (Kasap, 2001; Raffaelle et al. 2000). Each cell consists of a reverse biased pn+ junction, in which the light crosses with the heavily conservative and narrow n+ region. Photons where the light energy exists 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, 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 the light intensity and independent of the cell voltage. Several research efforts, which have been conducted so far, demonstrate that photovoltaic cells can produce sufficient power to maintain a micro-system. Moreover, a three dimensional diode structure constructed on absorbent silicon substrate helps increase efficiency by significantly increasing the exposed internal surface area of the device (Sun et al. 2005). Overall, photovoltaic energy conversion is a well-known integrated circuit 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.

Human Power

Researchers have been working on many projects to generate electricity from human power such as exploiting, cranking, shaking, squeezing, spinning, pushing, pumping, and pulling (Starner & Paradiso, 2004). For example, some types of flashlights were powered with wind-up generators in the early 20th century (US patent 1,184,056, 1916). Later versions of these devices, such as wind-up cell phone chargers and radios, became available in the market. For instance, commercially available Freeplay's (a commercial company) wind up radios make 60 turns in one minute cranking which allows storing of 500 Joules of energy in a spring. The spring system drives a magnetic generator and efficiently produces enough power for about an hour of play.

Another human powered device was introduced early in the 20th century by Robert Adler, a battery-free wireless remote control for Zenith televisions. The design was called "Space Commander" and was introduced in 1956. The

system consisted of a set of buttons that hit aluminum material to produce ultrasound. The produced ultrasound energy was decoded at the television to turn it on, change channels and mute the volume (Adler, Desmares, & Spracklen, 1982). Adler's "Space Commander" design was then replaced by the active infrared remote controls and is being used in many current remote control systems.

Normally, an average human body burns approximately 10.5 MJ every day, which is equal to about 121W of power dissipation. Power dissipation occurs in the average human body either actively or passively in daily life motions that make the human body an attractive ambient energy source. Researchers have proposed and conducted several studies to capture power from the human body. For example Starner has researched and investigated some of these energy harvesting techniques to power wearable electronics (Starner, 1996). MIT researchers took these studies and suggested that the most reliable and exploitable energy source occurs at the foot during heel strikes when running or walking (Shenck & Paradiso, 2001). This research initiated the development of piezoelectric shoe inserts capable of producing an average of 330 $\mu W/cm^2$ while an average person is walking. The first application of shoe inserts was to power a low power wireless transceiver mounted to the shoe soles. The ongoing research efforts mostly focused on how to get power from the shoe, where the power is generated, to the point of interest or application. Such sources of power are considered as passive power sources in that the person is not required to put extra effort to generate power because power generation occurs while the person is doing regular daily activities such as walking or running. Another group of power generators can be classified as active human powered energy scavengers. These types of generators require the human to perform an action that is not part of the normal human performance. For instance, Freeplay has self powered products that are powered by a constant force spring that the user must wind up to operate the device (FreePlay Energy, 2009). These types of products are very useful because of their battery-free systems.

Energy Storage Technologies

Conventional electrochemical batteries power most of the portable and wireless electronic devices that are operated by electric power. In the past few years, electrochemical batteries and energy storage devices have improved significantly. However, this progress has not been able to keep up with the development of microprocessors, memory storage, and sensors of electronic applications. Battery weight, lifespan and reliability often limit the abilities and the range of such applications of battery powered devices. As technology scales down the physical size of electronic devices, the proportion between energy need of such devices and the battery technology is expected to further increase. Also the necessity for proper maintenance of batteries, with the need to either change or recharge them is very important. This is a serious constraint to computing methods 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 constraints do not minimize the benefits of batteries as an energy source. Batteries can be categorized by their energy density or with respect to volume and weight, respectively called volumetric and gravimetric energy density (Ganesan, 2006). Table 1 shows some typical values of energy densities and self discharge values for commercially available batteries. It is significant to note that these values of energy density are the most common options available today, but then differ according to the applications or systems.

Table 1. *General characteristics of batteries. (Ganesan, 2006)*

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

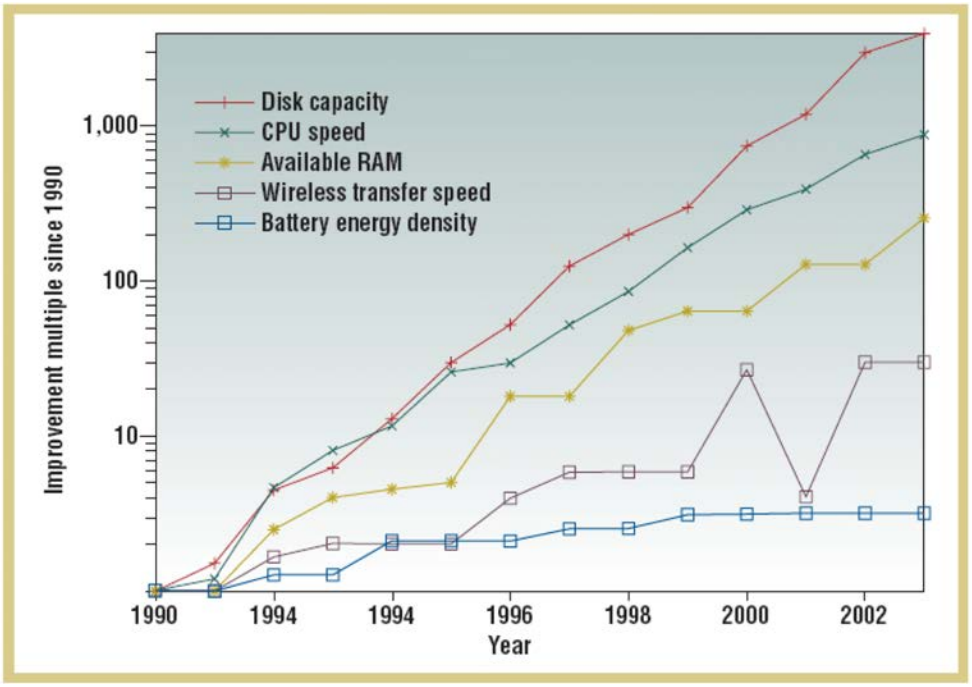
Secondary rechargeable batteries are in general a better choice for ubiquitous or wearable systems because they can be recharged in several ways and, in many cases without extracting the battery from the system (Ganesan, 2006). One possibility to recharge such batteries is to use energy harvested from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

According to recent studies, reliable sources to store energy in low power energy harvesting systems are batteries and ultracapacitors (Dinesh & Abhiman, 2005). Li-ion, NICD and NIMH are good examples of rechargeable battery types. Maxwell, Samsung, and NEC corporations are working on increasing the efficiency of ultracapacitors by decreasing their size. As an example Maxwell developed a small size ultracapacitor with 5V, 2F, 2.7mAhr specifications (Maxwell Technologies PC-5 Ultracapacitors, 2009).

Battery technology could grow to keep pace with other technologies, as components of the electronic devices became smaller and required less power allowing growth in today's wireless and mobile applications explosion. In Figure 2 the capacity increase of some crucial devices for computing technologies is shown since 1990s. As the Figure indicates, battery technology has the slowest growing trend in mobile technology (Paradiso & Starner, 2005). To overcome this slow trend in battery technology it is necessary to move to another energy source which is ambient energy harvesting and storage.

Figure 2. Relative improvements in laptop computing technology from 1990–2003.

Ultracapacitors (Supercapacitors)



Latest progress in capacitor technology has led to the development of the ultra (super) capacitors, with a capacitance value of the order of 1kF. Such remarkably large capacitors, however, present an energy density around 3 Wh/kg, which is still very much away from the average battery values for low power applications. The major advantages of ultracapacitors are the supplied peak power, and the number of cycles they produce (Supercapacitors, 2009). These characteristics make them more especially suitable for automotive applications than to low power electronic devices, where batteries are still the alternative application for energy storage. The capacitors accumulate energy as an 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 an 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 much higher 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 as noted by Chapuis (2006).

Energy Harvesting & Controller Circuits

There has been a variety of energy harvesting circuit designs and developments in which such devices were different from each other according to the ambient energy source characteristics. It is not viable to use the same circuitry to capture energy from solar power, mechanical vibrations, waste mechanical energy, or human powered systems for energy harvesting systems. One of the examples of developing an energy harvesting circuit is a converter and controller design for micro power energy harvesting by Shengwen et al. (2005). The design of a pulsed-resonant AC-DC converter and an integrated circuits controller was also developed. This system has been designed, fabricated, and tested for harvesting energy from low voltage sources. The demonstration of energy harvesting for battery charging using power sources between 2μW and a few hundred mWs was also conducted. At the end of this study the efficiency of the system was reported to range between 60% to 70%.

Several other circuit techniques were described in the literature to achieve the needs of circuit design used for ambient energy harvesting systems. It was also proposed that eliminating AC/DC conversion increases the efficiency of vibration energy harvesting. For this purpose, self-timed circuits, power-on reset circuitry, and memory for energy harvesting power supplies were investigated by Amirtharajah et al. (2006). The study reported that the proposed circuit techniques can be applied to other ambient energy sources for energy harvesting. At the end of the study, a chip to test energy harvesting circuits was designed for a 0.18μm logic process. It is claimed by the authors that the developed circuits can be used with solar or thermal energy harvesting. The designed circuits can also be applied to interface with inductively powered devices such as biomedical implants, embedded sensors, and RFID tags for barcode systems as reported by Briole et al. (2004).

Battery Charging Circuits

The energy scavenging system needs a charger capable of capturing and transferring intermittent low energy bursts to a rechargeable battery. Maximum battery life, capacity, and energy content of a rechargeable battery are normally achieved by adding a constant current/constant voltage charging system. Primarily, a low preconditioning charging current is applied to the battery to make sure the cell voltage required at least a minimum voltage to start charging. Then, the constant-current stage follows with the application of a full charging current, until the battery capacity nears the end-of-charge voltage. This procedure differs from one battery brand to another. Afterwards, the constant-current phase follows the application of a full charging current, until the battery voltage nears the end-of-charge voltages typically between specified battery range voltages. In such devices, the cell voltage increases quickly during the constant current phase, before allowing the system to reach full capacity (Portable Power Design Seminar, 2004). Therefore, quick charging of the cells by simply applying a constant charge current achieves just between 40% and 70% of its maximum potential capacity. Both charging steps are therefore necessary to charge the battery completely. Lopez, Gonzalez, Viera, and Blanco (2004) found that the charging circuit relies on the nature of input energy that is to be stored in the battery. In this study, it was found that the charging current applied to the battery can be either permanent or alternating. Permanent charging methods may utilize linear and switching regulators. A linear regulator linearly manages the conductance of a series pass device using a feedback loop to regulate the output against variations in load current and supply voltage, constantly supplying current. Linear regulators are similar to resistive voltage dividers in that they can only source voltages below the input supply.

Conclusion

The literature review lead to the conclusion that several and options that can provide new resources to portable or wireless electronics devices within the energy harvesting systems already exist. Possibilities of overall dependence on ambient energy resources may remove some constraints required by the limited reliability of standard batteries. Ambient energy harvesting can also provide extended life span and support to conventional power systems. Also the energy harvesting, conversion and storage circuit systems investigated including variety of low power energy harvesting, conversion, and storage technologies research attempts. Ambient energy sources were classified as energy reservoirs, which may allow portable or wireless electronic systems to be completely battery free or self sustaining.

References

Adler, R., Desmares, P., & Spracklen, J. (1982). Ultrasonic Remote Control for Home Receivers, IEEE Trans. *Consumer Electronics, 28* (1), 123–128.

Amirtharajah, R., Wenck, J., Collier, J., Siebert, J., & Zhou, B. (2006). *Circuits for Energy Harvesting Sensor Processing.* DAC The 43rd Design Automation Conference, San Francisco California.

Briole, S., Pacha, C., Goser, K., Kaiser, A., Thewes, R., Weber, W., & Brederlow, R. (2004) AC-only RF ID tags for barcode replacement, in ISSCC 2004 *Digest of Technical Papers*, pp. 438-9.

Chapuis, M. (2006). *Energy Harvesting for Wireless Sensor Networks. WSN,* Advanced Technology, Phoenix International.

Dinesh, B., & Abhiman, H. (2005). *Energy Harvesting Methodologies for Wireless Sensor Nodes*. Erik Johnson School of Engineering, The University of Texas.

DiSalvo, F. J. (1999). Thermoelectric cooling and power generation. *Science, 285*, 703-706.

FreePlay energy, (2009). Retrieved July 1, 2009, from http://www.freeplayenergy.com/products

Kasap, S.O. (2001). *Optoelectronics and Photonics. Principles and Practices*, New Jersey: Prentice-Hall.

Ganesan, D. (2006). *Energy Harvesting Techniques – I. Lecture notes*, Computer Science Department, University of Massachusetts Amherst. Retrieved June 16, 2009, from http://www.cs.umass.edu/~dganesan/courses/fall06

Halber, D. (2006). *Researchers fired up over new battery. News Office Correspondent*, Massachusetts Institute of Technology. Retrieved July 5, 2009, from http://web.mit.edu/newsoffice/2006/batteries-0208.html

Lopez, J., M., Gonzalez, J., Viera, C., & Blanco, C. (2004). Fast-charge in lithium-ion batteries for portable applications, 26th Annual International Telecommunications Energy Conference, 19-24, 2004.

Maxwell Technologies PC-5 Ultracapacitors. (2009). Retrieved June 28, 2009, from http://www.maxwell.com/ultracapacitors/products/small-cell/pc-5.asp

Mikami, S., Tetsuro, M., Masahiko, Y., & Hiroko, O. (2005). *A wireless-Interface SoC Powered by Energy Harvesting for Short-range Data Communication*. IEEE 0-7803-9162-4/05 2005.

Paradiso, Joseph A., & Starner, T. (2005). *Energy Scavenging for Mobile and Wireless Electronics*. Published by the IEEE CS and IEEE ComSoc 1536-1268/05 © IEEE.

Portable Power Design Seminar. (2004). Texas Instruments. Retrieved July 5, 2009, from http://focus.ti.com/lit/ml/slyp085/slyp085.pdf

Raffaelle, R.P., Underwood, J., Scheiman, D., Cowen, J., Jenkins, P., Hepp, A. F., Harris J., & Wilt, D. M. (2000). *Integrated solar power systems*. 28th IEEE Photovoltaic Specialists Conference, 1370-1373.

Roundy, S., Wright, P. K., & Rabaey, J. (2003). A study of low level vibrations as a power source for wireless sensor nodes. *Computer Communications, 26*, 1131-1144.

Rowe, D. M. (1999). Thermoelectrics, an environmentally-friendly source of electrical power. *Renewable Energy, 16*,1251-1256.

Roundy, S., Wright, P. K., & Rabaey J. (2004). Energy Scavenging For Wireless Sensor Networks With Special Focus On Vibrations. New York: Kluwer Academic Publishers.

Shenck, N. S., Paradiso, J. A. (2001). Energy Scavenging with Shoe-Mounted Piezoelectrics, IEEE Micro, 21, 30-41.

Shengwen, Xu., Khai, D. T. Ngo, Toshikazu, N., Gyo-Bum, C., & AttmaSharma. (2005). *Converter and Controller for Micro-Power Energy Harvesting*. IEEE 0-7803-8975-1/05.

Starner, T., & Paradiso, J. A. (2004). *Human-Generated Power for Mobile Electronics*. Low-Power Electronics Design, C. Piguet, ed., CRC Press, chapter 45, 1–35.

Starner, T. (1996). Human-powered wearable computing. *IBM Systems Journal, 35* (3), 618-629.

Self Contained Generating and Lighting Unit (1916), US patent 1,184,056, Patent and Trademark Office, 1916.

Stordeur, M., & Stark, I. (1997). *Low Power Thermoelectric Generator – self-sufficient energy supply for micro systems*. 16th International Conference on Thermoelectrics, 575 – 577.

Sun, W., Kherani, N. P., Hirschman, K. D., Gadeken, L. L., & Fauchet, P.M. (2005). A three-dimensional porous silicon p-n diode for betavoltaics and photovoltaics. *Advanced Materials, 17*, 1230-1233.

Supercapacitors. (2009). Retrieved July 3, 2009, from http://www.nec-tokin.com/english/product

Power Management of a PV Solar - Savonius Wind Hybrid Powered Illumination System Using the Arduino Microcontroller

Dr. Mike Asoodeh
Southeastern Louisiana University, 500 Western Ave., Hammond, LA 70402, 985-549-2314, asoodeh@selu.edu

Mr. David Wekesa Khasenye
100 Janes Lane, Hammond, La 70401, 985-549-2314, dwekesa@gmail.com

Abstract
Conservation is especially crucial for any stand alone, Solar PV-Wind turbine Hybrid System. Conservation may be achieved by switching the system off when not in use, using lower energy components, using better batteries and reducing energy consumption when not in full use or making the system more sensitive to light intensity during the switching on/off phase of operation, or adding an auxiliary power unit so that power can still be generated when there is no sunlight. This research project presents a proof of concept idea of using Solar PV-Wind turbine Hybrid powered systems for small scale applications. The aim is to show that our system could be used as an advertising light box, and achieve the same goals as a standard mainline system. It also aims to show how important using simple power management techniques to conserve energy is for a renewable system by the effect it can have on system sizing and consequent viability. The paper shows that, indeed, savings can be made from use of this system in remote areas as opposed to areas where cheap, abundant mainline power is available.

Introduction
The main aim of this research work is to develop a low cost, Solar PV-Wind turbine Hybrid, illumination solution that can be fashioned into an advertising light box that looks at the topic of energy conservation with emphasis being placed on how and when the system turns on and off and how the lighting system is implemented. The system will then be compared with a similar main line powered advertising light box. The system is to be implemented using solar powered Light emitting diode (LEDs) with aim of improving battery life and system longevity.

It is expected that simulations of the proposed control algorithm will outperform the conventional control systems in terms of reduction of power wastage in the turn on and turn off stages of the system. It is also expected that the circuit and algorithm will eventually be integrated with a battery charging system and be successfully implemented around a low-cost microcontroller using the solar photovoltaic panel as the external sensor unit. The overall system efficiency is expected to have increased power conservation. The need of conservation is apparent due the limiting factor of the how much power can be generated and stored by a solar powered system to meet the set out needs. As shown by Simoes and Franceschetti (2000) in their implementation of a RISC-microcontroller based Photovoltaic System for Illumination system.

At present most of the systems focus on system efficiency, but leave gaps in the area of conservation. Reduction of electrical energy loss can be achieved through several means, energy efficiency i.e. using systems that do the same thing with less energy use and energy conservation i.e. reducing unnecessary energy usage. The aspect of conservation is especially crucial for the stand alone, battery powered solar system (Simoes, 2000). Conservation can be achieved by switching the system off when not in use or at least reduce its energy consumption when not in full use.

At the core will be the Arduino Microcontroller and its related open source language. The Microcontroller will function as the power management system of the system (Simoes and Frsnceschetti, 2000; Arduino, 2008)

As stated earlier, the test bed will be an advertising light box. If it can be proven to be viable solution, the system will allow for future work in real world cost benefit analysis of a practical implementation of the solution. In the next sections, I review the research and formulate the research solution.

Background

The development of completely stand alone solar powered illumination systems is as recent as the development of larger lower cost solar panels in the 1990s. These systems have been few and far between, due to the efficiency of the solar panels, batteries and lighting systems. The two main restrictions for using solar energy are the high initial installation costs and the very low photovoltaic cell conversion efficiency ranges of 12% up to a maximum of 29% for very expensive units. LEDs, which will be used in this research, reduce this indirect form of energy loses.

Another important component is the battery system. Until recently, Lead Acid Batteries have been the standard for practical application, but new battery technology of higher energy densities, can be shown to have a lower energy per unit cost than the cheaper lead acid batteries depending on battery usage. The final challenge has been to bring all this separate parts into one seamless system. The simplest has been to use microcontroller to implement the control systems. This is mainly because of the small size and low cost of microcontrollers.

The Control system for this project will be the Arduino microcontroller. The Arduino community describes the Arduino on the user website (Frequently Asked Questions, 2008) as follows:

> "An Arduino board consists of an Atmel AVR microcontroller (ATmega168 in newer versions, ATmega8 in older versions) and complementary components to facilitate programming and incorporation into other circuits. Each board includes at least a 5-volt linear regulator and a 16MHz crystal oscillator (or ceramic resonator in some variants). The microcontroller is pre-programmed with a boot loader so that an external programmer is not necessary"

Designing the System

The goal is to develop and compare a practical application of a solar PV-Wind turbine Hybrid powered illumination system as similar as possible to a mainline powered illumination system. The selection of the advertising illuminations system as a platform was to test the hypothesis of potential benefits. Furthermore, a systems approach to the problem ensures that apart from the energy system, illumination technology and the method by which the system switches on/off, all other variables will remain the same.

Using the methodology described in the Kenya Renewable energy association Solar PV Sale Manual, the power rating of each component is multiplied by the number of the same components and finally multiplied by the number of hours the component will be in use to come up with the components daily energy requirement (DRE). The total daily energy requirement of the whole system is then obtained by summing up the individual DREs. The Number of hours that the LED tube is on is limited to 8. This is because it will be switching on/off ever so often during the night (in sleep mode. This is where most of the energy conservation will take place (Kenya Renewable Energy Association, 2007).

We then size for our battery system. A few things need to be considered. The first of which is the Depth of Discharge (DoD) of the battery and the amount of extra energy storage we need in case our system does not produce our minimum daily energy requirement. This would be in the case of low wind speeds and cloudy days. To get the figure we need, we allowed for 2 days of Extra Storage days and a battery with a Depth of Discharge of 80%.

Finally we obtain the rating for our charge controller, which will be determined by the value of the system daily energy requirement (AH). From the table the value is 4.45Ah, thus we can the use of a charge controller with 5 A

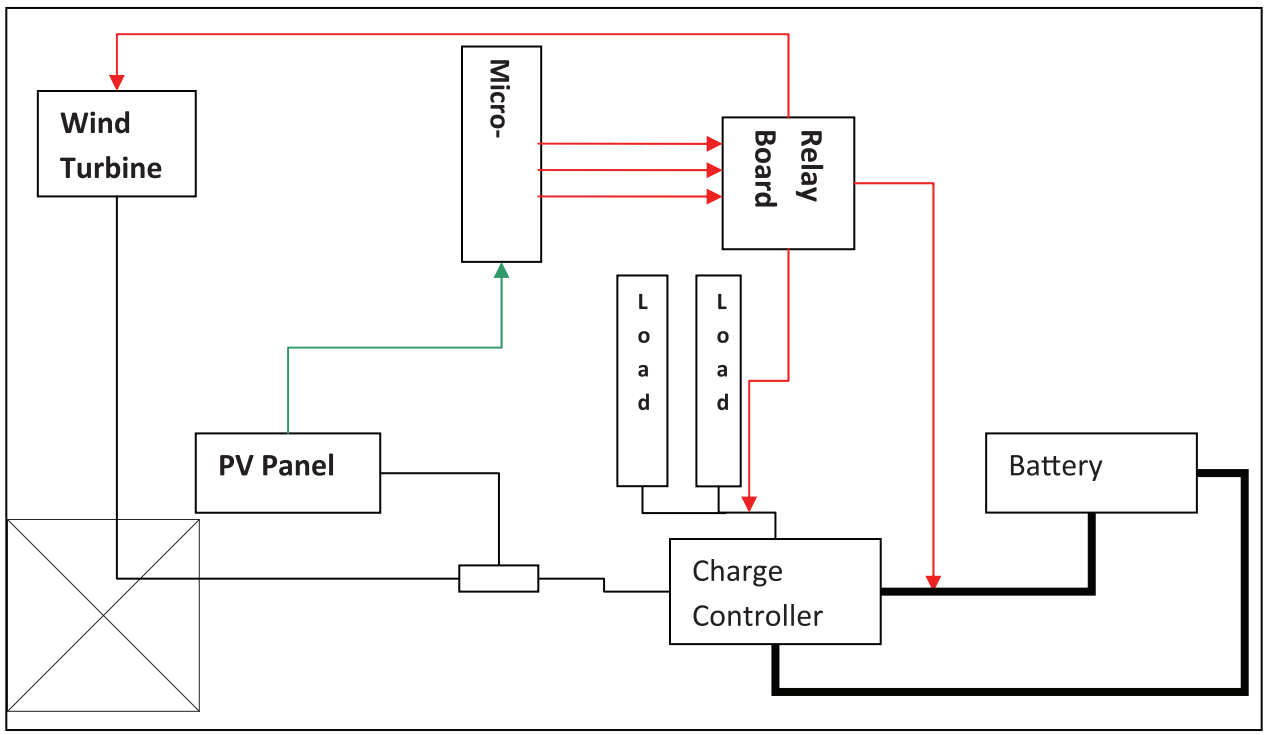
rating would be adequate. From this initial analysis, we can now determine the size of our system and how much power the solar panel needs to generate. For this project we selected a solar panel with a 5W peak power and a maximum current of 0.29A. Assuming that we have at least 5 peak hours a day, we can safely assume that the solar panel will be able to charge the system to meet our demands. However if that is not the case, the wind turbine will be charging almost of the times that there is wind, day or night, so it should be able to adequately cover any energy deficit due to lack of sun power. From our initial analysis, it can be deduced that the energy produced need not be that much. Hence the rational for selecting the Savonius wind turbine.

Furthermore, our initial analysis shows that a 5 Watt solar panel would do the job adequately. Thus a solar panel of 5 watts was selected. It would be expected the electrical properties of the selected panel will follow that of the electrical characteristics of the PV module.

There are several configurations for the Savonius turbine. For this project the 'S' shaped type was selected, due to simplicity in terms of function and form. To build this type of Savonius turbine, a PVC pipe was cut in half and attached to an aluminum rod. The wind captured in the 'scoops' provides the kinetic energy to rotate the turbine. The turbine could be made more responsive to wind with a trade off in efficiency by adding additional 'S' shaped vanes below or above, at a 90 degree angle the first one (Grinspan, et al, 2001).

The system was to power 12 volt dc, super bright LED 'fluorescent'-like tube lights, see Figure 1. The LED tube lights replace the lighting of fluorescent tube lights by having a similar shape and approximate lighting angles while using less energy.

Figure 1. *Electrical System Design*



The bold lines in Figure 1 indicate the power to and from the battery. Not shown are the power buses going to the microcontroller and the relay board. The red lines show a switching command, e.g. the relay switches the lights on or off as instructed by the controller, thus limiting the loading time. The green lines indicate a sensing operation. The microcontroller senses the state of the PV panel and determines what option should be taken.

