How Do We Use Research To Improve the Engineering and Construction Industry?

Final Report

NSF Contract #9700436 CMS

Workshop Co-Sponsored
by the
Construction Industry Institute
and
National Science Foundation

May 13-14, 1997
Austin, Texas

Preface

In early 1996, members of the Academic Council of the Construction Industry Institute discussed the need to address new issues related to construction research as we prepare for the year 2000 and the next hundred years of growth and development of the engineering and construction industry. The Council under the leadership of its chairman, Hal Yoh, approached the Construction Industry Institute (CII) and the National Science Foundation (NSF) to explore sponsorship of a workshop for recognized leaders from academia and industry to creatively explore for a day and a half, how research is used to improve the engineering and construction industry.

Between 1975 and 1984, the National Science Foundation sponsored five workshops to explore construction industry research needs. Each workshop contributed significantly to establishing needs and directions for construction research. In 1983 the Construction Industry Institute was founded to identify and fund research for the construction industry. Since then, considerable research has been completed and findings have been implemented which have made a notable impact on the cost effectiveness and competitiveness of the construction industry.

This report summarizes the proceedings of the workshop held in Austin, Texas on May 13-14, 1997. Fifty-two representatives from academia, industry, engineering, and construction participated in the workshop. This workshop was co-funded by CII and NSF in cooperation with the construction programs at Arizona State University, University of Florida, Oklahoma State University, Oregon State University, and the University of Texas.

The goal of the workshop was to creatively analyze the processes through which research topics are identified and the result applied. With the accomplishments and research efforts of the past decade as a background, workshop participants focused on the future. A strong business participation maintained an alignment with current and future industry needs.

A major undertaking such as this workshop, requires the contribution of many individuals. A special thanks is extended to Dr. Richard Tucker, Director of the CII and Dr. Ken Chong of the NSF for their guidance and financial assistance. Thanks are also given to the facilitators and recorders of the five break-out sessions: 1) Greg Howell and Jimmie Hinze, 2) Mike Vorster and Peter Bopp, 3) Peter Van Nort and Bob Jortberg, 4) Chris Hyvonen and Bill Badger, and 5) Deborah Grubbe and Hal Pritchett. The Academic Council wants to especially recognize and express its appreciation to Garold Oberlender for preparing and editing this report. Members of the Council provided valuable ideas and assistance in development of the workshop agenda, invitees, and general coordination. The staff of the CII greatly assisted in the logistics and hosting the workshop.

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Executive Summary

After a morning session devoted to background presentations, the participants divided into five working groups to address specific aspects of the overall workshop theme: ***How do we use research to improve the engineering and construction industry?*** The discussions and creative thinking of each group surfaced many innovative approaches to produce research results of future benefit to the engineering and construction industry. The following paragraphs summarize key elements of the five working groups. A more detailed description of the discussions of each working group is contained in the text of this report.

1. How do we go from incremental to break-through research?

The group began its discussion by defining breakthrough and its relation to incremental research. What is breakthrough research and how can it be achieved? How does it differ from incremental research and what can be done to coalesce incremental research results into breakthrough findings? Is there a continuum along which incremental research results can lead into breakthrough finding? Must breakthrough be the objective of a research project for breakthrough to be achieved? Is the difference a matter of funding?

It was concluded that the issue is not a matter of going from incremental to breakthrough research but rather to identify and foster breakthrough conditions. Some conditions are more conducive than others for breakthrough research to occur. For example, conditions such as a crisis can be converted into major opportunities. Ideas must be nurtured as they develop and a number of "breakthrough incubators" were identified. This nurturing of ideas is what will induce the breakthroughs. Technology, Practices and Mindset were defined as three distinct areas of research focus, each needing different approaches and conditions to allow breakthrough to occur.

The approaches used by various research institutions were reviewed and tabulated. It led to the recognition that there are specific reasons why these institutions address research differently and that there is no one model that fits all research objectives. Each model has strengths and has produced breakthroughs, but each also has its own unique obstacles. CII, for example, started with research objectives "for the industry" and evolved over time to a research strongly oriented to its member's goals. The success of the CII and its research can be attributed to some extent to the efforts of its strongest members. This collaboration and linkage of industry with academia is a particular strength that can lead to breakthroughs.

2. What are creative processes to form and identify research opportunities?

The group began its deliberations by brainstorming issues and topics related to creative processes to form and identify research opportunities. Initial discussions ranged from defining what creativity means in terms of the construction industry to the storage, dissemination and renewal of knowledge. The group developed models of today's

processes of how research in construction is identified, funded, produced and how the results are recorded and made available for implementation. Three research cycles were identified as described below:

Research Cycle "A" - The institutionally and privately funded research.

Institutions such as CII scan industry groups, sponsor companies, professional societies and universities, asking them to submit research proposals based on their specific needs. Proposals are reviewed by a panel of professionals who assess the potential for development of the proposals into a research project. A limited number of the proposals are approved for funding each year. In most cases the results meet the expectations and are published and disseminated to sponsoring entities who integrate the findings and recommendations into their new projects to improve industry practices.

Possibilities for improving this model were discussed and specific insights developed:

- Scan member companies in the field, at the worker's level
- Scan sub-contractors, suppliers, vendors
- Conduct interviews for a deeper exploration of research needs (problems)
- Create Focus Groups to solicit research needs (problems)
- Utilize benchmark data and metrics to derive research needs
- The success of this research cycle is very dependent on showing success
- There is a need to better identify and publicize research successes
- More pre-planning of research projects is needed

Research Cycle "B" - National research agendas

This cycle is driven by needs of the general society such as roads, water distribution and treatment, military installations, etc. Sometimes a national crisis such as a flood or earthquake, will initiate a review of industry practices and identify areas of improvement. The basic criteria for funding is the potential to increase knowledge and create breakthroughs. The funding is broad based and defined by a statement of intent of the researcher in response to a request for proposals. Results are typically published in technical journals and accessible to anyone interested. They constitute the nation's "storehouse of knowledge and information." These results trigger many diverse and sometimes unexpected applications.

Opportunities for improvement of Research Cycle "B" were identified as:

- Development of advocacy groups like the Business Round Table construction groups
- Using the results of Cycle "A" to identify new research needs or opportunities
- Sharing among universities and industry to create a larger and unified constituency
- Better networking among universities and between universities and industry
- Scanning emerging technologies to identify opportunities for use and development
- Scanning associated industries to identify common research opportunities
- Better data about the construction industry

Research Cycle "C" - Non-funded research at universities

This model describes the open research going on at all university graduate levels. About 50% of construction research at universities is this type of research, with no specific funding sponsor. The research is conducted by graduate students who work for credit hours as partial fulfillment of the requirements for an earned graduate degree. Ideas for research topics are from recommendations of faculty advisors, review of literature from previous research, personal contacts in industry, or expanded research from previous graduate students. Results are published as a thesis or dissertation and usually published in technical journals accessible to anyone interested. The results are often incorporated in future research and the basis for the continuous growth of knowledge.

The group identified several future opportunities:

- Encourage companies in the construction industry to take advantage of the non-funded research that is performed at universities
- Increased linkage between research universities and the business community
- Encourage organizations like CII to funnel unused research suggestions to universities
- Get organizations like CII to encourage their members to participate
- Dissemination of the knowledge created by such non-funded research through organizations like CII
- Identification and publication of successes of non-funded university research

Group Conclusions of the Three Models:

After discussion the three models, the group identified the following four conclusions:

- Converting innovation into practice will create new demand for innovation and research.
- Our "storehouses of knowledge" must be continually replenished.
- To accelerate progress we must link, collaborate and share much more than we do today.
- The attitude between industry and academia must be changed to make this collaboration possible.

3. How to address industrial, general building, and infrastructure sectors?

This group addressed the different research needs of the industrial, building, and infrastructure sectors. They specifically considered four points: The similarities and differences among the sectors.

- The critical topics of each sector.
- What is not being addressed today.
- What can be done to address these items in each sector.

A discussion of the nature of the three sectors led to the conclusion that, although there are many similarities, there are also significant differences. The construction process itself is similar. The primary differences are related to the culture of the owners and the environment in which projects are planned and executed. These differences greatly impact the research needs and the effectiveness in implementing results. Another difference that significantly impacts research and the dissemination of its findings, is the different language or terminology utilized within each sector.

A number of potential research areas were listed, that are not being adequately addressed today:

- Performance Metrics - Buildings and Infrastructure Sectors
- Communications - Buildings and Infrastructure Sectors
- Exporting of Site Work Hours Off Site - Buildings and Infrastructure Sectors
- Constructability - Buildings Sector
- Technology Selection - Infrastructure Sector
- Supply Chain Management - All Sectors
- Craft Education and Training - All Sectors (NCCER is not enough)
- Cost/Schedule Controls - Buildings Sector
- Scope Definition for Design/Build Projects - All Sectors
- Automation - Buildings and Infrastructure Sectors

Four preliminary conclusions surfaced:

- Research should be relevant to all three sectors
- A stronger liaison between the sectors is needed
- Effective communication channels among the three sectors are required
- Research products should be adapted and expressed in terminology relevant to the three sectors.

4. How can the engineering and construction industry learn from research?

This group examined the barriers to implementation of innovations and then discussed how the industry embraces change and how organizations / infrastructures / cultures could be modified to implement these changes. The group developed five principles required for change to happen in the engineering and construction industry through the implementation of new technologies and transfer of information:

1. **Must have value to the owner** - Most changes happen when demanded by the owner. The owner, who allocates and controls funding must see financial value in any change.
2. **Proof that it works** - This demand is the first defense against change. The fact that research mostly happens in a controlled environment while the implementation occurs on the job site easily leads to questioning the applicability of new practices or technologies.
3. **Collection and dissemination of information (Implementation culture)** - Where to find the information and how to disseminate it is a major challenge. To impart credibility, an innovation oriented culture needs the support of a high level person as a champion and a formal information collection and dissemination system.
4. **Agents-of-change** - For changes to happen in most organizations or companies, a champion has to be designated. This champion is responsible for implementing a change or innovation. A strong driver of change is the competition with peer companies and the competitive advantages derived from an innovation. Probably, the most powerful change-agent is a “crisis." When a crisis appears, the drive, the threat, and motive are in place to improve technologies and change inefficient practices.

5. Owner Protocol - There must be continuous feedback and activation of innovations. The creation of permanent facilities involves a series of' processes including planning, design, procurement, construction, maintenance, and operations. Often neglected is the aspect of improving the next undertaking by applying the experience and lessons learned from the just completed job.

5. How do we use what we know about people to achieve results?

This group's discussion addressed eight aspects:

Leadership vs. Management.

The key characteristics for effective leadership/management/followership in the construction industry need to be identified and studied. Based on such information a core curriculum should be developed so that academia and industry can develop consistent leadership skills for the industry.

Teamwork.

All participants in the construction process need to reach a deeper understanding of the concepts of effective teamwork. Studies should be funded aimed at integrating teamwork into the engineering curriculum using the many existing products and successful industry programs.

Understanding of Personality Characteristics, Instruments and Psychology.

