ADVANCES IN CONSTRUCTION PROJECT MANAGEMENT

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Dynamics Congress – Istanbul, Turkey – April 2012
Private accredited university
Located close to downtown Chicago
Approximately 8,000 students
Four campuses
Engineering, architecture, design, sciences, business, and law

Construction Engineering and Management Program
- Located within the CAEE Department
- Established in 1981
- Well recognized nationally and internationally
Contents

- Challenges in Construction Project Management Research
- Construction Project Management Research at IIT
  - Dynamic scheduling
  - Dispute prevention
  - Risk of contractor default
  - Bidding practices
  - Women in construction management
Advanced Critical Path diagrams and computational analysis tools to find the longest path through a network

- Parametric linear programming algorithms
- Ford & Fulkerson’s algorithm

Min

\[ \sum_{i,j} Z_{ij} = \sum_{i,j} (k_{ij} - C_{ij} X_{ij}) \]

CONSTRAINTS

- \( X_{ij} \leq D_{ij} \) All activities
- \( X_{ij} \geq d_{ij} \) All activities

\[ \sum_{\text{path } 1} X_{ij} \leq \lambda \]
\[ \sum_{\text{path } i} X_{ij} \leq \lambda \]
\[ \sum_{\text{path } n} X_{ij} \leq \lambda \]

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Challenges in Construction Project Management Research
Historical Perspective - 1955-1975

- Simulation and optimization of construction processes
  - Queuing theory
  - Simulation models

\[
P_0 = \frac{1}{\sum_{n=0}^{s-1} \frac{(s \times \rho)^n}{n!} + \frac{(s \times \rho)^s}{s! \times (1 - \rho)}}
\]
Challenges in Construction Project Management Research
Historical Perspective - 1955-1975

- Modeling and optimizing bidding processes
- Computerized Critical Path calculations
- Improving construction safety
- Studies about worker motivation
Challenges in CEM Research
Historical Perspective - 1975-1990

- Assessing risk allocation in construction contracts
- Investigations in innovation, management science, organizational theory, and strategic planning
- Attempts to combine computerized design tools, database design and management, and artificial intelligence applications
- Development of intelligent tools to visualize construction scheduling and control
- Development of expert system prototypes
- Use of genetic algorithms and artificial neural networks in solving construction management problems

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Challenges in CEM Research
Historical Perspective - 1990-2010

- Development of web-based systems to enhance cost, time, quality, safety, and organizational performance
- Use of sensors and sensor networks (e.g., RFID) to achieve automation and optimization in construction processes
- Visual modeling of building systems (3D), development of 4D/5D systems to manage schedule and cost
CM Research at IIT

- Dynamic scheduling
- Dispute prevention
- Risk of contractor default
- Bidding practices
- Women in construction

- Repetitive scheduling
- Quality management
- Sustainable systems
- International construction
- Contracting

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Dynamic Scheduling Systems

Synchronized Visualization of Construction Operations and the Work Schedule

- 4D/5D CAD systems
  - PMS-GIS

- 4D/5D Video systems
  - PHOTO-NET
    - PHOTO-NET I
    - PHOTO-NET II

- Automatic progress control
4D CAD Systems

☐ Koo and Fischer
☐ Bentley Schedule Simulator by Jacobus Technology
☐ SmartPlant Review by Telegraph
☐ Balfour Technologies’ FourDviz technology
☐ Visual Project Scheduler (VPS)
☐ Common Point 4D (CP4D) by CIFE/Stanford U
☐ Kamat and Martinez
☐ Retik and Shapira
4D CAD Systems

- After 1987 (3D drawing + work schedule)
- Involves analysis of the work at planning and design stages, and analysis of the project in the post-completion stage (forensic analysis)
- Impossible to update work program in a synchronized way with construction operations
- Only objective: visualization, not management
- Single level of detail
- Impossible to monitor parameters like cost and safety
- No web-based applications
Geographical Information Systems (GIS)
Project Monitoring System with Geographical Information Systems - PMS-GIS

- Architectural design done using AutoCAD
- Project broken down into activities
- Work schedule done using P3 Primavera
- AutoCAD files transferred to ArcView
- Activity themes created in ArcView
- Database established in ArcView
- Percent complete information input
- 3D drawings created in ArcView
- 3D drawings and P3 work schedule synchronized
PMS-GIS – Exterior walls – Month 2
Advantages of PMS-GIS