To keep the system simple, a design decision was made to have the system charged by a charge controller as opposed to using the microcontroller Pulse Width Modulation PINs to **charge the system**. The charge controller allowed for higher power ratings (5 watts) and had safety features to ensure that the battery was not over charged or under charged. This way the system stayed healthy. The charge controller, which was SLR-CONTROLLER-005 from LED -tronics was rated at 12V with a max output of 5 Amps, took the incoming charging current from the Solar PV and Wind turbine and trickle charged the battery to a maximum value of 5 Amperes. This was more the sufficient to meet the prototypes energy needs.

The Arduino interfaced with the system by controlling relays. The 3 relays were switched on or off depending on the states of the input and the algorithms loaded on the microcontroller. In this way the low voltage, low power controller could interface with the higher voltage, higher current system.

The system was wired using 16-gauge copper wire. Due to the large number of wires crossing paths, the wires were labeled and connected via terminal strips. Two 12 terminal strips were used. Apart from giving the wiring an orderly appearance, they also allowed for the circuits to be tested via the terminal screw heads. This proved to be very useful.

As stated earlier, the Arduino Microcontroller is an open source collaborative effort controller. For clarity, the Arduino can be classified in two categories; Hard Ware and Software.

For this project, we made use of the Arduino's PIN 5(D2), 6 (D3), 7(D4) to actuate the relays and PINs 26 (A0), 25 (A1) as our input pins. The Arduino pins can accept only 5 volts into each pin. Since we were to have the microcontroller read the voltage of the solar panel, which has a maximum value of 21.5 volts, a simple voltage divider circuit had to be used to allow the reading of the voltage. The output voltage value would be given by the standard resistance transfer equation.

The Arduino website describes the Arduino programming language as being based on C/C++. Because of this, the code structure is pretty similar. In general Arduino programs can be divided in three main parts: structure, values (variables and constants), and functions. Each program is coded in freeware programming environment, also developed as a collaborative effort. The code developed in this environment is known as a 'Sketch'. Once the sketch is completed, it is complied and uploaded on to the microcontroller, which then executes the instructions. For this project the code was expected to do the following: read the voltage of the PV Panel, read the Voltage of the Wind Turbine, and control 3 Relays. We have the option to read in one more input that can accept an input signal from a sensor or other input device.

The Pseudo code that was used to develop the code was as follows: define Data types, define INPUT PINS and OUT PUT PINS, rESET Charge Controller every start up. (Switch on Relay1 for 10 Seconds, always Check for Voltage across generator, if Generator voltage is above threshold; then Actuate relay 2 (to cut of generator power supply to charging chip) else relay 2 stays off, check IF PV voltage has dropped below threshold (0.02 volts), if PV is below threshold; then Actuate Relay 3, Switch lights on and off every 30 minutes for the duration of night else keep Lights off. The pseudo code was then developed into an Arduino sketch and uploaded to the board.

Results and Analysis

The prototype was tested and it functioned as expected. A **final analysis using a** spreadsheet was done to find out how long it would take for the system to pay for itself. In areas where there is not power and the cost of getting the power to that area would be more than $1.00 per KWh over a 25 year period, the system manages to pay for itself at the end of its life time. At higher values of KWh, the system becomes more viable. It should also be noted that since our energy needs are lower due to the implementation of the load timing, the system may have lower maintenance costs due to longer battery life, and due to the reduction in overall loading and general reduction of the system size (Utilizing Light-Emitting Diodes, 2008).

Conclusion

The goal was to extend the power supply capability of the Solar Panel by tapping into another source of renewable energy and to develop a prototype that uses conservation to increase the lifetime of a renewable energy system by reducing its loading needs. From the data obtained, it would be plausible to conclude that such a hybrid system would function well, provided it is in an area of high wind and average sunlight resources. The boost in energy due to the presence of the wind turbine ensures that the system is always fully charged. Of great importance is the initial sizing to ensure that the system designed meets the system's energy needs. Furthermore, the addition of conservation of energy by limiting the loading time is even more significant for a renewable energy system, where the amount of power generated is limited to generating capacity and the size of the power storage, as compared to the always available mainline power. Indeed, the same conservation methods can be applied to a similar mainline system, but the added value of using renewable energy, with its benefits such as a cleaner environment and remote reach would be lost. The conservations method presented adds to the suitability of the renewable energy system by reducing the loading time and thus requiring less energy to be stored or generated. Thus the benefits of the renewable energy can be enjoyed for a longer period and at a reduced cost, at least in areas that are remote from main line power.

The research project presented here is a proof of concept idea of using Solar PV-Wind turbine Hybrid powered systems for small scale applications. For our case the application was to use the system as an advertising light box. For a light box to have maximum advertising effect it needs to be seen, therefore an addition to this project would be to have a motion sensor connector the microcontroller to turn the system on when it is in sleep mode. To be fair, the same could be done to a main line advertising light box, but the added value of this system is that it runs on renewable energy. This makes the system portable to any location where there is no power line. It essentially increase the advertisers reach. How much the reach is increased would be something that needs to be investigated further. However it does not take a stretch of the imagination to figure out that any rural or isolated highway spot with no mainline power which was hitherto a no profit zone can be turned into a spot where advertising can be done and revenues realized both for the advertiser and advertiser service providers. The similar concept can be developed further for lighting needs in places where lighting is not required on a regular basis, e.g. a shelter bus stop, or train stop. The light could come on when someone is present or at regular intervals when no one is present. Even better would be to have several systems, staggered in such a way that when less lighting is needed, some systems shut off, while are others on and alternating at regular intervals.

This research project is a contribution to ways in which renewable energy systems can be modified and adapted to meet needs in areas where it might not be initially considered. It is expected that a number of questions and ideas will come to the readers mind. It is the author's wish that the reader will be inspired by such questions and ideas to pursue further research in adapting renewable energy solutions to both old and new problems.

References

Frequently Asked Questions. Retrieved August 10, 2008, From Arduino. Website: http://arduino.cc/en/Main/FAQ

A. S. Grinspan, P. Suresh Kumar, U. K. Saha, P. Mahanta, D. V. Ratna Rao and G. Veda Bhanu "Design, Development and testing of Savounis wind turbine rotor with twisted blades" Proceedings of 28th National Conference on Fluid Mechanics and Fluid Power (2001), pp. 428-431.2001

Kenya Renewable Energy Association," Solar PV Sale Manual," Energy for Sustainable Development Africa Ltd.2007: Pg 20.

M. G. Simoes and N. N. Franceschetti, "A RISC-microcontroller based Photovoltaic System for Illumination Application," Proc. of IEEEAPEC Conf, Vol. 2, pp. 1151 -1156, New Orleans, LA, USA, 2000.

Utilizing Light-Emitting Diodes in Today's Energy Conscious World [Online Brochure].Retrieved August 20, 2008 from LEDtronics Tech Notes. Website: http://www.ledtronics.com/TechNotes/TechNotes.aspx?id=15

Wind Power Technologies in the United States: A Technical Comparison between Vertical and Horizontal Axis Wind Turbines

Dr. Rigoberto Chinchilla
Eastern Illinois University, Department of Technology, Charleston, IL 61920, (217) 581-8534, rchinchilla@eiu.edu

Dr. Samuel Guccione
Eastern Illinois University, Department of Technology, Charleston, IL 61920, (217) 581-7259, saguccione@eiu.edu

Mr. Joseph Tillman, P.E.
Lake Land College, Department of Technology, Mattoon, IL 61938, (217) 234-5549, jtillman@lakeland.cc.il.us

Introduction

The United States currently leads the world in wind energy generation with 25,710 MW (Clendenin and Seldon, 2009). Wind power continues to develop based upon more efficient designs for both horizontal axis wind turbines (HAWTs) and vertical axis wind turbines (VAWTs). This paper discusses basic design principles of wind turbines. Then it examines current designs of horizontal and vertical axis wind turbines and compares the performance of each technology. It concludes by exploring the direction of future commercial wind turbines and some possible effects wind power may have upon the economy.

Wind Resources

Wind is an abundant energy resource ultimately powered by the Sun. It is estimated that only around 3% of the Sun's thermal energy is transformed into wind energy. Recent studies show that current wind technology operating only in Class 3 wind locations is capable of producing approximately 72 TW of electricity (Stanford Report, 2005). This is forty times the amount of electrical power annually consumed worldwide and this clean power source is just beginning to be tapped on a large scale.

Wind energy is developing into a major alternative energy source. Over 94 GW of wind generators were operational worldwide at the end of 2007 (Vieira da Rosa, 2009). In the United States alone, 25,170 MW of wind energy generation was operational at the end of 2008 (Clendenin and Seldon, 2009). The reasons for growth are straightforward. Wind is an abundant energy resource which is clean and renewable. By its inherent nature, wind power has the potential to reduce the wildlife and human health impact caused by oil and gas drilling and fossil fuel consumption. Improvements in power electronics, materials, and wind turbine designs allow production to continually lower the cost of wind generated electricity making it today economically viable compared with most other fossil fuels.

Wind resources are measured on a seven division scale. Class 7 winds, above 19.7 mph, are considered superb. Class 1 winds, which are less than 10 mph, are considered poor. Today, most turbines are installed in locations where the minimal annual wind speeds are between 14.3 -15.7 mph or Class 3 winds. These Class 3 winds provide an energy density of approximately 300 W/m^2. The consistency and speed of these winds are major factors in locating wind turbine farms.

Lift and Drag

HAWTs and VAWTs transform the kinetic energy of the wind into mechanical and electrical power via the forces of drag and lift upon their rotors or blades. Some turbine models use a combination of these two forces for power

generation though in practice turbines designed around lift generating blades or rotors are far better suited for electrical production. The power coefficient, C_p, is a measure of a turbine's ability to transform power from a wind into usable electric or mechanical power. A higher C_p is preferred to a lower C_p value. This is coefficient is commonly found by the formula $C_p = P/(0.5\rho AV^3)$ where "P" is power generated, "ρ" is the air density, "A" is the area swept by the blades or airfoils, and "V^3" is the wind speed cubed.

Research in fluid mechanics led to the discoveries of theoretical upper limits for mechanical conversion for both lift generated and drag generated wind power. Betz's Limit states that a wind turbine operating upon lift can extract a maximum of 16/27th or 59.3% of the available power from a given breeze. This means that a lifting based airfoil with a C_p of 0.593 is at maximum theoretical efficiency. The equation for drag based turbines is different.

A drag based turbine operates on the difference between the velocity of the incoming air striking the blade and the velocity of the air immediately downwind of the blade (Malcolm, 2003). The power formula for these turbines is $P = 0.5\rho A(V - v)^2 vC_D$ where "ρ" is the air density, "A" is the area swept by the blades or airfoils, "V" is the wind speed, "v" is the speed of the rotor or blade, and "C_D" is the drag coefficient which is often close to 1.0. Maximum power occurs when the ratio of v/V = 1/3 which gives a maximum C_p equaling 4/27th C_D. Therefore, drag type turbines have a theoretical maximum C_p of about 0.15. Clearly, turbine rotors operating on lift are much more efficient than drag based rotors. Lift also allows a rotor to achieve a higher tip speed ratio (TSR).

Tip Speed Ratio

Because of lift, blade or rotor tips are able turn faster than the speed of the wind blowing through the blade assembly. The equation for tip speed ratio is TSR = (speed of blade tip) / (ambient wind speed). This ratio is a very important design element in wind turbine engineering (Copper and Kennedy, 2005). Johnson (1985) notes that tip speed ratios of 1 or greater are preferred for electrical production and many HAWTs have tip speed ratios approaching 10. However, as Gipe (2004) notes, aerodynamic noise is nearly proportional to tip speed and higher blade noise is a major complaint in the development of wind farms. Many large modern turbines operate at TSRs above 5. Turbines operating on drag have TSRs of 1 or less.

HAWT and VAWT Basic Parts

To capture wind energy, designers use two basic types of wind turbines, the horizontal axis wind turbine (HAWT) and the vertical axis wind turbine (VAWT). These two types of wind turbines share some common parts but primarily differ in the axis of their blade rotation. The blades of a HAWT spin on an axis which is parallel with the ground while the airfoils of a VAWT spin perpendicular with the ground.

The blades of an HAWT are attached to a hub and nacelle situated at the top of the tower. The hub is a streamlined cap into which the blades are fitted. The nacelle is usually rectangular shaped and houses the electrical alternator, gearbox and turning (yawing), and braking mechanisms. The yawing mechanism is needed to keep the HAWT turbine facing the wind as well as turning it away from any dangerous high winds. VAWTs are more varied in shape and arrangement.

The airfoils or scoops of a VAWT are attached to a central tower or shaft around which they revolve. VAWTs usually lack a tower mounted nacelle as the gearbox and electrical generator/alternator are located near the ground. Because of their rotation, VAWTs also lack a yawing mechanism though they sport a braking mechanism to protect the turbines during very high winds. The HAWT and the VAWT each have unique strengths and operating characteristics. A closer look at each type will explain the domination of the modern wind market by HAWTs and will show the potential of new VAWT designs.

Figure 1. *US Wind Speed and Annual Average Wind Power Map (Courtesy of the National Renewable Energy Lab)*

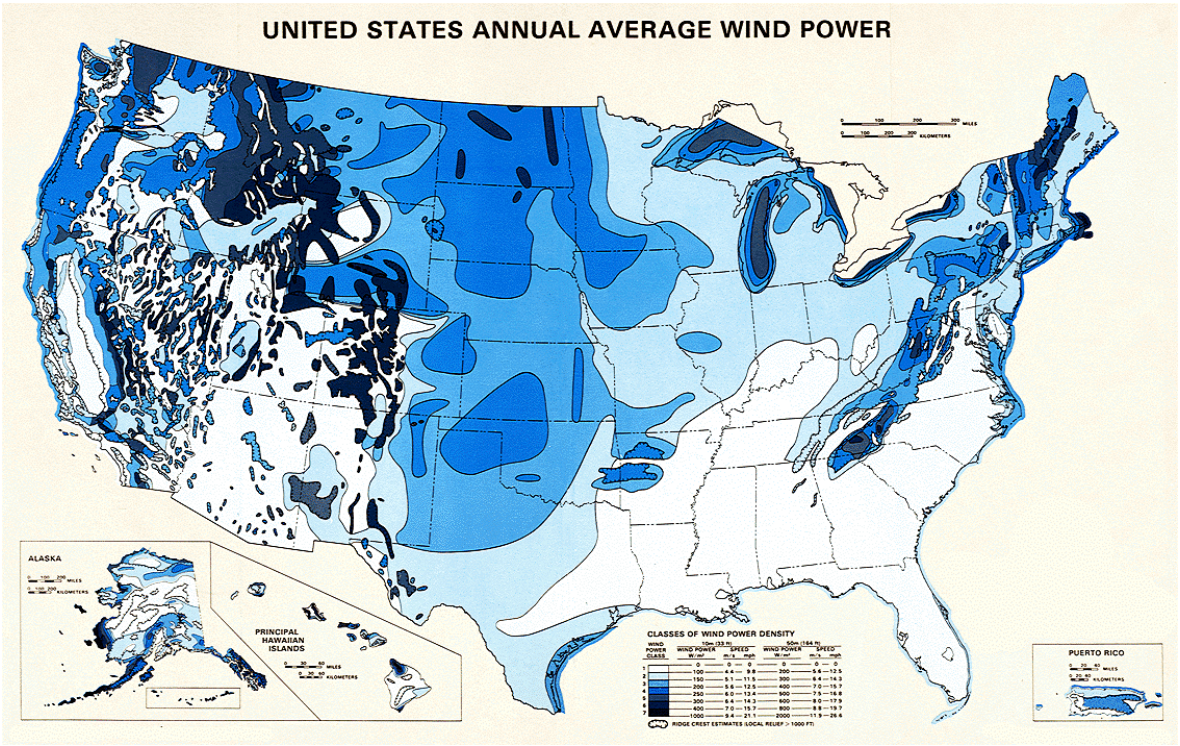
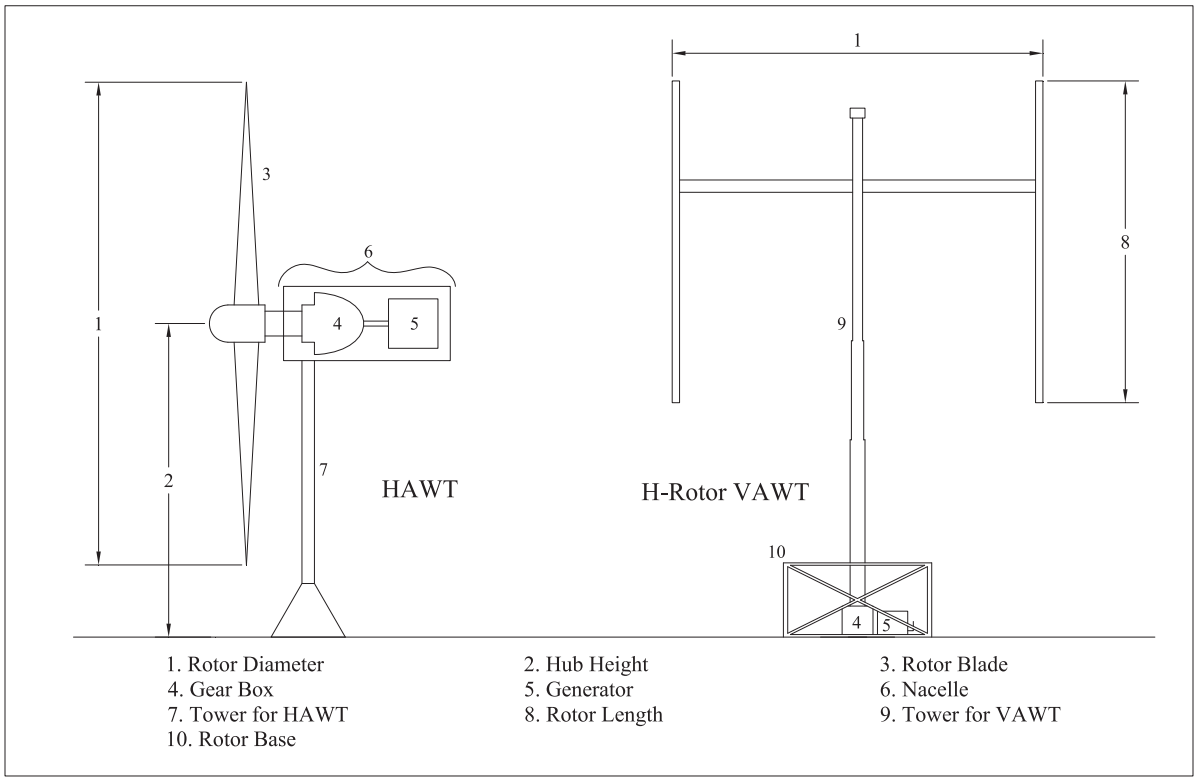


Figure 2. *Diagram of the Basic Parts of a HAWT and a modern H- rotor VAWT*



HAWT Advantages

The majority of wind turbine design currently focuses on the HAWT. Today, greater than 90% of wind turbines are HAWTs (Vieira da Rosa, 2009). Though the VAWT design is far more ancient, forms of the HAWT have dominated wind power for centuries. As Cheremisinoff (1978) notes, HAWTs were introduced in Europe beginning about AD 1200. Over the next couple of centuries, Dutch innovations to the rotor design allowed for improved lift generation so that VAWTs no longer saw widespread use.

Modern HAWTs are currently favored for electrical generation for several reasons. First, the arrangement of the blades allows nearly their full area swept to always be interacting with the breeze. This maximum exposure to the wind improves the C_p of a modern HAWT. Modern HAWTs have low blade solidity (ratio of blade area to the actual swept area). Because of low solidity, a breeze encounters less resistance on its path through the swept area of a modern three-bladed HAWT (Copper and Kennedy, 2005). This aids the blades or airfoils in the production of lift. Nearly all modern HAWTs produce their power through lift while the traditional American farm wind mill with its large number of blades was primarily a drag operated device. Because of this factor, the newer HAWTs enjoy a much higher coefficient of performance, C_p, than the older agricultural types. Johnson (1985) writes that modern HAWTs have C_p values ranging from 0.30 to 0.45 with most towards the upper end of the range. Because of these design traits, modern HAWTs account for nearly all commercial electricity generating wind turbines currently in operation (Gipe, 2004).Though very successful, the modern HAWT is not without criticisms or weaknesses.

HAWT Disadvantages

A very common objection to wind farm development is the rhythmic noise from the rotation of the blades. Sources of this noise can vary from trailing edge blade noise relating to turbulence to the effect of unsteady loading noise caused by the change in wind velocity caused by the presence of the tower to mechanical noise from the gearbox and yawing mechanism (Wagner, Bareib, and Guidati, 1996). Empirical evidence shows that common large commercial HAWTs can output sound pressure levels ranging from 58 dBA to 109 dBA (Rogers, Manwell, and Wright, 2006). The lower end of the range is often just above ambient noise sound pressure levels in some rural environments and the sound pressure level drops off rapidly with distance.

A second common objection concerns the aesthetics of large HAWTs. Though this topic is subjective by nature, it is often a very important issue during the planning stage of wind farm development. Many landowners fear that their property values will decrease if a wind farm is built near their property. Part of this fear is reduced by the $3000-$5,000 annual lease that many rural landowners receive per turbine installed upon their property. Some criticism has been brought about wind technology and the danger to avian species. Much of this concern stems from early wind farm construction in California. During the late 1970s and early 1980s, some farms were unfortunately sited in migratory bird paths. In light of these past mistakes, guidelines have already been developed by most states (Association of Fish and Wildlife Agencies, 2007). Current statistics shows that avian deaths due to wind turbines are approximately 0.02% of all the avian killed by other human built structures in the nation (Sagrillo, 2003). Massive construction of wind turbines nevertheless, have to be done carefully in order to protect wild life.

Finally, there are three technical issues that demonstrate the limitations point of HAWT design. First, HAWTs cannot operate in high winds. Generally, the large turbines must yaw or turn their blades out of the wind and apply a brake when wind speeds reach above 25 m/s or about 55 mph. Unfortunately, the power available in any wind is directly proportion to the velocity of the wind cubed so many large turbines are unable to harness this power. Secondly, HAWTs operate best where there is little obstruction such as on rolling hills, in mountain passes, or offshore. HAWTs are operationally challenged in most urban environments. Finally, the size of the HAWT is reaching an upper limit. Massive 5 MW wind turbines with blade diameters of 126 m currently hold the title as largest wind turbines. Though this is not the maximum structural or material limit, an end is in sight (Marsh, 2005). It is doubtful that reliable 10 MW HAWTs will ever be built. In light of all these criticisms and disadvantages, a renewed interest has been shown in vertical axis wind turbines, VAWTs.

VAWTs

The VAWT (vertical axis wind turbine) is the lesser known type of wind turbine. In VAWT designs, the air scoops or airfoils rotate perpendicular to the direction of the wind. As Gipe (2004) notes, there are two principle designs of VAWT, the Savonius type and the Darrieus type though there are several configurations of the Darrieus type. Modifications of the famous Darrieus "eggbeater" style and the H-rotor Darrieus type are the focus of much current research.

VAWTs were first recorded about 2,200 year ago in ancient Persia and were primarily used to grind grain (Cheremisinoff, 1978). In more recent times, the Finnish engineer S. J. Savonius created his first VAWT in 1922 (Peace, 2004). A typical Savonius design uses two S-shaped blades or cups for the rotor though some versions often incorporate more blades. Johnson (1985) writes that Savonius rotors are primarily drag turbines since their tip speed ratio is generally less than 1.

This low tip speed ratio greatly limits their use in electrical production though these VAWTs develop high starting torque which is useful in mechanical applications such as pumping water or air and grinding grain. According to Johnson (1985), a well built Savonius style wind turbine has a C_p of around 0.30 which is considered useful and reasonably efficient but its low tip speed ratio makes it better suited for operation of mechanical pumps. Savonius VAWTs have two advantages in that they are simple and inexpensive to construct and are self starting, even in low wind speeds.

In 1931, Georges Darrieus patented his VAWT in the United States (Bernhoff, Eriksson, and Leijon, 2006). Instead of cups catching the wind, the Darrieus model uses two or three curved blades which have a cross section similar to an airplane wing hence it is a lift producing turbine. The blades of a traditional Darrieus turbine are curved and joined together at the top and bottom while being bowed outward in the middle. This shape is called a troposkein, which is Greek for turning rope (Johnson, 1985). Later, an H-form Darrieus turbine called a Giromill was developed using straight rotors with a symmetrical wing cross section.

VAWT Advantages

VAWTs have several strengths which are just now beginning to be utilized. Most VAWTs have a low cut-in speed so that they produce at least a little electricity in low wind speeds. Many VAWTs have a TSR of only 2 to 3 which equates to some useful power production but with less noise generation. Because they can intake wind from any direction, VAWTs can operate in turbulent and variable wind conditions far better than HAWT designs (Berry, 2009). In fact, VAWTs can often operate in higher wind speeds than their HAWT counterparts which equates to greater energy generation under these conditions. These advantages have led both designers and politicians to consider adding VAWTs to urban environments (Ragheb, 2008). VAWTs often have their gearbox and electrical alternator located near the ground which facilitates easier maintenance. Some new VAWT designs have a C_p approaching 0.40 and allow for greater turbine density per parcel of land (Allan, 2007). Marsh (2005) notes that new H-rotor VAWT designs may also break the 10 MW barrier as the orientation of the blades coupled with modular manufacturing techniques allow VAWTs to be constructed larger than HAWTs. However, there are reasons why VAWTs have not seen more widespread use in wind farms.

VAWT Disadvantages

Efficiency still is a major drawback to the use of VAWTs in commercial power production. State of the art HAWTs can realize C_p values approaching 0.50 while the best VAWTs see C_p numbers a little better than 0.40. Johnson (1985) notes that most VAWTs average C_p values in the 0.30s. Secondly, VAWTs have traditionally have not been located on towers. This often limits the turbine's access to higher winds and thus higher electrical production. Historically, VAWTs ~~have~~ cost more to operate and maintain than HAWTs. The Flo Wind Company supplied a fleet of several hundred VAWTs located in the Californian mountain passes of Altamont and Tehachapi which operated for 20 years before maintenance costs caused the machines to be retired (Sagrillo, 2005). Finally, traditional Darrieus rotors are not self starting and the manufacture of their blades is a challenge because of the bent shape which adds expense to the turbine. Research and design of H-rotor Darrieus models is seeking to overcome both the self

starting and manufacturing issues of the "eggbeater" style. Table 1 below compares the current HAWT and VAWT technologies.

