Information Technology, Construction Innovation, and NIST

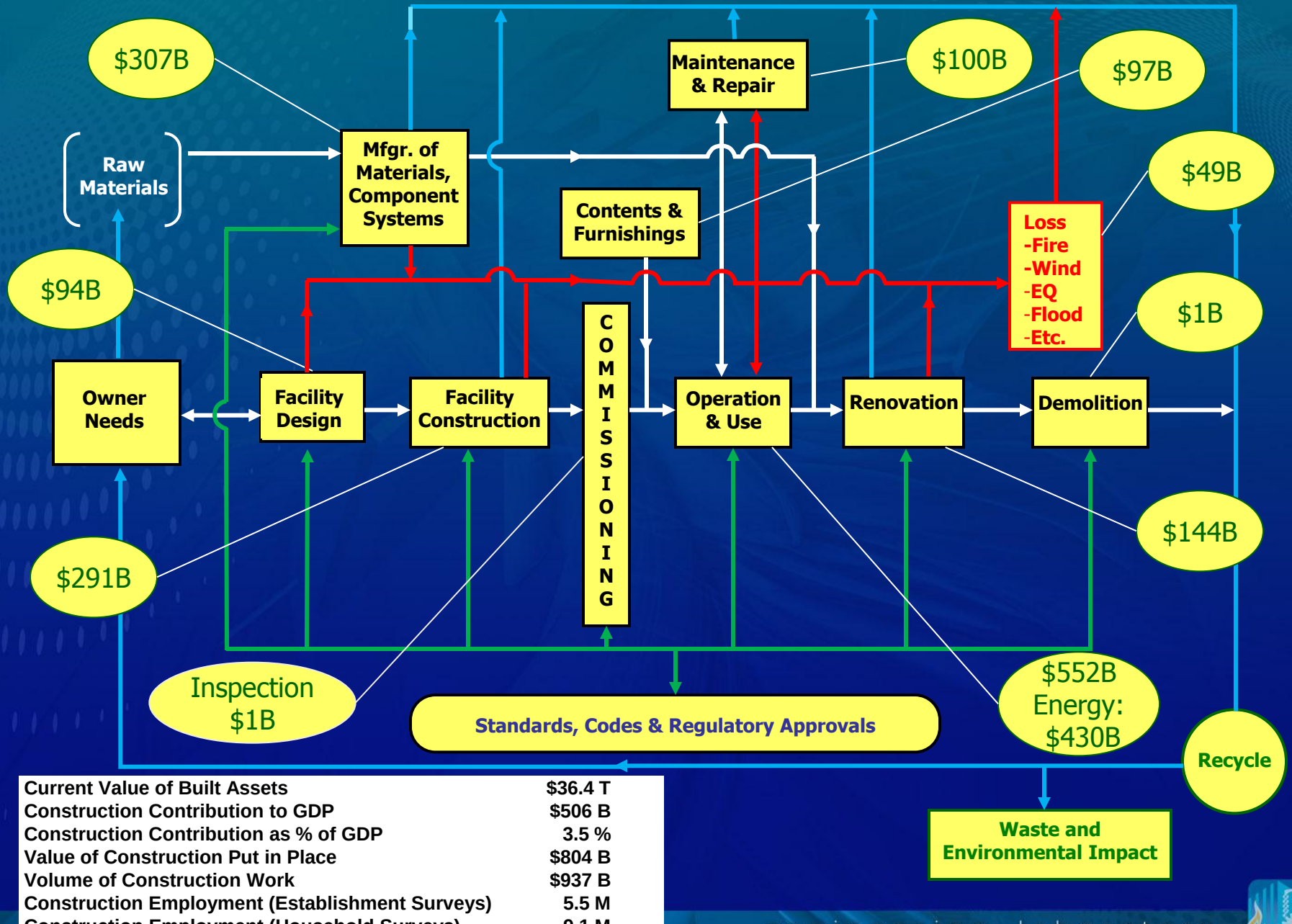
January 18, 2012
Information Technology
and Innovation Foundation,
National Press Club

Bricks and Bits: Transforming the Construction Industry Through Innovation

Dr. S. Shyam Sunder
Director, Engineering Laboratory
National Institute of Standards and Technology
U.S. Department of Commerce

NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

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

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

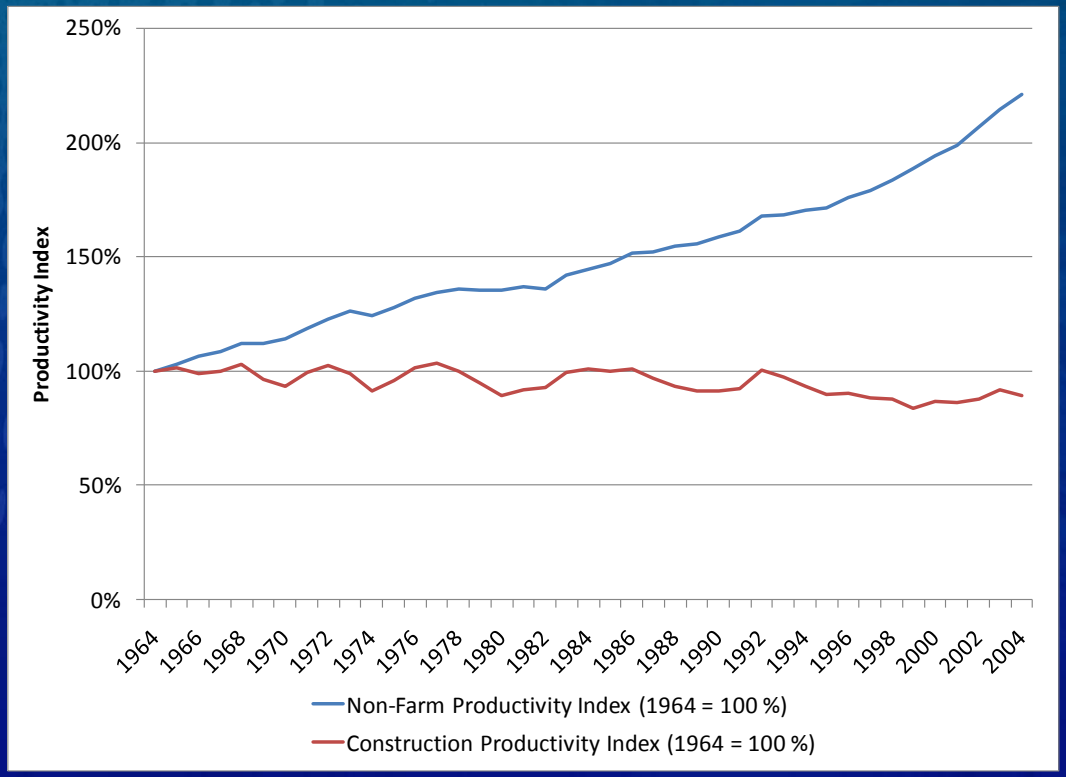
Fire safety organizations – fire risk management; fire fighter safety

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
- Report from *The 1985 Workshop on Advanced Technology for Building Design and Engineering*, NRC 1986
- Other Studies Conducted by:
  - Construction Industry Institute (CII)
  - Construction Users Round Table (CURT)
  - Federal Facilities Council (FFC)
  - FIATECH

Productivity and Competitiveness



Source: Teicholz, Paul. "Labor Productivity Declines in the Construction Industry: Causes and Remedies." *AECbytes Viewpoint*. Issue 4. April 14, 2004.

- 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."

NIST GCR 04-867

NIST U.S. Department of Commerce
Technology Administration
National Institute of Standards and Technology

Advanced Technology Program
Information Technology and Electronics Office
Gaithersburg, Maryland 20899

Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry

Michael P. Gallaher, Alan C. O'Connor, John L. Dettbarn, Jr., and Linda T. Gilday

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)

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

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

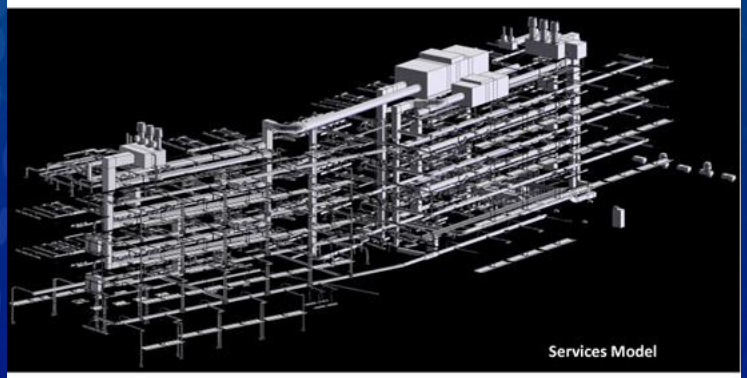
- Widespread use of interoperable technology applications and Building Information Modeling (BIM)
- Improved job-site efficiency through more effective interfacing of people, processes, materials, equipment, and IT
- Greater use of prefabrication, preassembly, modularization, and off-site fabrication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

IT Trends in Construction, Buildings, and Infrastructure

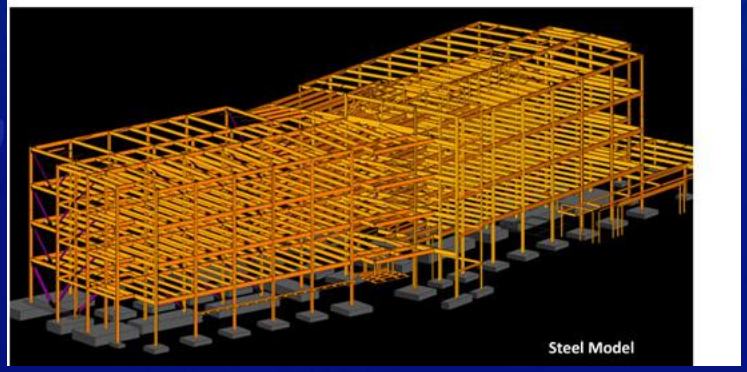
- Industry sectors have different levels of adoption
  - Driven by contractual models and life cycle metrics
  - Process industry: early adopters and leaders in usage
  - Commercial/institutional buildings: adopting LC costing and BIM
    - GSA, educational institutions, hospital owners
  - Infrastructure: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