- Decision-making in the construction phase (not only visualization purposes)
- Observing progress in individual activities as well as in smaller work packages
- Updating the work schedule easily as long as the scheduler is familiar with ArcView
- Seamless operation of ArcView, P3 and AutoCAD
- Monitoring of cost, safety, materials, labor resources, equipment, etc. through a database
- Web-based system possible

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4D Video System – PHOTO-NET

- Project broken down into activities
- Work schedule done using P3 Primavera
- Events on construction site recorded by camera system using time-lapse photography
- Time-lapse movie and P3 work schedule synchronized
- Percent complete information input
- Synchronized time-lapse output of movie and work schedule

Dynamic Scheduling Systems
- PMS-GIS
- PHOTO-NET
- Automatic progress control

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PHOTO-NET I – Video Operations in the Field
Video Operations

- NTSC Standards: 30 frames/second
  - PMS-GIS

- Problems of filming with NTSC standards
  - Playing time = Filming time
  - Electronic storage

- In the time-lapse system, filming speed is lowered but playing speed remains 30 frames/second

- After experimentation, the optimum filming speed was determined to be 1 frame/second
PHOTO-NET II AND III – Second and Third Generations

- Use more than one camera
- Use advanced digital cameras
- Transfer data through wireless Internet connection
- Allows remote control of the cameras
- Calculate optimum filming rate (frame/second) automatically based on hard disk capacity and project duration
- Produce printed reports (bar charts, cost curves, etc.)
Placing concrete on Suspended Slab at Level 1.


Weekly Cumulative Percentage of Progress

Weeks

2/7/2002 Next Day
Stop Close

10:00 AM
Advantages of PHOTO-NET II

- The project manager is able to monitor construction progress relative to as-planned schedule on a day-by-day basis
- Higher management is able to monitor project progress through the cameras
- Probable disagreements between owner and contractor are prevented

http://www.remontech.com/what-we-do/dynamic-scheduling/
http://remontech.com/tutorial1.swf
Automatic Progress Control

- 3D/4D model
- Point cloud data
- Registration
- Object definition
- Progress measurement

Dynamic Scheduling Systems
- PMS-GIS
- PHOTO-NET
- Automatic progress control
Automatic Progress Control – Lab Experiment
Camera shots, point cloud model, 3D model, and progress

<table>
<thead>
<tr>
<th>Schedule</th>
<th>DAY 0</th>
<th>DAY 1</th>
<th>DAY 2</th>
<th>DAY 3</th>
<th>DAY 4</th>
<th>DAY 5</th>
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</table>

<table>
<thead>
<tr>
<th>DAY 0</th>
<th>DAY 1</th>
<th>DAY 2</th>
<th>DAY 3</th>
<th>DAY 4</th>
<th>DAY 5</th>
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<tr>
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<td>![Image]</td>
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<td>![Image]</td>
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<tr>
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<td>P₁ = 0%</td>
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<td>P₁ = 0%</td>
<td>P₁ = 0%</td>
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</tr>
<tr>
<td>P₂ = 0%</td>
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<td>PSlab = 0%</td>
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<td>Overall = 0%</td>
<td>Overall = 16%</td>
<td>Overall = 40%</td>
<td>Overall = 60%</td>
<td>Overall = 80%</td>
<td>Overall = 100%</td>
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## Progress on Day 3

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<td>Column A</td>
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<tr>
<td>Column B</td>
<td>Partially completed, 40%</td>
</tr>
<tr>
<td>Column C</td>
<td>0% completed</td>
</tr>
<tr>
<td>Column D</td>
<td>100% completed</td>
</tr>
</tbody>
</table>

Progress measured by using the system corresponds to observed actual progress.
Conclusion – Dynamic Scheduling Systems

- Bar charts and CPM schedules do not convey the spatial aspects of the planning information
- 4D-CAD systems developed so far have limitations
- PCS-GIS and PHOTO-NET compare favorably to existing systems
- Automatic progress control improves productivity
- Being able to visualize project activities and the work schedule in a synchronized way improves project controls and minimizes disagreements

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References


CM Research at IIT

- Dynamic scheduling
- Dispute prevention
- Risk of contractor default
- Bidding practices
- Women in construction

- Repetitive scheduling
- Quality management
- Sustainable systems
- Minority firms in construction
- Contracting
Prevention of Disputes

Observations in the Construction Industry

- The construction business is risky
- Few construction contracts are completed without disagreements
- Disputes are resolved at different forums
- A dispute-free environment is most desirable
A dispute-free environment is most desirable
Prediction

A prediction is a claim that a particular event will occur in the future

- A prediction is not an informed guess or an opinion
- Prediction is not prophecy (astrology, numerology, fortune telling, etc.)

