Information Technology, Construction Innovation, and NIST

Bricks and Bits: Transforming the Construction Industry Through Innovation

January 18, 2012
Information Technology and Innovation Foundation, National Press Club

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Impacts of Construction Industry Supply Chain in 2010

- **Current Value of Built Assets**: $36.4 T
- **Construction Contribution to GDP**: $506 B
- **Construction Contribution as % of GDP**: 3.5 %
- **Value of Construction Put in Place**: $804 B
- **Volume of Construction Work**: $937 B
- **Construction Employment (Establishment Surveys)**: 5.5 M
- **Construction Employment (Household Surveys)**: 9.1 M

- **Raw Materials**: $307B
- **Mfgr. of Materials, Component Systems**: $94B
- **Contents & Furnishings**: $291B
- **Maintenance & Repair**: $1B
- **Loss - Fire - Wind - EQ - Flood - Etc.**: $144B
- **Waste and Environmental Impact**: $552B
- **Recycle**: $49B
- **Energy**: $1B
- **Owner Needs**: $307B
- **Facility Design**: $94B
- **Facility Construction**: $291B
- **Commissioning**: $1B
- **Operation & Use**: $100B
- **Renovation**: $7B
- **Demolition**: $1B
- **Recycle**: $552B
- **Impacts of Construction Industry Supply Chain in 2010**

- **Standards, Codes & Regulatory Approvals**: $430B
Construction: An Engine for Growth

• The construction industry accounted for $506 billion of U.S. GDP in 2010
• The value of construction put in place was $804 billion in 2010
  – New construction: $547 billion
  – Renovation: $257 billion
• New construction and renovation create increased demand for energy, water, and services

The construction industry plays a significant role in shaping the U.S. economy
Key Drivers for Change in Construction

• Global competition, growth of international trade, and rapid pace of technological change

• Demand for:
  – energy efficient and sustainable construction
  – better quality, higher performing, and innovative products and facilities
  – higher productivity and lower cost construction

• Renewal of Nation’s aging physical infrastructure ($2.2 T est.)

• National security and disaster resilience
Key Challenges Facing Construction

- Enhancing productivity at all levels
- Reducing waste and inefficiencies in labor and material control (25-50%)
- Distributed supply networks; industry fragmentation; inadequate innovation ecosystems
- Enabling innovation and competitiveness:
  - Better metrics for characterizing, monitoring, controlling, and optimizing performance
  - Life-cycle performance (versus minimum first-cost) based investment options
  - Technical basis and tools to support emerging standards, codes, and regulations
  - Filling significant pre-competitive R&D gaps
# Stakeholder Interests

**Materials and product manufacturers** – motivation to innovate; productivity (cost, cycle time)

**IT and engineering service providers** – responsive to market demands

**Owners and operators** – productivity (cost, cycle time)

**Contractors/homebuilders** – productivity (cost, cycle time), safety

**Standards and codes organizations** – public, personal, corporate risk; market access

**Fire safety organizations** – fire risk management; fire fighter safety

**Property insurers** – financial risk management
Prior Construction Industry Studies

- Business Roundtable’s Construction Industry Cost Effectiveness Project, 1977
- *A National Strategy for Improving Productivity in Building and Construction*, NRC 1980
- Other Studies Conducted by:
  - Construction Industry Institute (CII)
  - Construction Users Round Table (CURT)
  - Federal Facilities Council (FFC)
  - FIATECH
Productivity and Competitiveness

- General perception that industry productivity is declining
  - -0.6 % per year
  (+1.8% per year non-farm productivity increase; significant improvement in some work processes)

- Debate over root cause
  - Underinvestment in construction R&D
  - Shift in output mix
  - Slow growth in capital/worker

- Debate and uncertainty continue as no industry-level productivity measures exist

Key Factors Affecting Construction Productivity

• Use of Industry Best Practices
• Technology Utilization
• Skilled Labor Availability
“The cost of inadequate interoperability in the U.S. capital facilities industry: $19.2 billion per year.”
What is Interoperability for Construction?

