WORKSHOP ON
CONSTRUCTION ENGINEERING
BASIC RESEARCH

Final Report

Robert I. Carr
William F. Maloney

September, 1982

THE UNIVERSITY OF MICHIGAN
DEPARTMENT OF CIVIL ENGINEERING
CONSTRUCTION ENGINEERING AND MANAGEMENT

Prepared Under Contract No. CEE-8209538
For The National Science Foundation

Workshop on Construction Engineering Basic Research

Final Report

Held at The University of Michigan
Ann Arbor, Michigan
May 24-26, 1982

Sponsored by: American Society of Civil Engineers
National Science Foundation
Construction Research Council

Prepared under Contract No. CEE-8209538
for the National Science Foundation

Principal Invesigators: Professor Robert I. Carr
Professor William F. Maloney

Construction Engineering and Management
Department of Civil Engineering
The University of Michigan
Ann Arbor, Michigan 48109

TABLE OF CONTENTS

INTRODUCTION

The University of Michigan Department of Civil Engineering conducted a Workshop on Construction Engineering Basic Research in Ann Arbor, Michigan on May 24-26, 1982. The purpose was to encourage basic research by civil engineering faculty in construction engineering and management. The Workshop drew together the core of such research faculty in America to develop an awareness of opportunity and an enthusiasm to analyze and explain the fundamental elements of construction.

Each engineering discipline is founded upon a comprehensive set of theories. Basic or fundamental research is the development of such theories through attempts to (1) put a scientific base under empirical knowledge or practice, (2) produce scientific explanations of natural phenomena, or (3) develop new methods of engineering analysis. Only through such basic research does a well founded theory of construction engineering and management emerge.

An overall view of the Workshop is given by this introduction. The main body follows to report the five sessions of the Workshop. Appendices provide a detailed schedule of the Workshop, list of participants, and summaries of basic research topics suggested by the participants before they attended the Workshop. All of this information is unique and gives the reader benefit of the ideas and interaction of the participants.

The Workshop was sponsored by the National Science Foundation and the American Society of Civil Engineers Construction Research Council and funded under grant CEE-8209538 by the National Science Foundation. The program consisted of five half day sessions on the following major areas of construction research:

Workshop Topics

Session I - Definition of Basic Research in Construction Engineering and Management

Session 2 – Basic Research in Construction Engineering Management

Session 3 – Basic Research in Construction Engineering Analysis and Design

Session 4 - Basic Research in Construction Engineering Uncertainty

Session 5 – Basic Research in Construction Engineering Human Resource Management

Prospect Directors for the Workshop and Chairmen of the Workahop Steering Committee were Robert I. Carr and William F. Maloney of the University of Michigan. Members of the Steering Committee were David B. Ashley, University of Texas, Austin; Neal B.H. Benjamin, University of Missouri, Columbia; Raymond E. Levitt, Stanford University; Harold D. Pritchett, Oregon State University; and Robert M. Stark, University of Delaware. Professors Benjamin, Levitt, Pritchett, and Naloney moderated sessions, as did Daniel W. Halpin, Georgia Institute of Technology. Robert B. Harris of the University of Michigan wae heavily involved from the conception of the Workshop to responsibility for recording its progress.

Need for Workshop – The Construction Research Environment

Construction engineering and management has developed as a specialty area within civil engineering over the past 25 years. Graduate degree programs were first established in 1954 and 1955 at the University of Michigan and Stanford University. Programs soon followed at the University of California at Berkeley, University of Missouri and University of Illinois. Today, these programs stand with those at the other top civil Engineering departments of America as a strong, growing area of civil engineering. At many engineering schools, including Michigan and Stanford, more graduate degrees are awarded in construction engineering and management than any other civil engineering specialty.

These graduate programs have concentrated on professional training of engineers at the masters level. Little attention has been given to Ph.D. research. There has been little support for research activities, and the support which has been available, from industry and from mission oriented government agencies, has focused on specific industry problems with immediate payoffs. Most programs have had input of advice and money from industry interested in a source of construction engineers and managers with "practical training." Students working toward their Ph.D.'s have too often been encouraged to do dissertations on "practical" problems which would have immediate application.

All of this has discouraged rather than encouraged research and has made the pursuit of basic research peripheral to the main mission of many faculty. However, professors recognize a need for analysis and design theory in construction as in structures, geotechnics, hydraulics, and other areas of civil engineering. They see that much of standard practice rests more on habit and folklore than upon sound theory. Many have worked to develop a base for the construction courses they teach and for professional practice. However, a strong basic research direction has failed to emerge, due to the lack of maturity of construction engineering and management as an area of attention, lack of financial support for research (especially basic research), lack of research experience and emphasis among predecessors and mentors, and strong discouragement by close, important industry supporters.

The primary vehicle for communication of research results in construction engineering and management is the American Society of Civil Engineers, through paper sessions at its meetings and conferences (sponsored primarily by the Construction Division and Construction Research Council) and its proceedings (primarily the *Journal of the Construction Division*). The research focus of the ASCE technical committees, representing academia and industry, has been on applied research. The Construction Research council, for the most part representing academia, has focused on identifying potential research sponsors. ASCE has not provided sufficient encouragement for construction basic research. However, it does provide an essential forum for communicating research results.

Earlier Workshops

There have been three major workshops that have focused on construction research. The University of Michigan "Short Course in Construction Engineering" in 1972 collected 32 engineering faculty for 4 weeks in Ann Arbor to study construction engineering and management education. It was a landmark in construction education, establishing a direction for the many programs gust starting to grow and developing comraderie among construction educators so vital to construction education and research since that time. Its focus was more on educational needs than on basic research.

The Stanford workshop on basic research in the construction industry in 1975 had representatives from industry and academia interact to bring attention to research needed by the construction industry. However, its thrust was more applied than basic due to strong industry input.

The more recent workshop on specific projects in productivity research for the construction industry in 1978, initiated by the University of California at Berkeley and held at the National Bureau of Standards, attempted to elicit financial support from mission-oriented government agencies to solve construction industry productivity problems. The sessions, headed by industry and government leaders, focused on chart proposal statements by academics and possible impacts of the research on industry productivity. The emphasis was upon immediate application to increase productivity.

It is obvious the atmosphere in which construction academic research has lived has not been conducive to basic research. The test for research acceptability has been its immediate impact on industry economics. Researchers have felt apologetic about research that "merely" advances knowledge. It is time that this view should change, but such change requires a thrust to give it momentum and respectability. The short workshop focusing on construction basic research definition, methodology, opportunity, and need will facilitate a change in attitude among academic researchers. They can proceed to satisfy their basic interest and curiosity as a mutually supportive peer group.