Niels Bohr stated:
"Prediction is very difficult, especially if it's about the future."

Mathematical and computer models are frequently used to both describe the behavior of something, and predict its future behavior
IIT Research on Predicting the Outcome of Litigation

- Analysis of court data - 1994
- Artificial neural networks (ANN) - 1998
- Case based reasoning (CBR) - 1999
- Boosted decision trees (BDT) - 2005
- Ant colony system (Ant Miner) - 2007
- Universal Prediction Model (UPM) – 2009-2010
- Computerized information acquisition – 2011-2012
Illinois Court System

Claim
Settlement
Circuit Court
Acceptable
Appellate Court
Decision
Decision
Acceptable
Supreme Court
Decision
Acceptable
Affirmed or Reversed
Affirmed or Reversed
END
Yes
END
END
Yes
Yes
END
Yes
No
No
No
END
Remanded
Remanded
Remanded
Remanded
Remanded
Artificial Neural Networks (ANN)

- Inspired by the structure of biological systems
- Artificial neurons used to develop an artificial neural net
- Nets with numerous interconnections among different neurons
- Capable of carrying out parallel computations for different tasks, including prediction

- Analysis - 1994
- ANN - 1998
- CBR - 1999
- BDT - 2005
- Ant Miner - 2007
- UPM - 2009-2010
- Info acquisition - 2012
Artificial Neural Networks (ANN) Study

- 45 input elements
- 1 output element
- 102-case data set
- 12-case test set
- Brainmaker (back propagation)
- Experimentation with variations of the data, the cases, and the parameters of the program
Methodology of the ANN study

1. Defining feature names and input types
2. Deciding training parameters
   - Unsuccessful
   - Training and testing
     - Successful
     - Different combinations of parameters exhausted
       - Yes
       - Solution
     - No

Artificial Neural Networks (ANN)

Prediction rate: 67%
Case Based Reasoning (CBR)

- Problem-solving paradigm that utilizes the specific knowledge of previously experienced cases
- Mimics human reasoning
- Makes use of a cyclic process of retrieving past experiences, reusing, revising and retaining them
Case Based Reasoning (CBR) Study

- 43 input elements
- 1 output element
- 102-case data set
- 12-case test set
- Esteem
- Experimentation with similarity assessment methods
Methodology of the CBR Study

Definition and Objectives for the CBR Problem

Defining Feature Names (All Features and Restricted Features)

Deciding Feature Values

Inputting the Cases into Case Base

Deciding Similarity Assessment Method

CASE-BASE

Inputting the Target Cases

Retrieving Cases and Generating Similarity Scores

Calculation Methods for Selection

Adapting

Final Solution

Design Stage

Run Stage

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Case Based Reasoning (CBR)

Prediction rate: 83%
Decision Trees

Decision trees are simple tools that can
- Handle large amounts of complex information
- Generate alternative decisions
- Lay down the implications of these decisions

Boosting

- Boosting refers to a method that “boosts” a weak learning algorithm into a strong learning algorithm
- It produces an accurate prediction rule by combining rough and moderately inaccurate rules of thumb

Analysis - 1994
ANN - 1998
CBR - 1999
BDT - 2005
Ant Miner - 2007
UPM - 2009-2010
Info acquisition - 2012
Boosted Decision Tree (BDT) Study

- 40 input elements
- 1 output element
- $102 + 12 + 18 = 132$ cases in data set
- See 5
- Experimentation with data and test sets, and with boosting trials
Boosted Decision Trees (BDT)

Prediction rate: 90%
Ant Colony Systems

- Ant colony optimization is part of Swarm Intelligence that is based on the collective behavior of decentralized, self-organized systems.
- Real ants lay down pheromones directing each other to resources while exploring their environment.
- Artificial ants mimic the behavior of real ants.
- The use of ant colony optimization as a classification system (Ant Miner) is rather new.