The key characteristics of successful people at all levels in the construction industry need to be identified and understood. Also the different ways different cultures think - including the feminine culture. Engineers have a reputation as not being people oriented. This attitude, if true, needs to be changed through education and awareness.

Quality of Life of the Employee and the Family's Well Being

The 50- to 65-hour workweeks, common in construction, destroy family values. The companies of the future will have to address this and a number of other new issues to stay competitive.

External Culture

There are cultural trends external to companies both in the US and outside the US that successful companies must understand and embrace today and even more so in the fixture. They include factors from the changing family life style to globalization of the industry.

Internal Culture

Successful companies understand the dominant role their internal culture plays. There is a need to be able to evaluate a culture and its impact on people's performance. The most successful cultures are based on trust, loyalty, and innovation.

Education, Training and Development

Increasing skills and knowledge (development) are required for the success of any organization and individual. A company must identify the key skills it requires, and give each individual the responsibility for acquiring and developing the knowledge and experience that will allow her/him to progress. Companies will have to provide and support environments that offer opportunities for development. A high-priority in this area is the development of competent construction site supervisors.

Summary Comments by the CII Academic Council

Many important issues and insights surfaced during the discussions of the five workshop groups and the ensuing collective discussions. Significant improvements in the conduct of research, the attainment of results, and the adoption of those results in industry could be achieved through further development of ideas and suggestions raised in the workshop.

Near-term efforts need to be focused on examining these issues and insights and converting them into cohesive and comprehensive action plans that can be undertaken by academia and industry. Plans need to be developed to further pursue some of the insights and address the key issues raised in the workshop. Below is a partial list of initiatives for further consideration:

- Establish mechanisms to foster and develop breakthrough research incubators as described in this report.
- Encourage funding/backing of research by government (e.g. construction research programs/grants) and by industry (e.g., provide investment incentives).
- Encourage organizations that fund construction research to funnel unused research suggestions to universities.
- Develop effective communication channels among the three construction sectors and produce research products that are adapted and expressed in terminology relevant to the three sectors.
- Facilitate sharing of information, collaboration, and linking between researchers in universities, and between universities and industry.
- Establish a mechanism to collect, from the worker's level in industry, pressing topics for research and make them available to the universities for consideration in their planning processes for future research.

1.0 Introduction

Arrangement of this Report

This report contains a summary of the discussions of the CII/NSF Workshop, held on May 13-14, 1997 in Austin Texas. Section 1 describes the background and objectives of the workshop. Section 2 is a summary of the welcoming remarks and challenges to the five working groups. Section 3 through 7 provides a detailed summary of the discussions and insights generated by each of the five working groups. Section 8 provides a summary of closing remarks and Section 9 is a roster of participants.

Background

The rapid globalization of business enterprises, combined with extensive reorganizing and downsizing of companies, has heightened the demands placed on the engineering and construction industry. This has created an unprecedented global competition and a need for innovative construction-related research. New and effective ways must be found to transfer and incorporate the research results into the engineering and construction industry.

Previous Workshops

Between 1975 and 1984 the National Science Foundation sponsored five workshops to explore construction industry research needs. Each workshop contributed significantly to the body of knowledge for establishing needs and directions for construction research. Although the five workshops had different specific objectives and varying formats, each had the primary purpose of developing a research agenda. This agenda was developed through an exchange of ideas between funding agencies, practitioners, and academics.

A workshop on "Goals for Basic Research in Construction" was organized by Professor Boyd C. Paulson, Jr. at Stanford University in April 1975. The workshop which involved a limited number of academic and industry participants concentrated on four general subject areas: 1) manpower and organizational development, 2) management methodologies, 3) innovations in construction methods, and 4) construction industry dynamics.

A second workshop, organized by Professor Keith C. Crandall, was held at the National Bureau of Standards in May 1978. The workshop, entitled "Formulation of Specific Projects in Productivity Research for the Construction Industry", involved participants of the mission-oriented government agencies. The workshop reviewed the building and heavy sector and included seven areas of emphasis: 1) management, 2) labor, 3) design/construction interface, 4) capital budgeting and finance, 5) technology, 6) regulatory, and 7) public policy.

A third workshop, organized by Professors Robert I. Carr and William F. Maloney, was conducted at the University of Michigan in May 1982. Entitled "Workshop on Construction Engineering Basic Research", the workshop involved construction educators and focused on the identification of a number of basic research needs in Construction Engineering and Management, Analysis and Design, Uncertainty and Human Resource Management.

A fourth workshop was organized by Professor Ray E. Levitt and Mr. Peter Lansley and held under the auspices of the National Science Foundation and the Science and Engineering Research Council of the United Kingdom. The 1983 workshop was held at Stanford University and addressed the "Management of Construction Projects by Clients: The Design of Appropriate Organization Structures."

A fifth workshop was organized by Professors Richard L. Tucker and David B. Ashley as a result of events involving the Business Roundtable and the formation of the Construction Industry Institute. The workshop was held at the University of Texas in February 1984 to identify topics and directions for future construction research. The workshop agenda focused on research needs in five areas: 1) industry-wide, 2) design and procurement, 3) project management, 4) site activities, and 5) construction technology.

Workshop Objectives

All of the previous workshops, conducted between 1975 and 1984, have contributed significantly in identifying research needs and topics. Since no national workshop had been held since 1984, the purpose of this workshop was to review the accomplishments and research efforts of the past decade as a background to focus on the future. In particular, the workshop goal was to address opportunities and challenges to identify processes which produce break-through research to benefit the industry. An additional objective was to identify creative methods and techniques to transfer and incorporate the results of the research into the engineering and construction industry.

Workshop Format

The two-day workshop was designed to provide a forum for researchers, research sponsors, and research benefactors to address the above issues. The workshop was conducted in five working groups which addressed the following topics:

1. How do we go from incremental to break-through research?
2. What are creative processes to form and identify research opportunities?
3. How do we address industrial, general building, and infrastructure sectors?
4. How can the engineering and construction industry learn from research?
5. How do we use what we know about people to achieve results?

Attendees discussed issues related to the five topics in an open format that promoted creative thinking and innovative approaches to produce research results which will be of future benefit to the engineering and construction industry. Attendees represented faculty from universities with graduate programs in construction engineering and management, major construction firms, major engineering design firms, large construction project owners, and research organizations outside the construction industry.

The workshop began with a welcome by the CII Academic Council Chairman, Hal Yoh, followed by self-introduction of workshop participants. Dr. Richard Tucker made opening remarks to lay the workshop's foundation and focus on the future.

The facilitator for each of the five working session was introduced. Members of the academic community and professionals from industry were represented in each group. Each working group then devoted the first afternoon brainstorming and exchanging ideas pertaining to issues related to their assigned discussion topic. A member of the CII Academic Council served as a recorder to capture the comments and ideas that were generated. A summary of each break-out session was presented to the entire workshop the next morning, followed by open discussions and comments.

2.0 Opening Remarks

Welcome Remarks

Dr. Ken Chong
NSF Director of Structural Systems and Construction Processes

Our economy, security, and quality of life depend to a large measure on the vitality and efficiency of its constructed infrastructure. A society that neglects its physical infrastructure will lose its ability to transport people, goods, and information efficiently. Furthermore, the society will be less able to meet the needs of its citizens for housing and employment, clean air and water, adequate energy, and control of disease, and a healthy economy.

This CII/NSF Workshop is organized to address the important topics of incremental/break-through research, creative processes for research opportunities, aspects in industrial, general building and infrastructure sectors, technology/knowledge transfer, construction management, and others.

The last major construction workshop provided useful information and rationale for the NSF construction automation initiative. I am sure you all will have a very productive and fruitful workshop. I look forward to reading your proceedings.

Workshop Objectives

Hal Yoh
President, Day & Zimmermann, Inc.

As chairman of the CII Academic Council, Hal Yoh welcomed participants to the CII/NSF co-sponsored workshop on behalf of the Construction Industry Institute and the National Science Foundation. After self introductions by each participant, he reviewed the background that lead to this workshop, and provided a summary of the five National Science Foundation sponsored workshops that were held between 1975 and 1984 to explore construction industry research needs. The following paragraphs are excerpts from Hal Yoh's opening statements and comments on the objectives of the workshop.

This two-day workshop is offered to provide a forum for researchers, research sponsors, and benefactors to address issues related to our workshop theme: How do we use research to improve the engineering and construction industry? Our objectives are:

- To foster interaction between academia and industry in hopes that this dialogue continues. This is the first time in 13 years that an equal number of people from industry and academia have met to discuss this issue. In the past, industry and academics have met separately on this issue.
- To identify the current barriers and issues that are preventing the engineering construction industry from becoming more effective.
- To determine how research can help to solve the overcome barriers.
- To generate new research topics that can be funded by NSF, CII, or other funding mechanisms.

The mission of each working group is to present their synthesis and consensus to the entire group for open discussion and recommendations. As participants approached the break-out session, they were challenged to:

- Innovations
- New ideas
- Improvements for our industry

In the end, what we are looking for isn't just identifying barriers and issues. We can all easily list those today. We are looking for new ideas, methods, or processes that can radically change the engineering and construction industry.

In your break-out group, reach some consensus and a priority list. A path forward could identify who, what, when or how, or just say we need to explore this topic more. A report of the workshop will be produced and widely distributed.

The Challenge of Construction Industry Research and Implementation

Dr. Richard L. Tucker, Director
Construction Industry Institute

The following are excerpts from the opening remarks by Dr. Richard L. Tucker, Director of the Construction Industry Institute:

Before 1984, the construction volume of 127 countries was as follows:

	$ billion
USA	327
Japan	292
Western Europe (17)	325
Eastern Europe (8)	264
Total =	1,208
Other (100)	224
Total =	1,432

The fragmentation of the engineering and construction industry is illustrated by the following data:

- 1,000,000 contractors
- 50,000 design firms
- 6,000,000 craftsmen
- 180 trade associations
- 10,000 building code jurisdictions
- 15 national labor unions

Before 1984 there were few graduate engineering programs, most of the emphasis was on construction management, and many publications were naïve with little industry acceptance. There was minimal research funding for construction and little interface between industry/academia.

The big picture today is world population growth, large underdeveloped countries, aging facilities, international competition, sophisticated approaches, and accelerating change. Key global events include Japan's emergence as an economic and technical challenger, the opening of eastern bloc countries, the formation of the European Economic Community in 1992, a shift of resources away from the military and environmental consciousness.

There are positive factors in the U.S., including: open and competitive markets, historical strengths in user industries, historical strengths in suppliers, strong engineering universities, and an innovative industry. However, there are threats to the U.S. leadership, including low U.S. construction research and development, weaknesses in assimilating new technologies, growing weaknesses in related industries, potential shortages of engineers and skilled workers, and procurement based on cost rather than quality.

There have been catalysts that have shaped and influenced our effort to improve the engineering and construction industry. Professors Clark Oglesby and Robert Peurifoy were pioneers in promoting construction education at the university level. In 1979, the publications of the CICE project of the Business Roundtable opened the issue of increasing the cost effectiveness of the construction industry. The previous NSF workshops on research for the construction industry provided valuable information to formulate the research agendas in the U.S.