Table 1: *Comparing HAWTs to VAWTs*

	HAWT	VAWT
Efficiency	X	
Cost/kWh	X	
Cut-in speed (starting speed)		X
Cut-out speed (stopping speed)		X
Operation in turbulence		X
Scaled to 10 MW and beyond		X

Future of Wind Power

HAWTS will continue to dominate large scale wind farms for several years. VAWTs will continue to develop in niche markets such as in urban area where their better aesthetics and ability to operate in turbulent air make them a natural fit. In many Class 2 wind locations, small VAWTs may see significant installations as some forms of this type of wind turbine is adopted as low wind machines. Massive VAWTs may also develop for offshore locations as HAWTs near their structural and manufacturing limits.

The future of wind power is very bright indeed even though the current world wide recession has caused some changes in plans. T. Boone Pickens has cancelled his planned massive wind farm in west Texas and instead is planning smaller wind farms in the Midwest and Canada where transmission lines are already in place (Associated Press, 2009).

The US government is expecting to invest $150 billion of dollars over the next ten years to create green collar jobs (Walsh, May 2008). Wind power has the potential to generate up to 10% of all the energy generated in the USA by 2025. Consistently the US society has been loosing the traditional blue-collar job due to overseas outsourcing, green-collar jobs could even those loses and provide the middle class stable high-tech and well paid jobs (Walsh, October 2008).

According to the Audubon Society (2009) "Every megawatt-hour produced by wind energy avoids an average of 1,220 pounds of carbon dioxide emissions. If the United States obtains 20 percent of its electricity from wind power by 2020, it will reduce global warming emissions equivalent to taking 71 million cars off the road or planting 104 million acres of trees." It can not be predicted precisely the societal and environmental consequences of massive implementation of wind turbines but it is a consensus that those consequences will be minor in comparison with the ones that result from the burning and drilling of oil and form a new job base in a new economy.

References

Allan, S. (2007). Will TMA Wind blow away the competition. *Pure Energy System News*. Retrieved June 19, 2007 from http://pesn.com/2007/02/01/9500453_TMA_Wind_going_commercial/

Associated Press. (July 7, 2009). T. Boone Pickens calls off massive Texas wind farm. Retrieved July 12, 2009 from http://www.cnbc.com/id/31785977/

Association of Fish and Wildlife Agencies. (2007). Existing wind power siting guidelines. Retrieved July 2, 2009 from http://www.fishwildlife.org/agency_science_Siting_wind.html
Audubon Society. (2009). Audubon's position on wind power. Retrieved July 2, 2009 from http://www.audubon.org/campaign/windPowerQA.html
Bernhoff, H., Eriksson, S., & Leijon, M. (2006). Evaluation of different turbine concepts for wind power. *Renewable & Sustainable Energy Reviews*, 12(5), 1419-1434.
Berry, A. (2009). Small vertical axis wind turbine technology ideal for urban settings. Retrieved July 12, 2009 from http://windguys.com/2009/06/16/small-vertical-axis-wind-technology-ideal-for-urban-settings/
Cheremisinoff, N. P. (1978). *Fundamentals of wind energy*. Ann Arbor, MI: Ann Arbor Science.
Clendenin, J., & Seldon, S. (2009). Wind energy grows by record 8,300 MW in 2008. American Wind Energy Association. Retrieved June 14, 2009 from http://www.awea.org/newsroom/releases/wind_energy_growth2008_27Jan09.html
Cooper, P., & Kennedy, O. (2005). Development and analysis of a novel vertical axis wind turbine. The University of Wollongong, Australia. Retrieved October 15, 2008 from http://api.ning.com/files/X2CDnBHSLTUCxwajMKVx0x172VNi4GrlFEx9uW5cpMXOm6cFr4kPUUgBdO9EJJQKpI47IKUK1LyOrOgj6MD07WSI1x3XVd/Cooper_Paper_Wind.pdf
Gipe, P. (2004). *Wind power*. White River Junction, VT: Chelsea Green Publishing Co.
Johnson, G. L. (1985). *Wind energy systems*. Upper Saddle River, NJ: Prentice Hall.
Malcolm, D. (2003). Market, cost, and technical analysis of vertical and horizontal axis wind turbines Task#2 VAWT vs. HAWT technology. Global Energy Concepts, LLC. Retrieved August 2008 from http://www.wind-sail.com/docs/WS030504.PDF
Marsh, G. (2005). Tilting at windmills utility-scale VAWTs: Towards 10 MW and beyond? Refocus, 6(5), September/October, 37-42.
Peace, S. (2004). Another approach to wind. *Mechanical Engineering*, 126(6), 28-31.
Ragheb, M. (2008). *Wind turbines in the urban environment*. Retrieved July 12, 2009 from https://netfiles.uiuc.edu/mragheb/.../Wind%20Turbines%20in%20the%20Urban%20Environment. pdf
Rogers, A., Manwell, J., & Wright, S. (2006). Wind turbine acoustic noise. University of Massachusetts at Amherst, Department of Mechanical and Industrial Engineering.
Sagrillo, M. (2005). The myths & mysticism of vertical axis wind turbines. *Windletter*, 24(2), 1-3.
Sagrillo, M. (2003). Putting wind power's effect on birds in perspective. Retrieved July 7, 2009 from http://www.awea.org/faq/sagrillo/swbirds.html
Stanford Report (May 20, 2005). New global wind map may lead to cheaper power supply. Retrieved June 5, 2009 from http://news.standford.edu/news/2005/may25/wind-052505.html
Vieira da Rosa, A. (2009). *Fundamentals of renewable energy processes.* 2nd ed. New York, NY: Elsevier.
Wagner, S., Bareib, R., & Guidati, G. (1996). Wind turbine noise. Berlin, Germany: Springer.
Walsh, B. (October 20, 2008). Saving the working class with green-collar jobs. *Time*. Retrieved July 6, 2009 from http://www.time.com/time/health/article/0,8599,1852183,00.html?iid=sphere-inline-sidebar
Walsh, B. (May 26, 2008). What is a green-collar job, exactly. *Time*. Retrieved July 6, 2009 from http://www.time.com/time/health/article/0,8599,1809506,00.html

Management

Management

Application of Theory of Constraints to Sustainable Manufacturing: A Case Study

Dr. Nilesh N. Joshi
Morehead State University, Department of Industrial and Engineering, Technology, Morehead, KY 40351, 606-783-2417, n.joshi@moreheadstate.edu

Abstract

Many manufacturing companies are struggling to survive during these troubled economic times. Companies operate in an environment of cause and effect. These cause-and-effect relationships can be very complicated, especially in complex manufacturing operations. Theory of Constraints (TOC) is a management philosophy that provides techniques to study these relationships in a simplified manner and to address the root causes of the problems. In this paper, the author applies TOC philosophy to explain complex cause-and-effect relationships of a struggling small scale manufacturing organization. The author develops three distinct logic trees to address failed operations of the company and its root causes. The trees include: the Conflict Resolution Diagram, the Current Reality Tree, and the Future Reality Tree. The paper will be useful for engineering and technology management professionals in manufacturing field, who are trying to address cause-and-effect relationships of undesirable effects within their respective organizations.

Introduction and Background

Theory of Constraints (TOC) is a management philosophy proposed by Goldratt (1984). This philosophy is based on systems thinking and is prescriptive in nature. Goldratt (1994) extended this philosophy to include logical trees that study complex cause-and-effect relationships in a manufacturing organization. Goldratt's logical trees-based theory instantly became famous because it provides manufacturing professionals with simple yet powerful tools to study complex manufacturing operations within their respective organizations and resolve problems. More work on the TOC and its applications can be found in Mabin et al. (2001), Yang et al. (2002), and Blackstone (2001). Some of the underlying principles of the TOC are listed below (Dettmer, 1997):

- The systems are like chains and they do contain strong as well as weak links. The goal is to search the weakest link in the system and to strengthen it.
- Any large system consists of various subsystems. Each subsystem has its own local optima. If the subsystems are independent of each other, then the larger system will perform optimally when all its subsystems perform at their local optima. But in reality, the subsystems are not independent. There is always a degree of interdependence and variation. Hence, the global optimal point of the overall system is not necessarily aggregation of the local optimal points.
- The systems are based on cause and effect relationship. In most cases, these relationships are complex in nature. It is important to study these relationships in order to solve the problems in the system.
- Core problems in the system are usually manifested through undesirable effects.

Three logical diagrams proposed by Goldratt (1994) are developed in this paper to study operations of a troubled small job-order manufacturing company in Albuquerque, New Mexico[1]. The company designed, manufactured and sold different types of mountings for passenger vehicles. Some example mount types manufactured by the company were two-way radio mini mounts, mobile docking stations, cellular communications mounts, and public safety mounts. Company's primary customers were large public corporations-such as Motorola, Bell South, etc. This company was chosen for the case study because it was accessible and willing to be observed.
This company, like any other company, was established with the purpose to generate revenue. The company's goal was to satisfy customers and to generate more revenue now as well as in the future. Satisfied customers play a fundamental role in present and future financial success of the company along with other factors. Although

[1]The name of the company is not disclosed in the paper for confidentiality reasons. The company was recently purchased by another Fortune 500 company.

customer satisfaction is a prerequisite, it still may not be able to create as much revenue as expected. In such a case, company will not be in business to satisfy its customers. Hence, both the aspects of the company's goal were equally important.

The components of the company that were studied consisted of four departments: Production, Sales and Marketing, Engineering, and Accounting. The Production Department consisted of sheet metal fabrication, powder coat finish, and assembly department. The Sales and Marketing Department consisted of a sales manager, a graphic designer, and a service manager. The Engineering Department was responsible for product development. The Accounting Department was responsible for financial reporting, collecting money and paying money to the suppliers. These departments could be considered as the links of a chain. They were interlinked to produce the product and collect money from the customer.

The very first task in this study was to put together a list of undesirable effects (UDEs) within the company. With the help of company management, and using 4 UDEs from Goldratt (1994), a list of 16 UDEs was composed. After further discussions, some of the UDEs were modified reducing them to 11. Next, a visit was coordinated to the plant to observe and analyze the plant operations using TOC tools. The visiting team was able to identify several constraints such as inadequate communication, delivery delays, and sales and capacity imbalance. The team also identified several strong links such as fast prototype production or turnover, dedicated staff and customer orientation.

From the UDEs, the team proceeded to the development of first logical tool: the conflict resolution diagram. Working backward from UDEs and the conflict resolution diagram, the team developed the *Current Reality Tree*. Finally, the team developed the *Future Reality Tree*.

Current Condition of Existing Study System

This section describes the team's observations of current condition of the study organization. In recent years, competition in the market was intense. This industry had created more supply than demand. The market demand was insufficient for the company to sustain operations. Additionally, any contract over 200 items that the company received, its sister companies received a portion of the requirements to that contract. The company's market also presented pressure to reduce prices due to the competition. Company's operating expenses were high compared to its competitors. This is an undesirable effect because the company could not afford competition in the market.

The company's strategic partners rated it each quarter in multiple categories to determine a score for evaluation. To remain on their preferred supplier list, company needed to maintain a certain level of performance that included annually reducing the price for its products. In this particular market, demand was inversely proportional to the price of the product. Thus, the pressure to increase company's sales resulted in the need for reducing prices.

The company had only one full time sales manager. The company sold most of its products and services indirectly to the customer through its strategic partners. The company also sold directly to the customer that owned a fleet of vehicles, such as a police department. Market segmentation requires more resources, but the company had insufficient resources to concentrate on all the markets. The business from existing strategic partners was insufficient to reach the break-even point. The pressure to increase company's sales overloaded the sales person.

In recent years, the company reduced costs by downsizing its staff. In the same period, the sales level declined from 24 million to 9 million dollars. Even though the company had access to an external sales staff, the staff of its strategic partners, this staff knew either little or nothing about company's products and services. Management used standard cost of the product to determine its price. In reality, management did not know the true cost of its products. A budget for the product was determined in the design and development phase with input from the customers. Price breaks were determined to promote high volume purchase orders and provide incentives to distributors and representatives. Capturing overhead was very difficult since the volume of the product was hard to predict.

Management had no formal plan of activities in the plant. Orders were released to the shop floor and closed when completed. Often, parts fell off the critical path for completion. Many components used for each assembly were used in multiple kits. Management looked at jobs individually, not collectively. This caused an unexpected peak in demand for some components with limited supply. Rejects and rework was another cause for inaccurate scheduling.

There was a lack of communication and teamwork in the plant. Employees often tried to avoid their responsibilities and blamed each other for any failure. The lack of communication resulted in all kinds of conflicts in the organization. In short, employees only concentrated on their local optima. They were not aware of the overall goal or the global optima of the company.

Following list of UDEs was developed to formalize the team's observations of the existing condition of the company:

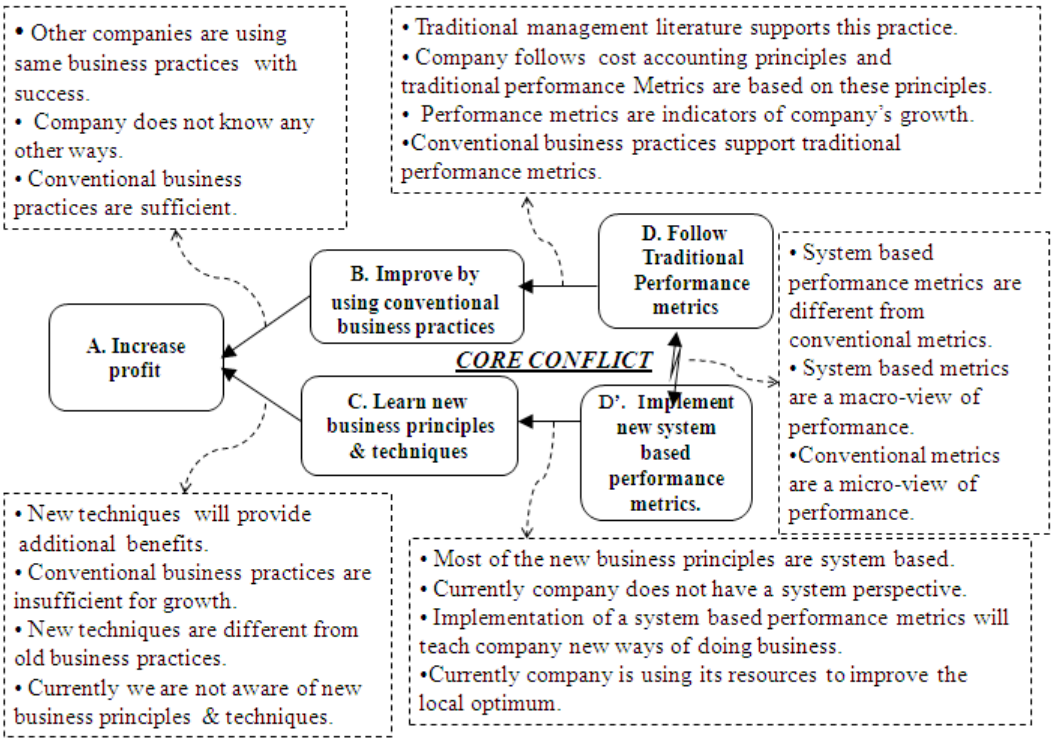
- Competition is fierce than ever.
- Market presents pressure to reduce prices.
- Salespeople are overloaded.
- Current sales level is insufficient to sustain the company.
- Management does not know how much to charge for its products.
- Delivery dates to customers are missed.
- Job and material scheduling is poor.
- Lack of cooperation and teaming among workforce.
- External sales force (sales team of the strategic partners) is unaware of company's product/service portfolio.
- Company's quality management system costs too much.
- Operating expenses are too high.

Conflict Resolution Diagram (CRD)

CRDs are used to resolve the conflicts within the system that cause most of the core problems in the system (Sproull and Sproull, 2009). A conflict happens when two sides do not agree in their thinking irrespective of sharing a common goal. Each conflict can be represented by a unique CRD. Once primary conflicts in the system are identified and CRDs are formed, a core CRD is developed. The core CRD is an integration of all the CRDs and it shows the holistic picture of conflicts and causal relationships. The core CRD forms the base of the Current Reality Tree that will be discussed later.

Initially, the team identified three important conflicts in the company and developed respective CRDs. Each of the selected conflicts was from a different area within the company. After analyzing three conflicts together, the team determined that there was some generic conflict of the larger system that they can be translated to — the Core Conflict Cloud (CCC). The team identified this root cause conflict and developed the core CRD in order to resolve the conflict (see Figure 1). In Figure 1, block *A* represents the common shared goal by the two sides. Blocks *B* and *C* represent the requirements to obtain this goal. Blocks *D* and *D′* represent the prerequisites that are in conflict. The solid arrows connecting these blocks show causal relationships, and the dotted arrows lead to underlying assumptions for the respective causal relationships. The dotted arrow that is emerging from the conflict between *D* and *D′* leads to the underlying assumptions for the conflict. All these assumptions need to be challenged and will be challenged when the team develops the future reality tree.

Figure 1. *Core Conflict Resolution Diagram*



Current Reality Tree (CRT)

CRT is a logical cause and effect diagram that shows current state of the system. It shows the causal relationships among various system states that depict current reality and their originating causes. In the CRT, underlying causes lead to various effects in the organization. These effects in turn become cause for other effects. These causal relationships are shown using blocks and arrows. The team developed a CRT to study the previously listed 11 undesirable effects (UDEs) in the company and their causes. The developed CRT was large and was not possible to show in its entirety in a single figure. So, it is broken in different parts (see Figures 2, 3, 4, 5 and 6). Previously developed CRD diagram formed the base of the CRT and UDEs formed the branches. The blocks in the CRT were numbered to facilitate its breaking in several parts. The CRT has several root causes. These root causes are shown in the Figures by the blocks that have arrows coming out of them, but no arrows going in. The term *FOL* mentioned in the several blocks representing root causes in the CRT figures means *Fact of Life*. These root causes are not necessarily positive or negative, rather they are just facts of life and they need to be studied further (Dettmer, 1997).