- Analysis
- ANN - 1998
- CBR - 1999
- BDT - 2005
- Ant Miner - 2007
- UPM - 2009-2010
- Info acquisition - 2012
Ant Colony Systems Study

- 38 input elements
- 1 output element
- \(102 + 12 + 18 + 19 = 151\) cases in data set
- Ant Miner
- Experimentation with data and test sets
Ant Colony Systems Methodology
Ant Colony Systems (Ant Miner)

Prediction rate: 92%
Universal Prediction Model (UPM)

- Involves a large number of combinations of data consolidation methods, attribute selection methods, base classifiers, and meta learners
- Involves a large number of experiments (brute-force method)
- Totally automated process in WEKA

- Analysis
- ANN - 1998
- CBR - 1999
- BDT - 2005
- Ant Miner - 2007
- UPM - 2009-2010
- Info acquisition - 2012
## Knowledge Environments

<table>
<thead>
<tr>
<th>Knowledge Environment</th>
<th>Authors</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapid Miner (Formerly known as Yale)</td>
<td>Artificial Intelligence Unit of the University of Dortmund, Germany</td>
<td>[<a href="http://sourceforge.net/projects/Yale/">http://sourceforge.net/projects/Yale/</a>]<a href="http://sourceforge.net/projects/Yale/">http://rapidminer.com</a><a href="http://rapidminer.com">http://rapidminer.com</a></td>
</tr>
</tbody>
</table>
Universal Prediction Model (UPM)

Data

Pre-Processing
- Data Consolidation
- Attribute Selection

Classification using Hybrid systems
- Base Learner
- Enhancing Algorithms

Hybrid Classifier System

Assessment

Data Consolidation

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Universal Prediction Model (UPM) Test

Pre-processing and Attribute Selection

Data Consolidation
6 datasets

6 Unsupervised Attribute Filters
Original
Add Noise
Normalize
Remove Useless
Replace Missing
Values
Class Order

Attribute Selection
12 combinations

3 Subset Evaluation Methods
Correlation-based Classifier Subset Consistency Subset

4 Search Methods
Best First Genetic Search Greedy Stepwise Rank Search

Development of Hybrid Systems

4 Base Classifiers
J4.8 (C4.5)
REP Tree
J Rip
Part

3 Meta Learners
Boosting
Bagging
Multi Boost AB

11 Combinations of Base Classifiers
J4.8 (C4.5)
REP Tree
J Rip
Part

3 Ensemble methods
Grading
Stacking C
Vote

Total of 3,528 experiments

72 * (11*3) = 2,376 experiments

72 * [4+(4*3)] = 1,152 experiments

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Universal Prediction Model (UPM)

Prediction rate: 96%
## Comparison of Results

<table>
<thead>
<tr>
<th>Artificial Intelligence Machine</th>
<th>Prediction Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial Neural Networks</td>
<td>67%</td>
</tr>
<tr>
<td>Case Based Reasoning</td>
<td>83%</td>
</tr>
<tr>
<td>Boosted Decision Trees</td>
<td>90%</td>
</tr>
<tr>
<td>Ant Colony Systems</td>
<td>92%</td>
</tr>
<tr>
<td>Universal Prediction Model</td>
<td>96%</td>
</tr>
</tbody>
</table>
Conclusion – Prevention of Disputes

- Accuracy of prediction is dependent upon quality of input data
- The number of attributes should be commensurate with the number of cases
- Experimentation is essential in all AI applications
- A large number of cases is required

UPM is the most versatile system that can be used in any domain with confidence
Computerized Information Acquisition

- Text searching algorithms, software, open source systems
  - Lucid Solr by Lucid Imagination
  - Fast by Microsoft
  - Seamark by Endeca
  - Google
  - Dieselpoint Search
  - Autonomy

Analysis
- ANN -1998
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- Info acquisition - 2012

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Managing the Risk of Contractor Default

- The research literature focuses on company success factors
- Can we learn from company failures?
Business failure probabilities by age
<table>
<thead>
<tr>
<th>Environment/Response Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CELL I</strong></td>
</tr>
<tr>
<td><strong>Weighted (%)</strong></td>
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<tr>
<td><strong>Occurrence</strong></td>
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<tr>
<td><strong>BUDGETARY ISSUES</strong></td>
</tr>
<tr>
<td>Insufficient profits</td>
</tr>
<tr>
<td>Heavy operating expenses</td>
</tr>
<tr>
<td>Insufficient capital</td>
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<tr>
<td>Burdensome institutional debt</td>
</tr>
<tr>
<td>Receivable difficulties</td>
</tr>
<tr>
<td><strong>HUMAN/ORGANIZATIONAL CAPITAL ISSUES</strong></td>
</tr>
<tr>
<td>Lack of business knowledge</td>
</tr>
<tr>
<td>Lack of managerial experience</td>
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<tr>
<td>Fraud</td>
</tr>
<tr>
<td>Lack of line experience</td>
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<tr>
<td>Lack of commitment</td>
</tr>
<tr>
<td>Poor working habits</td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
</tr>
</tbody>
</table>