The CII was established in 1983 by 22 founding members in response to the need for construction research. The mission of CII is to identify and perform research and to implement the results. Research is accomplished as a partnership between owners, contractors and engineers, and academia. Other research centers have also greatly contributed to the construction research effort. These centers include CIFE, ACE, CICA, CERF, Penn State, Georgia Tech, Illinois, MIT, as well as centers in other countries.

In our efforts to improve the construction industry, the feasibility tests are twofold: payoff potential (impact) and do-ability. The evolution of CII's efforts has been research, implementation, education, and measurements

There are several major industry trends today; changing owner requirements and contractor roles, globalization, skilled work force shortages, increased role of suppliers, reduced cycle time requirements, and increased capital effectiveness requirements. Industry today is moving to fully integrated/automated project processes.

Another trend today is restructuring. Owner reorganizations and internal company changes are widespread. This has caused outsourcing, alliances, contractor consolidation, and experimentation. These events present both challenges and opportunities.

How can we get better? By providing basic elements, committing to improvements, developing new improvement tools, implementing them and measuring the results. The elements of improvement include planning, standardization, controls, human resources, communications, and technology.

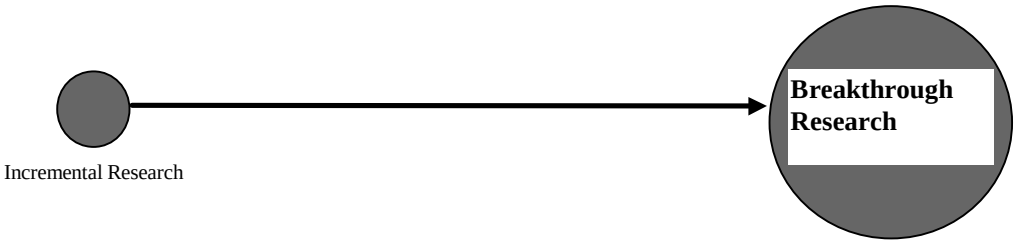
Today project management is a recognized discipline and a part of many academic programs. There has been improvement in recognition of research contributions. We are broadening our research areas. The future looks positive. The potential exists for continuous improvement, breakthrough, and implementation.

3.0 How do we go from incremental to break-through research?

Facilitator: Greg Howell
Recorder: Jimmie Hinze
Participants: David Ashley, U.C. Berkeley
Reg Gagliardo, Burns and Roe
Bud Griffis, Columbia University
Carl Haas, University of Texas
Chuck McGinnis, CII
Marty Schofield, Hilti, Inc.
Jack Snell, NIST

This working group engaged in several discussions in trying to decipher the underlying issue being posed by the question. The first discussion addressed the definitions of the terms, especially the meaning of incremental research and breakthrough research. Several questions were raised in this discussion. Is there a clear dichotomy between incremental and breakthrough research? Can incremental research become breakthrough research through some significant findings? Must breakthrough research be the objective of a research project in order for breakthrough research to occur? Is the difference a matter of the amount of funding provided to conduct the research? Is there a clear difference between incremental research and breakthrough research? Is there a continuum along which incremental research leads into breakthrough research? Is the breakthrough: a) the concept and/or tool; b) the application in industry of the concept and/or tool; or c) both a) and b)?

The nature of the question was interpreted to say that there is a clear difference between incremental and breakthrough research. At the same time, the question seems to imply that incremental research is a "lead in" to breakthrough research. This question was viewed as reflecting the following relationship between incremental and breakthrough research:



While there was no consensus on the answers to the above questions, the team members eventually decided that establishing a clear consensus of the relationship of incremental research to breakthrough research was not essential. It was felt that the issue was not so much a matter of going from incremental research to breakthrough research, but rather the central issue was to have breakthrough research. The question was essentially rewritten to say "How can breakthrough research be achieved?" Phrased in this manner, the workshop team was not burdened by having to come up with a definitive description of incremental research. Despite this, the group members continued to draw distinctions between incremental research and breakthrough research.

What is Breakthrough Research and How Do We Achieve It?

While the distinction between incremental and breakthrough research was never made to the group's satisfaction, considerable discussion focused on defining breakthrough research. Research that is focused five years into the future is not breakthrough. Great findings may also evolve from the efforts of solving simple problems. It was generally agreed that breakthrough research had elements of the following:

- It makes possible significant and relatively immediate change
- It addresses a problem generally perceived by all

While no lengthy lists of past research were developed that would warrant the label of breakthrough, spreadsheets and object technology were two recent computer developments that were felt to meet the criteria of breakthrough.

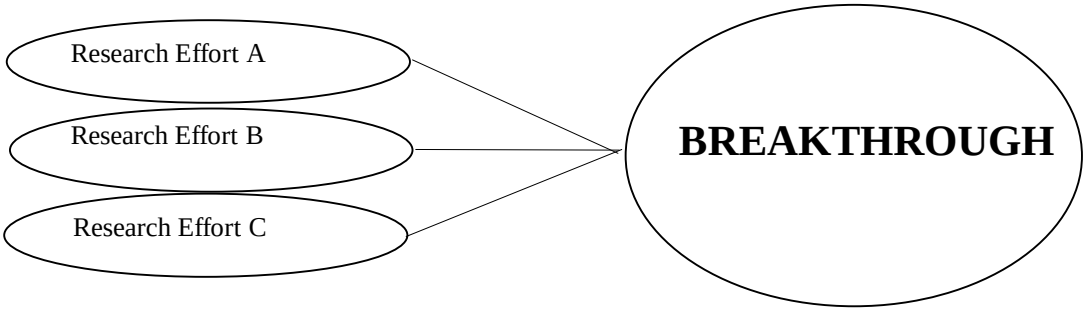
A lament of the group was that much of what we do is still 19th century in nature. Examples of smaller breakthrough research that might help get us into the 21st century include long life (70+ years) highways, ironable asphalt, three-dimensional positioning, quick deck repair methods and materials, and accurate mapping techniques. Advances in TQM are also warranted as progress in these area has been slow. Some of the answers to achieving breakthrough in construction may consist of adapting technology already developed and operational in other industries.

It was suggested that breakthrough research does not generally present itself as the immediate goal of an effort. Research studies that have grandiose goals are generally poorly funded resulting in slow progress, while companies will often spend huge sums of money to make only incremental advances. Although great ideas may come from lightly-funded studies, it was generally felt that breakthrough research requires the commitment of significant funding amounts. Breakthrough is also frustrating when the final objective is not believed as being achievable. To some extent, the achievement of breakthrough requires the removal of paradigm blocks.

Much of the construction research conducted in academia occurs in departments of civil engineering. Historically, construction research lags behind the more classical types of structural research projects conducted in civil engineering. Because of tradition or some other reason, research on management issues has often not been regarded as being on par with studies conducted with conventional testing machines. This has posed a problem, especially for faculty members in civil engineering departments who must seek tenure through the support of faculty members who have developed their careers in the more traditional fields of civil engineering.

Construction research lags traditional civil engineering research projects. Since this is a real issue for academic promotion, it is not uncommon for faculty in construction management programs to develop research agendas in the areas of materials as well. The idea that the "Big university is a relic" can lead to the destruction of the ability to do breakthrough research. Perhaps we need to change the way that research is viewed. Construction research tends to be approached with conservatism, with a high degree of success being projected at the onset of the research effort. A greater willingness to take chances may be one way to achieve breakthrough. One example was developed using the fusion research as a possible model. Multiple approaches are employed to achieve fusion,

but only one needs to be successful. And yet, there is no guarantee of success. Is the construction industry to explore possibilities with such odds?



Three different research efforts, but only one needs to be successful

The traditional research model stifles the ability to do breakthrough research. Much of the problems still lies in the inability of defining breakthrough. There is an inference that incremental research is easy, that incremental research is applied research and contributes only in a small degree to our body of knowledge. Does incremental research have a shorter time fuse? It was felt that this was not clear as sometimes continued small contributions (persistent incremental gains) will over time make a significant difference. It was also felt that research required a certain amount of time, such as 3 to 5 years, as well as the appropriate political or financial support. This was noted in the area of construction safety which has improved notably in the past twenty-five years.

It was noted that the Construction Industry Institute (CII) started with goals "for the industry" and that it has evolved to more member oriented goals. This is perhaps a logical progression. The research of the CII reflect the interests of the members. The success of the CII can be attributed to a large extent to the efforts of its strong members. Some members now want a few good ideas. Would CII be willing to invest 25% in breakthrough research? This may become a reality at a low cost if we take advantage of cross-over technology.

The Center for Integrated Facilities Engineering (CIFE) Model uses seed money to identify potential areas of research. From this, large projects sponsored by consortium are created. Money directly influences the magnitude of the projects undertaken.

Problem solving is incremental while breakthrough research results from changes in the mental process.

It was postulated that conditions often present themselves that make it more conducive for breakthrough research to occur. These occurrences are major opportunities that open the doors for significant change. Examples of such conditions that may spark breakthrough include the following:

major disaster
unique opportunity
new technology

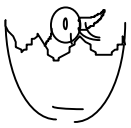
The approaches utilized by various research institutions were examined. They are summarized below:

Comparison of Research Models

ISSUE	CII	NIST	UNIV.	COMPANIES
Center of attention	Project focus	Core of Researchers	Topic: single investment	Problem/tool focus
Output	"Tool"	- Old NIST: results in a report -New NIST: project w/impact	Archival papers "Human capital"	Competitive advantage
Link research to outcomes	• Outcomes to research not available • Measures	The product and outcome defined at once	Consultants, impact on industry Little-through students	ROI
$/Project	Small: $150K	Big: 1000K/yr.	$20-500 K	0-$10 million
Organizational emphasis	Volunteer	Professional Staff	Grad students and some staff	Staff and Consultants

These might be thought of as models of how to manage research. It must be recognized that these institutions address research differently for a reason, i.e., one model does not fit all research objectives. Each model has strengths and each can produce breakthrough. But each has its own unique obstacles.

Each model must find fertile eggs and then learn how to turn and heat the eggs properly so that they can hatch. This means that sustained efforts might be well warranted and that long-term funding should be considered.



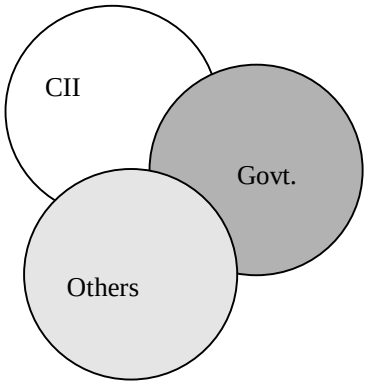
We must nurture the ideas as they develop. This concept introduces the breakthrough incubator.

Breakthrough Incubator Model

ISSUE	Breakthrough Incubator
Center of attention	Clear vision, objective and goal
Output	Competitive advantage
Link research to outcomes	Linking outcome to investment "ROI"
$/Project	Critical mass plus guarantee of continuation
Organizational emphasis	Research staff (intellectual continuity)

We need to form new alliances among the organization involved in research. We need partnering of research efforts, as illustrated below.

Make New Alliances: Partnering



As noted, one research model does not fit all. Each model can come up with a breakthrough - but each has obstacles, such as duration or focus. This brings up the question of efficiency and "range".