Figure 2. *Current Reality Tree (Part-1)*

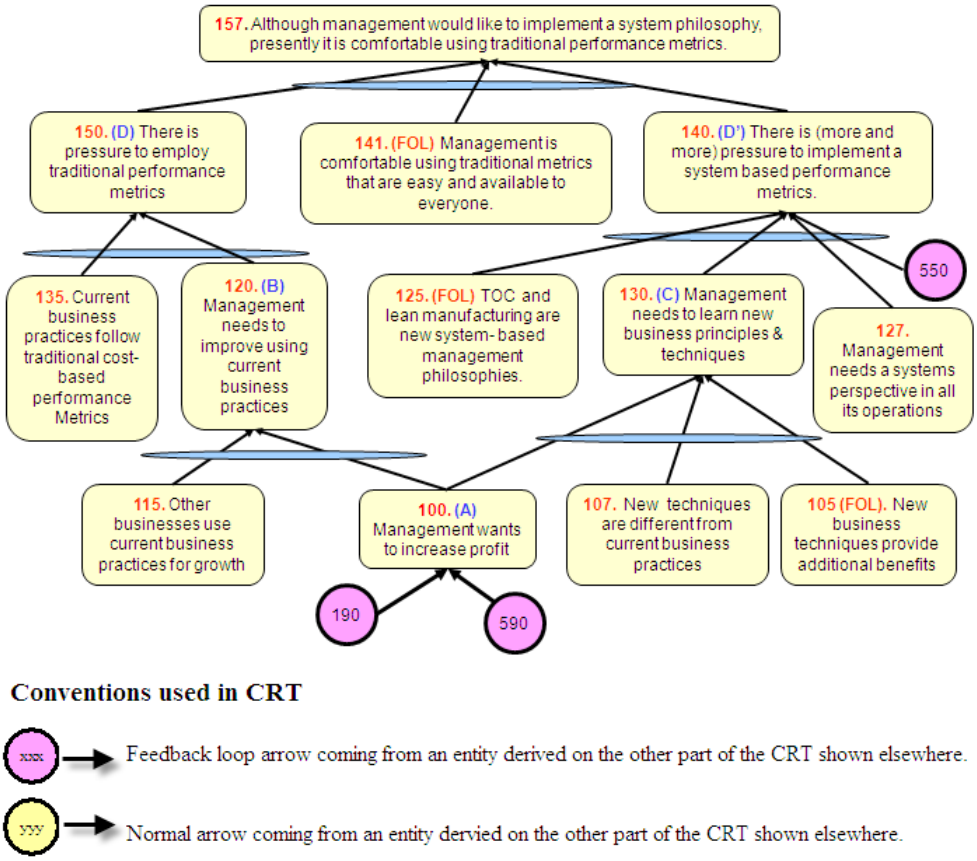


Figure 3. *Current Reality Tree (Part-2)*

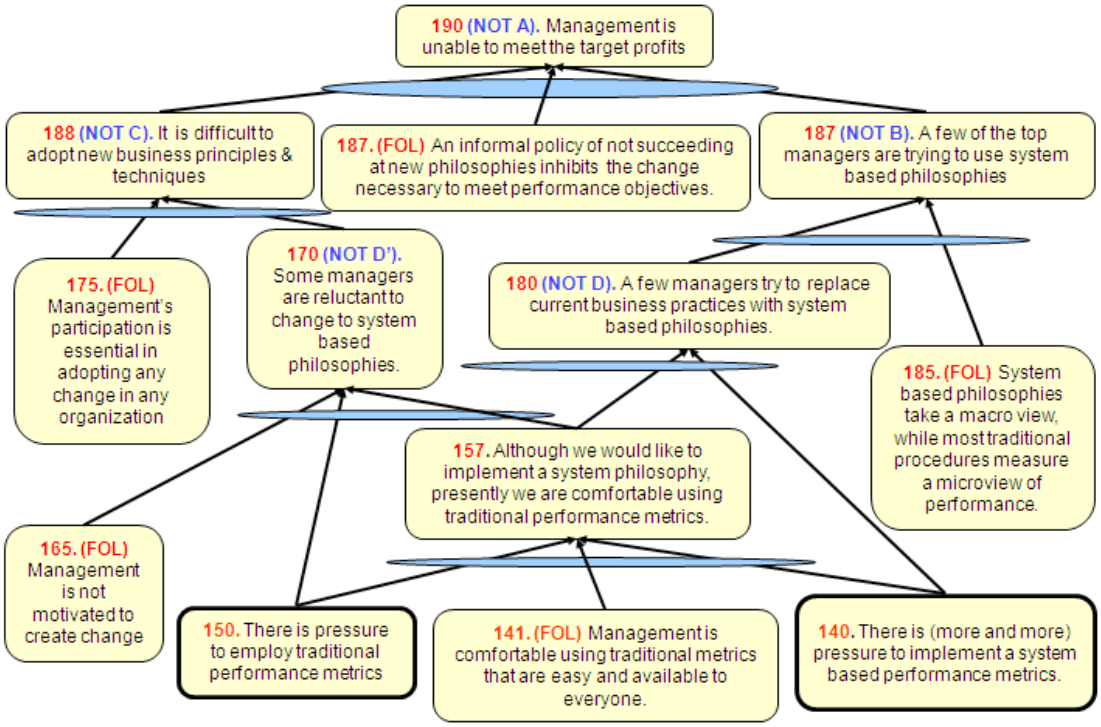


Figure 4. *Current Reality Tree (Part-3)*

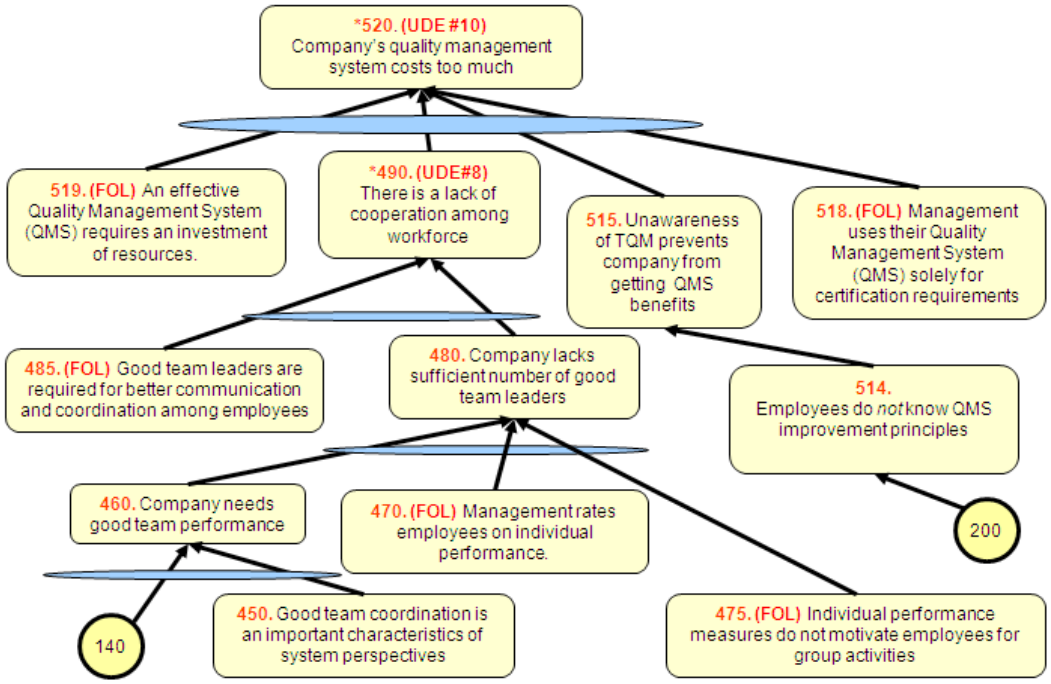


Figure 5. *Current Reality Tree (Part-4)*

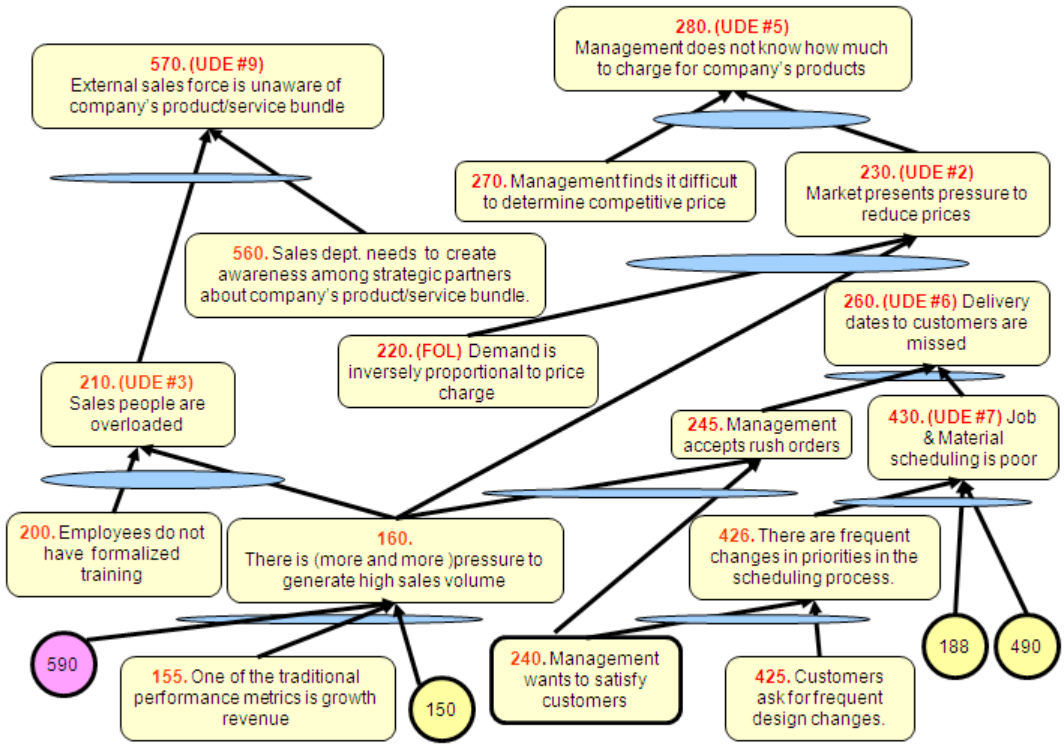
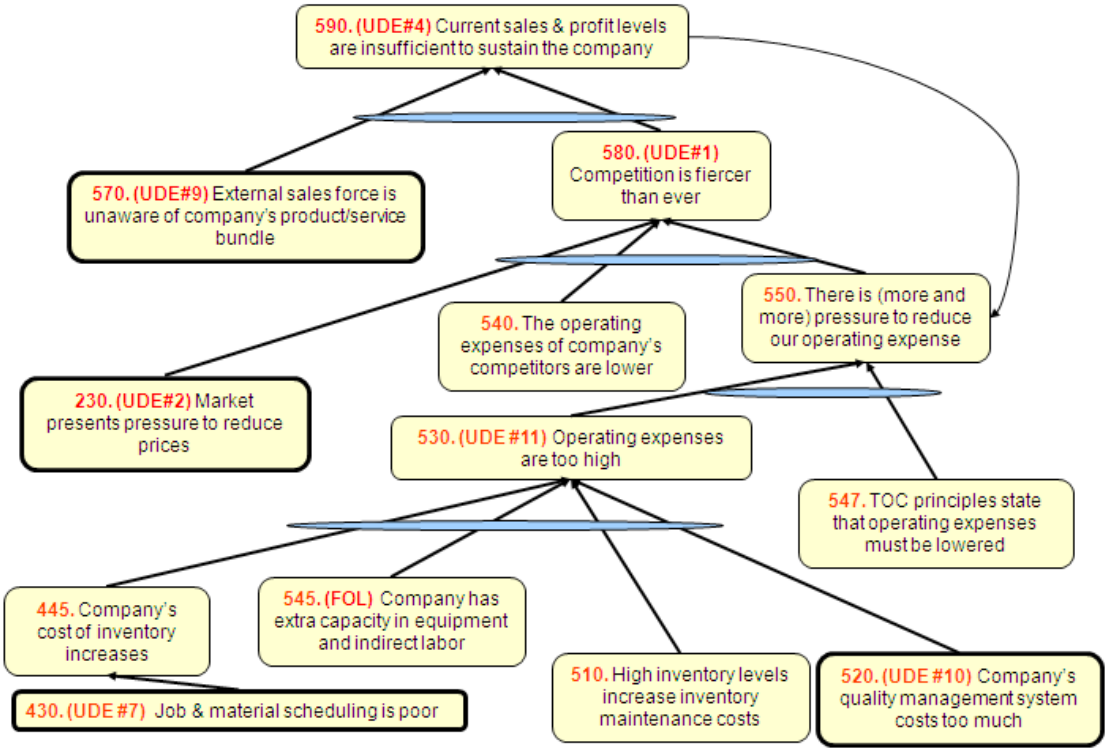


Figure 6. *Current Reality Tree (Part-5)*



The well-built CRT confirmed that the core conflict was indeed the root cause for all the problems. The CRT was useful in answering the first crucial question that the team wanted to address: *what to change*?

Future Reality Tree (FRT)

The FRT is a sufficiency–based logic structure designed to reveal how changes to the status quo would affect reality- specifically to change UDEs to Desirable Effects (Dettmer, 1997). It guides management in figuring out what to change to. First step in developing a FRT is to develop injections. An injection is referred to any new idea (policy, action, etc.) that breaks the current reality problem or core conflict. In order to develop these injections, the team again focused on the core conflict and its underlying assumptions shown in Figure 1. The team developed one or more injections for each of the assumptions in the CRD. Some of these injections were feasible and some were not. Many of the feasible injections were used in the construction of the FRT. The developed FRT is broken into parts for the presentation purpose (see Figures 7, 8, and 9). It is similar to the CRT in structure. Only difference is that it uses injections and shows the future desirable reality of the system. You will notice several blocks with the term, *INJ* in the FRT diagrams. These blocks represent the injections that need to be injected into the system to achieve the future desirable effects. You will also notice the blocks with the term, *DE*. These blocks represent the desirable effects.

Figure 7. *Future Reality Tree (Part-1)*

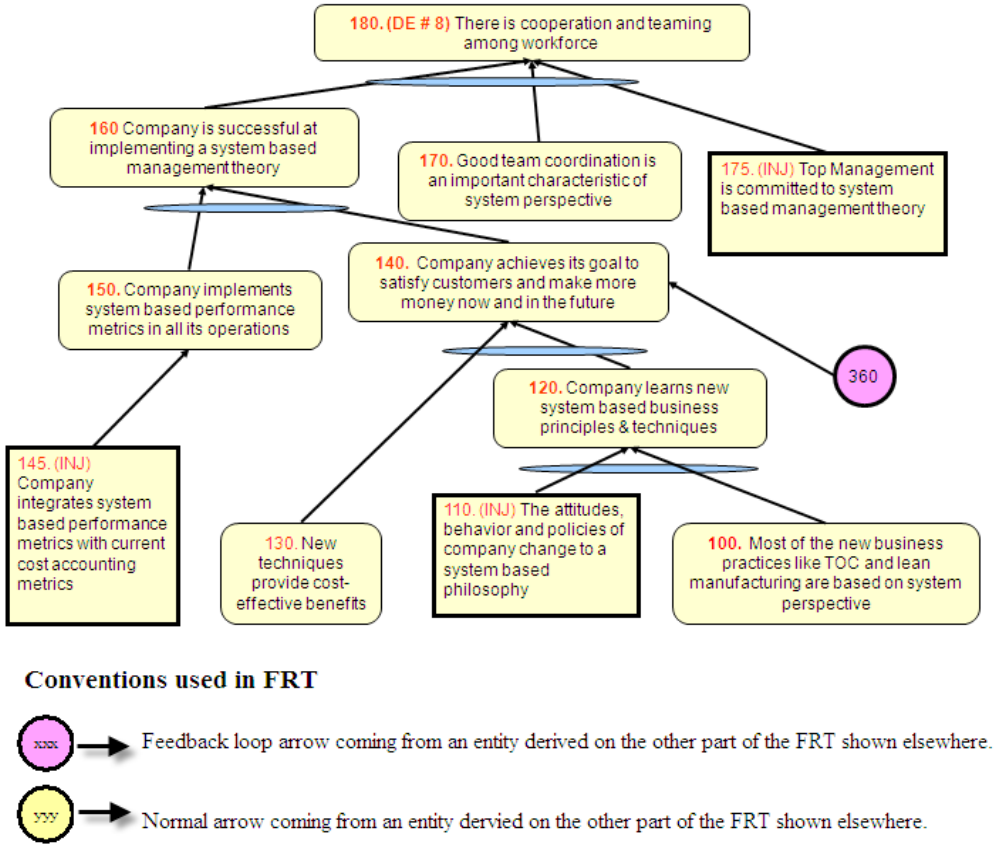


Figure 8. *Future Reality Tree (Part-2)*

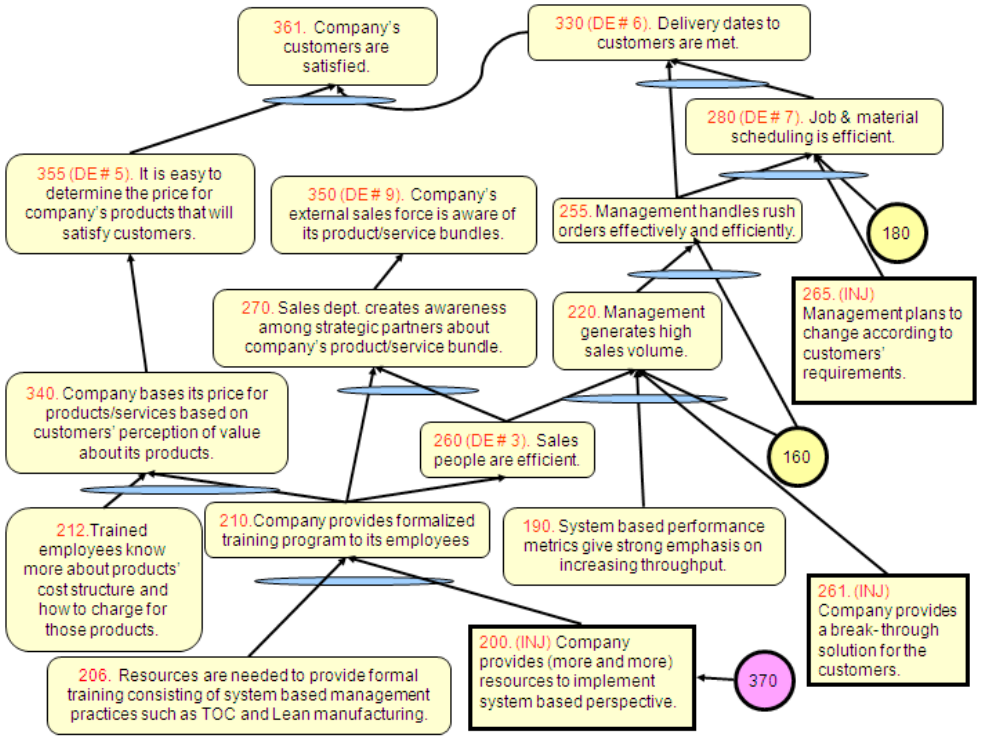
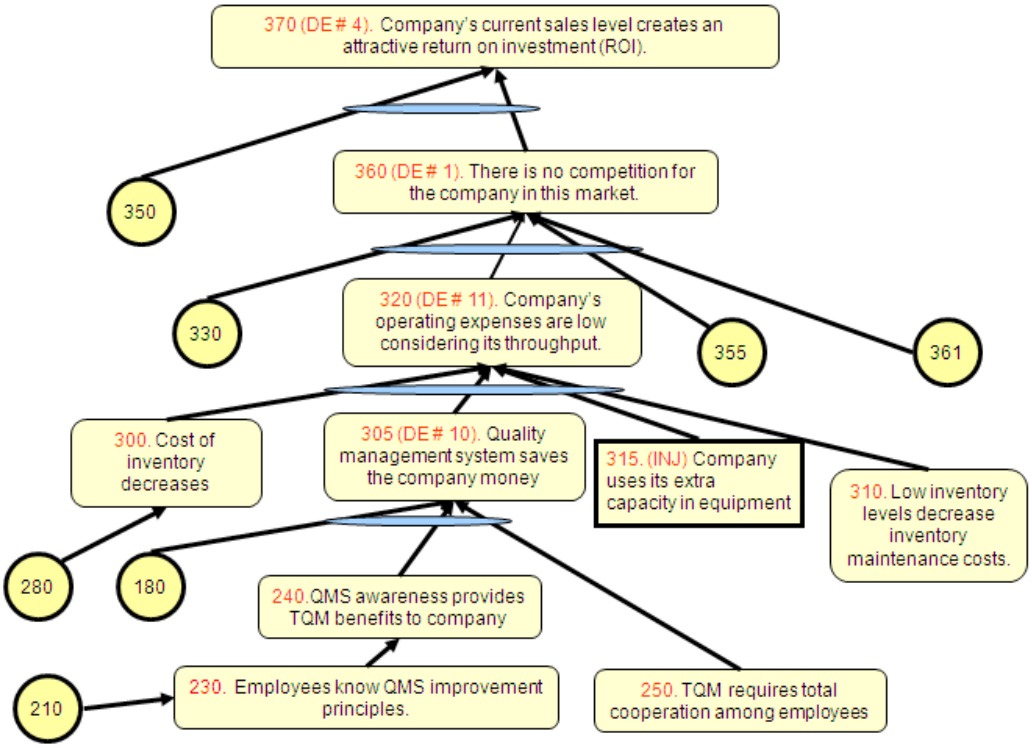


Figure 9. *Future Reality Tree (Part-3)*



Summary and Conclusions

The logical diagrams developed in this paper were based on the team's frequent visits to the company, discussions with the management, and several brainstorming sessions among the members of the study team. These diagrams helped the team to identify conflicts prevalent in the company, to analyze complex cause and effect relationships within the company, to depict the current reality and its undesirable effects, and to resolve the conflicts and generate solutions that would eventually lead to future desirable reliability and to achieve sustainable manufacturing operations. The proposed injections affect the need to change attitudes, behaviors, and policies of the company. Management learned the TOC philosophy and its significance to day-to-day company operations through the use of CRD, CRT, and FRT.

Acknowledgment

The author is grateful to W. Conway and C. Inza, graduates of Anderson School of Management at the University of New Mexico for actively participating in the team's brainstorming sessions and contributing to the development of logical structures in this paper. The authors are grateful to Prof. R. Reid of the University of New Mexico for his invaluable guidance to the team during the project. Finally, a special thanks goes to Prof. A. Zargari from the Morehead State University for reviewing the paper and providing valuable inputs.

References

Blackstone J.H. (2001). Theory of constraints - a status report. International Journal of Production Research, 39(6): 1053-1080.

Dettmer H.W. (1997). Goldratt's theory of constraints: A systems approach to continuous improvement. ASQ Quality Press, Milwaukee, WI.

Goldratt E.M. (1984). The Goal: A Process of Ongoing Improvement. First Edition. North River Press, Great Barrington, MA.

Mabin V.J., Forgeson S., Green L. (2001). Harnessing resistance: using the theory of constraints to assist change management. Journal of European Industrial Training, 25(2): 168-191.

Goldratt E.M. (1994). It's not luck. First Edition. North River Press, Great Barrington, MA.

Sproull B., Sproull R. (2009). The ultimate improvement cycle: maximizing profits through the integration of lean, six sigma, and the theory of constraints. CRC Press.

Yang C.L., Hsu T.S., Ching C.Y. (2002). Integrating the thinking process into the product design chain. Journal of Industrial Technology, 18(2).

Management

Can We Make Accounting Relevant Again? Non-Traditional Accounting Systems Can Drive Productivity and Future Prosperity

Dr. Mark Doggett
Western Kentucky University, Bowling Green, KY 42101, 270 745-6951, mark.doggett@wku.edu

Introduction

The financial information used for operational decision-making is inconsistent and current accounting practices encourage tampering. Recent monetary events created turmoil in the stock market and uncertainty in investments. Furthermore, accounting methods seem ineffective in discouraging unscrupulous behavior. Because the financial health of business is measured using Generally Accepted Accounting Principles (GAAP), what other choices exist for measuring fiscal performance? This paper provides an overview on a few potential alternatives to current accounting practice. One such practice is lean accounting. The other accounting systems are Activity Based Costing (ABC), Throughput Accounting (TA), and Resource Consumption Accounting (RCA). This paper will refer to the current financial accounting system as traditional.

Current Perceptions

Cunningham and Fiume (2003) asserted that accountants should be active partners in business processes rather than bean counters. Operations managers tend to exclude accountants from the day-to-day activities, creating barriers that prevent long-term improvement and organizational transformation. In essence, the traditional accounting systems are blocking economic progress. These authors suggested that accountants should be where the action is rather than in some distant building. This suggestion is meaningful when one reflects on the development of industrial technology, technology management, and applied engineering. These disciplines increased in importance because business and engineering did not speak the same language or work in close proximity. Hence, the notion of a shift from accounting control towards business advocacy and value added services has merit. As the speed of financial transactions increases through technology such as e-commerce, the need for collaboration is likely to increase, but the cultural barriers of a transformation from control (e.g., the Controller) to cooperative management are significant.

Jusko (2007) emphasized that the movement toward accounting alternatives was born out of frustration with traditional accounting systems that encourage managers to design batch-and-queue processes and build up inventory. When combined with hard-to-understand financial reports and complicated measurements, managers began to seek accounting systems that actively supported lean operations and accurately described financial performance. Conversely, the supporters for alternative accounting principles are still in the minority and most are outside of the accounting function.

How Traditional Accounting Distorts Improvement

Traditional accounting systems distort cost by allocating overhead and treating inventory as an asset. Furthermore, the traditional methods of building standard costs are prone to error and vary greatly from firm to firm, yet most senior executives treat them as accurate. Estimating the standard cost of a product is complex. The result is a confusing snapshot of financial performance and a list of variances no operational employee can understand. Worse still, managers may game the system by making unneeded products or expenditures (Cunningham & Fiume, 2003).

Nonetheless, most accounting managers cling to standard cost and variance tracking for three reasons. First, accounting managers think it is necessary for determining the selling price. This may have been relevant when labor and materials accounted for 90 percent of product cost, but is less important now that overhead and

materials account for the majority of cost. Increasingly, target costing, as an alternative to standard costing, is gaining favor. Target costing, as developed by Japanese companies in the 1960s, requires the selling price and desired profit to be determined at the beginning of the product development cycle. The planned selling price less the desired profit becomes the target cost. This forces marketing, design, engineering, and suppliers to negotiate tradeoffs and practice continuous process improvement (Feil, Yook, & Kim, 2004).

Another misconception is that accounting managers think standard costs and variance tracking help reduce product cost. However, in the modern economy, businesses should be reducing costs throughout the enterprise, not just individual products. Higher allocations of overhead cost make it difficult to make a definitive cost reduction other than reallocating overhead. In addition, unfavorable variances are difficult to trace unless the company has precise lot identification (Cunningham & Fiume, 2003).

Finally, accounting managers think they need standard cost to value inventory. Smaller inventories have a distinct cost advantage, but inventory accumulation produces favorable balance sheets in batch-and-queue systems. In traditional accounting, raw material is valued based upon its purchase price. As the material transforms into a finished product, its value increases. This value is capitalized into a measure of anticipated economic benefits. Unsold inventory becomes an asset reported on the financial statement. When the inventory is sold, it is expensed (deducted) from assets and reported as the cost of goods sold. However, the period for the expense is usually much later than the period of the purchase. Gross profit is the cost of goods sold subtracted from sales. Hence, when companies actively reduce inventory and increase inventory turns, the result is an increase in cash flow and a decrease in gross profit on the financial report (Huntzinger, 2007).

Inventory reduction also creates excess labor hours because workers are producing just-in-time, which drives down machine utilization rates. How do traditional managers react to having excess labor and machine time?—they sell it or layoff employees. This means that management must be able grow the business fast enough to offset productivity gains or risk losing employees. This is why it takes so long for an economy to bounce back after a recession using traditional accounting measures.

Return on Investment (ROI) is another distortion. Davis, Appel, & Cohn (2008) showed that adding higher than average segments to divisions or subtracting lower than average segments from divisions would improve ROI without any change in productivity. In addition, most employees do not have the slightest idea of what ROI means or how it is calculated. Consequently, ROI loses its effectiveness because few employees can relate it to their daily activities (Cunningham and Fiume, 2003).

From Cost Control to Cost Management

Art Bryne , former CEO of Wiremold, proposed inventory turns and customer service as two of the most important performance measures (Productivity Press, 2005), but perhaps more notably, he asserted that productivity is equivalent to profitability. Productivity means increased wages without increased prices because companies can sell their products for less while increasing the standard of living for employees. The basic formula for productivity is P = O/I where O is the output of the process and I is the input (or the aggregated resources) used to produce the output, typically expressed in units. Therefore, productivity increases when a company produces output using fewer resources. To convert to a financial measure, one only has to express the units as dollars and calculate profitability by subtracting the cost of producing the product from the sales revenue. Conversely, traditional financial statements do not tell a manager if productivity has increased, decreased, or stayed the same.

Changes in the physical environment produce productivity improvements, i.e., observable changes. If productivity increases with a favorable output to input ratio, then reducing waste is paramount. The seven wastes, first identified by Taiichi Ohno, the architect of the Toyota Production System (TPS), are the basis for lean manufacturing. According to Ohno (1988), processes must include only activities that add value from the customer's perspective. Deming (1982) added to this by saying that ""Measures of productivity do not lead to improvement of productivity. … Measures of productivity are like statistics on accidents: they tell you all about the number of accidents at home, on the road, and at the work place, but they do not tell you how to reduce the frequency of accidents" (p. 15).

To accelerate cost management, Cunningham and Fiume (2003) promote *plain-English financial statements*. The goal is to develop financial reports that meet the needs of both operations managers and GAAP. The preparation of standard Profit and Loss (P&L) statements is non value-added if managers cannot understand them. Financial statements should include financial as well as non-financial data. Maskell and Baggaley (2006) suggested the use of box scores in place of the P&L statement.

Vinas (2007) recommended that the way to gain support for lean accounting is to recognize that it is similar to visual thinking. Numbers are a form of symbols and in themselves are meaningless. However, the information behind the symbols is rich with information for decision-making if the right things are measured. Vinas argued that the adoption of *meaningful numbers* is more important than the numbers themselves.

Maskell (2007) suggested reducing the amount of misleading information given to the process manager. First, replace standard costing with value stream costing, that is, costing based upon the labor, materials, support, and facilities directly involved in the value stream for the selected product family. The result is that little or no allocation added to the product. Second, provide the value stream costing information to managers so they can make better decisions on pricing, profitability, make/buy, and products. Third, implement target costing to promote cooperative cross-functional processes throughout the product life cycle.

Using Alternative Accounting Systems to Turn Around an Economy

The following is a brief summary of ideas proposed by various authors on alternative accounting systems. Some might provide the incentives needed to stimulate economic activity and reward businesses for implementing lean practices, increasing sales, and providing high quality at low cost.

Lean Accounting

Engle (2005) described lean accounting as a variation of managerial accounting and noted that businesses may want to use it for operational decisions and use financial accounting for GAAP reporting. Lean accounting views inventory as unsold expense and uses market pricing for cost estimates. Kroll (2004) supported the idea of categorizing costs by processes (i.e., value streams), rather than by department, a key lean concept. Another key difference is the reporting of direct labor as a fixed, rather than variable cost.

Another feature of lean accounting is the emphasis on timely and responsive reporting. The rationale is simply to reduce levels of non value-added activity and complexity while increasing diagnostic capabilities to solve problems in a timely fashion. As a side benefit, accountants can begin to work on more interesting projects that actually eliminate much of the current reporting. The lean budgeting process also requires a different perspective on capital requests. With lean budgeting, net cost equals total cost minus inventory reduction. If the inventory reduction is greater than the capital investment, the project benefit is immediate and self-funding (Cunningham & Fiume, 2003).

One of the additional benefits of lean is increased cash flow. The liquidation of excess inventory creates instant cash for acquisitions and growth. When the acquiring company applies the same lean lessons to the acquired company, it provides a game plan to free up excess assets and reduce the payback period. This teaches managers to look at potential acquisitions as opportunity, especially in the reduction of service debt (Cunningham & Fiume, 2003).

Throughput Accounting (TA)

As proposed by Goldratt (1992), TA changes the organization's focus from cost reduction to increased throughput (defined as revenues through sales). Based upon the Theory of Constraints, TA evaluates the impact of every decision by comparing its affect on throughput against operating expense and the investment required. Actions or decisions that improve constraints (bottlenecks) improve throughput (Throughput Accounting, 1999). Using simple arithmetic, managers can quickly gage how actions affect profit and return on investment. For example, if operating expense is all the money the company spends to convert inventory into throughput, then net profit is simply the expense subtracted from throughput (sales revenue). Using the same logic, the return on investment is simply the net profit divided by the inventory (or investment) expended (Corbett, 2003).

TA does not attempt to allocate costs to individual products. Rather, costs are aggregated as a whole (Schragenheim, 2000). Producing unsold products does not count as throughput, but as investment. Thus, TA is a suitable management accounting technique for driving performance measures in the right direction and providing timely real-world indicators for decisions that benefit the entire firm, not just a single department.

Activity Based Costing (ABC)

As first defined by Kaplan and Bruns in 1987 and refined by Johnson and Kaplan in 1991, ABC assigns the cost of activities to a product. Each activity's cost is an estimate for all the labor, materials, equipment, subcontracting, and overhead consumed by an individual product. The intent of ABC is to identify and reduce indirect costs or overhead that drive up the cost per unit.

Mansuy (2000) conceded that ABC is another variant of an allocation system and that actual hours rarely reconcile with it. In addition, ABC requires intensive amounts of shop floor transactions are that are non-value added and may do nothing to provide increased accuracy. The key takeaway is that regardless of the accounting system, cost is not an absolute, but rather an estimate based on the selected overhead allocation method. Estimates of product cost are appropriate for GAAP.

Resource Consumption Accounting (RCA)

Financial professionals might refer to Resource Consumption Accounting (RCA) as a "refined ABC approach" (Krumwiede & Suessmair, 2007, p. 55) combined with the German management accounting practice *Grenzplankostenrechnung* (GPK). RCA applies costs to resources rather than products, and links the resource to activities. Unlike traditional accounting, the resource outputs are expressed as quantifiable units rather than dollars, allowing managers to better distinguish between resource consumption and cost. RCA makes excess capacity visible so that managers can make better decisions regarding resource acquisitions. When combined with activity-based resource planning, RCA can become a powerful budgeting tool for forecasting (Clinton & Keys, 2003).