Planning the Workshop

The idea for the Workshop at the University of

Michigan originated at an informal meeting of civil engineering construction faculty and William S. Butcher and Arthur A. Ezra at Massachusetts Institute of Technology in September, 1981. After that meeting, the project directors selected the Workshop Steering Committee, wrote a preliminary proposal, and circulated it to the Steering Committee. The elements of the proposal were discussed at the Construction Research Council meeting in St. Louis in October, 1981 and with Robert B. Harrie, Boyd C. Paulson, and Keith C. Crandall who had directed the past workshops. The feedback from these people went into the final proposal which was circulated to the Executive Committee of the Construction Research Council for endorsement and sponsorship by the Council. Upon receiving the Council's endorsement, the proposal was submitted to NSF where it received the approval and financial support requested.

The invited participants were selected for their past and current demonstrated academic research in construction engineering and management. A most important element of the Workshop was the interaction of participants, and the number of participants was limited to 25 faculty to encourage interaction during and between sessions. The group (see Appendix) represents the core of the construction academic research community. William S. Butcher and Arthur A. Ezra from NSF also participated in the Workshop, to make a total of 27 attendees.

Several weeks before the Workshop, participants submitted annotated lists of research ideas and needs, according to a guide prepared by the prospect directors. These lists were distributed to the session moderators for them to prepare summaries. The prospect directors and session moderators met in Las Vegas, Nevada, in April, 1982 in conjunction with the ASCE national meeting to firm up the format of the Workshop sessions.

As moderator of the first session, Neal Benjamin selected a few research ideas from participants lists and classified them according to his opinion of their basic nature. Each moderator of the other four sessions summarized the ideas from the participants annotated lists for the topics covered in his session. This five part summarization was distributed to the participants before their travel to Ann Arbor, to prepare them for interaction and sharing of ideas at the Workshop. These summaries are in the Appendix.

Description of the Workshop

The participants were together at the Workshop from breakfast in the morning through dinner in the evening. The formal sessions were from 8:30 in the morning until noon and from 1:30 to 5:00 in the afternoon. All attendees sat around a rectangle of tables so that each could participate in the discussion.

The first session was to identify what is meant by basic research in construction engineering and management. The full cession discussion among the participants increased their perspective of fundamental research in general, its relevance to construction, and its feasibility for civil engineering construction faculty to direct and perform* The major comments of the discssion are contained in the next section of the report. The comments have been edited to a readable form and to provide continuity out of context of the discussion.

The other four sessions discussed what was not known about construction engineering and management and was worthy of research. Each session covered a broad area of research, and every construction basic research topic had a home in at least one of the areas. The general format of the sessions was a formal listing, with some brief discussion, of needed research. The summarized lists prepared by the moderators from participants' lists were given attention, but the session lists were a separate compilation, subject to discussion from all participants. It was evident during the sessions that there are many equally important research topics which were not discussed and listed* The items on the list were recorded quickly on sheets of newsprint so that the participants ideas would not be lost and so that participants could see what had been said.

These lists served as the record of the sessions and make up the main body of this report. They have been edited so that readers of the report who were not at the sessions will be able to understand them out of context of the discussions from which they came.

We want to thank the session moderators for their heavy work,on a tight schedule prior to the Workshop as well as their leadership during the meeting. Particular thanks are due Jim Danek and Julie Woodbeck, secretaries at the University of Michigan. Jim typed the proposal and correspondence with participants. Julie took over just before the Workshop, kept the record at the Workshop and typed this report. We also thank William S. Butcher and Arthur A. Ezra for their encouragement of construction research and this Workshop and for their participation in it.

"This material is based upon work supported by the National Science Foundation under Grant CEE-8209538. Any opinions, findings, and conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the National Science Foundation. "

SESSION 1

DEFINITION OF BASIC RESEARCH IN CONSTRUCTION ENGINEERING AND MANAGEMENT

Following introductory comments by Robert Carr, Neal Benjamin, as moderator, introduced the concept of basic research. If each engineering discipline is founded on a comprehensive set of theories, what is that comprehensive set for construction engineering? He briefly discussed several research items submitted by participants, in the context of basic research.

There followed an open discussion by the participants about basic research in construction. The major ideas expressed by the participants are paraphrased below. Many comments are missing which, though valuable in their context, were not essential in reporting the basic discussion. Each statement is edited from notes kept by Carr, Harris, and Julie Woodbeck. We apologize to the people to whom each of the remarks are attributed for what are sure to be our mistakes in recording, summarizing, and paraphrasing their comments.

Butcher – Construction is a valid area of research in engineering and should have the chance to stand on its merits for NSF funding. Any funds for construction engineering research must come from other areas of civil engineering, but construction should have its chance. The studies which NSF supports are fundamental to the field, advance the state of the art, advance the frontier of knowledge. Basic research is generic, transferrable, establishment of cause and effect relationships, verifying hypotheses, refining the tools of the trade. Application to a specific problem is acceptable as an illustration.

Halpin - Results of such research is useful down the road in establishing a framework for the future.

Ezra - This group must consider what is compatible to a university environment. What things will contractors not fund?

Crandall - Contractors will fund short term questions.

Ezra - If individuals can capture benefits of research, government will not fund the research.

Levitt – We should consider what is academically interesting and enjoyable to work with.

Maloney - What can we do to explain behavior of people and systems?

Thomas – We should try to better understand construction processes and how the industry behaves.

Ezra – One model is that of the steam engine and thermodynamics. The steam engine came first, followed by a thermodynamic explanation. Maybe construction processes have this same characteristic. They now need an explanation.

Diekmann - In other areas of civil engineering, such as structures, one can easily go to the laboratory to gather research data. In construction, data gathering requires going to the site, and such data gathering is difficult at beet. How far back can we trace our history?

Ibbs - What about basic research in accounting and business?

Butcher - Construction is production side. Its counterpart is manufacturing within mechanical engineering. The production side is a legitimate area for fundamental engineering research.

Benjamin - Our inputs to construction engineering and management come from all disciplines. Can we narrow our research interests?

Willenbrock - There are steps of a science progression: scientists, then engineers, then constructors. We are more removed from pure science than is most engineering.

Butcher – We are not removed from design. Design of construction processes can't be separated from behavior and financial processes.

Ezra - We should consider what can be done, needs to be done, and will not be done by industry.

Paulson - We have an advantage because we can find needs for research. Some other engineering disciplines cannot.

Ezra - An example might be insurance. Can't we rigorously study it? What motivations and effects come from it? Just asking opinions of users is journalism, it's not research.

Halpin - We need models which can stand the test of time, which become basic.

Conclusion by several – We are back to knowledge that needs to be gained that industry will not fund.

Paulson - We must consider what is basic. Applied research on earthquakes is funded by mandate of Congress; whereas, soils or water chemistry need to be basic.

Butcher - The hardware items of construction are in structures, soils, materials, etc. and there is considerable current research in those areas. They are obviously civil engineering. Is insurance, accounting, or finance actually civil engineering? Or shall we handle only the hardware side of construction?

Paulson - What basic things about an organization can we measure and understand?

Crandall - The rest of civil engineering concentrates on design. We are resource people, multidisciplinary in our work.

Butcher - We must discover priciples. The Romans built roads, without understanding basic principles. We must take empirical practices and look within them to find principles, connections* Look at a process that works and try to make it better.