…the dynamic and seamless exchange of accurate, useful information on the built environment among industry stakeholders throughout the facility life cycle.
Breakdown of Costs by Stakeholder

Costs of Inadequate Interoperability by Stakeholder Group, by Life-Cycle Phase (in $ Millions)

<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>Planning, Engineering, and Design Phase</th>
<th>Construction Phase</th>
<th>Operations and Maintenance Phase</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architects and Engineers</td>
<td>1,220.8</td>
<td>178.2</td>
<td>19.0</td>
<td>1,417.9</td>
</tr>
<tr>
<td>General Contractors</td>
<td>589.0</td>
<td>1,533.7</td>
<td>61.1</td>
<td>2,183.7</td>
</tr>
<tr>
<td>Specialty Fabricators and Suppliers</td>
<td>536.2</td>
<td>2,136.0</td>
<td>---</td>
<td>2,672.2</td>
</tr>
<tr>
<td>Owners and Operators</td>
<td>936.7</td>
<td>1,088.5</td>
<td>10,941.8</td>
<td>12,906.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,222.1</strong></td>
<td><strong>4,936.1</strong></td>
<td><strong>11,021.9</strong></td>
<td><strong>19,180.2</strong></td>
</tr>
</tbody>
</table>

Source: RTI Estimates, updated to 2010 dollars

- OOs bore approximately $12.9 billion, or 2/3 of the total estimated costs in 2010 dollars
- AEs had the lowest costs at $1.4 billion
- GCs & specialty fabricators and suppliers bore balance at $2.2 billion and $2.7 billion
Advancing the Competitiveness and Efficiency of the U.S. Construction Industry

Task Statement: Identify and prioritize technologies, processes, and deployment activities which have the greatest potential to significantly advance the productivity and competitiveness of the U.S. construction industry.
Activities with Potential for Breakthrough Improvements

- Widespread use of interoperable technology applications and Building Information Modeling (BIM)
- Improved job-site efficiency through more effective interfacing of people, processes, materials, equipment, and IT
- Greater use of prefabrication, preassembly, modularization, and off-site fabrication and processes
- Innovative demonstration Installations
- Effective performance measures to drive efficiency and support innovation
IT Trends in Construction, Buildings, and Infrastructure

- Industry sectors have different levels of adoption
  - Driven by contractual models and life cycle metrics
  - Process industry: early adopters and leaders in usage
  - Commercial/institutional buildings: adopting LC costing and BIM
    - GSA, educational institutions, hospital owners
  - Infrastructure: starting to adopt BIM

- Interoperability is still a challenge
  - Coordination across industry efforts
  - Agreement on viable increments for adoption into practices
Typical BIM Usage and Benefits

Architectural
- Interference checking
- Clash detection
- Model coordination

Mechanical, Electrical, Plumbing
- More offsite prefabrication
- Fewer RFIs
- Reduced cost
- Higher quality deliverable

Structural
- Cost of upfront coordination is much less than fixing problems later in the field
The FIATECH Capital Project Technology Roadmap Vision of the Future

1. Scenario-based Project Planning
   - Requirements and Conceptual Design
   - What If?
   - Scientific Data
   - Business Case (Financial/Strategic)

2. Automated Design
   - Technical Approach
   - ROM Budget and Schedule
   - Technical Plan, Target Cost and Schedule
   - Schedule Information
   - Drawings and Models
   - Instructions
   - Budget
   - Specs and Contracts

3. Integrated Automated Procurement and Supply Network
   - Supplier Designs/Capabilities/Products and Services
   - Feedback of O&M Knowledge and Experience

4. Intelligent and Automated Construction Job Site
   - Materials, Equipment, Labor, Tools, Fabricated Products, etc.
   - Decision/Design Support
     - Capacity Mgmt.
     - Upgrades, Renovations
     - Conversions
     - D&D, Recycle, etc.