In a pilot study, Clinton and Webber (2004) established that RCA was able to measure significant changes in a product's profitability potential by (1) allocating directly to the consuming resource by quantity, (2) using replacement cost depreciation, and (3) removing excess capacity from product cost. In a survey of 148 German companies and 130 U.S. companies, Krumwiede and Suessmair (2007) found that 71% of German firms rated RCA as satisfactory as compared to only 24% for U.S. firms using traditional accounting methods.

Cultural and Systemic Barriers: Can We Make Accounting Relevant Again?

Organizations may choose to implement alternative accounting systems using a major overhaul while others may choose pilot projects. The choice seems to depend on how employees perceive change. Early adopters thrive on change, while anchor draggers (Womack, 2003) resist it. Most people are somewhere in the middle. The prevailing organizational worldview also plays a role in how managers initiate change. In hierarchical organizations, employees wait for direction compared to lean organizations where employees are encouraged to use their intelligence and creativity. Ideas and employee involvement are crucial to streamlining the accounting process and being competitive.

Do actions speak louder than words? This seems to be true for making fundamental changes to the accounting system. Cochran (2007) correctly emphasized that true change occurs only through interventions that force people to behave differently and breaks the cycle of a dysfunctional belief system. Many agents of change try to enact transformation by appealing to common values, but this is almost as difficult as convincing someone to change their political party or convert their religious faith. Managers would be more successful by concentrating on specific areas where they can demonstrate personal commitment and enlist others to do things differently. Some of the areas to concentrate on include continuing education, protection for early adopters, and acceptance of failure by those who actively engage in developing an improved accounting system. Specifically, accountants must be integrated as stakeholders within operational processes. Another key is the establishment of a communication plan to all organizational interests including the board of directors, shareholders, customers,

suppliers, financial institutions, employees, and external auditors. The communication should give a good explanation of the change that will occur, the benefits, and the challenges that lie ahead.

As with any new idea or practice, the road of change is full of potholes and attempting any sort of modification to an established system will be perilous. Juran (2003) said that the greatest resistance is cultural and traditional accounting practices are *deeply* embedded in corporate culture. Nonetheless, modern managers must be bold in order to enact the lasting and positive change necessary for future prosperity. A dysfunctional dependence on traditional accounting systems may have created one of the worst economic disasters in global financial history. Published sources prior to 2008 called for change, but now their advocacy for a new accounting mindset now seems prophetic. Accounting lost respect because it did not keep up with the needs of operational managers and fostered a negative perception of unresponsiveness and control. Can we make accounting relevant again?

References

Clinton, B., & Webber, S. (2004, October). RCA at Clopay. (cover story). Strategic Finance, 86(4), 21-26. Retrieved October 30, 2008, from Business Source Premier database.

Clinton, D. B., & Keys, D. E. (2003). Resource consumption accounting: The next generation of cost management systems. Focus Magazine 5, Retrieved May 19, 2009 from http://www.focusmag.com/back_issues/issue_05/pages/rca.htm

Cochran, D.S. (2007). The need for a systems approach to enhance and sustain lean. In Stenzel, J. (Ed.), Lean accounting: Best practices for sustainable integration (pp. 263-295). Hoboken, NJ: John Wiley & Sons.

Cunningham, J. E., & Fiume, O. J. (2003). Real numbers: Management accounting in a lean organization. Durham, NC: Managing Times Press.

Davis, H., Appel, S., & Cohn, G. (2008, Winter2008). Free lunches and ROI: A modern fable. Management Accounting Quarterly, 9(2), 16-25. Retrieved October 30, 2008, from Business Source Premier database.

Deming, W. E. (1982). Out of the crisis. Cambridge, MA: MIT Press

Engle, P. (2005, October). Keep your books lean. Industrial Engineer: IE, 37(10), 22-22. Retrieved October 9, 2008, from Academic Search Premier database.

Feil, P., Yook, K. H., & Kim, I. (Spring 2004). Japanese target costing: A historical perspective. International Journal of Strategic Cost Management, 10-19. http://www.iwbestplants.com/2007confpdfs/SolvingtheStdCostProblemBW.pdf

Goldratt, E. M. (1992). The goal: A process of ongoing improvement. (2nd Revised Ed.). Great Barrington, MA: North River Press.

Huntzinger, J. (2007). Lean cost management: Accounting for lean by establishing flow. Fort Lauderdale, FL: J. Ross Publishing

Johnson, H. T., & Kaplan, R. S. (1991). Relevance lost: The rise and fall of management accounting. Boston: Harvard Business School Press.

Juran, J. M. (2003). Leadership for quality: An executive handbook. New York: Free Press.

Jusko, J. (2007, September). Accounting for lean tastes. Industry Week/IW, 256(9), 35-37. Retrieved October 9, 2008, from Academic Search Premier database.

Kaplan, R. S., & Bruns, W. (1987). Accounting and management: A field study perspective Boston: Harvard Business School Press.

Kroll, K. M. (2004). The lowdown on lean accounting. Journal of Accountancy. Retrieved May 20, 2009 from http://www.aicpa.org/pubs/jofa/jul2004/kroll.htm

Krumwiede, K., & Suessmair, A. (2007, June). Getting down to specifics on RCA. Strategic Finance, 88(12), 50-55. Retrieved October 30, 2008, from Business Source Premier database.

MacArthur, J. (2006, Winter2006). Cultural influences on German versus U.S. management accounting practices. Management Accounting Quarterly, 7(2), 10-16. Retrieved October 30, 2008, from Business Source Premier database.

Mansuy, J. (2000, January). Activity-Based Costing can improve project bidding. Industrial Management, 42(1), 6. Retrieved October 9, 2008, from MasterFILE Premier database.

Maskell, B. H., & Baggaley, B. L. (2006) Lean accounting: What's it all about? Association for Manufacturing Excellence. Retrieved on May 8, 2009 from: http://www.leanaccountingsummit.com/LeanAccountingDefined-Target.pdf

Maskell, B. H. (2007) Lean accounting: Solving the standard costing problem. Presentation retrieved on May 8, 2009 from:

Ohno, T. (1988). Toyota production system: Beyond large-scale production, New York: Productivity Press.

Productivity Press. (2005). Lean culture: Collected practices and cases. (Original work published in the Lean Manufacturing Advisor, 1999-2005.) New York: Productivity Press.

Schragenheim, E. (2000). Challenge your thinking on Theory of Constraints (TOC) accounting. Constraints Management SIG. Quarterly newsletter, winter. Retrieved May 27, 2009 from http://www.goalsys.com/books/documents/Eli-TOCAccountingArticle.pdf

Throughput accounting: A TOC center white paper. (1999). The TOC Center Consulting Group. Retrieved on May 27, 2009 from http://www.tocc.com/Articles/TA_TOCC.PDF

Womack, J.P. & Jones, D. T., (2003). Lean thinking: Banish waste and create wealth in your corporation. New York: Free Press.

Management

Development of a Quality Management Course for Adult Learners using Backward Design

Ms. Gretchen A. Mosher
Iowa State University, 1551 Food Sciences Building, Ames, IA 50011, (515) 294-6358, gamosher@iastate.edu

Dr. Steven A. Freeman
Iowa State University, 104 Industrial Education II, Ames, IA 50011, (515) 294-9541, sfreeman@iastate.edu

Dr. Dennis W. Field
Eastern Kentucky University, 320B Whalin Technology Complex, Richmond, KY 40475, (859) 622-6781, dennis.field@eku.edu

Dr. Charles R. Hurburgh, Jr.
Iowa State University, 1541 Food Sciences Building, Ames, IA 50011, (515) 294-8629, tatry@iastate.edu

Introduction

Adult learners often have specialized needs and may bring different motivations to learning environments than traditional aged students (Cranton, 2006). For those who develop and plan workplace training programs for adults, these needs must be taken into consideration during the development, creation, and implementation of workplace educational programs.

A great deal of adult learning takes place in the work environment, and workplace educational programs often focus on process improvement and strategic organizational change (Kleiner, Carver, Hagedorn, & Chapman, 2005). The introduction of a quality management system can offer solutions for some of the concerns above and many other business issues, but successful implementation of a quality management system is often a significant change, requiring the support and understanding of all employees (Das, Pagell, Behm, & Veltri, 2008). This is especially true in bulk product processing industries such as agricultural storage facilities where control and replication of processes requires a new business philosophy for both management and employees, (Hurburgh & Lawrence, 2003).

This paper will discuss how the backward design process (Wiggins & McTighe, 2005) was applied to develop a quality management course for adult learners. Although the backward design process was developed for use by elementary and secondary teachers, this alternative design methodology compliments the special requirements of adult learners by maximizing learning and understanding. Increased understanding may then positively influence the success of a quality management program within the workplace.

Quality Management Systems for Bulk Processing Operations

Although the process controls and verification of standards inherent to quality management systems are not new to other world industries, these ideas are a radical departure from the commodity-based system typical of agricultural processing firms (Hurburgh & Lawrence, 2003). Preliminary research on the use of quality management systems within an agricultural processing facility demonstrated several benefits, including increased operating efficiency, a better ability to meet customer specifications, and tighter security controls (Laux, 2007).

When transitioning from a commodity system to a controlled quality-based system, one of the biggest challenges when implementing such a system in many organizations is the management and retraining of personnel. Although quality management systems have been shown to increase revenue, improve inventory management, and allow increased compliance with legal regulations in the commodity agricultural environment (Laux, 2007),

these improvements cannot be realized if employees are not trained appropriately for their new tasks. For this reason, workplace training plays a major role in the successful adoption of quality management systems.

Adult Learners in the Workplace

Increasingly, the adult work force in the United States is participating in work-related educational activities. Forty percent of adults surveyed stated they had participated in a formal occupational education program, and 58 % reported taking part in an informal learning activity related to their job during the 2002-2003 calendar year (Kleiner et al., 2005). With this increase in educational activity has come concern and interest regarding the most appropriate learning style for adults.

Several components must be considered when working with adult learners. Cranton (2006) describes adult learning as voluntary, but she acknowledges that motivation and interest levels may be dependent on several components which cannot be controlled by the educational facilitator. Ortega et al. (2003) suggest the success of non-credit educational programs and curriculum depend heavily on the appropriateness and relevance of the subject matter content. Cranton (2006) agrees on the relevancy of the content but adds that a strong leader or facilitator can improve even mandatory educational programs. Chrusciel (2004) believes the perception of personal gain by participants also plays a role in how successful an educational program (and the change which accompanies it) is. These are just a few of the factors which must be addressed when developing an adult education program for the workplace.

Traditional curriculum and program development approaches have used the theoretical framework developed by Tyler (1949). This framework develops curriculum by answering four fundamental questions:

1. What is the purpose and goals of the curriculum?
2. What educational experiences must be provided to meet these goals?
3. How must the educational experiences be organized for the most effective instruction?
4. How can the goals be evaluated to determine the effectiveness of the educational experiences?

Although Tyler's approach has been validated and tested by countless curriculum professionals since its inception, some scholars see major shortcomings to this approach. Tyler's framework is a model of efficiency, standards, competency, and cost effectiveness – leading to a technical perspective of curriculum planning that has been the hallmark of career and technical education for several decades (Plihal et al., 1999).

Plihal et al. (1999) suggest that many adult learners do not function well under Tyler's approach or by using a technical perspective. Moreover, Knowles (1984) hypothesizes that adult students are motivated more by factors internally conceived rather than forced upon them by external forces such as exams. In addition, Johnstone and Rivera (1965) stress that adults prefer practical, applied and skill based knowledge over academic, theoretical, and informational knowledge. To meet the needs of adults, information must be useful, applicable, and relevant to their workplace situation and context. Acknowledging the previous experience of adult learners is also an essential component of successful adult education (Dollisso & Martin, 1999). Tyler's model typically does not account for personal life experiences or any diversity in contexts and therefore is not well suited for adult learners.

Backward Design Curriculum Methodology

Several curriculum design methodologies have been introduced as alternatives to Tyler's model and one of these is backward design. Backward design differs from traditional curriculum design in several ways. First, rather than defining goals, developing content around these goals, and assessing the goals at the end of the unit, backward design begins by determining what students should know at the end of the program or unit (called big ideas) and works backward from there to develop an assessment framework, create learning activities and align content appropriately.

Second, rather than treating all areas of knowledge as equally important, content areas are classified by relative importance within the curriculum. After determining which topics are the most important, educational activities and the curriculum scope and sequence can be developed based on the significance of the concepts rather than

simply moving sequentially from topic to topic.

A final difference between backward design and other curriculum approaches is the emphasis on the learning activities. Rather than determining the content based on a textbook or other external teaching aid, learning activities are developed to engage students so they understand concepts and patterns important to comprehension of the big ideas for the topic or program. Although these differences may not seem significant, they represent a radical and revolutionary departure from conventional curriculum design methodologies.

Although the backward design procedure is not intended to be a rigid methodology, it does follow a thoughtful and purposeful path focused on maximizing student learning. Backward design can be summarized by three steps (Wiggins & McTighe, 2005):

1. Identify desired results
2. Determine acceptable evidence
3. Plan learning experiences and instruction

Because the curriculum approach of backward design complimented many of the characteristics of adult learners, the backward design approach was chosen as the curriculum design methodology for the development of a continuing education program on quality management systems for a professional organization within the grain processing industry. The next section of the paper will describe the backward design methodology as it was applied to a quality management systems course for adult learners.

Methodology

The first step of identifying the desired results is perhaps the most difficult because it requires the instructor to prioritize and make choices about which content to include and which content to drop from the program. Ideally, educational programs could cover every conceivable bit of information the learner could possibly need, but this approach is not possible or practical. As part of the process of prioritizing subject area content, the educator might consult curriculum standards, learning outcomes, or, as in the case with work-related education for adults, the desired behavior or task changes.

One way many educators determine the desired results is by developing broad subject concepts into enduring understandings. These understandings are the "big ideas" of the program. All students are expected to complete the educational program knowing these concepts. In addition, all course content must be connected to at least one of these big ideas and core tasks (Wiggins & McTighe, 2005). Because of the broadness of the big ideas and core tasks, an educational program often has a small number of big ideas and core tasks. The big ideas and core tasks developed for this program are listed in Table 1.

Table 1. *Big Ideas and Core Tasks of Quality Management Educational Program*

1.	Quality management systems are a means of requiring discipline and reproducibility in a production process.
2.	Quality management systems are easily integrated with standard operating procedures and normal business activities.
3.	Quality management systems can be used as a solution for procedure-based business needs.
4.	Quality management systems depend on a strong framework of management, evaluation, and cost-benefit analysis.

Once the big ideas and core tasks have been identified, the next step is to determine how to know if the learners have attained the knowledge and skills needed for these concepts by creating acceptable evidence of learning. Tasks and criteria are developed to measure the learner's level of understanding and knowledge of each big idea. For adults in a work environment, this might include criteria such as observations, performance appraisals, or unit production quotas or it may also include the ability to perform specific skills or actions. Once learner tasks and criteria are created and an evaluation plan is established, developing relevant and appropriate content to support

the tasks becomes relatively straightforward (Wiggins & McTighe, 2005). Acceptable evidence of learning for this program is identified in Table 2.

Table 2. *Acceptable Evidence of Learning*

At the end of the course, students will be able to:
1. Create a basic process flow analysis of their operations area and identify critical control points for quality, economics, and security.
2. Write basic procedures and work instructions following a prescribed quality format.
3. Integrate daily procedures and tasks into a quality management system configuration.
4. Collect and organize data from daily operations for use in evaluation and cost-benefit analysis.
5. Work effectively with other team members to continually improve facets of the quality management system.

The development of specific content is the final step. During the third step of planning learning experiences and instruction methods, the educator must consider the specific knowledge, skills, and activities needed for the learners to reach the desired results and how the information generated by these learning experiences will be presented. This portion of the curriculum includes the specific content for each learning session and may consist of an overview of the lesson, learning outcomes specific to that session, presentation format and media needs, source materials, and the facilitator or leader of the session, if applicable. A condensed example of learning experiences and instruction methods for one unit is shown in Figure 1.

Figure 1. *Learning Experiences and Instruction Methods*

Unit 4: Quality Management System in Inventory Management
Learning Outcomes:

1. Explain the financial importance of inventory management for the grain storage facility.
2. Summarize the challenges of inventory management in the grain storage facility.
3. Describe how quality management systems can address several identified inventory management issues within the grain storage facility.

Source Materials: Laux dissertation

ISO 22005, 22006, 9001:2000 documents

Hurburgh Power Point Presentations 2002-2008

Facilitator: C. Hurburgh **Media:** Power Point software

Additional information that could be added includes a bullet point outline of the content of the lesson and additional specifics on the presentation format. However, the information shown above gives both students and facilitators a good idea of the scope of the unit. At this point, the bulk of the intellectual development on the unit is complete. All that remains is to fill in the content details.

Implications and Recommendations

Introducing change into an organization is never easy and a quality management system represents substantial organizational change. However, firms which do not make strategic changes do not grow, therefore, finding an effective way to reach adult learners within an organization is imperative to continual strategic and quality improvement (Carr, 2000).

It is well known that adults learn different than younger students (Cranton, 2006). Adults have different motivations and experiences and tend to learn better in more realistic environments. The backward design methodology allows instructors the flexibility to develop learning environments based on practical, relevant, and applicable knowledge rather than being constrained by material from a textbook or other external source.

If the organization knows what information it needs to pass on to its employees, backward design can be used to develop an educational program to teach that information. In addition, the limited emphasis on testing and the ability to classify information by its relative importance gives leaders and facilitators a better tool to emphasize content that is particularly important and focus less attention on smaller points and details. Developing the evaluation plan and summative goals first allows the content of the course to be directly linked to learner evaluation, positively influencing their knowledge and achievement.

In the case of quality management systems, where employee participation and behavior are key components of the program's success, it is especially important to ensure the relevancy of the content and to have a strong evaluative framework. Backward design allows for both of these items. Because of this and the user-friendly nature of the framework from both the learner and educator perspective, the backward design methodology should be a strong contender for use in the development of any workplace adult education program.

References

Carr, A. (2000). Critical theory and the management of change in organizations. Journal of organizational change management, 13(3), 1-11.

Chrusciel, D. (2004). Considerations for dealing with significant organizational change. Unpublished doctoral dissertation, Iowa State University. Dissertation Abstracts International A65/08.

Cranton, P. (2006). Understanding and promoting transformative learning: A guide for educators of adults (2nd ed.). Jossey-Bass: San Francisco, CA.

Das, A., Pagell, M., Behm, M., & Veltri, A. (2008). Toward a theory of the linkages between safety and quality. Journal of operations management, 26(4), 521-535.

Dollisso, A. & Martin, R.A. (1999). Perceptions regarding adult learners' motivation to participate in educational programs. Journal of agricultural education, 40(4), 38-46.

Hurburgh, C.R. & Lawrence, J.D. (2003). The need for quality management systems. Resource: Engineering and technology for a sustainable world, 10(9), p. 29.

Johnstone, J.W. & Rivera, R.J. (1965). Volunteers for learning. Aldine Publishing: Chicago, IL.

Kleiner, B. Carver, P., Hagedorn, M., & Chapman, C. (2005). Participation in adult education for work-related reasons: 2002-03 (NCES 2006-040). U.S. Department of education, National Center for Education Statistics. Washington, D.C: U.S. Government Printing Office. Downloaded July 6, 2009 from http://www.nces.ed.gov/pubsearch.

Knowles, M.S. (1984). Andragogy in action: Applying the principles of adult learning. Jossey-Bass: San Francisco, CA.

Laux, C.M. (2007). The impacts of a formal quality management system: A case study of implementing ISO 9000 at Farmer's Cooperative Co., Iowa. Doctoral dissertation, Iowa State University. Dissertation Abstracts International B68/07.

Ortega, R.R., Tormoehlen, R.L., Field, W.E., Balschweid, M. & Machtmes, K.L. (2003). Determining critical subject matter content for a safety certification program for youth employed in agricultural production. Journal of agricultural education, 44(4), 67-79.

Plihal, J., Laird, M. & Rehm, M. (1999). The meaning of curriculum: Alternative perspectives. In J. Johnson and C.G. Fedje (Eds), Family and consumer sciences teacher education: Yearbook 19. Family and consumer sciences curriculum: Toward a critical science approach (pp 2-22).Peoria, IL: Glencoe/McGraw-Hill.

Tyler, R.W. (1949). Basic principles of curriculum and instruction. University of Chicago Press: Chicago, IL.

Wiggins, G. & McTighe, J. (2005). Understanding by design (2nd ed.).Association for supervision and curriculum development, Merrill/ Prentice Hall: Alexandria, VA.

Management

Using Mock Recall Data to Measure Continuous Quality Improvement

Ms. Gretchen A. Mosher
Iowa State University, 1551 Food Sciences Building, Ames, IA 50011, 515 294-6358, gamosher@iastate.edu

Dr. Chad M. Laux
Purdue University, 309 Knoy Hall, West Lafayette, IN 47905, 765-648-2905, claux@purdue.edu

Dr. Charles R. Hurburgh, Jr.
Iowa State University, 1541 Food Sciences Building, Ames, IA 50011, 515 294 8629, tatry@iastate.edu

Introduction

Continuous quality improvement is essential to firms who wish to function within a global business environment. Strategic quality improvement is often facilitated through a formalized quality management system (West & Cianfrani, 2004). Quality management systems have been used for many years in industries such as manufacturing and health care to improve efficiencies and maintain high levels of customer satisfaction (Deming, 2000; Bowersox et al., 2007), but their use in processing industries such as food and agriculture is a more recent trend (Hurburgh & Lawrence, 2003). These systems provide a way for firms to focus on customer requirements and tighten their supply chains by clearly defining and controlling their operations and processes (West & Cianfrani, 2004).

The development of a quality management program has many steps and planning may require twelve months or longer. Implementation may take several additional months (Hurburgh, 2002). Because of the many resources needed to develop and implement a quality management system, an assessment of the program's efficiency is necessary. An effective evaluation plan is important for two reasons: first, to determine the effectiveness of the implementation and second, to facilitate continuous improvement within the organization (Fitzpatrick et al., 2004; Laux & Hurburgh, 2008).

An impartial third party audit provides validation needed for quality management system certification or other documentation of strategic quality measures (Hurburgh, 2002). Audits occur infrequently and are usually performed by outside personnel. The need exists for a quicker, internal, and more frequent way to evaluate a quality management system. This paper will discuss mock recall as a possible tool to evaluate a quality management system for a processing firm more quickly and frequently using internal personnel.

Quality Management Systems in Processing Firms

Process controls and verification of standards inherent to quality management systems are not new to other industries, but these ideas are a major departure from business as usual for commodity-based food and agricultural firms (Hurburgh, 2002). Preliminary research has illustrated several benefits for agricultural and food processing facilities which implement quality management systems. Research completed by Laux (2007) illustrated the following benefits for the agricultural processor studied:

- Improved operating efficiency resulting in process cost savings
- Increased ability to meet customer product requirements
- Provided tighter food security controls

Quality management systems have the potential to provide greater inventory and process control. To take advantage of this, some type of an evaluation must be used on a regular basis. To assist in this effort, continuous improvement tasks are coordinated by personnel to keep the quality system relevant and meaningful (Taormina & Brewer, 2002). Data collected from daily operational tasks allows the firm to measure the program's success as well as provide data for future decision-making.

Recalls in the Processing Industry

The goal of manufacturers and processors is to prevent recalls. Although recalls are unpredictable, it is in the best interest of the company to manage any recall that does occur so that it runs as smoothly as possible (Kaletunc & Ozadali, 2002). To facilitate an organized and well-prepared recall, a documented recall program should be developed by the firm before a recall occurs (Keener, 2007). A recall plan is also an important component of inventory and process control, and can also address food traceability concerns (Laux & Hurburgh, 2008).

A written recall plan includes several parts; each component tested for effectiveness through a mock recall exercise. A mock recall is designed to occur randomly and is typically unannounced (Keener, 2007; Mosher & Brumm, 2008). The goal of a mock recall exercise is to test the recall procedure(s) by evaluating the firm's ability to locate and isolate all of its product(s). The exercise may be timed and may also employ a third party to evaluate both the recall procedures and the firm's performance on the mock recall (Keener, 2007).

Legislative Requirements

Mock recalls are based on requirements of the U.S. Public Health Security and Bioterrorism preparedness and Response Act of 2002 (Food and Drug Administration, 2002). This legislation requires all companies involved in the food and feed industry to register with the Food and Drug Administration (FDA). Section 306 of the 2002 Act requires all companies to register and keep records identifying immediately previous sources and the immediate subsequent recipients of materials used in food and feed (Food and Drug Administration, 2002). Companies have used mock recalls before but the legal requirements of FDA traceability have prompted many organizations to develop and employ mock recall exercises for the first time (Foukes, 2005).

To facilitate timely information release for potential recall, FDA requires a company to produce the records within 24 hours of the initial request (Food and Drug Administration, 2002). However, the legislation only requires that the records are presented within 24 hours. The agency does not specify the veracity of the data collected. Records may not necessarily be accurate or complete – but if they are produced within the required time frame, they meet the legislative regulation. To help firms prepare, mock recalls are often instituted within a quality management system (Laux, 2007). A mock recall in a quality management system measures data accuracy since a thorough analysis may be performed during and after the exercise, unlike an actual recall event.

Conducting the Mock Recall

To conduct a mock recall, the facility manager randomly chooses a product and announces that the product in question must be identified and isolated from the remainder of the goods. In the case of a mock recall, the product which cannot be verified as safe may remain in storage, in an authentic recall, all products which cannot be confirmed as safe would be destroyed.

The frequency of the mock recall exercise may vary, depending on two factors. First, the maturity of the quality management program and recall plan and second, past performance on previous mock recall exercises are also noted (Foukes, 2005). A mature quality management system with a recall plan may only conduct a mock recall drill once or twice annually. An organization with a new quality management system and recall program may need additional drills. Past performance should also impact the frequency of mock recall exercises. If the firm performs poorly on a series of mock recall exercises, additional practice with recall procedures may be warranted (Foukes, 2005).