Stark - We should focus on problems. When we look at estimating, how it is done, it looks haywire. There is a lot we don't understand.

Diekmann - Colony Oil Shale project just went down the tube. The estimate of $2 billion became $8 billion.

Comments by several - Estimating is now an art, not a science, and we need to make it a science. We don't know the variables, much less the relationships among them and their effects.

Tucker - We need data, any data, without too much regard to statistical niceties. Measuring productivity is a major challenge, even defining it is. We need better technologies, interfaces, and controls.

Carr - We need data that is sufficiently well defined by its source, sampling techniques, and statistical reporting. Otherwise it is not useful.

Halpin & Ezra - We need a good framework for data, for contractors and researchers. Need a reference system for data. Need a theory of data collection so that data, over time, is useful.

Stark - Agrees; however, has found he cannot trust data he has not collected himself.

Willenbrock - We deal with time, cost, quality, safety, resources, and methods. How are we different from other civil engineers?

Larew - Need some way for faculty to determine which topics are researchable.

Benjamin – The coincidence of different participants naming similar topics on their preworkshop lists of research needs shows that different people agree on researchable topics.

Butcher discussed how input on construction gets into NSF – There is some chance that after some years there will be a formal program in construction. This requres a strong message, which includes presure from a significant number of proposals. NSF will review any proposal. The arbitrary current home of construction is Water Resources and Environmental Engineering of which Ezra is Program Director.

Pritchett - Not all research work in construction is by civil engineers. Business also has some. Conetruction is interdisciplinary.

Butcher - If proposal is from business it is the content which is important in determining how it will be handled. NSF can also handle, in one of its other programs, research that is nontraditional to civil engineering – behavioral for example.

Paulson - One can't get NSF funds without writing a proposal. Submit proposals, learn from the process, and correct oneself. Money is also in a variety of places. One

can also learn from reading and discussing proposals of one's colleagues in other areas.
Stark – We will have a program when pressure is high.

Butcher – The average success rate on proposals submitted to NSF is about 40%. This is somewhat misleading because it includes ongoing projects and experienced people. Rate is lower in Water Resources and Environmental because of strong presure, including recent cuts in other sources of research funds in that area. Cannot expect an acceptance rate higher than 20K, particularly for those who do not yet have a successful track record. Within Civil Engineering there is a separate program in earthquakes which has a high priority and competition is not as stiff. This includes disasters and hazards in general but earthquakes in particular.

Several comments concerned what were appropriate as faculty projects – One or two faculty and one or two students funded at $30,000 to $70,000 per year, about what is appropriate for a doctoral thesis, was considered particularly appropriate.

Halpin - Considering the scale of a typical project, one should direct efforts toward developing bulding blocks of research projects which were each of a manageable size.

Carr - Should we be concerned that this discussion session does not provide a definition of basic research?

Crandall - We are gaining perspective on basic research. We are paying new attention to the word "principles". Examining and establishing principles of construction.

Maloney - We are a baby discipline. We need to collect data, make connections among processes, perform research on these processes, and develop a theory of construction.

Cost Estimating Example

It had been decided earlier in the session that the last 30 minutes were to be spent in developing a basic research approach to cost estimating. The picture of basic research in cost estimating which was developed was this:

- Variables of cost estimating: Resources that go into a job
  - Resource requirements: definition or characterization, quantity, rate of use, cost

  - Resource management
  - Combinatians of random variables
  - Equation of motion of job
- Basic principle requiring investigation is uncertainty
  - How to minimize?
  - Correlation among variables?
  - How can the unanticipated be included?
- Types of records of costs and production which are meaningful for estimating future costs

SESSION 2

BASIC RESEARCH IN CONSTRUCTION ENGINEERING MANAGEMENT

The session was opened by Ray Levitt, moderator, looking at the construction process in terms of an input-output model. The inputs of manpower, materials, machinery, and money are transformed into the outputs of construction. The transformation process is construction engineering management. Construction engineering management can be analyzed at several levels:

- Task: method optimization
- Subproject: system optimization
- Project: resource balancing
- Company strategy: finance, marketing, diversification
- Structure of participants in industry: organization theory, contracting practices

It can also be viewed in terms of variances. Management allocates resources through planning, monitors performance to determine variances, generates alternatives to correct variances, evaluates the alternatives, and reallocates resources to correct variances.

Basic research for construction engineering management was discussed at each of the five levels listed above. The research topics which were suggested during the discussion are presented below.

TASK

- Detailed task planning is currently inadequate
  - What is the correct or optimal level of task planning?
    - How detailed should the planning be?
    - What is the economic tarde off between the extent of planning and field performance?
    - How should plans be communicated?
  - Development of a detailed micro level planning system
    - Information flow for planning in the construction organization
  - Training for planning
- Task design
  - Method(s) to be employed in performing the task
  - Weather impact on various methods and tasks
  - Crew design
  - Factors that interrupt task performance
  - Degree of mechanization
- Develop models of quality control/quality assurance
  - Define quality
  - How much quality is enough?
  - Measurement of quality
  - Organization for insuring quality
- Need for diagnostic techniques
  - Scale models
  - Logistics and operations analysis

  - Computer graphics
  - Data archives
  - Simulation models, possibly as tools for foremen
- Selection and utilization of cranes and hoists

SUBPROJECT

- Communications, especially those between foremen
- Interrupts
- Diagnostic monitoring using the techniques listed under the TASK discussion
- Inventory levels
- Quality control/quality assurance
- Impact of organization structure

PROJECT

- Organization of the prospect staff
- Staffing of professional positions
- Site layout as a dynamic process
- Uniformity and independence of activities including design format and cost and schedule reporting
- The issues listed under TASK and SUBPROJECT were also identified as researchable issues at the PROJECT level

COMPANY

- Development of data bases
- Optimum sire of project, including influence of technology
  and constructability
- Strategic planning
  - Definition and evaluation of markets

  - Identification and assessment of competitors
  - Pricing (bidding)
- Disaggregation
  - Subcontracting
  - Procurement
- Use of multiple prime contractors

INDUSTRY

- Development of data bases
- Organization of the industry
  - Joint ventures
  - Competitive bidding and statistics related to it
  - Financing
  - Standard contracts
  - Collusion
  - Codes and regulations
- Issues identified at the company level for optimum size of projects and disaggregation were repeated at this level

The participants were asked to list several specific research topics based upon discussion during the session. The following topics were identified:

- Quality Engineering
- Organization Structures
- Work Packaging
- Project Delivery Systems
- Detailed Task Planning

- Site Layout

The participants were then asked to select three topics from this list for an indepth discussion of issues to be researched. Quality Engineering,, Detailed Task Planning and Site Layout were selected by vote of the participants. Research issues which should be addressed for each topic are presented below.

QUALITY ENGINEERING - discussion led by Boyd Paulson

Not much is known about this topic, which was considered to be good for basic research.