| **CELL III**                | **CELL IV**     |
| **Weighted (%)**            | **Weighted (%)** |
| **Occurrence**              | **Occurrence** |
| **BUSINESS ISSUES**         | **MACROECONOMIC ISSUES** |
| Business conflicts          | Industry weakness | 22.73 |
| Family problems             | Poor growth prospect | 0.28 |
|                              | High interest rates | 0.06 |
| **NATURAL FACTORS**         |                  |
| Disaster                    |                  |
| **TOTAL:**                  |                  |
| **TOTAL:**                  |                  |

<table>
<thead>
<tr>
<th>Administrative systems and procedures</th>
<th>Strategic long term planning</th>
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<table>
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<th>Response</th>
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</tbody>
</table>
Input/Output Model of Business Failure/Survival

**SYMPTOMS**

**PERFORMANCE FACTORS**
- Insufficient profits: 46.3%
- Heavy operating expenses: 32.8%
- Burdensome institutional debt: 10.3%
- Inadequate sales: 3.9%
- Business conflicts: 3.6%
- Receivable difficulties: 2.7%
- Not competitive: 0.5%

**ORGANIZATIONAL FACTORS (39.3%)**
- Human, organizational and financial capital
  - Insufficient capital: 47.2%
  - Lack of business knowledge: 21.2%
  - Fraud: 9.7%
  - Lack of managerial experience: 5.4%
  - Family problems: 5.1%
  - Lack of line experience: 3.7%
  - Lack of commitment: 3.4%
  - Poor working habits: 3.4%
  - Overexpansion: 0.8%

**ENVIRONMENTAL FACTORS (60.7%)**
- Macroeconomic and natural factors
  - Industry weakness: 87.2%
  - Disaster: 11.6%
  - Poor growth prospects: 1.0%
  - High interest rates: 0.2%

**FAILURE**

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Early Detection of Decline

- Early detection of decline
- Successful turnaround and desired performance
- Undesirable decline that can lead to failure

Time

Performance

Early detection of decline

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Methods of Transferring Risk

Prediction of contractor default using GA training strategy

Predicted occurrence of default
Less than 0.5
Transfer
Avoid
Risk Averse
Owner's risk behavior
Transfer
Risk Neutral
Retain
Transfer
Risk Seeking

Augment owner contingency according to probable losses
Transfer of Risk to Subcontractor

- Bonding
- Retainage
- Insurance
Conclusion – Risk of Contractor Default

- Company failure is age dependent
- There are liabilities of newness, adolescence and smallness
- Most causes of failure can be prevented by short-term management action
- It is possible to predict the state of decline by using non-financial data
- The owner can use intelligent/economic protection against contractor default
- Subcontractor default is an important part of the risk equation
References


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Bidding Practices from the Point of View of the Owner

- Detection and prevention of unbalanced bids
- Detection and prevention of collusive bids
- Detection and prevention of claims games
Detection and prevention of unbalanced bids

Mathematically Unbalanced Bids
- Front loading
- Individual rate loading

Materially Unbalanced Bids
- $PW_{\text{lowest bidder}} > PW_{\text{other bidders}}$

Reject lowest bid
### UNBALANCED BID DETECTION AND ANALYSIS USING ENGINEER’S ESTIMATES

<table>
<thead>
<tr>
<th>Bid Item No.</th>
<th>Quantity</th>
<th>Payment Schedule</th>
<th>Engineer’s estimate</th>
<th>% of Price Range</th>
<th>Upper Limit</th>
<th>Lower Limit</th>
<th>Bidder 1</th>
<th>Bidder 2</th>
<th>Bidder 3</th>
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<td>25%</td>
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<td>2,700.00</td>
<td>3,486.00</td>
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<td>25</td>
<td>9,800.00</td>
<td>25%</td>
<td>12,250.00</td>
<td>7,360.00</td>
<td>9,131.00</td>
<td>9,573.00</td>
<td>11,054.00</td>
<td>11,170.00</td>
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</table>

**Total Cost:**

- **13,129,973.00**
- **13,352,406.00**
- **13,431,480.00**
- **13,498,876.00**
- **13,782,980.00**

**Total Cost with consideration of time value of money:**

- **12,215,634.88**
- **12,301,675.71**
- **12,105,128.63**
- **12,133,094.75**
- **12,370,932.43**

---

**Bid Analysis**

Select Bidder to be Analyze:

- **Bidder 1**

**Step 1:** Check out of range unit price

**Step 2:** Check frontloading

**Step 3:** Check present value

**Microsoft Excel**

Bidder 1 has materially unbalanced the bid. Bidder 5 becomes the lowest bidder if time value of money is considered.