5. Intelligent, Self-maintaining and Repairing Operational Facilities
   - Electronic As-Builts
   - Facility Sim Model w/ Processes, Materials, etc.

6. Real-time Project and Facility Management, Coordination and Control
   - Plan Updates
   - Detailed Work Packages Command/Control Instructions
   - Real-Time Status
     - Technical
     - Schedule
     - Cost
     - Issues
   - Real-Time Operational Status
     - Systems
     - Processes
     - Infrastructure

7. New Materials, Methods, Products and Equipment

8. Technology- and Knowledge-enabled Workforce

9. Lifecycle Data Management and Information Integration

Fully integrated and highly automated project processes coupled with radically advanced technologies across all phases and functions of the project/facility lifecycle.
NIST’s Unique Mission

To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.

- **Mission focus**: Targeting Investments to Advance U.S. Innovation and Boost Economic Recovery
- **Deep research expertise** underpins technological innovation – e.g. lasers, memory, GPS, wireless
- **Non-regulatory status** enables important role as a convener that facilitates collaboration between industry and government

**Cybersecurity**: Improved response to cyber threats

**Nanomanufacturing**: New measurement tools for advanced materials manufacturing

**Energy**: Measurements and standards for energy security
NIST IT-Focused R&D on Construction, Buildings, and Infrastructure

- **Systems Integration for Construction Applications:** To integrate engineering information systems used in complex construction networks to improve life-cycle construction and facility performance

- **Smart Construction Systems:** To enable real-time monitoring, control, and optimization of on-site construction processes

- **Embedded Intelligence in Buildings:** To improve building operations to achieve energy efficiency, occupant comfort, and safety through the use of intelligent building systems

- **Smart Utility Infrastructure:** To measure, control, and optimize the performance of utility grids at the system, subsystem, and end-user levels
NIST Role in the Smart Grid

• Measurement science
  – Metering
  – Wide area monitoring (synchrophasors)
  – Power electronics
  – Building energy management
  – Others …

• Standards (EISA role)
  – Interoperability
  – Cybersecurity
Need for Productivity Metrics

• Why Are Productivity Metrics Needed?
  – Productivity Impacts Project Outcomes
  – Measuring Productivity Establishes Norms
  – Implementing Improvement Opportunities is Key to Excellence in Project Execution

• Measuring Productivity is a Challenge
  – Levels of Analysis: Task, Project, Industry
  – Metrics Change as a Function of Level of Analysis
  – Heterogeneous Outputs
NIST Collaboration with CII’s Benchmarking and Metrics Program

- NIST GCR 09-925
- Analyzes how technology utilization and best practices affect engineering and construction productivity
- Project-level productivity measures (ratio of total installed cost to work hours) based on CII data, where each data point represents 16 to 49 projects

This diagram demonstrates that project-level productivity can be tracked over time.
NIST Special Publication 1101

- Comprehensive survey of the literature of construction productivity at task, project, and industry levels
- Includes an annotated bibliography on key documents in productivity measurement with an emphasis on the construction industry
- Identifies data challenges and potential solutions
  - Knowledge gaps suggest opportunities for innovations to produce new metrics and tools
Partners Representing Construction and Building Industry

Construction Industry Institute
- Board of Advisors
- Breakthrough Strategy Committee
- Benchmarking and Metrics Committee
- Cost of Inadequate Interoperability Study
- Workshops and Conferences
- Research Teams

FIATECH Consortium
- Capital Projects Technology Roadmap
- Cost of Inadequate Interoperability Study
- Automating Equipment Information Exchange
- Intelligent and Automated Construction Job Site
- Building Information Modeling
- Workshops and Conferences

Building and Fire Codes and Standards
- Technical Guidelines
- Measurement Techniques
- Performance Prediction Tools
- Committees, Councils, and Boards
- Workshops and Conferences
- Collaborative Research
- Publications
- Working Groups
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