Consider a research project management approach as illustrated below.

Research Needs

Area of research: **Technology focus**	What is needed?
Identify the need	Large financial commitment
Test and evaluate	Long term commitment, staff continuity
Coordinate	Facilities for conducting research
Provide expertise for implementation	
CII can do some more in these areas	

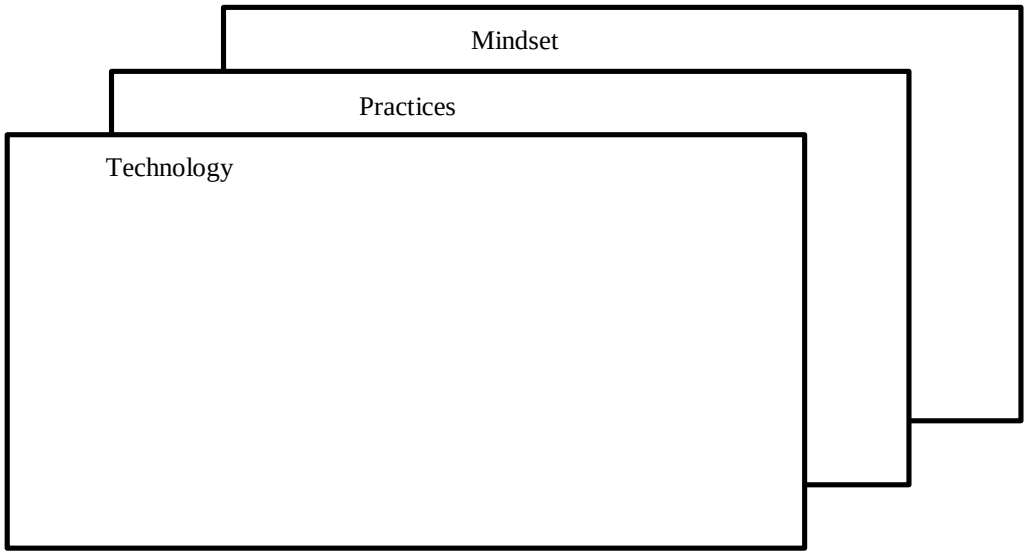
Area of research: **Practices focus**	What is needed?
Identify the need	Field observation and data
Test and evaluate	Interaction with practitioners
Coordinate	Establish or develop the system model
Provide expertise for implementation	Experiments conducted, risk assessed
	Leadership and vision

Area of research: **Mindset focus**	What is needed?
Identify the need	Understanding of processes
Test and evaluate	Understanding of constraints
Coordinate	Understanding of assumptions
Provide expertise for implementation	Understanding of the environment
	Inspiration and collaboration

Breakthrough research can be enhanced by long-term time commitment of key researchers to provide leadership.

The path forward

- This is a partial job, it needs to be finished
- There is encouragement, move forward down the road
- Identify the obstacles within each organization
- Identify opportunities, areas of research
- Foster collaboration, especially in the beginning
- Accept the risk that is associated with breakthrough research
  - Provide low risk environment for experiments (mat'ls vs. practice)
  - Perhaps government can take higher risks than the private sector
- Nurture intellectual continuity and stimulate it, but maintain collaboration across the industry
- Consider the role of government in research areas and topics of interest



Consider alliances with other industries, e.g., construction, auto industry, etc.
Gain from new ideas, assumptions, differing views

4.0 What are creative processes to form and identify research?

Facilitator: Mike Vorster, VPI
Recorder: Peter Bopp, DuPont
Participants: Robert Carr, University of Michigan
Edd Gibson, University of Texas
Joe Haegelin, Texaco (retired)
Dan Halpin, Purdue University
Garold Oberlender, Oklahoma State
Robert Poirier, Flour Daniel
Dennis Schroeder, BE&K
Jon Vanden Bosch, CII

This breakout group began its deliberations by brainstorming issues and topics related to creative processes to form and identify research opportunities. The discussions were held in a round robin fashion, with each participant providing ideas, concepts, and thoughts on new and innovative methods to form and identify research of relevance to the engineering and construction industry. Each participant was asked to consider what has been done in the past, what is currently being done, and what are potential new and innovative methods. Participants were asked to provide their thoughts in an open format, with no restrictions regarding priority or importance, but to simply explore their mind on issues and topics. Below is a list of the issues and topics that were identified:

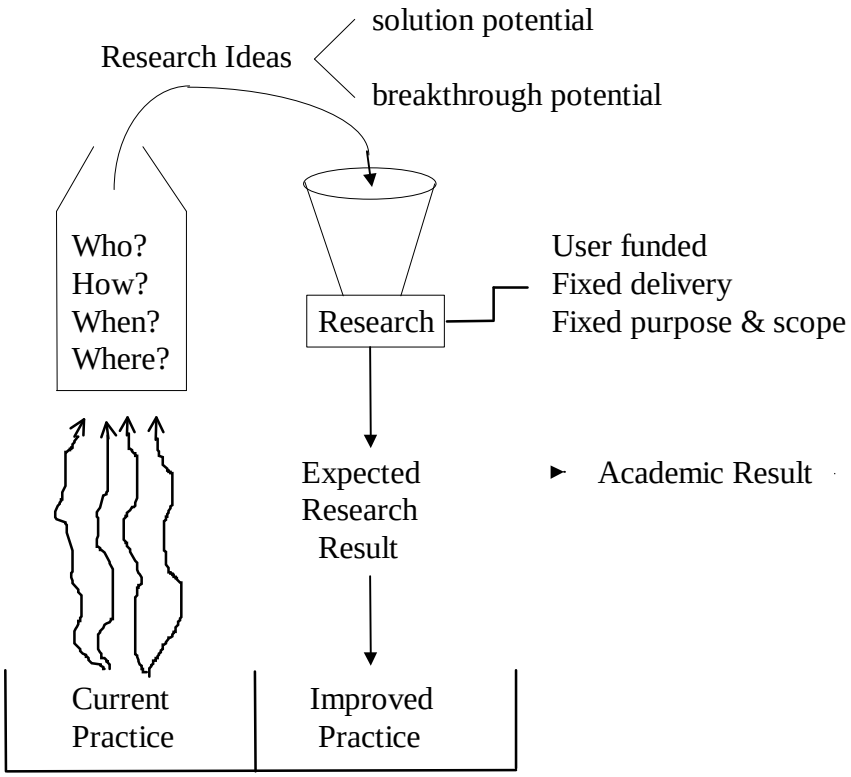
- Research - is it long term opportunities? Or short term fixes?
- Are short driven (short term) fixes and long term improvements very different in process and result?
- Creativity - must consider diversity of people, different perspectives, increased complexity.
- What is creativity? How do we define it? Where do we find it? In engineering and in construction.
- What are creative methods of identifying important things to do?
- How are problems perceived, felt, and tackled?
- How do we quantify the needs for construction research?
- Technological advances cascade additional long term advances.
- Exploratory approaches lead to innovation advances (or may lead to dead-end)
- There are Technology vs. Management issues in research
- Basic research builds a storehouse of knowledge (for later usage)
- We need challenge or motivation to do research

- Creative research - can be funded vs. non-funded
- Input of research into practice is too slow
- We need more "bottoms-up" input to identify research topics and to implement
- We need to be aware when our "Storehouses of Knowledge" are being depleted
- Our knowledge of what is in the "Storehouses of Knowledge" is incomplete and fragmented
- Crisis is the pre-eminent research trigger. Is there one today?
- Breakthrough research - due to crisis? Must have acceptance of new ideas.
- Innovation as the result of deliberate strategy and approach
- Serendipity is the mother of inventions
- What is a research cycle? Are there more than one?
- What is our current practice? What other ways are conceivable?
- For the system to work, we must apply results
- We must show improvements, create demand
- Where do we get research ideas? From people at the job-site? We need cultural change to promote mutual exchanges to benefit the entire industry.
- Where do we get research ideas? From other industries? Consider the following:

Electronics Industry	Construction Industry
giga users	owner - narrow scope
repetitive	one time
large volume	small volume
schedule driven	cost driven
high tech	low tech
high opportunity	low opportunity
short term product life	long term product life
small $/unit	large $/unit

After reviewing the above list of issues and topics, the group agreed that there could and should be several models to represent creative processes to form and identify research opportunities. These models should integrate the producer of the research and the user of the research results. The research model should be a continuous cycle. The group then developed three models describing today's cycles that identify, fund, produce and disseminate research.

Research Cycle "A"



Examples: CII Research and other Funded Academic Research

Today's Practice:

- scan sponsor companies
- scan professional societies
- scan universities and other research organizations
- scan industry groups
- review of completed work

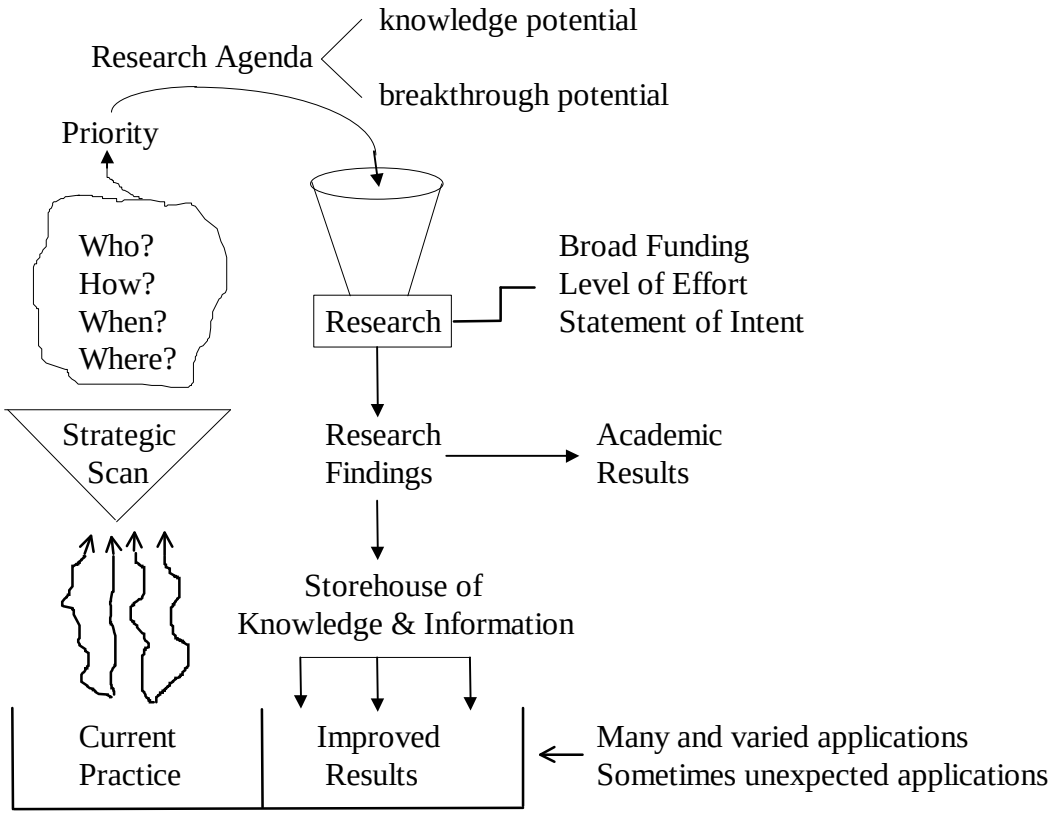
Possible Future Practices:

- scan member companies at the field (worker's level)
- scan sub-contractors, suppliers, vendors
- interview to solicit research needs (problems)
- focus groups to solicit research needs (problems)
- utilize benchmarks and metrics to get research ideas
- solicit information from customers (business units, operating groups, project close out files)
- internet chat rooms, bulletin boards to obtain feedback on research topics
- Create many more "hoppers" into which research opportunities can be fed

Insights:

- success of Model "A" depends on showing success
- we need to better identify our successes
- we need more pre-planning of research projects

Research Cycle "B"



Examples: NSF, Macro-research, Foundation Programs

Today's Practice:

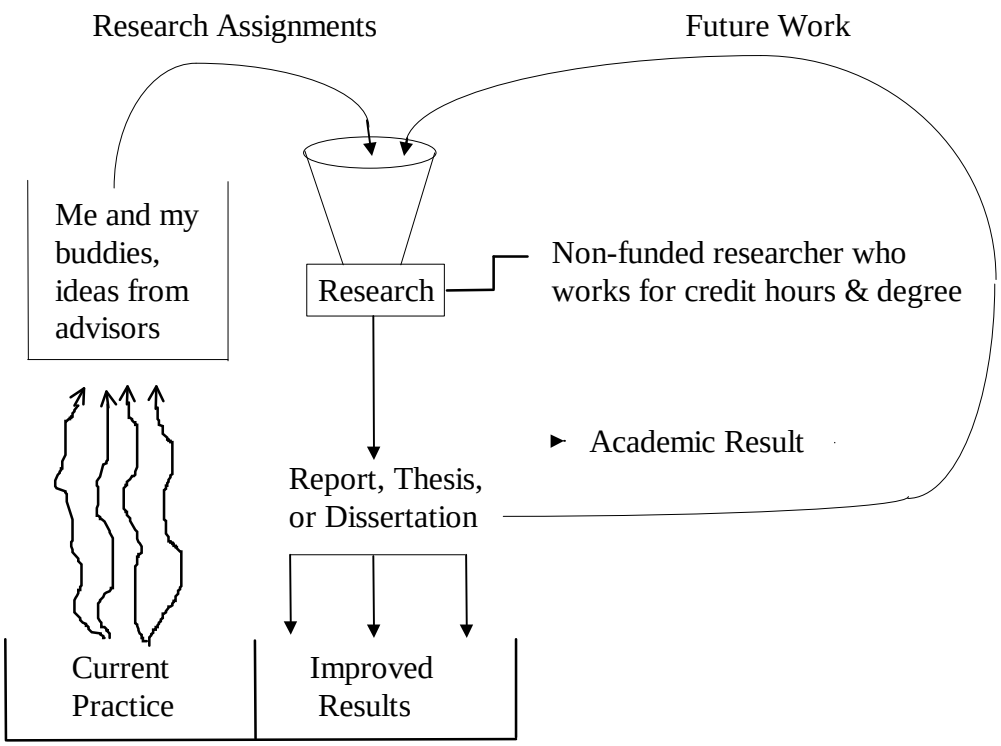
- often driven by societal needs (infrastructure)
- sometimes driven by crisis (such as war)
- no national strategy (society's benefits)
- influenced "some" by who you know
- low priority, seen as private industry issue in the U.S.

Possible Future Practices:

- develop advocacy groups like the Business Round Table construction groups
- scan emerging technologies to identify opportunities for use & development in construction
- use the results of Model "A" as means of identify research needs and opportunities
- cooperate and share among universities & industry to create a larger and unified constituency
- better networking and alliances among universities
- need better networking between universities and industry
- scan associated industries to identify common research opportunities
- better data on our own construction industry
- support and influence organizations like CII
- need to better identify and publicize our successes

Insight: Model "B" is extremely weak in the US for construction research

Research Cycle "C"



Examples: >50% of the research at universities is open research

Today's Practice:

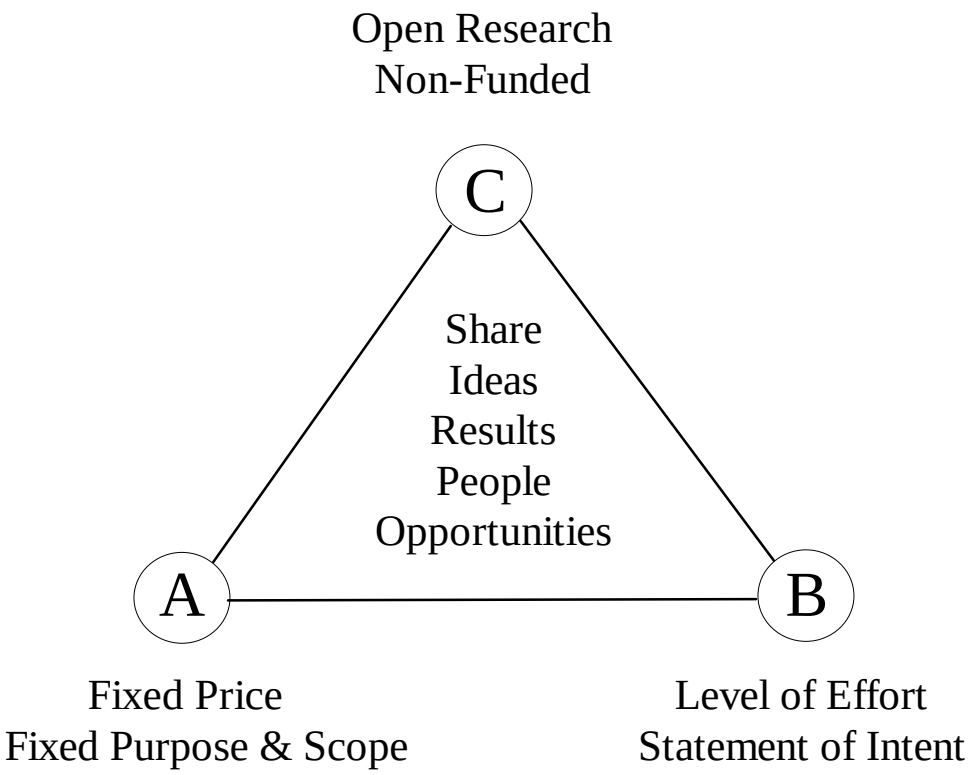
- ideas from faculty advisors
- review of literature from other research
- personal contacts in industry
- follow-up research from previous students
- interest of student from previous work
- contacts between faculty of other universities

Possible Future Practices:

- increase linkage between research universities and the business community
- encourage industry and universities to form alliances
- use the opportunity to create alliances and bridges with CII and business community
- link to CII, ASCE, CRC, etc. to funnel unused research suggestions to universities
- get organizations like CII to encourage their members to participate
- disseminate to universities any knowledge of non-funded research opportunities from organizati like CII (e.g. provide to universities the research topics that did not receive CII funding)
- identify and publicize successes better

Insights: the construction industry should take advantage of the non-funded research that is being conducted at all universities

After reviewing the previous research cycle models, the working group discussed options to improve the research process. There was general consensus among participants that communications between the research community should be enhanced. It was agreed that increased cooperation between researchers, and between researchers and the engineering/construction industry would lead to improvement in identifying research opportunities to better serve the industry. To create processes to form and identify research opportunities, the working group developed the following model to illustrate the interaction among the three previously identified Research Cycles and how an improved sharing of ideas, results, and people would benefit all the research done for and by the engineering and construction industry.



- A, B, and C are stations of the journey to seek knowledge
- The activity in one becomes the basis for another

To accelerate progress we must link, collaborate, and share much more than we do today !

Conclusions

After discussing and refining the research model cycles and the need to increase the emphasis of mutual sharing of ideas and results among the research community, the group arrived at the following conclusions about the "who, how, when, where," etc. for creating processes to form and identify research opportunities:

- A change in attitude between industry and academia is required to promote mutual exchanges that will benefit the entire engineering and construction industry.
- To find research topics, we need to:
  Look at other industries
  Look at mature storehouses of knowledge needing replenishment
- Converting innovation to practice will create demand for new and more innovation
- The disappearance of political world challenges reduces the support for building "storehouses of knowledge". Existing storehouses are being used by everybody and will be depleted without being replenished at equal rate. This works against the mindset which supports long-term strategic or basic research.
- There needs to be a mechanism to **tell** us what is in the "Storehouses of Knowledge". Need attention to "get the information out".
- We must look more outside "our realm".
- It is always difficult to solve a problem not recognized as "today's problem"
- We need breakthrough advancement (e.g. Ford's assembly line) which in turn precipitates many other developments (such as automobile parts manufacturers)
- We need to "Network" more to accelerate the progress initiated by CII
- Need to create awareness of research successes to create demand for more research
- We need to tap into industry led improvements and successes (safety, labor relations, etc.)
- We need a data base about research expertise with focus on specialization.

5.0 How to address industrial, general building, and infrastructure sectors?

Facilitator: Peter Van Nort, H. B. Zachry
Recorder: Bob Jortberg, CII
Participants: Howard Bashford, Brigham Young
Bru Brubaker, NASA
Paul Chinowsky, Georgia Tech
Peter Miller, Kiewit Industrial
Art Morstadt, Eli Lilly
Jim O'Conner, University of Texas
Jim Rowings, Iowa State University

Peter Van Nort as facilitator observed that individuals participating in this breakout session included two owners and two contractors in each of the three sectors and four academics. Each participant had experience in each of the three sectors.

The discussion concerning the nature of these three sectors and their similarities and differences led to the conclusion that they are both similar and different and that the differences are significant. It was recognized that the construction process itself has many similarities.

Within each sector, there are projects that look like projects in other sectors, and this confirms the earlier view that the activities involved in the construction have significant similarities. However, the owners and ultimate users of a project are not necessarily the same, and that the impact of this among the different sectors is very different. This was developed earlier in this discussion concerning the difference among the owners.

There is a significant amount of earth moving and site development in virtually all projects, although it is recognized that earth moving and heavy civil work is predominant in the infrastructure sector. All sectors employ structural steel and reinforced concrete to some degree, and all sectors include mechanical and electrical systems.

The heavy industrial sectors involve significantly more mechanical systems with a major component of heavy piping installations. The heavy industrial sector also tends to include more process control systems. The discussion developed the point that the primary differences may be related to the culture of the owners and the environment in which projects are planned and executed. Owners of heavy industrial projects typically not only plan and execute the projects, but also own and operate the projects after completion of construction to generate a return on the investment associated with the

project. These owners are intimately involved in the identification of project opportunities, in the definition of the scope of projects, and in the engineering, procurement, and construction activities. The engineering work is typically dominated by process engineers, and construction is typically performed by construction contractors.