- Appropriate level of detail to be included in design: schematic vs. shop drawing; percent of design which should be completed before start of construction.
- Paying for substandard quality: adjustment of price for quality which is acceptable, but below that specified.
- Impact on productivity of stringent quality specifications versus consequences of reduced quality specifications.
- Effective organization structures and operating for quality assurance programs.
- Specification and measurement of design quality; quality of the contract documents. Effect of bad drawings and confusing specifications on construction process.

DETAILED TASK PLANNING – discussion led by Richard Tucker

The following list of areas in which research should be conducted was developed for this topic:

- Efficient planning methods: how to plan and what tools to use
- Identifcation of interfaces
- Identification of planning tasks
- When should planning take place
- What training in planning should be conducted?
- Communications: up, down, sideways, and out
- How should the expertise of foremen be utilized?
- Crane and hoist selection and utilization
- Simulation models as tools for foremen
- Scale models
- Computer graphics
- Logistics and operations managment
- Data archives

Other issues that were seen as requiring research were these: Why is detailed planning resisted in the United States? Why does it take outside intervention (owners, etc.) to affect a change? Why does planning return to its previous levels after 60 to 90 days?

SITE LAYOUT – dicussion led by Dan Halpin

The question addressed was: Is there a theory for optimum layout? The answer was no. What is currently done, if anything, is to describe the site on a scale drawing and then cut out pieces of paper to represent the various areas and place them on the drawing. These two items require research:

- Identify and describe construction sites by their physical characteristics and movement of resources throughout the site, possibly in terms of $/distance.
- Develop a programming model for job cites, probably using computer graphics. This should include changes from start to finish in Job site layout.

SESSION 3

BASIC RESEARCH IN CONSTRUCTION ENGINEERING ANALYSIS AND DESIGN

The session was opened by Hal Pritchett, moderator, who asked each of the participants to introduce themselves and to provide the group with information as to their background, education, and research interests.

Pritchett stated that Manpower + Materials + Machinery + Money + Management = Profit in the construction industry, and the objective of this session is to specify research necessary in engineering analysis and design to improve the profitability of the industry and reduce costs to owners.

Pritchett made a presentation on the influence curve described in Barrie and Paulson's _Professional Construction Management_ to illustrate where engineering analysis and design impact the construction costs. It was estimated that design and construction account for 20' of the life cycle coste of a facility, financing 40%, and maintenance and overhead 40%. Only 2% of the life cycle costs are expended upon planning and design of the facility, as opposed to planning its construction. The influence curve is based on projects from Fluor. The curve requires validation, and differences between types of construction and prospects need to be determined.

The decision was made to work through the list of topics compiled by Pritchett from the responses of the participants. Much of the research required falls within the purview of the traditional civil engineering disciplines of structures, soils, and materials. Discussion was focused on the actual construction of the facility and the engineering required to construct it rather than on the engineering of the facility itself. The research needs identified are, therefore, germane to construction even though the research may be categorized as structural, geotechnical, etc. in nature.

ROOFING

- Development of an overall generalized model
  - Materials problems
  - Construction problems
  - Liability
  - Building codes
  - Design of flat roofs
  - Cost of design decisions
- Acquisition of longitudinal data
- Erection sequences and construction loads
- Role for construction engineers in roof failure investigation

CONCRETE AND ASPHALTIC PAVING

- Onsite vs. offsite recycling
- Concrete cutting techniques

MATERIALS HANDLING

- Conveyor, vertical, and people transport
- Site planning to optimize material handling
- Energy utilization
- Equipment design, particularly for unique applications
- Cycle times for all materials
- Development of a model of materials handling that addresses the interaction of different cycles and rates
- Optimization of blasting operations

TEMPORARY SUPPORT STRUCTURES

- Development of criteria and design standards
  - Sensitivity of shoring and scaffolds to differential settlements
  - Loads on stakes and braces during construction
  - Temporary support capacity of soils
  - Shoring as a dynamically loaded system
- Impact of design assumptions on the construction process
- Role for construction engineer in the investigation of the failure of temporary structures

CONCRETE AND CONCRETE ADDITIVES

- Impact of superplasticizers
- Impact of additives on imbeds
- Finishing
- Vibrating, with particular attention to the liquification of concrete under vibration
- Impact of additives on curing and quick-curing

- Control of design specifications during concrete manufacturing

END PERFORMANCE SPECIFICATIONS

- Actual and required quality of contract documents
- Problem of shop drawing designs differing from original designs
- Responsibility for quality
- Development of a scientific basis for the rules of thumb promulgated in "quality" specifications

INNOVATIVE CONSTRUCTION EQUIPMENT

- Improved energy efficiency
- Lower noise level
- Increased capacity, prodctivity, mobility, and versatility

The bulk of equipment research should be carried out by the construction equipment industry, not universities. University researchers can play an important role, however, by identifying areas needing innovative equipment. One area that was believed to hold significant future benefits for the industry is robot development, partial automation, and remote control capability for equipment.

DATA BASES

The onsite acquisition of data for research purposes is a significant need which requires industry cooperation to use construction sites as research labs. Because of the interventions required to collect data, it is necessary to sell project owners on the need for the research and the benefits to be obtained from the research. Once this is done, it will likely be necessary to have the owner include the research effort in the contract documents to gain the cooperation of the contractor. A feasibility study is needed to determine if this is possible.

VALUE ANALYSIS AND DESIGN

- Computer design
- Computer tracking of changes
- Impact of changes on design
- Value engineering and its acceptance

MODULARIZATION

- Development of models to determine feasibility
- Onsite vs. offsite prefabrication
- Preaseembly

TUNNEL BORING

- Time-cost trade-offs between the cost of investigation of the site to optimize the set up of the boring machine for the specific soil and the use of a boring machine set up to handle a variety of soils

ENVIRONMENT

- Costs and benefits of subsidizing seasonal prospects
- Effects of altitude
- Impact of weather on offshore construction
- Cost impact of severe conditions

- Impact of environmental considerations on safety
- Impact on worker productivity
- Impact of radioactivity and other harsh environments
- Control of the environment

SESSION 4

BASIC RESEARCH IN CONSTRUCTION ENGINEERING UNCERTAINTY

Dan Halpin, moderator, introduced the session by saying uncertainty is pervasive in construction engineering and management, and there is a fairly large body of literature addressing construction uncertainty. The impact of uncertainty on all elements of the construction process had risen repeatedly in each of the preceding sessions. Halpin then led the participants through the major topics within which he had summarized their uncertainty research ideas (Appendix). Since the original ideas had come from the participants, there was at least one person familiar with each idea on the summary. This led to discussion of basic questions which were worthy of research. The list below was the work product of the session.

SCHEDULING UNCERTAIN DURATIONS

- Variables which contain uncertainty
  - Productivity (skills)
  - Weather
  - Management
  - Economic factors
  - Variations in supply
  - Detailed logic
- Descriptions of duration probability distributions.
  - Easily understood and estimated by managers

- For different scheduling systems (PERT type, simulation, max-min)
- Flexible
- Characteristic distributions for different types of activities.