Several recall scenarios may be tested by a mock recall exercise. A forward recall attempts to locate product sent from a supplier to an unknown customer or firm. The forward recall is often used as part of Good Business Practices (GMPs); it is not typical of most recalls requested by the FDA. More frequent is the backward recall: a contaminated product must be traced from the customer to the supplier and originating manufacturer (Laux & Hurburgh, 2008).

When a firm has accurate records of suppliers and subsequent customers, a recall of a single ingredient is easily handled. However, a more challenging situation is a recall of a finished product, where multiple contaminated ingredient are unknown and accompanying lot numbers of all raw materials must identified and located. This type of scenario may severely test the 24 hour time limit (Foukes, 2005).

Performance Indicators

Several indicators may be measured during a mock recall exercise. Two events are tested for effectiveness: the ability to trace products or ingredients and how well the recall team communicates and functions during a recall scenario (Foukes, 2005). Additional information gathered during a mock recall may include the number of hours required to provide the recall information required by the FDA and the potential financial loss from suspect product which cannot be identified or located (Mosher & Brumm, 2008).

Methodology

Data for this evaluation was taken from summaries of a series of mock recall exercises completed in 2006, 2007, and 2008. An example of a mock recall procedure is shown in Appendix A.

Several research questions guided the collection and analysis of mock recall data.

1. Can mock recall data be used to evaluate the yearly performance and compliance of processing sites per the 24 hour requirement of the Bioterrorism Act of 2002?
2. How can mock recall data be used to measure effectiveness of recall procedures?
3. Can mock recalls provide a rapid method of evaluating continuous quality improvements in organizations using quality management systems?

Results

This project examined a quality management system that was implemented within an agricultural processing facility. Two performance indicators are measured in a mock recall: the time in hours needed to produce the required records and the amount of product which would be destroyed if the source or recipient could not be verified. The second of these indicators could be used in a second tool used to measure the effectiveness of the quality management system. This tool is known as the traceability index and it is described in greater detail by Laux and Hurburgh (2008).

Using SPSS version 14, several data sets were analyzed. The first set was the number of hours needed to produce all required records. The number of hours was defined by the time the mock recall was returned to management by email subtracted from the time it was delivered. The mean number of hours it took the processing facilities to run the mock recall exercises each year were measured. A significance test compared the group means of each year's data and a confidence interval was constructed to determine the magnitude of the difference among years within a 95 percent confidence level (Bonett & Wright, 2009).

The second piece of data was an examination of the traceability index. This measure assigns a quantitative measurement of the source(s) of the current inventory of grain held by the facility and determines the effectiveness of the mock recall. Table 1 displays the mean number of hours and the mean traceability index values of each year and 95% confidence intervals for each mean value.

Table 1. *Means and Confidence Intervals for Recall Hours and Traceability Index Values*

Measure	Year	Mean	95% Confidence Interval Bounds
Recall Hours	[1]2006	11.75	Lower 5.12 Upper 18.37
Recall Hours	[2]2007	18.01	Lower 12.08 Upper 23.94
Recall Hours	[3]2008	5.28	Lower 1.76 Upper 8.81
Traceability Index	[1]2006	417.35	Lower 110.22 Upper 724.47
Traceability Index	[2]2007	443.46	Lower 296.30 Upper 590.62
Traceability Index	[3]2008	320.36	Lower 54.53 Upper 586.19

[1]n = 9; [2]n = 16; [3]n = 18

Significance tests were performed to compare the recall hours needed and the traceability index values each calendar year. Table 2 illustrates these results.

Table 2. *T-Tests of Differences in Group Means*

Measure	Years Compared	Mean	Significance
Recall Hours	[1]2006 [2]2007	8.55 16.63	0.296
Recall Hours	2007 [3]2008	16.63 4.52	0.010*
Recall Hours	2006 2008	8.55 4.52	0.013*
Traceability Index	[4]2006 [5]2007	386.20 443.46	0.438
Traceability Index	2007 [6]2008	443.46 277.47	0.640
Traceability Index	2006 2008	386.20 277.47	0.921

* Significant at p-value of 0.05; [1]n = 21; [2]n = 19; [3]n = 23; [4]n = 10; [5]n = 16; [6]n = 27

Discussion and Implications

The measurement of the number of hours needed to gather information for a mock recall exercise showed interesting patterns. From 2006 to 2007, an increase in the number of hours needed for the firm to provide the required information from a mock recall was noted, but not significant. However, great improvement was documented in 2008, confirmed by significant differences in the number of hours needed in 2008 with those in 2006 and 2007. The relatively narrow confidence interval in 2008 also provides data which illustrate improvement in the quality management system.

Basic data from mock recall exercises can be used as a very rough measure of the success and yearly improvements of a quality management system, the traceability index provides data on information accuracy. The effectiveness of the recall information is what will determine the effectiveness of an actual recall event (Foukes, 2005). Thus, the traceability index provides an important evaluative component. Traceability indices are high with no significant improvement from year to year.

Large confidence interval boundaries also indicate a wide distribution of values, leading to the conclusion that while the quality management systems may allow the firms to meet the legislative requirements, the goal of tighter inventory management has not been met by the majority of the firms. The narrowest confidence interval was noted in 2007, but the mean value of the traceability index was the highest of all three years' data. This indicates that 2007 was not a positive year for improvements in inventory management or traceability capabilities for the organization.

This specific case does show that the mock recall exercise can be used as an evaluation tool for both the recall procedure and for a quality management system focusing on traceability and inventory control. Two factors which play a role in the power of mock recall to assist in evaluation is the quality of the data and the number of exercises to evaluate. The data collected must be valid and usable and this quality level rests heavily on employee actions. If employees do not collect daily operations data appropriately, evaluation of the system using mock recall exercises is much more difficult, if not impossible. In addition, the greater the number of exercises to evaluate, the more opportunities the firm has for feedback and refinement of their mock recall procedures and their quality management system. Ultimately, greater improvement in these areas may lead to improvements in quality processes at the organizational level.

Although many firms find mock recall exercises to be an inconvenience, the evaluative potential of mock recalls will assist the firm in the event of an actual recall. Without rehearsal, organizations will find themselves unprepared. Many quality management systems include product traceability as a requirement, therefore, it is in the best interest of firms to follow through with mock recall to measure effectiveness, prepare for future events, and ensure continuous quality improvement.

References

Bonett, D.G. & Wright, T.A. (2009). Using confidence intervals in supply chain and operations research. *Journal of supply chain management*, 45(1), 26-33.

Bowersox, D., Closs, D., & Cooper, M.B. (2007). *Supply chain logistics management*. New York, NY: McGraw Hill.

Das, A., Pagell, M., Behm, M., & Veltri, A. (2008). Toward a theory of the linkages between safety and quality. *Journal of operations management*, 26(4), 521-535.

Deming, W.E. (2000). *Out of the crisis*. Boston, MA: MIT/CAES

Fitzpatrick, J.L., Sanders, J.R., & Worthen, B.R. (2004). *Program evaluation: Alternative approaches and practical guidelines.* (3rd ed.) New York: Longman.

Foukes, M. (2005). A survival guide to traceability and recall. *American Institute of Baking (AIB) Quarterly*, Spring 2005, 11-13.

Hurburgh, C.R. & Lawrence, J.D. (2003). The need for quality management systems. *Resource:Engineering and technology for a sustainable world,* 10(9), 29.

Hurburgh, C.R. & Hansen, R.S. (2002). Quality management systems for agriculture: Principles and case studies. Presentation given at the 2002 Integrated Crop Management Conference, Ames, IA, December, 2002.

Kaletunc, G. & Ozadali, F. (2002). Understanding the recall concept in the food industry. The Ohio State University Extension Publication AEX-251-02. The Ohio State University: Columbus, OH. Downloaded on July 7, 2009 from http://ohioline.osu.edu.

Keener, K. (2007). A recall program: Hazard analysis critical control point. Purdue University Extension Publication FS-23-W. Purdue University: West Lafayette, IN. Downloaded on July 7, 2009 from www.foodsci.purdue.edu/outreach.

Laux, C.M. (2007). The impacts of a formal quality management system: A case study of implementing ISO 9000 at Farmer's Cooperative Co., Iowa. Doctoral dissertation, Iowa State University. Dissertation Abstracts International B68/07.

Laux C.M. & Hurburgh, C.R. (2008). Using quality management systems to meet food traceability requirements of the Bioterrorism Act of 2002. In *Selected Proceedings Papers – 41st Annual Conference of the National Association of Industrial Technology.* Nashville, TN, 18-22 November.

Mosher, G.A. & Brumm, T.J. (2008). Quality management systems in agriculture. In *Preservation of grain quality*. Internal text used by Iowa State University Department of Agricultural & Biosystems Engineering. Iowa State University: Ames, IA.

Taormina, T. & Brewer, K.A. (2002). *Implementing ISO 90001:2000: The journey from conformance to performance.* Prentice Hall PTR: Upper Saddle River, New Jersey.
United States Food and Drug Administration. (2002). Establishment and maintenance of records under the public health security and bioterrorism preparedness and response act of 2002. Docket No. 2002N-0277. FDA: United States Health and Human Services: Washington, D.C. Downloaded on October 26, 2006 from: www.fda.gov/oc/bioterrorism/bioact.html
West, J.E. & Cianfrani, C.A. (2005). *Unlocking the power of your qms: Keys to business performance improvement.* American Society of Quality, Quality Press: Milwaukee, WI.

Appendix A – Mock Recall Procedure

Copyright 2005 Farmer's Cooperative Company

Procedure for Commodity Grain Recall:

The Grain Marketing Manager shall initiate the recall by calling the Location Manager. The notification of recall shall be made via telephone, and shall also be documented in writing and may be transmitted via FAX or e-mail. The recall notification shall include as much pertinent information as possible such as:

- Reason for the recall
- Customer name
- Date and scale ticket number (if known)
- Train ID number

The Location Manager shall lead the recall process, with the assistance of designated personnel, who are assigned responsibility for the following:

1. Locate and secure for future reference retained grain samples. If testing or grading procedures are available, conduct an initial examination to determine if reported problem can be identified in the sample.
2. Identify all bins that contributed to the loading of the train (if applicable).
3. Determine for <u>each</u> bin, a point in time when it was known that the contamination did not exist determined by (which ever is later):
   a. Date of previous uncontaminated shipment from bin.
   b. Date of bin being completely emptied.
4. Compile scale ticket identification of all receipts and in-house transfers put into bins from the point in time when no contamination was known to exist.
5. Compile a list, based on Scale Ticket identification, of dates and names of all possible origins of contaminated grain.
6. Compile a summary of the recall.
7. To assist in identifying the records normally associated with a recall, FC QMS Form, *Commodity Grain Recall Record Checklist* shall be filled out. The Location Manager shall compile a folder containing copies of applicable records which may include:
   - *Recall Notification* noting Train ID Number or Scale Ticket Number and issues necessitating the recall.
   - *Loading Order*
   - *Grading Comparison*
   - *Stock Transfer Report*
   - *Quality & Quantity Blending Spreadsheet* for train being recalled
   - *Quality & Quantity Blending Spreadsheet* for previously loaded trains (Any train loaded from bins associated with recall)
   - *In-house Bin Transfer Log*
   - *Empty Bin Sanitation Log*
   - *Bin Entry Permits*
   - *Scale Ticket Report* for all bins associated with recall
   - *Customer Position Report*
   - *Scale tickets* (If requested by Grain Marketing)
   - *Nonconforming Grain Report* (ISO 9001:2000 locations)
8. As soon as possible, the Commodity Grain Recall Report and documentation folder shall be delivered to, the Grain Marketing Manager at which time all information shall be reviewed.

Manufacturing

Manufacturing

Horizontal vs. Vertical Axial Flux Wind Turbine Design and Manufacture

Dr. John L. Irwin
Michigan Technological University, School of Technology, Houghton, MI 49931, 906 487-2525, jlirwin@mtu.edu

Abstract

Two undergraduate student senior project designs are presented comparing the advantages and disadvantages of horizontal verses vertical axis residential wind turbine designs (HAWTs and VAWTs) using identical axial flux alternator units. The design parameters, project budgets, bench test power/speed curves, and physical testing results are discussed. The HAWT project has eight foot diameter, wooden, fiberglass coated blades; and the VAWT project has three foot diameter, four foot high, aluminum blades using the "Lenz Wing" shape. (Lenz, 2005) The alternators consist of a polyester resin & fiber glass cloth constructed stator disk that is sandwiched between two magnet rotors. Magnetic flux passes through the assembly producing alternating current. Variables that are used to compare the two designs are the materials and manufacturing costs; manufacturing methods utilized; wind speed vs. power output curves; and bench and field testing. Contrary to the belief of certain experts in residential wind power, this VAWT design was found to be less expensive and labor intensive to manufacture than the HAWT. The efficiency of the turbines has not yet been determined because of lack of field testing data. Bench testing illustrates similar amperage being produced in the two alternators, but the power output curve is different based on assumptions made for miles per hour of wind speed necessary to produce a given revolution per minute for the turbines. Based on these assumptions the HAWT is predicted to have a higher power output in Watts at lower wind speed, approximately 1100 Watts at 18 mph, where the VAWT would need nearly a 40 mph wind to produce the same 1100 Watts.

Introduction

Because of recent interest in green technologies related to wind energy there is significant debate on the topic of a HAWT and VAWT wind turbine design. Some of the most recent turbines on the market are VAWTs, which manufacturers claim are quiet, efficient, economical and perfect for residential energy production. The debate is over the high cost of manufacturing and efficiency of the VAWT as reflected in a recent Mother Earth News interview, by Alison Rogers, with Mick Sagrillo, veteran residential wind power authority in the following statement;

> "The bottom line is, vertical axis turbines are less efficient, and it takes more materials and labor to make the things. It's pure economics. Things make it in the marketplace because number one, they work, and two, they're cost effective. If you have a technology that's more cost effective and more reliable, than the competing technology, the competition is going to fall out of the marketplace." (Rogers, 2008)

Savonius and Darrieus Models

Recently, some VAWT blade designs which use an airfoil wing design have been designed to challenge the claim of less efficiency and high cost of manufacture. There are two different types of blade designs for VAWTs; one is the Savonius model that resembles an anemometer which has three cups rotating on a shaft; and the other is the Darrieus model that resembles an egg beater with blades that have a flat side and a curved side to create lift. The air passing over the airfoils (wind turbine blades) are converted into rotational momentum which spins the generator similar to the HAWT models, but the difference is that the HAWT blade swept area always faces the wind using a furling tail similar to the way a weather vane works. The VAWT swept area is a cylinder perpendicular

to air flow, but while part of the "swept area" is working the other blade or blades are not at an optimal angle to generate lift. The challenge in a VAWT design is to optimize the shape and angle of the Savonius blade to minimize the drag caused by the blades not facing into the wind. (Rogers, 2008)

The Lenz Wing

A turbine blade designer, E. Lenz, using a combination of Savinous design along with the venturi theory came up with a design that is similar to the Darrieus, but with wings similar to the Savonius, and a triangular drum in the middle to guide the flow of air. The "Lenz Wings" are simply constructed using plywood and aluminum flashing to form the airfoil blades. Lenz credits all those before him for their unique and innovative work in this field, and especially Hugh Piggott for helping him with the formulas for working out the wing angles based on the Darrieus type of blade design. The diagram below shows the 2 foot diameter by 2 foot high design from a top view. (Lenz, 2005)

Figure 1: *Lenz Wing*

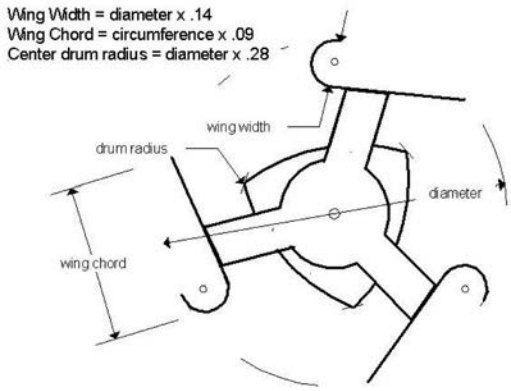


Figure 2: *Lenz2 Wing*

Later the Lenz2 Wing design was introduced without the center drum using a modified wing shape and angle, supported on the top and bottom with bearings. This unit measures 3feet in diameter by 4 foot tall and produces a reported 52 watts of power in a 12.5 mph wind with a 12 pole 3 phase alternator. This is the basis to the VAWT design used by the spring 2009 senior project team with an innovative blade mounting system and alternator arrangement. (Lenz, 2005)

Hugh Piggott HAWT blade design

The fall 2008 senior design team modeled their HAWT turbine after the Hugh Piggott design described in the publication, "How to Build a Wind Turbine", which outlines designs for 4 foot, 8 foot, and 12 foot diameter blades and corresponding alternators for residential use. (Piggott, 2005) The 8 foot diameter blades using wood construction rather than molded fiberglass were selected because of the one-off design circumstances. Three blades are used in the design to limit the amount of drag at higher speeds. For instance, four blades would create more torque and would start the blades turning at lower wind speeds, but would limit the power at high speeds because of the increased amount of drag.

The tip speed ratio (TSR) for HAWT designs are much higher than for the VAWT designs. The TSR is the speed the blade tips travel divided by the wind speed at that time. For the 8 foot diameter HAWT blade design a TSR of around 7 means the speed of the blades at the tips are turning at a speed 7 times that of the wind speed. The two foot diameter Lenz design has a reported TSR of only about 1.3 partially because of the small diameter. One noted disadvantage of a high TSR is that it causes noisy operation and erosion of the blade surface. The assumption used for calculating the electrical power/speed curve (using metric units) is that RPM=(wind speed x TSR x 60)/

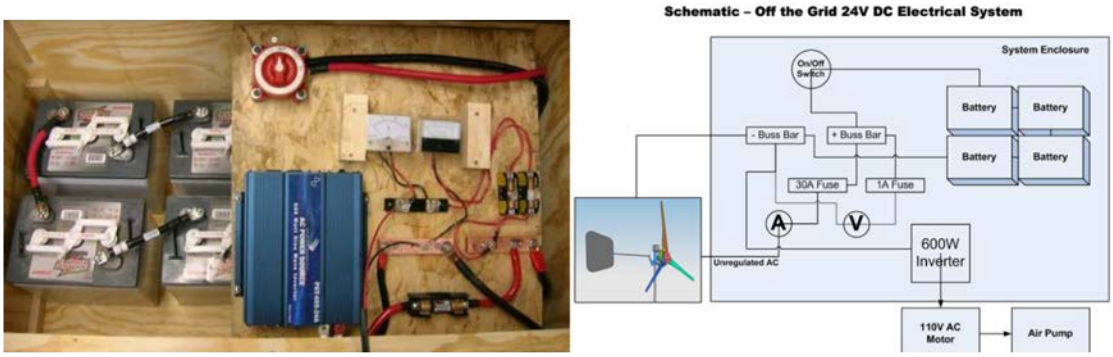
circumference, or wind speed= RPM x circumference/TSR x 60. For example, in a 7 mph wind (3 m/sec) this corresponds to 167 RPM that the turbine will run in the best conditions. (Piggott, 2005)

The Hugh Piggott blade design calls for a specific blade shape that changes in size and angle from the tip to the root defined at 6 stations spaced 8 inches apart. Each station has a specific width, drop and thickness. The blades can be carved using hand tools, but the senior design team opted to create a 3D model in NX5 CAD/CAM software to generate a tool path which was post processed to M & G code for a Haas VF3 machining center. Using a 3/8 diameter ball end mill the program created 3 identical blades that had the exact geometry necessary for the proper Darrieus wing lift.

Design Parameters

Both the VAWT and the HAWT designs use an identical alternator design consisting of two magnet rotors with 12 magnets each, and one stator made up of 10 coils producing a 5 phase alternating current at 24 volts. An identical battery box was used for bench testing purposes, which later was fitted with charge and load controllers as well as other safety devices for use in the field.

Figure 3: *battery bank*



Four golf cart batteries were used which is a good capacity match to the size of the turbines and is a method commonly used for wind turbines of this size. There is a marine battery switch on the positive lead to turn on or off both charging and discharging of the batteries. There is a voltmeter wired in parallel protected by a 1 Amp fuse, this is to measure the level of charge in the battery bank. On the input side of the battery bank is an ammeter which is protected by a 30 Amp fuse. The ammeter is wired to a shunt which is wired in series to the output of the alternator. The ammeter measures the voltage drop of the shunt and displays the current output of the turbine. By multiplying the output current times the voltage of the system, the power output of the system can be determined. Another feature of this battery bank is a 600 Watt pure sine wave inverter protected by a 60 Amp fuse which is used to convert the stored DC to AC that can be used by household appliances.

Alternator Design

The steel disks can be purchased prefabricated or machined from 5/16 inch thick mild steel plate. The magnets are Neodymium iron boron NdFeB plated block magnets. A magnet positioning jig was built from ¼" plywood in order to equally space the 12 magnets on the steel disk. The jig was placed on the steel disk and the magnets were carefully placed on it in their proper location. Contact cement was used to permanently hold the magnets into place.

Figure 4: Rotor Magnets, Painted Rotor, and Rotor Mold

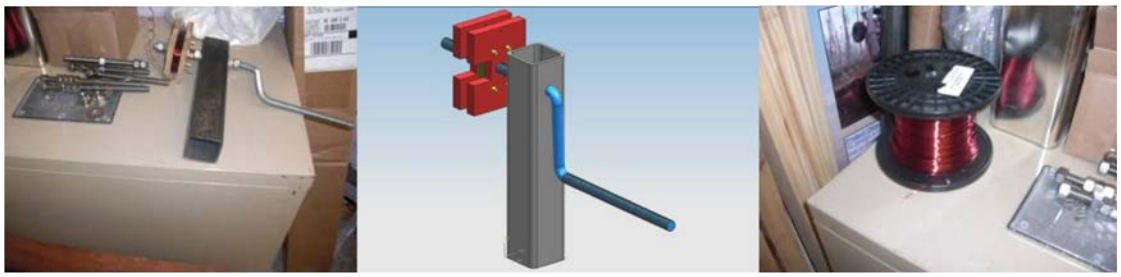
In order to pour resin into the assembly, a plywood mold was created. The molds for the rotor consist of a base, center mold, and the lid. The steel disk and magnet assembly were placed into the mold, and fiber glass cloth was placed above the assembly. The resin and catalyst where mixed and poured into the mold, and the mold lid was bolted and clamped down into the base and mold center. The resin was allowed time to be cured before disassembly and surface finishing of the stator. The air gaps in the rotor surface were filled with epoxy in order to protect the magnets from corrosion. The rotors were then sanded, primed and painted.

The alternator consists of a stator disk that is sandwiched in between the two magnet rotors. Magnetic flux passes through this assembly and produces alternating current. The stator is made out of polyester resin & fiber glass cloth and consists of ten coils. The coils are made using # 18 enamel winding wire, also known as magnet wire.

Figure 5: *Stator, Rectifier and Stator Mold*

The coils were manufactured using a coil winder made by the team. The number of turns of wire in each coil determines the speed of the wind turbine and the voltages it produces. The number of turns used was 150 producing approximately 24V. The coil winder and the wire reel were clamped down onto the work bench. The wire was fed between the cheek pieces of the coil winder, and the winder was then reeled counting each turn. Electrical tape was used to secure the coil from unwinding before removal from the winder.

Figure 6: *Coil Winder, CAD model, and Copper Wire*



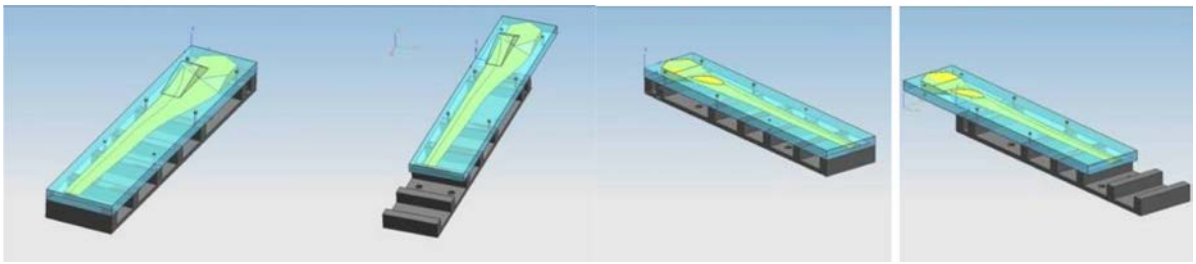
The coils were equally laid out in an 8" diameter circle formation. The rings neutral was soldered onto the start of each coil, and extension wires were soldered onto the output of the coils. In order to pour resin into the assembly, a mold was required to form the shape of the stator. The mold parts for the stator consist of a base, center mold, and the lid. The coil and wire assembly were placed into the mold, the fiber glass cloth was placed below and above the assembly, and finally the resin and catalyst where mixed and poured into the mold. The mold lid was bolted and clamped down into the base and mold center. The resin was allowed time to be cured before disassembly and surface finishing of the stator.

Project Budgets

Disregarding the cost of the battery box and alternator, which were identical for the VAWT and the HAWT turbine the remaining components of the design consist of the blades, mounting structure, and hardware. The method of blade construction has been introduced briefly, but the detail manufacturing methods, cost of materials, and time invested has not been discussed.

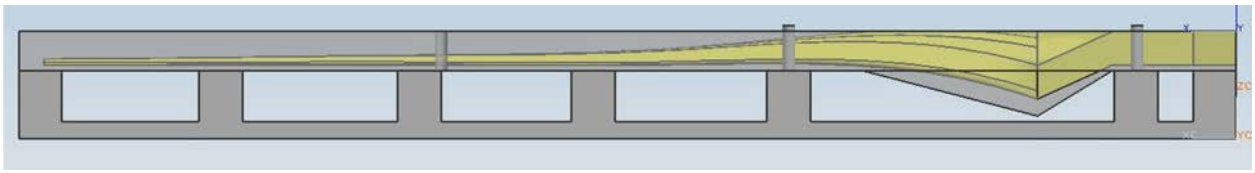
A fixture for machining the blades added an additional cost for the HAWT design. The VF3 machine center has a travel of 36" and the tool path was over 48". To locate the part twice without losing the program reference zero offset settings location, a jig with four locating dowels was used so the part could be lifted and indexed so the second half of the blade could be machined. The process was repeated to machine both the top and the bottom of each blade.

Figure 7: *HAWT Blade Fixture*



The blank (shown in blue) has a unique shape, this was chosen to shorten machining times and wood scrap. To get a work piece with this shape, each blank was laminated using 12 strips of select pine which was free of defects and knots. Three of the strips have a unique shape to allow for the ear that sticks above the rest of the blade, are joined using weather-proof glue.