The light industrial/general building sector owners include several different categories such as pharmaceutical owners, for example, who are involved in light industrial facilities as well as buildings and to some extent with infrastructure sectors projects as well. Many general buildings are constructed by developers who are entrepreneurs and build facilities as investments without the intent of becoming the owner/operator of the facility once completed. A large number of building projects are sponsored by governmental activities in which case the owner is the general public. In these cases, the identification of requirements, definition of scope, and the management of the engineering, procurement, and construction process is typically managed by political entities, many of whom have little experience in planning and execution of capital projects. In addition, there are many differences in the project drivers for the three sectors and in the stakeholders. There may also be differing incentives. As a result, the business environment in which capital projects are planned and executed is different. This is then reflected in the research needs for the sectors.

The majority of infrastructure projects are pursued by governmental entities, notably the U.S. Army Corps of Engineers, the Naval Facilities Engineering Command, and the U.S. Air Force, as major owners of federal facilities. In addition, many infrastructure projects are pursued as elements of heavy industrial facilities, typically water treatment and waste water treatment facilities. The State Highway Departments or Departments of Transportation are involved in the highway and bridge construction component of the infrastructure program. The engineering and project capability of the governmental agencies involved in infrastructure construction vary widely throughout the United States.

The group concluded that while the activities performed in the engineering and construction of projects in the three sectors have many similarities, the differences, particularly the differences in the owner organizations, can have a major impact on research in support of the three sectors. One significant difference that impacts research is the different language or terminology utilized within the sectors. For example, in the building sector, preconstruction services are often performed by the construction contractor. In the heavy industrial sector, the owner often involves the contractor in the pre-project planning and in the constructability efforts of a project. In substance, these activities performed are basically the same. An industrial owner, however, may not relate to the term “preconstruction services” and a general buildings owner or a developer may believe that pre-project planning is not relevant to his projects.

The products of construction industry research should make the relevance of the findings to all sectors very clear. Most construction industry research at this time is structured to address larger and complex owner, project, and contractor organizations, and many smaller owners and contractors feel that the products of this research is not relevant to their needs. The smaller owners and contractors recognize that it is expensive to conduct significant construction industry research, and that they themselves are not in a position to either perform research with their own resources or to participate in those organizations that are performing construction industry research. The result of this is that smaller owners and smaller projects do not benefit as extensively from construction industry research as do larger owners and more complex projects. This is true of all sectors and is not unique to either of the three sectors. After in-depth discussion of the significance of these differences, the group concluded that it was not clear how to deal with these differences and the impact which they have on construction industry research. A series of issues were developed to provide a basis for the development of a path forward. These issues/facts are summarized below:

With respect to the Construction Industry Institute, it was recognized that all CII members should become involved in all three sectors, even though their primary involvement in the Construction Industry Institute work may be only in one of the sectors. The group recognized that many organizations are in fact doing construction industry research, including the National Electrical Contractors Association, Mechanical Contractors Association of America, the Roofers Sheet Metal Contractors, and the American Subcontractor Association, as well as the work being done by the Construction Industry Institute.

It was recognized that the results of research are not reaching the future leaders in all sectors of the industry. While there may be fairly extensive distribution of the results of research for industrial projects, there is a less effective distribution for buildings and infrastructure. With respect to Construction Industry Institute publications, there was a general view that they have for the most part been written by authors from the heavy industrial sector, and that they therefore are steeped in the language of that sector. An effort to utilize language that will be meaningful to all sectors would be helpful in the acceptance of the results of CII research by practitioners in the light industrial/general buildings and infrastructure sectors.

The group recognized that at the time of the formation of the Construction Industry Institute, the strength of the leadership was primarily focused on the heavy industrial sector. Strong leadership from other sectors will be necessary not only for CII, but for all organizations involved in construction industry research. The group concluded that it would be desirable to have mechanisms for the distribution of the results of research relevant to all business sectors and to schools with construction programs which are not involved in research, either that performed by CII or others.

The group felt that it would be appropriate to study CII Publication 41-2, Barriers to Implementation. The following matrix has been extracted from that publication and annotations have been made in the far-right hand column indicating the relevance of 13 CII concepts to the industrial buildings and infrastructure sectors with the letter "S" indicating where there was strong relevance and the letter "A" where there is either an average or lower relevance.

Group Perception of Sectors and Importance of Concepts

CII Products and Concepts

P - Primary Publication
S - Secondary Publication

Concepts	34-1 · Constructability implementation guide	37-1 · Team building · Improving project performance	43-1 · Project change management	AT-3 · Implementation process for improved quality	SP-013 Manual for special project management	SP-007 Assessment of Architect/Eng practice	SP-008 Assessment of contractor practice	SP-009 Assessment of construction industry practice	SP-010 Assessment of owner practice			— Industrial	— General Buildings	— Infrastructure	Notes
Constructability	P				S							S	A	S	(1)
Continuous Improvement		P		P	P							A	A	A	
Contract Relationships/ Equitable Risk Sharing					S							S	S	S	(2)
Design Effectiveness												S	S	S	(3)
Education & Training					S							S	A	S	(4)
Effective Project Organization		P	P		P	P	P	P	P			S	S	S	(5)
Materials Management					S	S	S	S	S			S	A	A	(6)
Partnering					S							S	S	S	(7)
Project Controls			P		P	S	S	S	S			S	S	A	(8)
Quality Performance Management & Measurement		P		S	S	S	S	S	S			S	A	S	
Safety					P		P	S	S			S	S	S	
Scope Definition & Control			P									S	S	A	(9)
Technology Exploitation & Automation of Process					S	S	S	S	S			S	S	S	(10)

S : STRONG ISSUE
A : AVERAGE OR LOWER ISSUE

(9) Indicates CII publications not available at time research effort was underway

There are additional CII concepts which have been developed since the time of this publication, but it was felt that including this matrix in the report of the sector workshop would provide a higher level of understanding of degrees of difference and the degrees of similarity and the relevance of CII products to different industry sectors. The diagram suggests a model for the consideration of the environment in which different sectors function, the criteria and constraints imposed upon each sector, and how language, culture, and project critical processes all can be considered along with the consideration of CII products and other research products to develop both a business plan and research program within an individual organization.

The group addressed the issue of what is not being addressed. This led to the development of the following list of potential research areas which are not being addressed at this time or being addressed, perhaps, in a less than significant way:

Performance Metrics ——— Buildings and Infrastructure Sectors
Communication ——— Buildings and Infrastructure Sectors
Exporting of Site Work Hours Off Site —— Building and Infrastructure Sectors
Constructability ——— Building Sector
Technology Selection ——— Infrastructure Sector
Supply Chain Management ——— All Sectors
Craft Education and Training ——— All Sectors (NCCER is not enough.)
Cost/Schedule Controls ——— Buildings Sector
Scope Definition for Design/Build Projects – All Sectors
Automation ——— Buildings and Infrastructure Sectors

Conclusions:

This group concluded that if the Construction Industry Institute, in particular, desires to reach the light industrial/general buildings and infrastructure sectors, it would have to dramatically change its approach. This does not necessarily mean that it should change the topics it addresses, but that clear visibility of the relevance of CII work to all sectors should be an important aspect of the products of CII research. It was the view of this group, as well, that research supported by the National Science Foundation should be published in such a way that its relevance to all building sectors will be apparent.

The group also identified a need to establish liaison among all entities performing construction industry research. Workshops of this nature jointly sponsored by NSF and CII are one mechanism for establishing and maintaining this liaison. The group recognized the liaison activities, including the several alliances of the Construction Industry Institute.

The third conclusion addressed the liaison activities of CII with the recommendation that a more aggressive approach be taken to identify communication channels to the light industrial/general buildings and infrastructure sectors.

The group recognized that it would be desirable for the Construction Industry Institute, in particular, to adapt and modify several of its existing products so that they are relevant to both the light industrial/general buildings and infrastructure sectors.

6.0 How can the engineering and construction industry learn from research?

Facilitator: Chris Hyvonen
Recorder: Bill Badger
Participants: Glenn Ballard, Ballard Management
Lance Bell, Clemson University
Jim Carroll, Fluor Daniel
Jim Lammie, Parsons Brinckerhoff
Calin Popescu, University of Texas
Hugh Rice, FMI
Bob Ryan, CII
Tony Songer, University of Colorado

This breakout group **was asked to reexamine "How can the industry learn from research?" The group later added the auxiliary question of "How can the industry use what it learns from research?"**

Our Charge The charge of the work group was to discuss the barriers to implementation, determine how the industry embraces change, and how could organization/infrastructure/culture be modified to implement these changes. The first order of discussion was to re-identify the barriers which reduce the effectiveness in implementing research information.

The group identified these significant barriers to implementation:

Risk -- In using new technology and information transfer, the industry implementers or decision makers encounter a number of risks and questions. The first is the risk of the unknowns. Will the results be what is promised? If problems occur will there be liabilities? Who will be responsible? The drive to complete engineering and construction within budget, on time, safely, and without hassle meditates against using many new technologies. The "let others work out the difficulties" attitude makes the industry slow to accept change. Risk seems to be the greatest barrier to implementation.

Lack of incentives to do so -- When companies are driven by competitive markets to keep cost down and investment low, only a few of the new research products are implemented. Within certain companies there are champions that drive decision makers into testing selected technologies if there is the belief that a competitive advantage exists. The incentives to implement new technologies and to make changes are not generally part of the company culture.

Standards and codes difficulties -- The systemic view in governmental regulatory organizations is to protect us. This drive to protect us has built-in barriers to not accepting change. The changes in code and standards are delayed until each change has been proven successful. The proof that something will work usually rests with the designer or builder who is attempting to implement a change. While the facility owner, the buyer of the new construction, is the funding agent. The beneficiary of most changes is the user of the facility. These divided responsibilities and coordination of cost, benefits, and funding between the players makes this a significant coordination barrier.

Information overload -- The wide range of information concerning the engineering and construction industry that is available makes identification, collection, distribution, and assimilation of new information difficult. The e-mail and world wide web have added to the overload of data received from employees, customers, professional societies, the phone, and printed hard copy. How to locate, screen, and select the appropriate information challenges us all. There is too much data, which sometimes makes it difficult to find what we need.

No champion to promote transfer -- The recognition that a local champion is needed to implement change may be the first organizational barrier. It appears that few companies have a formal system to introduce innovation into their company. The progressive companies endorse employee education and career development, but do little individual research. Additionally, few companies recognize the need to systematically import research knowledge. Those companies that have in place champions seem to accept change better.

Not part of the company culture -- Many company cultures operate in a competitive market with a lean management style and under a compressed schedule. Changes not promoted and championed may be resisted. An implementation program may be a systematic way to introduce new information and to make changes. The pace of the current business environment may make change more difficult to implement.

Can't quantify benefits of education -- The manager who is concerned about return on investment may attempt to have education measured as a dollar investment. Many agree that indeed education is a good investment, but recognize the difficulty in measuring the benefits. Most professionals will intuitively agree that education is worthwhile and the benefits of education will have to be accepted on faith. Some real challenges may be how to quantify the benefit of education or how to build faith in education.

Formal system -- We are not sure if there are more or less barriers in the formal system of implementation since there are so few formal systems in operation. There is a feeling within the group that the lack of any system of implementation is a barrier.