- Characteristics of uncertainty. Which characteristics lead to which distributions?
- Relationship between variables
- Level of independence
- "Ripple effects" on uncertainty
- Characterization of weather and its impacts on construction
- Fundamental study of probabilistic networks, to lead to better understanding of relationships, interactions, and behavior and to develop to better probabilistic models
- Tools to develop and predict durations
- Better updating methods, particularly to allow better control of schedule

RANGE ESTIMATING

- Model different estimate levels, from conceptual estimates to detailed estimates
- Independence vs. dependence of cost variables
  - Characterize prospects to lessen effects of interdependencies
  - Models to handle correlated variables
  - Study relationships among variables

- Define or characterize uncertainty in cost elements

- Check basic assumption of successive approximation
- Value of information for subsurface work
- Characterize uncertainty on non-typical projects

STRUCTURAL FAILURE AND CONSTRUCTION SAFETY

- Probabilistic design of shoring and other temporary support systems
- Nondestructive testing of structures
- Appropriate level of risk
- Relationship between risk (probability of failure) and consequence
- Effect of overtime, inclement, or emergency conditions
- Define risks through structural failure and construction accident investigations
- Worker attitude toward risks and the influence of a safety program on those attitudes

CONTRACTURAL RISK

- Optimal distribution of risks among owners, designers, contractors
- Risk implied by specifications
- Level to which risk should be reduced in design before work is contracted
- Acceptance of risk versus shift in responsibility

BIDDING AND MARKUP ANALYSIS

- Strategy for competing against other contractors
- Strategy for awarding contracts
- Factors that make up a bid (cost, estimate, etc.)

- Influence of multiple projects

IMPACT OF UNCERTAIN PHENOMENA

- Distribution of resources
  - Under uncertain activity durations
  - Uncertain resource availability
  - Among multiple projects
- Subsurface conditions
- Impact of market uncertainty

DECISION THEORY

- Validate variable weights and establish their sensitivity
- Validate decision theory – does it work for construction decisions
- Employee attitudes toward risk and their influence on decisions
- Application of fuzzy sets to construction
- Applications of artificial intelligence to construction - capturing the expert opinion
- Further develop decision methodology for construction

PROCESS AND PROJECT SIMULATION

- Simulation of interaction among correlated variables
- Simulation of nonsteady state process conditions
- Simulation and other gaming techniques as a tool for personnel selection and training
- Scale models of construction operations
- Simulation of site planning
- Include group dynamics in simulation models

SESSION 5

BASIC RESEARCH TOPICS IN CONSTRUCTION ENGINEERING
HUMAN RESOURCE MANAGEMENT

The session was started by Bill Maloney, session moderator, and the decision was made to utilize the compiled list of topics (Appendix) submitted by the workshop participants as the agenda for discussion. Maloney, in his opening comments, emphasized the need to discuss the topics within the context of basic research, with a particular emphasis on the development of a theory or theories of worker behavior and performance. Many, if not most, of the topics submitted have been researched extensively in industries other than construction, and construction researchers need to build upon the research conducted in those industries.

WORKER MOTIVATION

- Develop a comprehensive model of worker motivation and performance
  - What motivates construction personnel, at all levels from craftsmen to professional employees?
  - Relationship between an individual's motivation and performance on the job
  - Influence of inadequate resources
  - Impact of collectively bargained work rules
  - Existence and impact of peer pressure
  - Role of life style and expectations

  - Influence of rework
  - Influence of management and management systems
  - Perception of risk and its influence on job behavior
  - Construction worker needs: existence, relatedness, growth

TRAINING

- Personnel development for work in unknown environments such as remote locations, possibly including outer space
  - Training in tools, methods, and procedures that are unknown
  - Supervisory training
- Training for contingencies
- Training to analyze situations, make decisions, and not wait for supervision
- Optimal level of worker training relative to supervision: Untrained or poorly trained workers require close ' supervision; well-trained workers require less supervision. How much training is necessary to optimize worker and supervisor performance? The supervisor needs time to plan and organize future activities as well as oversee current activities. The trade off is economic.
- Measuring effectiveness of construction training programs:
  With workers employed by more than one employer during a year, training effectiveness is difficult to measure
- Spreading training costs equitably throughout the industry: Workers are highly mobile and contractors are reluctant

to train workers for their competitors

- Advantages of worker mobility in reducing need for training

LABOR FORCE

- Demographic characteristics of construction workers, including education and experience.
  Construction employment demographics. Primary versus secondary employment, hours worked, seasonal characteristics, number of employers and duration of each employment.
- Mobility of construction workers and distinguishing characteristics of mobile workers: Differences by craft. Influence of job site, project duration, overtime opportunity and economic conditions.
- Mobility of construction professionals
- Culturally determined differences among workers on domestic prospects and international projects

LEADERSHIP

Research into leadership in construction requires an interdisciplinary approach. This should include construction researchers, typically individuals from civil engineering or construction engineering and management programs who possess the knowledge of construction processes and interaction, and researchers from the fields of organizational behavior or industrial, organizational, or social psychology who possess the knowledge of leadership processes and theories. Several issues requiring research are:

- Demographic and behavioral characteristics of effective construction managers
- Different leadership styles in construction and their effectiveness
- Influence of project size and type on effective leadership style
- How can effective leaders be selected?
- Is leadership in construction different from leadership in other fields?
- Develop theory of leadership which incorporates the many variables on a construction prospect
- Substitutes for leadership in construction that reduce the need for formal leadership

LABOR RELATIONS

- Influence of unions on worker motivation through peer pressure, collectively bargained work rules, or other mechanism
- Mechanisms and procedures for labor relations on nonunion projects
- Influence of construction unions and jurisdiction on development and adoption of technological advances

SAFETY

- Construction worker and supervisor attitudes toward personal risk and safety on and off the job: When faced with two methods of doing a job, one safer than the other, what influences the decision on method?
- Perception of risk and risk avoidance: Differences among crafts and other employment demographics
- How can workers be motivated to perform in a safe manner? Effectiveness of motivational techniques on construction safety performance
- Engineering construction projects for improved safety
- Cost accounting and benefit/cost analysis for safety and accidents
- Can safety performance be used effectively to prequalify contracts?

PERSONNEL FUNCTIONS

- Performance evaluation of construction personnel
- Personnel management and administration methods for changes in prospect characteristics as large or unique projects move through different stages of completion

ORGANIZATION STRUCTURE

Considerable research is needed, particularly in organization of construction projects and prospect oriented companies. Attention can be given to other prospect oriented industries such as aerospace. Among the many questions concerning construction are these:

- Relationship between worker productivity and the number of supervisory and staff (professional) personnel
- What is the relationship between crew size and productivity on cyclic processes?
- Is there an optimal job design (set of activities for an individual worker)?
- How should jobs be structured to foster effectiveness in worker performance and satisfaction?
- How can large projects be structured to provide more work force involvement and reduce the "smell cog in big wheel" syndrome?

PERFORMANCE MEASUREMENT

The diversity in construction tasks and lack of exact repetition has frustrated measurement of production. Mechanisms must be developed to measure and correlate performance of different tasks, crews, activities, crafts and prospects for all levels of personnel. The most basic need is for standard units to measure individual and crew level performance on construction tasks.