Figure 8: *HAWT Blank and Blade*



After the blades were machined they had to be sanded extensively to create a smooth surface. After each blade was sanded to its final shape, each blade was fiber glassed with one layer of fiberglass (S-glass) with polyester resin. This made the blades much more rigid and durable.

Figure 9: *HAWT CNC Tooling Marks and Fiberglass*

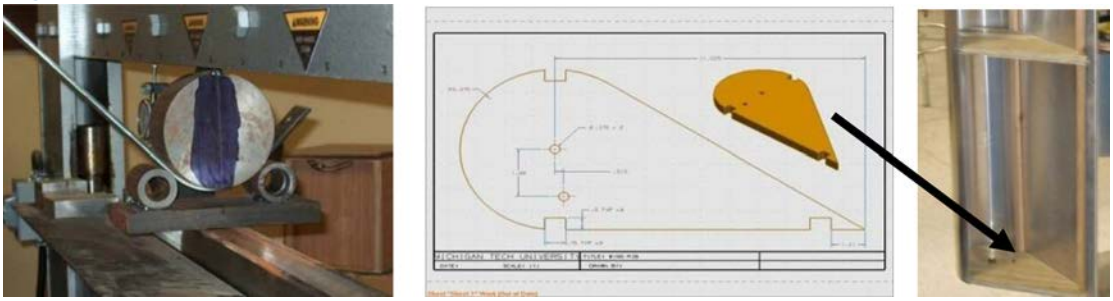
The HAWT bracket assembly is what supports the entire weight of the turbine, as well as what turns the machine into the wind and away from the wind in high wind or storm conditions.
The bracket assembly is manufactured using simple steel cross-sections which include angle iron and structural pipe. The 1 ¼" stub axle and trailer hub is welded directly to the assembly.

Figure 10: *Trailer Hub Mounting Assembly*

The material for the HAWT blades including material for the fixture was $310.38, and the steel mounting bracket and mounting hardware was $165.60. The manufacturing time for the blades was extensive requiring approximately 24 hours to set-up and run the CNC program, and to complete the blades with manual sanding and fiberglass another 16 hours is necessary. Another 12 hours of manufacturing time is necessary for the cutting and welding of the mounting bracket.

The cost of materials and construction time for the VAWT is considerably less. The blades required cutting 9 tear drop wing ribs from ½ inch thick pressure treated plywood. The ribs are milled with three runner slots and one center hole plus a slot for the blade to be positioned at different angles. There are three ribs for each wing, but only the top and bottom rib require the holes and the slot, the middle rib only needs the runner slots milled. The blade runners are cut to size from a cedar plank using a table saw. There are three runners for each blade, each 4 foot long. Once all the ribs and runners are cut to size, the aluminum sheeting is cut to size and rolled to form the wing shape of the blades. The next step is for the blade supports to be made using 1/4" flat stock steel or aluminum to save weight, and a break press can be used to form the bends. First there needs to be two holes drilled in each end of the supports in order to be connected to the blades and the hub assembly plate. Once the holes are drilled a die can be used for bending the supports to the correct radius, giving the supports the correct dimensions needed.

Figure 11: *VAWT Blades and Supports*



The base assembly consists of a steel tube 1/2" by 4" in diameter by 30" tall; it is welded to a base plate that is 1/4" thick by 18" in diameter. The generator mounting plate is welded to the top of the tube along with a 1985 Chevy 4X4 spindle welded to the top of the tube. After taping the spindle off in order to not be powder coated, the blade supports, the blade support hub plate and the base can be powder coated to protect from corrosion.

Figure 12: *VAWT Blade Mounting Base Assembly and Blade Supports*

The material for the VAWT blades was $164.96, which is nearly half of that necessary for the HAWT, and the steel mounting base and mounting hardware was $118.30. The manufacturing time for the blades was less than half that of the HAWT, requiring approximately 8-10 hours, and another 8-10 hours for cutting and welding the mounting base.

Bench Test Power/Speed Curves

For the HAWT power/speed calculations the formula; RPM=(wind speed x TSR x 60)/circumference, and the formula; Blade Power=.15 x Diameter^2 x WindSpeed^3, using metric units was used. (Piggott, 2005) First the plot of Battery Charging Power showing Watts verses RPM was made from collecting amperage and voltage readings from the ammeter and voltmeter while running the turbine at various speeds. A variable speed 3-Phase 1-HP electric motor via belt drive was used in place of wind power as a test. A belt drive was chosen because of the 5 degree upward angle of the bracket and the awkward four-hole bolt pattern of the hub assembly. A 10" wooden sheave was turned on a lathe and a 3" belt sheave was fitted on the motor to allow a v-belt to transfer torque between the two. Using the assumption that the TSR is 7 for the 8 foot HAWT the calculations were made to estimate the power output for wind speed.

Figure 13: *HAWT Bench Test*

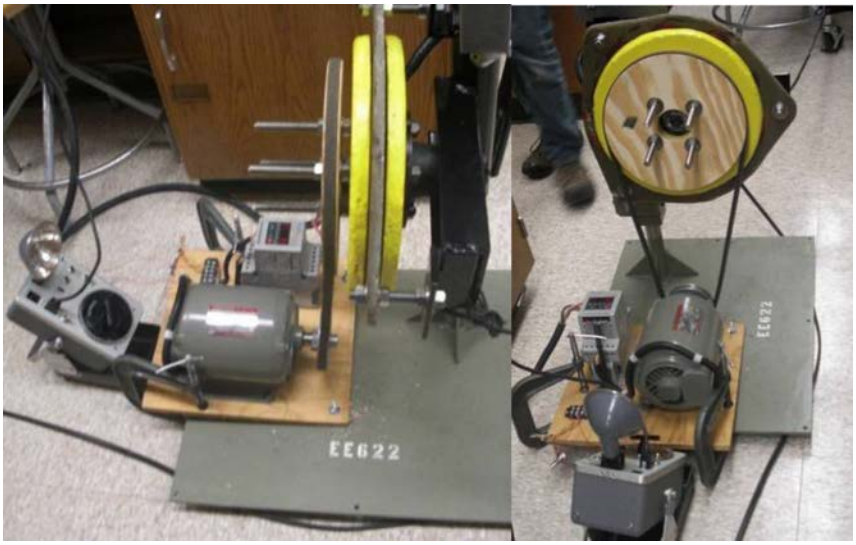


Figure 14: *HAWT Alternator Power vs. RPM*

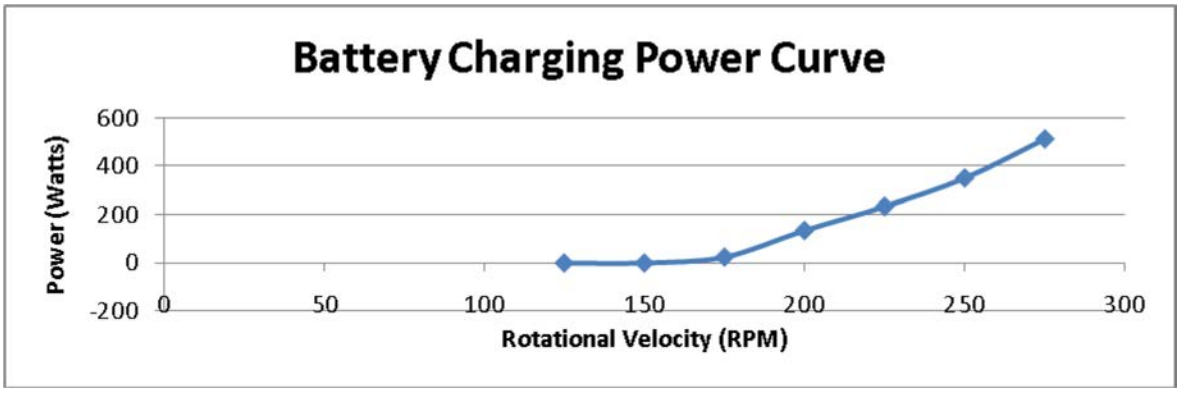
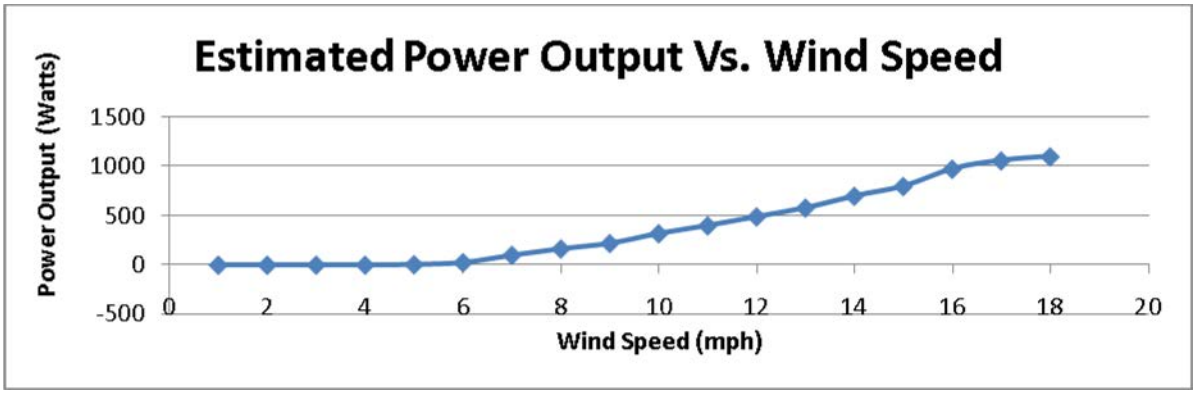


Figure 15: *HAWT Blade Power vs. MPH*

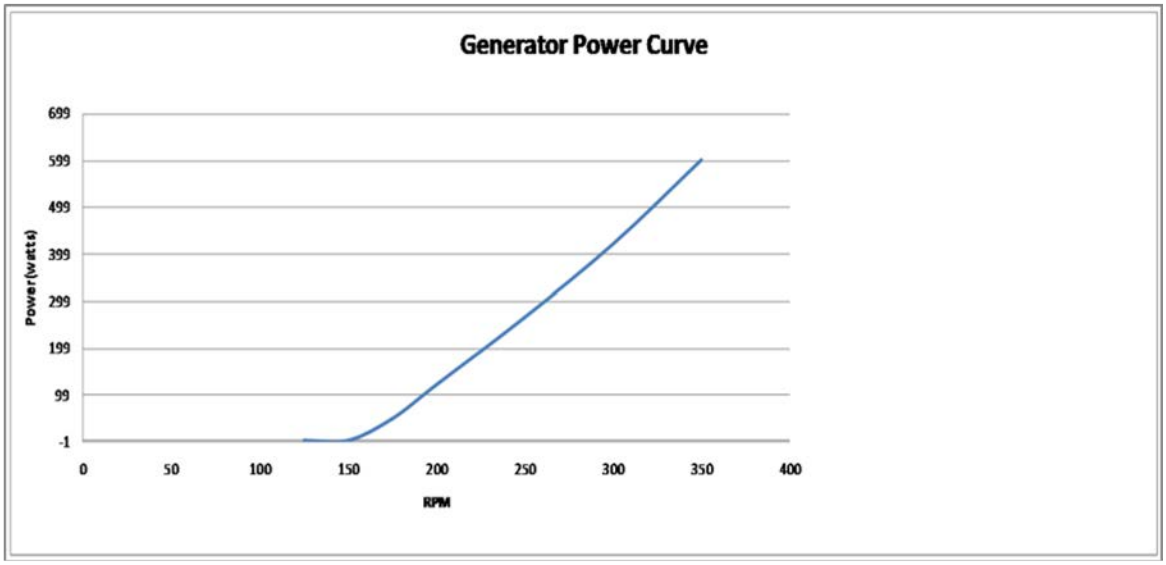


For the VAWT the bench test was performed using a variable speed vertical manual milling machine and a wooden clutch acting as the blade wind power for the generator.

Figure 16: *VAWT Bench Testing*

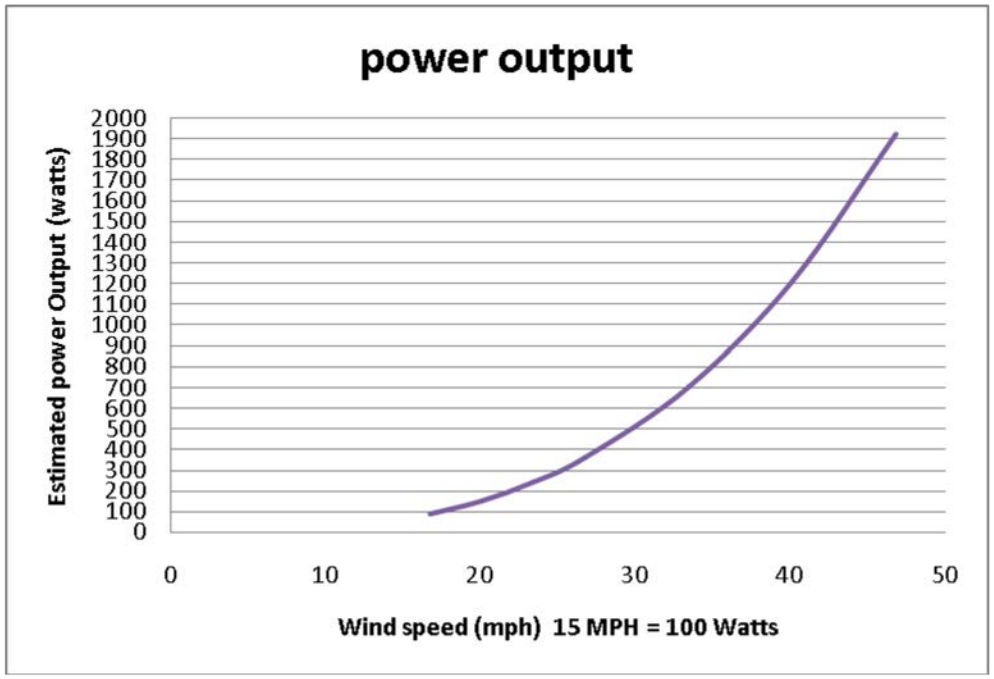
Using the variable speed controller on the mill voltage and current readings are recorded from the battery box gauges at different RPMs. The strobe tachometer was used to verify the RPMs of the mill. The first graph is the curve representing the power verses RPM.

Figure 17: *VAWT Alternator Power vs. RPM*



To calculate the Blade Power verses wind speed the power output was calculated using the formula; Watts output = .00508 x Area x Wind speed^3 x efficiency, with the Area in square feet (height x width), Wind speed in mph, and the efficiency was assumed to be about 31 percent. The wind speed necessary to create the RPM was calculated using the formula; Wind speed = RPM/(88 / (diameter x 3.14) x TSR), where Wind speed is in mph, diameter in feet, and the "88" is to convert the mph to feet per minute. The TSR for this machine for peak power is assumed to be 0.8, because it is a hybrid lift/drag machine in order for it to extract energy from both the upwind and downwind wings it needs to run slightly slower than the wind. (Lenz, 2005)

Figure 18: *HAWT Blade Power vs. MPH*



Physical Testing Results

The HAWT has been installed on a 40 foot tower in Mercer, WI to generate power for a bubbler system in a cranberry bog. The physical test results are unavailable at this time. The VAWT is being mounted on a 15 foot tower on the University campus to power a light to be used to advertise on the side of a campus building. These physical test results are also unavailable at this time.

Conclusions

Given the higher material and manufacturing costs of the HAWT, the VAWT is a more affordable design to be constructed by the average homeowner. In mass production the HAWT blades could be manufactured using a molded fiberglass lowering the manufacturing costs, although this design was intended to be a one-off production comparison. The bench test results for the two generators were very similar with the HAWT producing 513 Watts at 275 RPM and the VAWT producing 600 Watts at 350 RPM. This result is to be expected because the turbines use the same alternator design, with the only difference being the bearing hubs and mounting arrangement. The estimated power based on formulas taking into account assumed efficiencies and TSR values are only a prediction. The actual power output in given wind speeds can only be determined during actual physical testing. The estimates show that the HAWT produces higher power output at lower wind speeds, but the VAWT power output curve predicts a higher power output at high wind speeds. Maintenance and general repair of the VAWT should be simpler due to the fact that the VAWT does not need to be mounted as high, and the wings are made of strong durable materials not as fragile as the thin sectioned HAWT blades.

References

Lenz, E. (2005, August 28). *Lenz2 Turbine*. Retrieved January 27, 2009, from Windstuffnow.com: http://www.windstuffnow.com/main/lenz2_turbine.htm

Lenz, E. (2005, August 28). *VAWT*. Retrieved January 27, 2009, from Windstuffnow.com: http://www.windstuffnow.com/main/vawt.htm

Piggott, H. (2005). *How To Build a Wind Turbine*. Scoraig, UK: Scoraig Wind Electric.

Rogers, A. (2008, February/March). *Mother Earth News*. Retrieved February 4, 2009, from Wind Power: Are Vertical Axis Turbines Better? Q & A with wind expert Mike Sagrillo: http://www.motherearthnews.com/Renewable-Energy/2008-02-01/Wind-Power-Horizontal-and-Vertical-Axis-Wind-Turbines.aspx

Manufacturing

Marketing Your Manufacturing/Industrial Technology Program as Clean, Neat and Glamorous

Dr. Mark R. Miller
The University of Texas at Tyler, 75799, 903-566-7186, mmiller@uttyler.edu

Abstract
This paper will address how to change the way in which manufacturing is perceived in order to entice new students into manufacturing-related careers. In particular, specific details will be covered on how to increase enrollments for manufacturing and industrial technology programs while using limited or no new resources. A three pronged approach will be discussed that has worked effectively at The University of Texas at Tyler to triple the enrollment in the undergraduate Industrial Technology program in a time period of less than five years.

Introduction
Presently, manufacturing suffers from a poor public image that makes it difficult for industry to attract the new talent that is needed for the more advanced careers that are associated with current and future manufacturing careers (The Workforce Boards, 2004, p.10). The National Association of Manufacturers, commonly referred to as NAM (2003, p.9) noted that the manufacturing sector's image was "heavily loaded with negative connotations and universally tied to a stereotype of the assembly line." NAM (2009, p.9) also perceived manufacturing "to be in a state of decline." According to a survey of high school students reported in an online article by Benes (2005, par. 8), writer for the American Machinist, students described images associated with a career in manufacturing with phrases such as "serving a life sentence," being "on a chain gang," a "slave to the line," or even being a "robot." Almost all of the students queried, noted that they perceived manufacturing opportunities to be in stark contrast with the characteristics they desire in a career field.

McKenney and Narvaiz (2009, par. 5), from Deloitte LLP and NAM respectively, noted that their survey entitled, Public Viewpoint on Manufacturing, released in June of 2009 listed only 17% of American high school students as naming manufacturing as among their top two industry choices to start a career and that only 30% of their parents would encourage their children to pursue jobs in manufacturing. People's perceptions of career paths in manufacturing or industrial fields have also been tainted by the media and the recent downturn in the economy."

Although most Americans have negative views on manufacturing careers, McKenney and Narvaiz (2009, par. 4) noted that their survey also revealed that most Americans (81 percent) agreed that the United States manufacturing industry had a significant impact on their standard of living and was the top industry of importance to the economy.

Statement of the Problem
As previously noted, the public perception of manufacturing career opportunities has sunk to an all time low, thereby reducing the number of students who would be interested in enrolling in a manufacturing-related educational program. In order to reverse this trend, educators, advisors, and/or recruiters from manufacturing and industrial technology programs need to inform the public and prospective students of the latest trends in manufacturing and implement them into their programs.

Methodology
The most effective way of increasing enrollments for these programs is to change the mindset of prospective students and their parents by a three prong approach addressing: promotion, presentation, and placement.

Promotion

The first step to generating interest in the program is to promote manufacturing by reeducating undecided students as to what the latest trends are for manufacturing industries. A proactive approach needs to be implemented in order to generate new interest in manufacturing careers and how their focus has changed from dirty, smokestack factories with sweatshop conditions to clean, neat, and organized climate controlled manufacturing work environments with state-of-the-art technical gadgetry. In fact, the state of Connecticut community college system has implemented a campaign that was funded by the National Science Foundation and developed by the Regional Center for Next Generation Manufacturing (2005) entitled, "Manufacturing: It's not what you think!" Their promotion goes on further by stating:

> There's a great future in Connecticut manufacturing for young people like you. And it's not your grandfather's factory job anymore. It's super clean and high-tech! Exciting jobs in manufacturing are in hot demand. And in Connecticut these jobs pay an average of $52,000 a year plus great benefits!

A website was also created so that interested students can click on job titles and view short video clips on several of the clean manufacturing jobs with interviews from graduates who obtained the jobs. Similar things can be done with most manufacturing and industrial technology programs because many states have manufacturing advancement centers or other centers to assist manufacturers that typically offer video clips of clean and high tech industries. In addition, the Society of Manufacturing Engineers (SME) has a website entitled, "Manufacturing is cool" in which you can click on various objects and it tells you how they were made and more. SME is trying to promote manufacturing and manufacturing education so they want programs to link to their website.

Another way of promoting a manufacturing or industrial technology program is to have links to web pages that provide statistics for what the percentage of the state's GDP is made up from manufacturing, the percentage of manufacturing jobs for the state, the need for a well educated and highly skilled workforce, etc. as the Manufacturing Advancement Center (2009) does for a six state region in the northeast and how the Texas Association of Manufacturers (2009) lists important data regarding manufacturing growth and contributions to the state of Texas. In addition, The U.S. Census Bureau publishes an annual survey of manufacturers (www.census.gov) that provides a lot of important information regarding manufacturing. This data should not only be linked to a program's web site but it should also be posted on bulletin boards in the building that offers the program and/or all over campus for that matter.

The bottom line is that manufacturing and industry in general for that matter have earned a negative sentiment with the general public so as proactive positive promotion of manufacturing and industry is the only way to entice new students to enroll in manufacturing-related degree programs.

Presentation

You can promote manufacturing in a positive light as much as you like; however, if a new student visits your program and it looks like the traditional job shop or vocational lab from years past, then all these promotional activities are for naught. First impressions will always make or break most deals so be sure your program's departmental offices, laboratories, hallways, and any other related rooms reflect the new image for manufacturing. A nice, clean, and organized environment that welcomes most people needs to be the norm for your program. In fact, allow the secretary to make the office and laboratories look more "homey" by allowing her to add the accents that make a home look inviting. This also helps with the recruitment of more female students.

With the implementation of Lean Manufacturing at most industries, the 5 S's must be implemented at the academic department level as well. It is the opinion of this author, who has had the opportunity to tour numerous technology programs, that there is a lot of unnecessary clutter in most departments that should be shed to give a neater appearance for first time guests. Remember, the 5 S's (Dennis, 2006, p. 29) stand for: sort, set in order, shine, standardize, and sustain. This can easily be applied to any academic department, thereby; making a first impression to perspective students of a program that is neat and organized and one which everyone knows what to do and continues to do so. Therefore, if faculty and staff of a program keep in mind that at any time

during the semester a prospective student may be given a tour of the department, then they will keep it in better shape. A commitment must be made by everyone in the department to follow the 5 S's just like everyone must do in industry to stay competitive. A more specific example of how each of the 5 S's that can be applied to a manufacturing or industrial technology program are as follows:

Sort: As Dennis (2006, p. 29) notes, "the first principle of visual order is to sort out what you don't need." In academia where funding is in most cases scarce and hard to come by, faculty and staff have a tendency to hold onto items longer than their expected usefulness. Therefore, it is important that unused items be discarded or stored if necessary from the public's eye. All unused items should be placed in a storage room and tagged so all faculty and staff can determine if they ever use the item. If no one claims an item, then it should be properly removed from the department's inventory and disposed of according to university regulations. It is amazing how unwanted clutter can detract from a department's image.

Set in Order: Next, take a long, hard look at a department's laboratories and even offices and see if the equipment or furniture is positioned in the most efficient manner. In most cases, as funds become available, space if found to place equipment and typically the most recent and impressive piece of equipment is stuck in a corner somewhere with half of the packaging material still placed next to it. Many offices have desks that don't face someone entering the room. It should be noted that having your back to a new student in not the best way to welcome that student and his or her parents to a department.

Shine: As noted by Dennis (2006, p. 33), "Nothing raises your team's spirit like a clean, well-ordered workplace." Most faculty and staff would view that responsibility as that of the janitorial crew, however, we are not just referring to dusting. Does the main office have pictures, furniture and other items that look dated or have faded over the years? Do the laboratories have rusted, chipped up equipment that could use a coat of paint? Are the safety zone lines painted on the floor around machinery still legible? Most of these things go unnoticed because addressing these issues doesn't help most faculty with their promotion and tenure packages. At any rate, someone must be held accountable for these items if a department wants to continue to grow its enrollment.

Standardize: Now that the department has been cleaned up and organized, some type of visual record (pictures, written down criteria) should be kept so everyone knows who is responsible for maintaining what, how it should be done, and when it should be done. It is much easier to keep things organized and looking good if it is maintained periodically throughout the semester. Often times because no one is held accountable or even deemed responsible for a particular area, everyone thinks that someone else will clean it up. This will lead to the same messy and disorganized department in just a few months.

Sustain: Although everyone may be responsible for a certain area and been assigned duties that does not necessarily mean that they will continue to maintain their area. Faculty and staff must be recognized for their efforts, whether it be in their annual reports or through an employee of the month recognition effort. As budgets are cut more as the economy continues to decline, additional responsibilities are assigned to existing employees that can overwork employees to the point that the 5 S's become a passing fad. Leadership in the department must make this a priority and sustain the effort to keep the department looking good to prospective students.

Placement

Typically, when enrollments decline, administrators and faculty focus on new and innovative ways to recruit more students. However, if there are not any jobs available for the program's current graduates, then prospective students will look for another major before they invest their valuable time and money. Placement of graduates is a vital component to the strength of any program. Word of mouth advertising from content graduates with successful career opportunities is probably the best way to attract more students to a program.

It is imperative that faculty and staff keep job boards in hallways up to date with the latest postings. If faculty and staff are too busy with other duties, then departmental student workers need to be trained to find job announcements and post them on the bulletin boards and/or program websites. There is nothing worse than a

job board with job announcements posted from prior semesters. This leads students to think that there are not any jobs available with this major, so current students change majors and prospective students go elsewhere.