Principles of change The work group developed five principles required for change to happen. These principles of change were shaped in the environment of implementing new technologies and information transfer in the engineering and construction industry.

The principles of change are:

- **Must have value to the facility owner**
- **Ensure that it works,**
- **Collect and disseminate information mechanism,**
- **Active agents-of-change,**
- **Owner's protocol.**

1. Must have owner value -- The owner is defined as the facility owner company that buys engineering and construction services. ***Principle #1, is that most changes happen when demanded by this owner.*** This owner who allocates and controls funding must see financial value in any change. Business principles lead most companies to review proposed actions based on the return on investment (ROI). Even when values other than financial are available, ROI is most often used in final decisions. The value of improved communications was considered.

- **Demanded by facility owner**
- **Value added financially and value to society**
- **Return on investment in time and effort**
- **Improved communications**

2. Proof that it works – ***Principle #2, "proof that it works", is the first defense against change.*** The demand to prove that it works and then to answer the question of "what if it does not" is used often. The reality that research may have happened in a controlled environment and the implementation will happen on the job site lead to questions about applicability to this specific application. If it does not work, the cost is increased and time is lost. We hear comments like "I know that this worked in the past" and "I don't have time to experiment". Maybe the real issue is who pays for the proof-that-it-works effort**.**

Verification is the best counter argument to the proof that it works. If a prototype model is used, experimentation is conducted, and results are verified, the proof that it works maybe satisfied.

Benefits of new technologies when recognized by all parties involved help promote and sell change. Especially, financial benefits. If changes are perceived to financially help the engineering or construction agents, owners may be concerned that these gains are at the expense of a quality product. Usually the argument of cost saving has to be accompanied with tenet improvement in quality and the idea that the savings will be passed on to all.

Prototyping is an accepted way to introduce change. "Let's try it on a small project first and work out the short comings" has worked within the industry. Prototyping is most effective when driven by the owner.

Removing or reducing risk is a primary concern in proving that it works. New techniques are perceived to be risky even if historically this may not be true. Risk identification and sharing are not commonly accepted practices in engineering and construction (E & C) work. To implement change usually requires the change agent to bear all the risk.

Simplicity leads to better understanding and is more likely to be accepted. Complexity in itself slows the approval and acceptance process and delays changes even if understood by the Change-Agent.

Funding is required in proving it works and in implementing change. Funding for engineering and construction is usually provided by the owner and change is usually driven by the E & C provider. This second party approval requirement for funding change slows the process and acts as a barrier.

Codes may protect us to the point that innovation is difficult. The proof that it is within code rests with the change-agent.

3. Collect and disseminate information (Implementation culture) The first challenge is where to find the information and how to disseminate it. -- ***Principle #3, has two parts. If the source of information does not have credibility then it will not be accepted. If we do not have a champion, then we most likely can not disseminate it.*** An implementation culture needs support of a person like a Vice President for Research as a champion and an information and data collection and dissemination system. The exchange of information outside the company may require marketing to professional societies and professional organizations. To ensure that the implementation culture is changing, measurement of its effectiveness is required. Lastly, we need to reward those that implement.

- **VP for research**
- **Information and data collection and dissemination**
- **Market to professional societies and organization**
- **Measure effectiveness**
- **Reward implementation**

4. Agents-of-change – ***Principle #4, For changes to happen in most organizations or companies, a champion has to be designated or volunteered.*** This champion must be the caretaker of the change. Additionally, the chief operating officer must endorse and support the change initiative. The organization must create a formal process and establish the procedure to implement changes. Changes face the compliance requirements of all codes and standards. The free enterprise system requires companies to recognize achievement and reward success. Peer companies may be forced to change just to keep up with the competition. Finally, the most significant change-agent may be "crisis". When crisis happens, the drive, the threat, and motive are in place to make change.

- **Company champions**
- **CEO support**
- **Formal process**
- **Standards and codes**
- **Recognition and rewards**
- **Peer pressure**
- **Crisis**

5. Owner Protocol -- With construction a series of processes starting with planning, design, procurement, construction, maintenance, operations, and improvement may be needed. The owner who funds and operates the construction facility may not understand the value of changes, especially those up-stream in the process. ***Principle #5, The engineering and construction industry professionals need to do a better job of informing the owners on what is needed.*** The owner or buyers of construction should have the responsibility of leading the industry, but in many cases this leadership is passed to the E &C professionals. The owners are outsourcing E & C and responsibility to provide the owner with guidelines for E & C fall on the engineering and construction industry professionals. Principle number five is that the E & C professionals should narrate to the owner in a written protocol what to demand of our professionals.

- **Responsibility**
- **Guidelines**
- **What owners should demand**
- **Academic Partner**

Feedback of gained experience to the next construction job is weak. To address this issue, an academic partner concept was discussed that envisions a system of data collection, analysis, conversion into information, dissemination of knowledge, and implementation support. The proposed collection system would use academics from national universities, and the analysis and review could be done by teams of interdisciplinary experts.

Below is a description of the proposed academic partner concept, a four tiered engineering and construction information collection analysis, dissemination, and implementation system.

Level one effort would identify and select Academic Partners (APs) to serve on infrastructure projects. The APs would be selected from universities located geographically near the projects and for their expertise. The APs would be small multidisciplinary teams serving to generate ideas, provide innovation, identify improvements, collect lessons learned, and facilitate and monitor the feedback loop.

Level two effort would involve reviewing the semi-annually APs finding. This review could be operated by an interdisciplinary panel. The planning, design, engineering, construction, and operation cycles of infrastructure components would be dramatically reduced as project delivery systems are developing into design / build / maintain / retrofit modes. This reduced cycle time would mandate a compressed collection / analysis / information / dissemination / implementation / education process.

Level three effort would involve generation of electronic information dissemination. Under the AP concept, the academicians would live with the project, observe problems first hand, and develop timely lessons learned. The AP concept would focus its energies on how to improve the processes in real time.

Level four would involve the implementation of lessons learned. The mission of the AP would be to effect change through involvement of multidisciplinary teams designed to identify the impediments to rapid implementation of research.

The academic partner concept requires improved communication between the public, government, industry, owners, designers, engineers, constructors, and university partners, to accomplish unification of a fragmented industry directed at building and maintaining infrastructure.

- **For innovative, large, and unique infrastructure projects**
- **University professors included in project at start**
- **The AP to be a part of engineering and construction team**
- **APs will be the identifier and preparer of lessons learned**
- **Universities and industry working together to distribute the lessons learned**
- **The AP approach may reduce the educational feedback loop time**

The **Path Forward** involves development of an action plan on how to accomplish the results of the group four recommendations. The recommendations as developed by the work group need testing.

- **Develop "how" on each principle**
- **Design research to be used**
- **Develop metrics on implementation**
- **Test the recommendations**

7.0 How do we use what we know about people to achieve results?

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Participants: Glenn Blackburn, Amoco
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Deb Grubbe, the group facilitator, suggested that we start by inventing as we go and by discussing with each other why our assigned topic is important to each of us. The following ground rules were developed:

a. Listen for what is not said.
b. Question for clarification if you don't understand.
c. Only one person to speak at a time
d. Limit comments to three minutes.
e. Don't interrupt.
f. There are no bad ideas.
g. Allow time to capture ideas.

The discussion was opened by asking each participant to share their personal comments on the importance of the topic, "How do we use what we know about people to achieve results". Below is a summary of individual comments that were shared among the group.

- Throughout my career I have had interest in people due to the image that "the engineer is a nerd," who just works with equations and things. It has been a journey for me in self-education in this area for most of my career.

- The university needs to develop team learning. How do you grade teams, and how do they handle internal team dynamics? Many people don't want to change, so it becomes a challenge. Leadership and management; distinction between 3% leadership and 97% management; should be 40% leadership and 60% management. Academia needs to prepare students so they will be ready when they leave the university for industry.

- As a lawyer, my involvement is not until the project is in trouble. Over time it has come apparent to me that we are trying the same lawsuit over and over again. It is always people problems with compartments on narrow focus. It is people who turn problems into true conflict. The nature of the business creates conflict system - low bid, control, management problems and how to prevent minor skirmishes from becoming major problems. Much like being a marriage counselor, it is hard to get people to admit in advance there will be problems.

- My professional career has been focused on change. An example of one of the most difficult changes, is the transfer of ownership of a company. It requires energy and commitment to the people who must live with the changes that result from a transfer of ownership. There is much focus on the people who push the money buttons to champion change. Often, there is institutional and individual opposition to change.

- With my background in an agency of the federal government, my career has focused on leadership, change, etc. There appears to be a different perspective in academic concerning motivation/leadership. Project communications is a key factor in working with people and problems with projects.

- After completing my career in industry, I would like to understand the aspects I have seen throughout career. How can people work together, such as producing engineering standards? How do we get people to talk about everyday things and about themselves, to build true teams? The key to the topics of change is people.

- How do we achieve results using what we know about people? Some people express themselves easily, and some do not. When students go into industry, they must be ready. Different companies treat their people differently. How do you find the right company fit for students? Time management is an important element in behavior. We need to recognize individual time clocks and take advantage of those clocks for getting results.

The group next generated approximately 100 thoughts and issues about its topic: "How do we use what we know about people to achieve results?", plus the roadblocks, etc. The issues were separated into the following eight categories:

a. Leadership vs. management
b. Teamwork
c. Personality characteristics, understanding personality instruments, psychology
d. Quality of life (employee and family well being)
e. External culture
f. Internal culture
g. Education, training, and development
h. Other ideas affecting people.

The findings of the group are listed under these categories.

Leadership vs. Management

There should be more research to identify the key characteristics for effective leadership/management/followership in the construction industry. Current teaching is fragmented. A basic core curriculum should be developed so academia/industry can work from the same base to develop basic leadership skills for industry. The following issues were identified by the group:

- Managers should not abdicate their responsibilities by looking to their lawyers for decisions.
- Managers should be proactive, not defensive.
- Business decisions should be made by business people.
- Who is going to pay for change in the construction industry?
- Too many leaders avoid responsibility. Dollar driven not satisfaction driven.
- Give people good business excuses for doing the right thing.
- National attitude toward big government and its role to the individual
- Don't allow a dispute to go unresolved for more than x hours/day. (Marriage analogy; don't go to sleep mad).
- Are there events or ideas that have occurred in the past that can guide our thinking?
- Relating to directions or path to follow or not to follow. We don't seem to learn from the past
- When a problem comes up; fix the problem, don't fix the blame
- Many people change only when the pain (uncertainty) of staying where they are exceeds the pain of moving to a future condition
- The questionable ethics of nations leaders
- "Era of Change in the way we do business to survive global competition"
- Participants do not understand leadership
- Identification of communications problems
- Be a model to others mentor, counseling, training
- Lead vs. manage
- Conflict management

Teamwork

There is a need for a better understanding of teamwork by all participants in the construction process. Encourage NSF to fund study for integrating teamwork into engineering curriculum, and promote the use of existing CII products and other successful programs in industry.

- Motivation for team training.
- Dynamic matrix of teams.
- Multiple-discipline; matrix of project teams.
- How other than through survival can you create the bonds that result in true teams?
- Team building (How to do it effectively?)
- How to measure team effectiveness?