GROUP DYNAMICS

Applicability and adaptation of quality circle and other group dynamic techniques to construction projects with their finite durations and their multiple employers, crafts and tasks.

APPENDICES

WORKSHOP SCHEDULE

Monday, May 24, 1982

7:30	Breakfast buffet at Campus Inn
8:30-12:00	Session 1 - Definition of Basic Research in Construction Engineering and Management – Moderator: Neal B. H. Benjamin, University of Missouri Definition of basic research, classification of examples from construction and other fields, criteria for construction basic research, methodology for basic research, research experience and opportunities.
12:00-1:30	Luncheon at Campus Inn conference room
1:30-5:00	Session 2 - Basic Research in Construction Engineering Analysis and Design – Moderator: Harold D. Pritchett, Oregon State University Possible subtopics: construction equipment analysis and design, temporary services and utilities, temporary support systems, erection loadings and stresses, material characteristics relevant to construction processes, performance testing, environmental control, quality control.
7:00	Dinner at Pretzel Bell Restaurant (walk 5 blocks)

Tuesday, May 25, 1982

7:30	Breakfast buffet at Campus Inn
8:30-12:00	Session 3 - Basic Research in Construction Engineering Management - Moderator: Raymond E. Levitt, Stanford University Strategic planning, prospect planning and scheduling, cost systems, procurement, inventory, site layout, equipment management, engineering economy, work measurement, work improvement, financial management.
12:00-1:30	Luncheon at Campus Inn conference room
1:30-5:00	Session 4 – Basic Research in Construction Engineering Uncertainty - Moderator: Daniel W. Halpin, Georgia Institute of Technology Scheduling uncertain durations, range estimating, insurance and other risk analysis, impact of uncertain phenomena, bidding and markup analysis, nonlinear value systems, decision theory, quality assurance and reliability, resource dependability and use, process and project simulation, multiattribute decisions.
7:00	Dinner at Gandy Dancer Restaurant (walk 6 blocks)

Professor Neal B. H. Benjamin
Department of Civil Engineering
1043 Engineering Building
University of Missouri-Columbia
Columbia, MO 65211

Professor Leroy T. Boyer
Department of Civil Engineering
University of Illinois
Urbana, IL 61801

Professor James L. Burati
Department of Civil Engineering
Clemson University
Clemson, SC 29631

Professor Herbert W. Busching
Department of Civil Engineering
Clemeon University
Clemson, SC 29631

Professor Robert I. Carr
Department of Civil Engineering
University of Michigan
Ann Arbor, MI 48109

Professor Keith C. Crandall
Department of Civil Engineeering
University of California
Berkeley, CA 94720

Professor James E. Diekman
Department of Civil Engineering
University of Colorado
Boulder, Colorado 80309

Professor Daniel W. Halpin
School of Civil Engineering
Georgia Institute of Technology
Atlanta, GA 30332

Professor Donn E. Hancher
Department of Civil Engineering
Purdue University
West Lafayette, IN 47907

Professor Robert B. Harris
Department of Civil Engineering
University of Michigan
Ann Arbor, MI 48109

Professor Enno Koehn
Department of Civil Engineering
Purdue University
West Lafayette, IN 47907

Professor Richard E. Larew
Department of Civil Engineering
Ohio State University
2070 Neil Ave.
Columbus, OH 43210

Professor Raymond E. Levitt
Department of Civil Engineering
Stanford University
Stanford, CA 94305

Professor William F. Maloney
Department of Civil Engineering
University of Michigan
Ann Arbor, MI 48109

Professor Robert H. Mayer, Jr.
Department of Civil Engineering
University of Colorado
Boulder, Colorado 80309

Professor John W. Melin
Department of Civil Engineering
University of Illinois
Urbana, IL 61801

Professor Boyd C. Paulson
Department of Civil Engineering
Stanford University
Stanford, CA 94305

Professor Harold D. Pritchett
Department of Civil Engineering
Oregon State University
Corvallis, OR 97331

Professor Robert M. Stark
Department of Civil Engineering
University of Delaware
Newark, DE 19711

Professor H. Randolph Thomas
Department of Civil Engineering
Penn State University
University Park, PA 16802

Professor Weston T. Hester
Department of Civil Engineering
University of California
Berkeley, CA 94720

Professor Jimmie W. Hinze
Department of Civil Engineering
University of Missouri
Columbia, NO 65201

Professor C. William Ibbs
Department of Civil Engineering
University of Illinois
Urbana, IL 61801

Professor Richard C. Tucker
Department of Civil Engineering
University of Texas
Austin, TX 78712

Professor Jack H. Willenbrock
Department of Civil Engineering
212 Sackett Building
Pennsylvania State University
University Park, PA 16801

Dr. William S. Butcher
Civil Engineering
National Science Foundation
1800 G. Street, N.W.
Washington, D.C. 20550

Dr. Arthur A. Ezra
Water Resources & Environmental
Engineering Program
National Science Foundation
1800 G. Street, N.W.
Washington, D.C. 20550

SESSION 1
DEFINITION OF BASIC RESEARCH IN CONSTRUCTION ENGINEERING AND MANAGEMENT

BY NEAL B.H. BENJAMIN

The following have been selected from lists of topics proposed by workshop participants as suitable for "basic research". The have been arranged by session (there may be some overlap) and a personal Judgment has been made as to whether the topics are (A) definitely basic research topics, (B) moderately basic, or (C) definitely not basic research topics.

<u>Session 2 – Basic Research in Construction Engineering Management</u>

A. (1) Analysis of production transients in engineering.

(2) Integration of resource levelling with time-cost trade-offs.

B. (1) Research on evolution of organizational structure through project phase.

(2) Correlation of work sampling with delay surveys.
(3) Integration and interaction of CPM and inventory models.

C. (1) Study of current financing options.
(2) Use of insurance on large projects.

<u>Session 3 - Basic Research in Construction Engineering Analysis and Design</u>

A. (1) What is the optimum level of maintenance of heavy equipment.

(2) Optimal siting of construction plant.

B. (1) Incorporation of temporary facilities and final product.

C. (1) Methods for analysis of quality of bid documents, with predictions of quantity and likely areas for future change orders.

(2) Robotics in construction.

(3) Develop portable pipe extension process to eliminate field welding.

Session 4 – Basic Research in Construction Engineering Uncertainty

A. (1) Probabilistic models for construction-production-systems.

(2) To what extent can classical operations research techniques be applied to construction operations?

B. (1) Use of "fuzzy sets" in the interpretation of imprecise construction data.

(2) Bidding theory.

C. (1) Development of texts for grade school and high school on uncertainty.

(2) Identify the minimum number of samples required in construction quality control to assure reliability.

Session 5 - Basic Research in Construction Engineering Human Resource Management

A. (1) Identification of common personal characteristics of persons in various management positions in construction.

(2) Effectiveness of various motivational techniques on construction safety performance on medium to large scale projects.