As the economy continues to decline and jobs become even scarcer for everyone no matter what area they choose, post optimistic articles that note encouraging trends for job growth in manufacturing. In addition, even if the article focuses on another state, it will still let students know that certain manufacturing areas are growing and will need a highly skilled workforce. For instance, post, "Make it in America: The Apollo Green Manufacturing Plan" which can be found at the www.apolloalliance.org web site. The two page brief by Gordon (2009) discusses all the new clean energy manufacturing or "green" jobs that will be available through the billions of dollars spent on the government's stimulus package. In fact, it has a quote by President Barack Obama that states, "I do not accept a future where jobs and industries of tomorrow take root beyond our borders – and I know you don't either. It is time for America to lead again." What can be more encouraging to a new student then knowing that they may be placed in a clean and green job that even has the endorsement of the President?

Other articles that may be placed on the job board should not only note the future job growth, but also portray manufacturing in a different light. Weldon (2007) in an article entitled, "Making Manufacturing Glamorous," notes that NAM has partnered with Skills USA to undertake a major marketing and training program to champion the personal and professional rewards to the field of manufacturing through the program "Dream It. Do It." It states in the article that even though manufacturing jobs are on the decline, many of the so-called Baby Boomers are within a few years of retirement and their will be a huge shortage of skilled workers for manufacturing industries.

Results

Over the years, The University of Texas at Tyler's undergraduate Industrial Technology program's enrollment had steadily declined until its numbers barely justified the need for the faculty member who coordinated it. The three pronged plan previously stated to increase enrollment was developed and gradually implemented over the past five years to counter act this declining enrollment. During this time period, and while the economy slipped into a recession causing massive layoffs in the manufacturing sector, the enrollment for the program has almost tripled. Moreover, although there is currently a hiring freeze at the university, the administration approved the appointment of a new faculty member to assist with the program's growing enrollment.

Conclusion

Marketing is the key to selling most products and that is the reason why there are so many advertisements on television, radio, internet, and in the paper. Although marketing is an important aspect of our lives, most faculty have had little or no educational training in it. Faculty in university programs that service all the other programs on campus, such as English, History, Political Science, may not feel the need to attract majors, however, programs that do not offer service courses have to attract majors to stave off elimination. Therefore, it should be noted that a coordinated, team effort by departmental employees must be implemented to increase enrollments. This paper stresses the importance of first impressions, changing people's perceptions, and staying vigilant with lean tools such as the 5 S's. In addition, recruitment efforts must be followed by graduate placement services or retention rates will suffer.

References

The Workforce Boards of Metropolitan Chicago. (June, 2004). *Manufacturing workforce: Not disappearing - just changing.* Retrieved July 1, 2009, from http://www.workforceboardsmetrochicago.com/upload/Manufacturing_FNL.pdf

National Association of Manufacturers. (2003). *Keeping America competitive - how a talent shortage threatens U. S. manufacturing: Part I.* Retrieved July 1, 2009, from http://www.nam.org/AboutUs/TheManufacturingInstitute/NationalCenterfortheAmericanWorkforce/CareersinManufacturing.aspx?DID=%7BF4D5E221-B418-4319-AC8F-262D01B7122C%7D

Benes, J. (September, 2005). Finding and training tomorrow's machinists. *American Machinist*. Retrieved July 1, 2009, from http://www.americanmachinist.com/304/StateOfManufacturing/StateOfManufacturing/False/11579/Issue

McKenney, A. & Narvaiz, L. (June, 2009). Manufacturing ranked #1 industry for economic prosperity. *National Association of Manufacturers.* Retrieved July 2, 2009, from: http://www.nam.org/NewsFromtheNAM.aspx?DID=%7BBCF0ECDE-7C95-

4CAA-9EE3-9F5B59C14DCD%7D The Regional Center for Next Generation Manufacturing. (2005). *Manufacturing: It's not what you think.* Retrieved July 2, 2009, from: http://www.nextgenmfg.org/
Manufacturing is cool. (n. d.) Society of Manufacturing Engineers. Retrieved July 2, 2009, from: http://www.manufacturingiscool.com/
Healy, J. (2009). New England council report: Advanced manufacturing & changing perceptions. *Manufacturing Advancement Center*. Retrieved January 2, 2009, from: http://www.massmac.org/newsline/0906/article01.htm
Texas Association of Manufacturers. (2009). Manufacturing jobs: The best in Texas. Retrieved July 3, 2009, from: http://www.manufacturetexas.org/Manufacturing%20Jobs%20-%20The%20Best%20in%20Texas.pdf
U. S. Census Bureau. (2009). Publications: Manufacturing and mineral industries. Retrieved July 3, 2009, from: http://www.census.gov/prod/www/abs/manu-min.html
Dennis, P. (2006). *Lean production simplified: A plain-language guide to the world's most powerful production system*. New York: Productivity Press.
Gordon, K. (2009). Make it in America: The Apollo green manufacturing action plan. Apollo Alliance. Retrieved July 4, 2009, from: http://www.apolloalliance.org
Weldon, D. (July, 2007). Making manufacturing glamorous. Retail Digital. Retrieved July 4, 2009, from: http://www.retail-digital.com/Making-manufacturing-glamorous_1415.aspx

Safety

Safety

Potential Application of Artificial Neural Network Models for Enhancing the Revised NIOSH Lifting Equation

Dr. Farman A. Moayed, PE
Indiana State University, Department of Health, Safety and Environmental Health Sciences, Arena B-73, Terre Haute, IN 47809, 812-327-3072, fmoayed@indstate.edu

Dr. William Campbell
Indiana State University, Department of Health, Safety and Environmental Health Sciences, Arena B-74, Terre Haute, IN 47809, 812-237-3107, wcampbell6@isugw.indstate.edu

Abstract
It has been proven that manual lifting is one of the main causes of Lower Back Disorders (LBDs) among workers and LBDs are still a major health problem in industry. In 1994 NIOSH introduced a revised lifting equation which can be used to calculate the Recommended Weight Limit (RWL) based on several factors (*i.e.* load constant, horizontal, vertical, distance, asymmetric, frequency and coupling multipliers). Meanwhile additional studies show that other factors such as gender, physical condition (height, weight or body mass index) can affect LBDs other than the ones included in the Revised NIOSH Lifting Equation.

It will require a very complicated and sophisticated mathematical model in order to include all possible factors and evaluate a lifting limit or the possibility of LBDs. Recent studies have shown that Artificial Neural Network (ANN) models can be used successfully in order to evaluate complex models. Literatures and published research indicate that ANN models can perform better than conventional mathematical models in medical, epidemiological and health-related studies in predicting possible outcomes.

The major goal of this study is to create and use the best ANN model by including all possible factors and attempting to estimate the possibility of LBDs. An experiment can be designed in an ergonomic/human factor laboratory with relatively large sample. Subjects are required to perform a set of lifting tasks while wearing a measurement device to calculate the load on their spine. The probability of LBDs can be calculated for each subject first by using the NIOSH lifting equation and then with all task and personal factors. The comparison of results of both methods can show the effectiveness of ANN models to estimate the Recommended Weight Limit by using ANN models.

Introduction
In science and technology, including occupational safety and health (OSH) engineering, researchers always try to study a variety of systems by observation and measurement of external factors (inputs), their interrelation and their effects on the factors of interest (outputs). They conduct research and studies by constructing models which are usually mathematical.

The revised NIOSH Lifting Equation is one of the mathematical models that can be used to calculate the Recommended Weight Limit (RWL) for a specific set of task conditions that nearly all healthy workers could perform over a substantial period of time without an increased risk of developing lifting-related LBDs (Waters *et al.* 1994). The RWL is a product of seven multipliers and is defined by the following equation:

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM$$

The multipliers are explained in the Table 1.

Table 1. *Multipliers Influencing the Recommended Weight Limit*

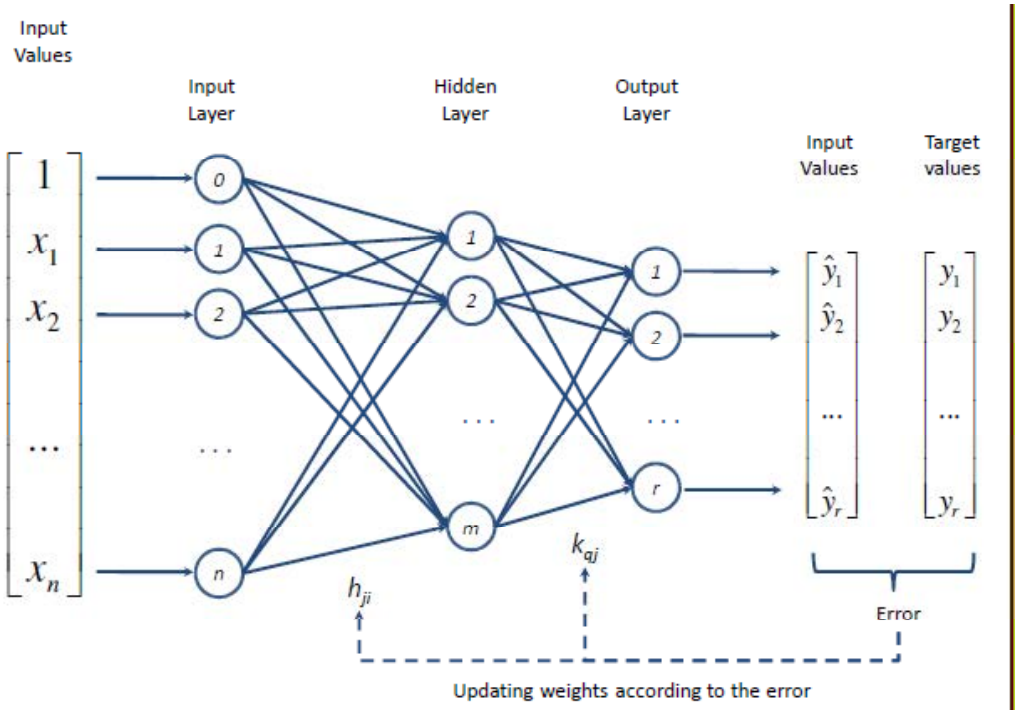
		Metric	US Customary
Load Constant	LC	23 kg	51 lb
Horizontal Multiplier	HM	$\frac{25}{H}$	$\frac{10}{H}$
Vertical Multiplier	VM	$1-(0.003\|V-75\|)$	$1-(0.0075\|V-30\|)$
Distance Multiplier	DM	$0.82+\left(\frac{4.5}{D}\right)$	$0.82+\left(\frac{1.8}{D}\right)$
Asymmetric Multiplier	AM	$1-(0.0032A)$	$1-(0.0032A)$
Frequency Multiplier	FM	From 0 to 1 based on the lifting frequency and work duration.	
Coupling Multiplier	CM	From 0.9 to 1 based on the coupling conditions	

It is obvious from the RWL definition and the multipliers that the only factors considered in NIOSH lifting equation are task-related. In other words there is no multiplier or factor in this equation that adjusts the RWL based on individual's capabilities. Campbell *et al.* (2009) have suggested that other contributing factors need to be added to the revised NIOSH lifting equation in order to have an appropriate and better estimate of RWL for any individual and reduce the risk of LBDs.

Studies show that there are other factors that can affect RWL and/or the probability of developing LBDs, such as age, gender, and body type/physical condition. As it is explained in the literature search section, men and women show different muscle strength which can affect their capabilities in lifting weights, thus the RWL should be different for them in order to reduce the risk of developing LBD. Also researchers have shown that the muscle strength has a negative correlation with age which means that muscle strength decreases as a person ages. This requires that a person's age be considered when deciding on RWL. Another major factor in developing an LBD is the body type or physical conditions. There is a relationship between obesity and LBDs which suggests that the RWL should be different for overweight workers in order to reduce the risk of developing LBDs.

The revised NIOSH lifting equation does not take individual factors into account and at the same time it would be very difficult to include all the factors in the RWL equation because it will make the model very complex. However artificial neural network (ANN) models are relatively new mathematical models that are widely used for data analysis and predicting possible outcomes such as developing LBDs. ANN models were first introduced by McCulloch and Pitts in 1943, and are algorithms patterned after the structures of human neurons with the goal of predicting an outcome variable based on the values of some independent variables (Cheng & Titterington, 1994). A typical ANN model is a network of large number of processing elements, called nodes (or artificial neurons), which learns from examples and processes the information. Learning process in ANN models is accomplished through special training algorithms that are developed based on learning rules to mimic the learning mechanism of biological systems (Hajmeer & Basheer, 2003; Cheng & Titterington, 1994; Zilouchian, 2001, Haykin, 1999; Johnson & Wichern, 1998). There are different types and architecture of neural networks that are fundamentally different in the way they learn. Figure 1 is a schematic demonstration of a typical

Figure 1 – *A schematic of a typical ANN model*



artificial neural network model. An ANN model consists of one input layer, at least one hidden layer, and one output layer. The number of nodes in the input layer is equal to the number of input variables. There is no general rule to determine the number of hidden layers and the number of nodes in hidden layer(s). It is very empirical and researchers can manipulate them in order to find the best model which fits their data set. However there are some general guidelines suggested by experts to select the initial structure and numbers for an ANN model (Nguyen *et al.*, 2003; Gallant, 1993).

One of the advantages of ANN models is that they can work with different types of variables without any pre-assumptions. They are capable of identifying complex and non-linear relationships between input and output variables. All ANN models should be trained in order to learn the complex patterns between variables before being used for data analysis. Once the model is trained with acceptable accuracy, then it can be used for data analysis. Different training algorithms have been developed by researchers in order to improve models' performance for better prediction. One of the most commonly and successfully used training algorithms for ANN models in occupational safety and health research is feedforward backpropagation (Yousefizadeh & Zilouchian, 2001; Zilouchian, 2001). In this type of models output variable is a function of all nodes in the hidden layer, and each node in the hidden layer is a function of input variables. No interaction is allowed between nodes of the same layer. The hidden layer allows the model to handle the nonlinearity and complexity of relationship of variables.

Literature Review

An online search was conducted on Ohiolink, Electronic Journal Center (EJC), Kluwer Journals, Academic Search Premier (EBSCOhost), IEEE Xplore, Compendex, Elsevier Journals, PapersFirst (FirstSearch), OmniFile Full Text Mega, Wilson Web, Conference Papers Index (CSA), Ergonomics Abstract databases and indexes, JSTOR, MEDLINE, AccessSience, Biological Abstracts, The CINAHL Databases, Health and Safety Science Abstracts, Health Sources: Nursing/Academic Edition, and Science Citation Index Expanded; which are available through the University of Cincinnati (UC) and Indiana State University (ISU) Libraries. Several Combinations of keywords such as artificial neural network (ANN), lower back disorder/pain (LBD/LBP), physical strength, NIOSH Lifting Equation were used for search.

The inclusion criteria were: *i.* publications in related peer review journals, books and conference proceedings, *ii.* published before July of 2009, *iii.* publications in English, *iv.* any analytical or theoretical articles. The exclusion criteria were: *i.* any ANN models other than supervised networks (such as self-organizing maps and etc.), *ii.* publications in languages other than English, *iii.* any training algorithm other then feedforward backpropagation.

Studies show that muscle strength and age are correlated (Fisher and Birren, 1947; Matheson *et al.*, 1996; Lindle *et al.*, 1997). Fisher and Birren (1947) were able to show that the hand strength (muscle strength in general) is in maximum in the middle twenties and decline constantly after that to 16.5% of its maximum strength. This means that older workers might change their lifting method and put more pressure on their lower back, which as a result can increase their risk of LBDs. Lindle *et al.* (1997) showed not only the muscle strengths declines by aging but also there is significant differences between men and women regarding their strength. The differences between their heights can also affect the load on their spine and lower back while performing a lifting task. The results of this study regarding the difference between genders and their muscle strength are supported by other researchers (Faigenbaum, 2008; Evans, 1995; Kumar *et al.*, 1978). Evans (1995) explains that the reason for such differences is sarcopenia, which is age-related reduction in skeletal muscle. This reduction is muscle mass is significant among different age and gender groups. Some researchers studied the effect of body type or physical conditions on strength. (Chaffin *et al.*, 1978; Janke *et al.*, 2007). Chaffin *et al.* (1978) showed that taller, heavier and younger subjects have larger muscle strength and are capable of lifting heavier weights. However they did not look at the overweight/obese workers and their capabilities in lifting weights. Meanwhile Janke *et al.* (2007) showed that overweight people have higher risk of developing LBDs, therefore when such people are to perform tasks involving lifting weight the RWL should be adjusted to reduce the risk of LBDs.

Regarding the modeling aspect, Basheer & Hajmeer (2000) demonstrated the application of ANN models to predict the growth of *S. flexneri* bacteria according to environment factors. They compared the performance of ANN model versus the traditional method (regression analysis). The result showed that ANN model can perform better than regression model. In a similar study Hajmeer & Basheer (2003) assessed the performance of a statistical model (logistic regression) against an ANN model to predict the bacterial growth of *E. coli* strain R31 based on temperature and water activity. According to their result the ANN model had a significantly better overall performance compared to logistic regression models.

Eftekhar *et al.* (2005) also showed that the performance of an ANN model was better than a logistic regression model to predict the mortality in head trauma based on initial clinical data of 1271 head injured patients. The performances of different ANN models were compared versus job-specific modules (JSMs) by Black *et al.* (2004) for assessing the occupational exposure to benzene for non-Hodgkins Lymphoma among 189 tanker drivers. The results concluded that ANN models' overall performance were satisfactory with the highest area under the ROC curve of 96 percent.

Zurada *et al.* (1996) used an ANN model to categorize a sample of 148 jobs into two groups of high and low risk of LBDs according to five variables associated with the characteristics of jobs and compared the results to the epidemiological and ergonomic method of categorization. The ANN model developed in this study was able to categorize 75 percent of jobs correctly which is comparable to the NIOSH Guide (1981 and 1991) that categorized the jobs 78.4 percent correctly. The researchers did not attempt to include personal characteristics into the ANN model.

Karwowski *et al.* (1994) concluded that ANN models can successfully work as an expert system that can classify jobs into two groups of high and low risk of lower back disorder. They developed an ANN model to classify 403 jobs from 48 manufacturing companies into high and low risk groups and the outcome was compared with the epidemical method. The result showed that the ANN model developed in this research was capable of classifying the jobs 75 percent correctly.

Moayed (2008) used a data set of construction workers to demonstrate that well structured and designed ANN models can significantly outperform logistic regression models (which are commonly used in occupational safety and health studies) to predict the probability of different occupational disorders (*e.g.* pain in different body joints such as neck, shoulders, lower and upper back, and etc.).

Objective

The current form of the revised NIOSH lifting equation only considers task-related factors to estimate the RWL. Adding new multipliers to the revised NIOSH lifting equation to include personal factors might be either impossible or reduces its validity and accuracy and make it more complicated. The main goal in this research proposal is to develop a new model (an ANN model) which includes all factors from the task and worker in order to estimate the RWL and/or the risk of LBDs better that the current NIOSH lifting equation.

Proposed Methodology

Sample: In order to develop a valid and accurate ANN model to estimate an appropriate RWL and/or predicting the probability of developing LBDs based on personal and task factors a relatively large sample is required, *i.e.* a sample of 500 subjects or more. The sample should include both genders, from 18 to 70 years of age; which is the age range among work force in industry, all body types; and ethnicities.

Instrument: The AcuPath™ Industrial Lumbar Motion Monitor™ (iLMM™) will be used to analyze the task and the loads on spine and predict the risk of LBDs. The iLMM is an exoskeleton of the spine that measures the position, velocity and acceleration of the spine in the sagittal, lateral, and twisting planes. The system also includes BackMetrix software whose risk model overcomes many traditional limitations in the analysis and redesign of the work environment.

Experiment: A set of lifting tasks with different characteristics (matching the multipliers of NIOSH lifting equation) will be designed. The subjects will repeat each lifting task multiple times and the load on their back will be measured using iLMM™, whose outputs can be used to compare the risk of LBDs for different subsets of sample, *i.e.* the risk of LBDs for male vs. female, and for different age brackets, or body types.

Data analysis: Different appropriate statistical tests and analysis will be applied to investigate the correlation between input variables (exposures), risk factors and output variables (outcomes) and their significances.
ANN model development: Once the correlations between exposures, risk factors and outcomes are studied, an appropriate ANN model will be created. The proposed model will have a three-layer (one input, one hidden and one output layers) or a four-layer (one input, two hidden and one output layers) structure. Different activation functions and initial values will be tested for the nodes in order to guarantee the best fit.

Expected Results: It can be expected that if only the NIOSH lifting equation be used to determine the RWL: *i.* Women might have higher risk of LBDs than men, *ii.* Different age brackets might have different risk of LBDs, *i.e.* older people will have significantly higher risk of LBDs compared to younger people, and *iii.* Different body types will have different risk of LBDs, *i.e.* overweight people might show higher risk.

Expected product: the product of this research will be a new ANN model which can be used to estimate the probability of LBDs for any worker while both task factors and personal factors are considered to determine the RWL.

Conclusion

By the end of this research a new model will be introduced to all researchers and practitioners in the field of occupational safety and health, with which they can evaluate the risk of LBDs and estimate the RWL more accurately by using both task and personal factors. This can help improve the quality of life for all workers by protecting them from hazardous lifting tasks and also reduce the direct and indirect costs of occupational injuries for businesses and industries.

References

Basheer, I. A., & Hajmeer, M. (2000). Artificial neural networks: fundamentals, computing, design, and applications. *Journal of Microbiological Methods, 43*, 3-31.

Black, J., Benke, G., Smith, K., & Fritschi, L. (2004). Artificial neural networks and job-specific modules to assess occupational exposure. *Annals of Occulational Hygiene, 48(7)*, 595-600.

Campbell, W. P., Perry, K. A., Sheldon, E. J., and Moayed, F. A. (2009). A Proposal to Study Additional Contributing Factors to the NIOSH Lifting Equation. *Proceedings of ASABE Annual International Meeting,* Reno, NV. June 21-24.

Chaffin, D. B., Herrin G. D., and Keyserling, W. M. (1978). Pre-Employment Strength Testing: An updated position. *Journal of Occupational Medicine, 20(6)*, 403-408.

Cheng, B. and Titterington, D. M. (1994). Neural networks: a review from statistical perspective. *Statistical Science, 9(1)*, 2-54.

Eftekhar, B., Mohammad, K., Ardebili, H. E., Ghodsi, M., and Ketabchi, E. (2005). Comparison of artificial neural network and logistic regression models for prediction of mortality in head trauma based on initial clinical data. *BioMed Central Medical informatics and Decision Making, 5(1)*, 3-10.

Evans, W. J. (1995). What is Sarcopenia? *The Journals of Gerontology, 50A*, 5-8.

Faigenbaum, A. D. (2008). Age- and Sex-Related Differences and Their Implications for Resistance Exercise. In T. R. Baechle, and R. W. Earle (Eds.), *Essentials of Strength Training and Conditioning, 3rd ed.* (pp. 141-158). Champaign, IL: Human Kinetics.

Fisher, M. B., and Birren, J. E. (1947). Age and Strength. *Journal of Applied Psychology, 31*, 490-497.

Gallant, S. I. (1993). *Neural Network Learning and Expert Systems,* Cambridge, Massachusetts: MIT Press.

Hajmeer, M. and Basheer, I. (2003). Comparison of logistic regression and neural network-based classifiers for bacterial growth. *Food Microbiology, 20*, 43-55.

Haykin, S. (1999). *Neural Networks, A Comprehensive Foundation,* (2nd ed.). Upper Saddle River, NJ: Prentice Hall, Inc.

iLMM™, http://www.nexgenergo.com/ergonomics/lumbarmm.html; Last visited July 9, 2009.

Janke, E. A., Collins, A., and Kozak, A. T. (2007). Overview of the relationship between pain and obesity: What do we know? Where do we go next? *Journal of Rehabilitation Research & Development, 44,* 245-262.

Johnson, R. A. & Wichern, D. W. (1998). *Applied Multivariate Statistical Analysis,* (4th ed.). Upper Saddle River, NJ: Prentice Hall, Inc.

Karwowski, W., Zurada, J., Marras, W. S., & Gaddie, P. (1994). A prototype of the artificial neural network-based system for classification of industrial jobs with respect to risk of low back disorders. In F. Aghazadeh (Ed.), *Advances in industrial ergonomics and safety VI* (19-22). Bristol, PA: Taylors & Francis Inc.

Kumar, S., Narayan, Y., and Zedka, M. (1998). Trunk strength in combined motions of rotation and Flexion/extension in normal young adults. *Ergonomics, 41(6)*, 835-852.

Lindle, R. S., Metter, E. J., Lynch, N. A., Fleg, J. L., Fozard, J. L., Tobin, J., Roy, T. A., and Hurley, B. F. (1997). Age and gender comparisons of muscle strength in 654 women and men aged 20–93 yr. *Journal of Applied Physiology, 83*, 1581-1587.

Matheson LN, Mooney V, Grant J, Leggett S, Kenny K. (1996). Standardized evaluation of work capacity. Journal of Back and Musculoskeletal Rehabilitation, *6,* 249-264.

Moayed, F. A. (2008), Constructing the Function of "Magnitude-of-Effect" for Artificial Neural Network (ANN) Models and their Application in Occupational Safety and Health (OSH) Engineering. *Ph.D. Dissertation*, College of Engineering, University of Cincinnati, OH.

Nguyen, H. T., Prasad, N. R., Walker, C. L., & Walker, E. A. (2003). *A first Course in Fuzzy and Neural Control.* Boca Raton, FL: Chapman and Hall/CRC.

Waters, T. R., Anderson, V.P., Garg, A. (1994). *Application Manual for the Revised NIOSH Lifting Equation*. DHHS (NIOSH) Publication No. 94-110.

Yousefizadeh, H. & Zilouchian, A. (2001). Neural network structures. In A. Zilouchian, & M. Jamshidi (Eds.), *Intelligent Control Systems Using Soft Computing Methodologies*. (pp. 39-66). Boca Raton, FL: CRC Press.

Zilouchian, A. (2001). Fundamentals of neural networks. In A. Zilouchian, & M. Jamshidi (Eds.), *Intelligent Control Systems Using Soft Computing Methodologies*. (pp. 17-38). Boca Raton, FL: CRC Press.

Zurada, J., Karwowski, W., & Marras, W. S. (1996). A neural network-based system for classification of industrial jobs with respect to risk of low back disorders due to workplace design. *Applied Ergonomics, 28(1)*, 49-58.