Personality Characteristics, Understanding Personality Instruments, Psychology

There is a need to capture the key characteristics of successful people at all levels in the construction industry, and we encourage CII to undertake a study aimed at this topic.

- Understand the different ways different cultures think, including the feminine culture.
- Engineers have a label as "non-people oriented" or "nerds".
- How can we change this attitude/image?
- Understanding personality traits; Myers-Briggs Hermann Brain Dominance, etc.
- You are not a wimp if you are willing to try to understand the other guy's point of view.
- Are there key characteristics of different persons who have become "successful" in various roles in our industry?
- A lot is known about people from other professions.
- How do we utilize the knowledge of outside professionals (business, psychology, sociology, communications, medical, computers, etc.) in improving the ability of persons in our industry?
- People are different; how do we optimize on these differences in work assignments and relationships?
- Engineering education - open to radical change for the first time in years, especially on people issues!
- Engineers have not been educated in "people issues."

Quality of Life Employee and Family Well Being

We recognize that competitive firms of the future will have to address the following issues.

- Dual career management.
- If you ask someone to take an unusual risk, give that person an opportunity to earn a reward.
- What requirements must be in place for company values and employee value to be in sync?
- Special programs - minority, disabled, underprivileged.
- Family matters, parenting as a priority; paid absences for family needs (like the Swedish system).
- Flexible benefits.
- Remember: 50- to 65-hour work weeks, destroy family values.

External Culture

There are cultures external to companies both in the US and outside the US that successful companies must embrace/understand today and even more so in the future.

- Promotion of adversarial relations.
- Construction industry fragmentation.
- Going to smaller homes and less space for families.
- Multiple-cultural studies as part of college curricula.
- Required cultural studies in our schools and communities.
- Every person in USA has foreign language capability.
- European Union/Asia Pacific and Western markets.
- Global cultures, need global expansion of thinking and markets.

Internal Culture

Successful companies realize internal cultures play a dominate role in organizations and there is a need to evaluate culture and its impact on peoples performance. There is a need to develop a culture of trust, loyalty, and innovation.

- What are key factors today?
- Geographic expansion of competitors.
- Political stability.
- Getting things developed cheaper.
- Because of global competition, companies are doing radical things to remain competitive.
- Do profits cause advances in construction?
- Will competition create advancement in construction?
- Need for principle-based work and decision processes.
- Today you must cooperate with competitors, but tomorrow you are a competitor
- To maximize success, how much of your competitive advantage do you reveal?
- Culture plays a dominate role in organizations.
- How do you evaluate culture and its impact on people's performance?
- How do you develop a culture of trust, loyalty, and innovation?
- People should develop an allegiance to the project, not just to their company.
- Today: look out for number one - me. Theory: If the project is a success, then all of the participants should do well, be a friend of the project.
- Have to work to be out of touch; "alone by design."
- Questioning the status quo.
- A youth-centered culture.
- A median-focus; lazy mental process
- How do you create an environment where people want to change?
- Do more with less.
- Short-term horizons.
- Economic stability.
- Social fragmentation.

Education, Training, and Development

- Company's only competitive advantage is how quickly their workforce can learn and apply.
- Increasing skills and knowledge (development) is required for the success of the organization and the individual. The company must identify the required skills, and the individual is responsible for identifying needs that will allow her/him to progress.
- Companies must provide and support an environment which provides opportunities for employee development. A high-priority area is the development of competent construction site supervisors.
- Modern communications impact home office, e-mail and home page.
- Attract higher quality field people for construction careers.
- The future requires people's careers to be broader, not deeper in a narrow specialty career. How do we train people for that flexibility?
- TQM principles well defined.
- Research area - what skills do people need to develop early in their careers? Who will provide training?
- Integration technology and people.
- What can we learn about people/culture change, business change from other industries? other fields?
- The work force - impact of immigrations policies; the best and brightest students and the core of the labor force are becoming non-American.
- Engineer your way to success; nine attributes - still good today.
- Must be computer literate and continue to learn.
- Self-knowledge and understanding part of educational process and ongoing through life.
- Educational requirements for a changing industry.
- Computer literacy and instant communications.
- Constraints of having qualified field supervision.
- Studies/understand - human motivation and need (Maslow's Hierarchy).
- Identify/select outstanding students in high school; decline of co-op programs; increase in summer jobs.
- Leadership training? Where, what when?
- Emphasis on quantitative measures.
- Must compete on a global basis.

Other

Questions about innovation and how this effects people are ongoing. A few are listed below:

- New artificial, light-weight building products in the future.
- If computers can play grand-master chess, why is there a need for people to design
  buildings, highways, refineries, etc.? What will be the future "value-added" of people in this industry?
- What is the model of a company (for handling people issues?)
- What are characteristics (values) of a model, successful company of the future in the engineering/construction industry?

Recommended Focus Areas

Leadership vs. Management; A study should be started to identify the key characteristics for effective leadership/management/followership in the construction industry.

Teamwork; There is a strong need for a better understanding of teamwork by all participants in the construction process.

Understanding Personalities; There is a strong need to capture the key characteristics of successful people in the construction industry, and we encourage organizations (such as CII) to consider undertaking a study which would encompass personality types.

Quality of Life; (Employee and family well being.) Successful companies realize that both internal and external cultures play a dominate role in organization. There is a need to evaluate these cultures and their impact on performance.

Education, Training, and Development; Increasing skills and knowledge is required for the success of an organization and its employees. The organization must provide and support an environment which provides the needed opportunities for employee development, particularly up through the project superintendent.

Other; Innovations in technology, communication devices and our global industry involvement will continue to challenge our people skills.

8. Closing Comments

Wrap-up Comments by CII Academic Council Chairman Hal Yoh:

General Summary:

- We need to continue communications and networking to promote research
- We need to understand the different research models.
- As a profession, we in the construction industry need to share information.
- How do we get the success stories out to the industry?
- How can one create an environment for risk and implementation?
- Our industry doesn't want to take risk, just get the job done.
- Our industry wants to get the job done, rather than looking at experiences from the project.

Where do we go from here?

- We need to recycle this workshop process again, to maintain a constant check-in.
- We need to take all this information and to something constructive with it.
- We need to document research success and spread the news.
- Are we placing too much emphasis on research results, with research as a means to an end, or do we need to consider research results vs. persons?

What are our group recommendations?

- Document our research successes, spread the news.
- We need a vehicle to discuss all the research that is being done, share successes.
- This workshop effort has made a good start, but we need much more work.
- We need a presentation at the Business Round Table
- We need to increase federal funding for construction research.
- We need a vehicle of change.

Final Closing by Dr. Richard Tucker:

1. Is There a Proven Role for Research in our Industry?

We now have quantitative data that shows two things. First, it ties the use of four best practices resulting from research to improved cost, schedule, and safety results rather dramatically. Second, it show that CII owners (who are assumed to be more aggressive in implementing research results) realize approximately an eight percent advantage of average capital investment costs in comparison to non-CII owners.

This data, along with information from many other sources, shows that the benefit/cost ratio from research is high for our industry; and yet, there is no "mad rush" for companies to participate nor is there an organized lobbying effort to make research a national priority. Obviously, our belief is that the answer is "yes" to the need for additional research. However, we still have a major marketing job ahead.

2. What is the Role of Academia in the Actual Project Delivery System? Is it only One of Furnishing Graduates or should the University Community be involved in projects?

If our professors are knowledgeable of state-of-the-art issues and current research implementation has a high payoff, then shouldn't companies be utilizing their knowledge? For example, shouldn't project management professors be members of corporate Boards of Directors? Other disciplines such as law, finance, insurance, and marketing are represented, often by faculty members. Why shouldn't major E-P-C companies have representation from state-of-the-art faculty in their basic businesses?

As an alternative, why not involve faculty (and perhaps graduate students) directly in projects? This approach might relate to an "Academic Partners" program. It would bring state-of-the-art knowledge directly to the project level. It could provide project documentation and an objective assessment of major issues and impacts as a project progresses. Although many details would need developing, the potential for mutual benefits appears to be high.

3. Is There a Different Industry Role in the Academic Process?

As a parallel to academic's role in the industry, should industry be more involved in our educational process? Industry has always been willing to provide lecturers, arrange field trips, and serve on program advisory committees. However, all of those activities have been conducted on an ad hoc basis. With the increasing recognition of the importance of education, particularly in the globalized environment, shouldn't we be looking for a different and more integrated educational approach? I feel that this workshop, in itself, illustrates the power of joint industry/academia activities. We should be looking for new paradigms rather than continuing our separated roles because of tradition.

4. Does the CII Model need Changing Regarding the Industry/Academic Roles?

The CII model basically has considerable involvement from owner and contractor personnel, since they are providing the funds. It has less personal involvement in major decision making from professors. It has worked well in terms of credibility of CII products, activities, and credibility. However, the only academic representation in strategic and operational issues has been through the CII director.

Is it time to consider a revision of the CII model, primarily to get more academic involvement? This workshop, involving roughly equal members of industry and academic representatives, has generated fresh thoughts and ideas. Perhaps it's time to consider expanding that approach to other applications. Similarly, should we be looking at different models for other research organizations? Certainly, even with CII's uniqueness, it is not the only organization with its mission of advancing the industry through research.

5. What is a Feasible Level of Efficiency and Duplication?

There are regularly stated comments relating to compilation of "all of the information" on a subject and putting it on the World Wide Web or something similar. (Incidentally, there is to much information for that to work.) There are also numerous suggestions related to non-duplication of effort. If that were feasible, we would have only one university teaching a particular subject. Some level of duplication is desirable, even in light of the desire to be efficient in our use of resources. Is this a fruitful area for pragmatic discussion?

6. How do we Better Market our Successes?

Our fragmented, but highly structured industry is still based principally upon experience. Thus, Change is difficult. How do we create a culture that embraces change? We have lots of evidence that different management approaches yield beneficial results.

7. Is our Industry Bigger than Civil Engineering (from an Academic Perspective)?

The major step changes in our industry, from an academic and research perspective, have resulted from CII and graduate programs developed in civil engineering departments. Fifteen years ago, most of the leaders in industrial projects had civil engineering backgrounds in formal education. That was natural since civil engineering has traditionally been a broad-based discipline. Now things have changed. Project management is recognized in many curricula, and many chief engineers in industry have degrees in other disciplines. Even among CII senior staff, the two latest additions have had other backgrounds. The last three Chairs of the CII Board of Advisors have had degrees in other disciplines. There is even discussion of creating separate academic programs in project management in order to capture its interdisciplinary nature. With the inherent resistance to change among university departments, it is possible that project management should be divorced from its strong tie to civil engineering?

8. What is the Follow-on Process from this Workshop?

There is obviously much material developed from this workshop that justifies a path forward. What should be the next steps? A report will be written, but will it just make interesting reading? Are there be some proactive efforts that will be justified? Hopefully, the CII Academic Council, as the workshop organizer, will be able to address this issued at its next meeting. However, all attendees should consider this issue and think of ways to maximize the benefits of this rather impressive effort.

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