B. (1) Determine the potential applicability and effectiveness of Quality Circles as a problem solving technique.

(2) What is the optimal division of labor.

C. (1) Educational programs for participants in outer space construction*

(2) Develop better procedures for evaluating construction personnel for promotion to foremen and superintendent levels.

(3) Interviewing, hiring, and retaining construction personnel.

SESSION 2
BASIC RESEARCH TOPICS IN CONSTRUCTION ENGINEERING MANAGEMENT

SUMMARIZED BY RAYMOND E. LEVITT

A. Decision Support Systems Engineering

(1) Development of Network Based Methodologies

- (a) Computerized time cost trade-off analysis improvement of techniques.
- (b) Techniques for assessing cause of delays: retrospective vs. real time*
- (c) Integration of resource leveling with time-cost trade-offs.
- (d) Measuring activity time distributions.

(2) Cost Engineering Methodologies

- (a) Effect of cost accounting procedures on quality of decisions.
- (b) Refine framework for modeling productivity.
- (c) Modeling the impacts of multiple design changes.
- (d) Treatment of inflation in economic decisions.
- (e) Process vs. unit cost data gathering.
- (f) Design of work packages to facilitate measurement.
- (g) Correlation of work sampling with delay surveys.
- (h) Electronic measurement of progress.
- (i) Better techniques for measuring design progress, delays.
- (j) Valuation of substandard work.

(3) Application of Systems/Optimization Techniques

- (a) Heuristics for site planning, recognizing dynamics.
- (b) Analysis of production transients in construction.
- (c) Process interaction on linear construction sites.
- (d) Crane or hoist location.
- (e) Progressive use of floor space for laydown.
- (f) Inventory models for material procurement; integration with CPM, storage constraints.
- (g) Two cycle production systems: stochastic effects on production.
- (h) Use of "fuzzy set" theory for imprecise data.
- (i) Use of artificial intelligence for nonroutine decisions.

B. Use of Computers in Construction Engineering Management

(1) Computer Systems Analysis and Design

(a) Methodology for design of database for large project planning and control.
(b) Coordinating data with jobsite distributed processing
(c) Enhanced computer graphics.
(d) Computer-aided engineering and design for microcomputers.
(e) Robotics in construction environment
(f) Impacts of CAD on decision-making.

(2) Man-Computer Interface ("Cognitive Ergonomics")

(a) Applications to project control.
(b) Numbering systems that are easily understood.
(c) User friendly systems - basic research on CPM, cost control, etc.
(d) Use of graphic displays.
(e) Faster input devices: "mouse", digitizer, etc.

C. Prospect Delivery Options

(1) Role of Architects/Engineers in construction oversight-implications for control of schedule, cost, quality*
(2) Analysis of subcontracting using markets/hierarchies framework.
(3) Impact of organizational structure on performance of large prospects.
(4) Research on evolution of organizational structure through project phases.

D. Risk Management and Insurance

(1) Methodology for identifying, linking risks.
(2) Methodology for insurance on large projects.

E. Estimating Techniques

(1) Development of conceptual estimating techniques.

F. Bidding Strategy

(1) Analysis of overhead and profit mark-up.

G. Financial Policy
(1) Study of current financing options

H. Logistics/Operations Planning

(1) Material packaging to facilitate deliveries of groups of materials.

SESSION 3
BASIC RESEARCH TOPICS IN CONSTRUCTION ENGINEERING ANALYSIS AND DESIGN

SUMMARIZED BY HAROLD D PRITCHETT

A. Roof Design and the Behavior of Roofing Materials

   (1) Roofs that continue to leak.

   (2) Structural failures.

B. Definition and Description of Concrete and Asphaltic Pavement Fracture Mechanisms

   (1) Important in the design and economic analysis of pavement breaking and cutting equipment.

   (2) Needed for the design and analysis of recycling equipment

C. Improved Materials Handling Systems

   (1) For highway and tunnel construction.

   (2) For industrial and high rise construction.

   (3) Cycle times and transport distances.

D. Need to Develop Criteria and Design Standards for:

   (1) Temporary support structures during construction (coffer dams, shoring, scaffolding, etc.).

   (2) Short term soil bearing capacities.

   (3) Temporary loads induced by construction equipment and materials during construction.

   (4) Structural support bracing during construction (wind, ice, snow, etc.).

E. Impact of Concrete Additives on the Construction Characteristics of Concrete Structures

F. Evaluation of End Performance Specifications

G. New Innovative Construction Equipment

(1) Energy and noise efficiency.

(2) Increased capacity and productivity.

(3) Increased mobility and versatility.

H. Temporary Utilities (Electrical, Water, etc.)

(1) Efficient portable units.

(2) Incorporate in permanent system.

I. On Site Research Data Acquisition Procedure

(1) Standard practice on major project.

(2) Prospects serve a major research facility.

J. Analysis of Crane Lifts for Construction

(1) Location.

(2) Accessibility.

(3) Support.

(4) Height.

(5) Capacity.

(6) Etc.

K. Value Analysis and Design Considerations

(1) Value engineering.

(2) Computer aided design

(3) Prospect delivery techniques.

L. Criteria for Intensive Quality Control and Quality Assurance Programs to Make Them Effective

M. The Creation of Portable Robots to Perform Repetitive Tasks (Like Automobile Industry)

N. Portable Pipe Extrusion Process for On Site Use,to Eliminate Field Welds

0. Improved Control on the Variability of Specified Design Strengths of Concrete, Found During Testing

P. Improved Modularization Techniques for Heavy and Industrial Construction

Q. Adaptable Tunnel Boring Machines for Variable Soil and Rock Formations

R. Concrete Handling and Placement

(1) Vibrating limitations.

(2) Transporting and placing.

(3) Effects on quality.

S. Construction Environment Considerations (Location, Climate, Season, Altitude, etc.)

(1) Offshore.

(2) Underwater.

(3) In space.

(4) Underground.

(5) Northpole - equator.

(6) Denver - Miami.

T. Basic Construction Research and Development Methods, Need to Become an Integral Part of the Overall Construction Industry Process on a Continual Basis

SESSION 4

BASIC RESEARCH TOPICS IN CONSTRUCTION ENGINEERING UNCERTAINTY

SUMMARIZED BY DANIEL W. HALPIN

A. Scheduling Uncertain Durations

(1) Character of uncertainty.

(2) Fall-off in production proportional to coefficient of variation?

(3) Distribution for activities - define probabilistic distributions.

(4) Causes of uncertainty - model the cause and effect relationship.

(5) Probabilistic models for construction production system.

(6) Better identification of construction related uncertainty.

(7) Fuzzy sets to study construction uncertainty.

(8) Weather effects in scheduling.

B. Range Estimating

(1) Character of uncertainty in estimating.
   (a) Variability in quantities, costs, times.
   (b) Correlation between variables in range estimating.

(2) Successive approximation in estimating as described by Lichtenberg.

(3) Risk analysis in construction estimating.

(4) Risk in estimating underground structures.