**OK**
Detection and prevention of collusive bids

- Formulation of regression model
  \[
  \ln(\text{BID}_{i,t}) = \beta_0 + \beta_1 \ln(\text{EST}_t) + \beta_2 \ln(DIST_{i,t}) + \beta_3 \ln(MDIST_{i,t}) + \beta_4 \ln(TOTAL_i) \\
  + \beta_5 \ln(RATIO_t) + \beta_6 \ln(NOBID_t) + \beta_7 \ln(AVERAGE_i) + \beta_8 \ln(DUR_t) + \beta_9 \ln(WON_{i,t}) \\
  + \beta_{10} \ln(ECON_{i,t}) + \varepsilon_{i,t}
  \]

- Acquisition of data
  - all bids
  - 108 contracts
  - awarded by a public agency
  - between 2001-2010
  - 80 bidders
  - min 2, max 26, ave 5 bids per contract
Detection and prevention of collusive bids

- **Analysis of the data**
  - The residual test (residuals must not be correlated)
  - The cost structure stability test (coefficients of the cost structure model must be identical)
  - Analysis of the bid distributions (cartel bidders are expected to bid higher than non-cartel bidders relative to the engineer’s estimate)
  - Analysis of model dispersion (cartel bids are expected to be more tightly concentrated than non-cartel bids)
  - Analysis of the differences in cost structures (the independent variables are expected to affect the models of cartel bidders and non-cartel bidders differently)
Conclusion - Detection and prevention of collusive bids

- Out of the 80 bidders it was found that 6 are likely to have colluded with each other.

- Validation: Out of the 6 potential cartel bidders, 1 was convicted of bidding irregularities, and 2 were investigated by authorities.
References

CM Research at IIT

- Dynamic scheduling
- Dispute prevention
- Risk of contractor default
- Bidding practices
- Women in construction

- Repetitive scheduling
- Quality management
- Sustainable systems
- Minority firms in construction
- Contracting
Women in Construction

- Women are underrepresented in the construction industry
  - Women in national workforce: 46%
  - Women in construction: 9.6%

- There are many reasons why construction is male dominated
Methodology of the Study
Are female CMs less competent than male CMs?

☐ Management Development Questionnaire (MDQ)
☐ Twenty competencies measured by eight statements each: a total of 160 questions
☐ Three rounds of electronic solicitation
☐ 1,400 project managers at random (www.salesgenie.com)
☐ 63 responses received (32 from men and 31 from women)
## Average STEN scores for Managerial Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>STEN scores</th>
<th>p-Value</th>
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<tbody>
<tr>
<td></td>
<td>Women</td>
<td>Men</td>
</tr>
<tr>
<td>Initiative</td>
<td>5.71</td>
<td>5.16</td>
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<tr>
<td>Risk Taking</td>
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<td>4.74</td>
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<tr>
<td>Innovation</td>
<td>5.65</td>
<td>5.13</td>
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<tr>
<td>Flexibility and adaptability</td>
<td>4.23</td>
<td>3.32</td>
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<tr>
<td>Analytical thinking</td>
<td>5.32</td>
<td>4.94</td>
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<tr>
<td>Decision making</td>
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<td>4.65</td>
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<tr>
<td>Planning</td>
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<td>Quality focus</td>
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<td>Oral communication</td>
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<td>Relationships</td>
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<td>Achievement</td>
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<td>Business awareness</td>
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<td>Learning orientation</td>
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<td>Authority and presence</td>
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<td>Motivating others</td>
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<td>Developing people</td>
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<tr>
<td>Resilience</td>
<td>3.77</td>
<td>3.84</td>
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</table>

---

Dynamics Congress – Istanbul, Turkey – April 2012
Conclusion – Women in Construction

- No statistically significant difference between men and women in 17 managerial competencies
- Women outperformed men in 3 managerial competencies
  - Sensitivity
  - Customer focus
  - Authority and presence
References


CM Research at IIT

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- Quality management
- Sustainable systems
- Minority firms in construction
- Contracting

Dynamics Congress – Istanbul, Turkey – April 2012
Recent Research in Construction Management at IIT

THANK YOU FOR YOUR ATTENTION