(5) Better means of coping with variability inherent in construction.

C. Risk Analysis

(1) Risk management of site and firm.

(2) Risk in reuse of materials for temporary support.

(3) Risk in form removal in concrete construction.

(4) Quality risk potential based on records of construction failures.

(5) Optimum allocation of contract risk.

(6) Are risk transfer mechanisms in construction contracts (i.e., differing site conditions clauses, etc.) really cost effective in reducing contingencies and therefore bid price. How should an owner decide which contract clauses are coat effective?

(7) Optimum percent of design prior to commencing construction.

D. Bidding and Markup Analysis

(1) Characteristics of contractor strategy for different types of bid competition (including those in which low bid is not winner).

(2) Is fastrack really a time and money saving approach?

(3) Bidding theory - does it work? Is it practical?

(4) Negotiated contracts vs. bidding? Contract form and productivity?

E. Impact of Uncertain Phenomena

(1) Construction firm fixed resources in an uncertain market.

(2) Uncertainty impact on market and firm.

(3) Study of causes of uncertainty and effects.

(a) Schedule versus plan versus update.
(b) Cost accounts (plan versus actual).

(4) Extent of exploration and testing under varying levels of uncertainty? Analytic tools? During design and predesign.

(5) How does uncertainty effect design and selection of equipment for tunnels, shafts, deep foundations?

(6) Use of fuzzy sets to analyze*

F. Decision Theory

(1) Utility and value analysis ("Nutzwertanalyse").

(2) Decision theory and optimization to short range prospect decisions based on use of micro-computer.

(3) Guidelines for decision making under uncertainty in construction management.

(4) Successive approximation in decision making – Lichtenberg concept to define most important parameters.

G. Prospect and Process Simulation

(1) Methods of examining correlated variables in simulation.

(2) Study production transients in construction processes using simulation.

(3) Process interaction of linear sites.

(4) Crew size determination based on simulation.

(5) Study transport and materials handling cycles in construction using simulation*

(6) Productivity estimation using simulation.

(7) To what extent can simulation techniques be applied to the building construction industry?

(8) Allocation of management resource using simulation.

(9) Simulation exercises to build more effective management teams?

(10) Site preparation and layout based on prospect simulation.

(11) Movement of facilities on a linear construction job study using simulation.

(12) Precast plant layout.

(13) Investigation of multicycle systems (balance, transients, probaility distributions).

SESSION 5
BASIC RESEARCH TOPICS IN CONSTRUCTION ENGINEERING HUMAN RESOURCE MANAGEMENT

SUMMARIZED BY WILLIAM F. MALONEY

A. Worker Motivation

(1) What needs are workers attempting to satisfy, variation by demographics.

(2) Impact of rework.

(3) Relationship between motivation and productivity.

(4) Impact of management and management systems on worker motivation

B. Training

(1) Educational programs need to be developed for managers, supervisors, and workers in outer space construction.

(2) Relative effects of on the job training vs. apprentice schools training for specific needed tasks vs. craft Journeyman range of tasks, in developing a stable, flexible, productive work force.

(3) Training for tasks vs. crafts; a systems study of this dealing with training costs, supervision costs, unemployment costs, motivational and productivity impacts, etc., is needed.

(4) Educating the educator and student for the educator and student for radical technological change.

(5) Resource requirements in training on mega-projects.

C. Labor Force

(1) Labor force characteristics: hours worked segregated on the basis of demographic variables.

(2) Stability of employment with one employer.

(3) Mobility and the distinguishing characteristics of mobile workers.

D. Leadership

(1) Relationship between leadership style and effectiveness.

(2) Determinants of effective leadership.

(3) Substitutes for leadership (characteristics of the job and the worker) that reduce the need for formal leadership.

E. Labor Relations

(1) Quantitative relationship between labor contract work rules and worker productivity.

(2) Effect of jurisdictional restrictions upon construction costs, market structures, and worker recruitment.

(3) Impact of dual allegiance of foremen on union prospects.

F. Safety

(1) Construction worker attitudes toward personal risk and safety on and off the job.

(2) Difference in accidents occurring in warm weather and cold weather.

(3) Effectiveness of various motivational techniques on construction safety performance on medium to large scale projects

(4) Effective safety management systems for construction companies.

(5) Worker disability: characteristics of disabled workers (disabled by either health or safety).

(6) Relationship between job characteristics and disability.

G. Personnel Functions

(1) Performance evaluation and review for all levels.

(2) Career development for construction professionals - planning for utilization.

(3) Interviewing, hiring, and retaining construction personnel.

(4) Develop better procedures for evaluating construction personnel for promotion to foreman and superintendent levels.

(5) Effect of various management functions (recruitment, organization, payments) upon management capabilities, attitudes, and other characteristics.

(6) What are the physical and mental skills, training, and experience required to have a fully qualified journeyman?

(7) Structure and effectiveness of compensation programs.

(8) Identification of common personal characteristics of persons in various management positions in the construction industry.

H. Organizational Structure

(1) Relationship between worker productivity and number of supervisory personnel on the job site.

(2) Relationship between worker productivity and the number of staff (professional) personnel on the project.

(3) Relationship between crew size and productivity on certain cyclic processes.

(4) Create structures on large projects that provide more involvement with the work force and reduce ("the small cog in big wheel" syndrome).

(5) What is the optimal division of labor?

(6) How should tasks be structured to foster effectiveness in terms of worker performance and satisfaction.

I. Environment

(1) Impact of weather on productivity.

J. Performance Measurement

(1) Develop craftsmen delay surveys to encourage participation and determine lost time.

(2) Productivity measurement and improvement for professional employees.

K. Group Dynamics

(1) Determine the potential applicability and effectiveness of quality circles as a problem solving technique of each level of the hierarchy.

L. Miscellaneous

(1) What are the human concerns that must be anticipated in accomodating robotics and other forms of automation in the workplace? How will the economists handle the displacement and retraining of blue collar and white collar workers supplanted by robotics and office automation? What psychological problems are involved when human beings work side by side or interact with automatons simulating various levels of intelligence?

(2) Where can technology make more effective and economical some of the general topics mentioned? For example, can interactive computer controlled video tape techniques improve employee training? Can real-time automated data acquisition through electronic video pattern recognition or other methods make regular productivity sampling and analysis more widely accepted? Could simulation exercises influence organizational behavior, or assist in building effective teams? With techniques of artificial intelligence, research have accurately simulated the diagnostic abilities of one of Massachusetts General Hospital's pathologists. Could A.I. techniques 8imilarly replace or supplement some kinds of project management or administrative functions?

(3) Human resource aspects of international point combines.

(4) Guidelines for the effective management of construction personnel on foreign projects.

(5) Problems of human resource management on superprojects.

(6) Dealing with stress in the construction environment.

(7) Study of reaction of job site personnel to the use of computers: (a) identify motivators; (b) identify demotivators; and (c) what constitutes a user friendly system.

(8) Impacts of variance on worker productivity and determination of mitigating influences from advancing forecasting and communication of impacts.