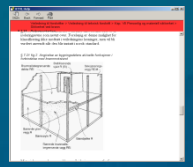
Mechanical, Electrical, Plumbing

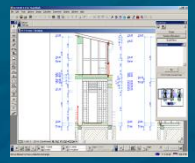


Structural

- Three separate models
  - Interference checking
  - Clash detection
  - Model coordination
- More offsite prefabrication
- Fewer RFIs
- Reduced cost
- Higher quality deliverable
- Cost of upfront coordination is much less than fixing problems later in the field

Laws and regulations
-Building regulations
-Building specifications

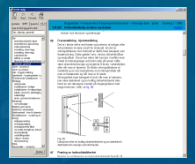




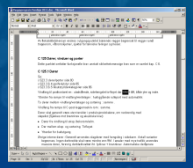
CAD software
-Drawings, calculations
-Architect, engineer,…

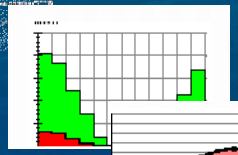
VRML
-Visualisation, 3D models

Knowledge databases
-Best practise knowledge
-Own practice

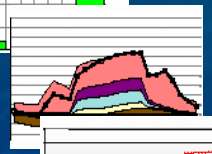


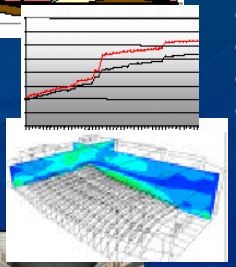
Briefing
-Functional req.
-Estimates
-Conditions
-Requirements

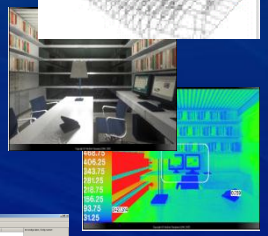




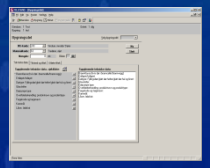
Simulations
-Comfort
-Ventilation, heating
-Life cycle cost
-Light, sound
-Insulation
-Fire, usage
-Environment
-Life time predictions

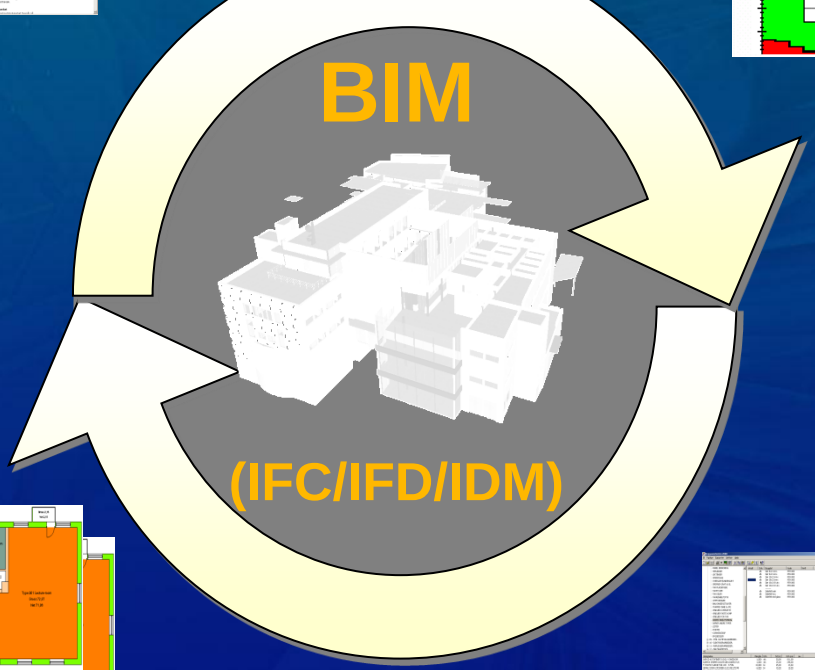




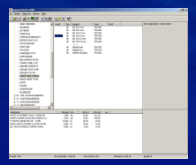


Demolition, refurbishment
-Rebuild
-Demolition
-Restoration



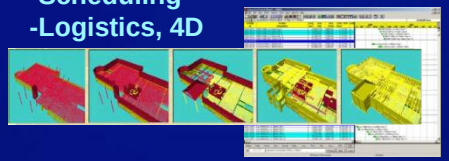


Facility management
-Letting, sale, operations
-Maintenance
-Guaranties



Specifications
-Specification sheets
-Classification standards
-Estimates, accounting

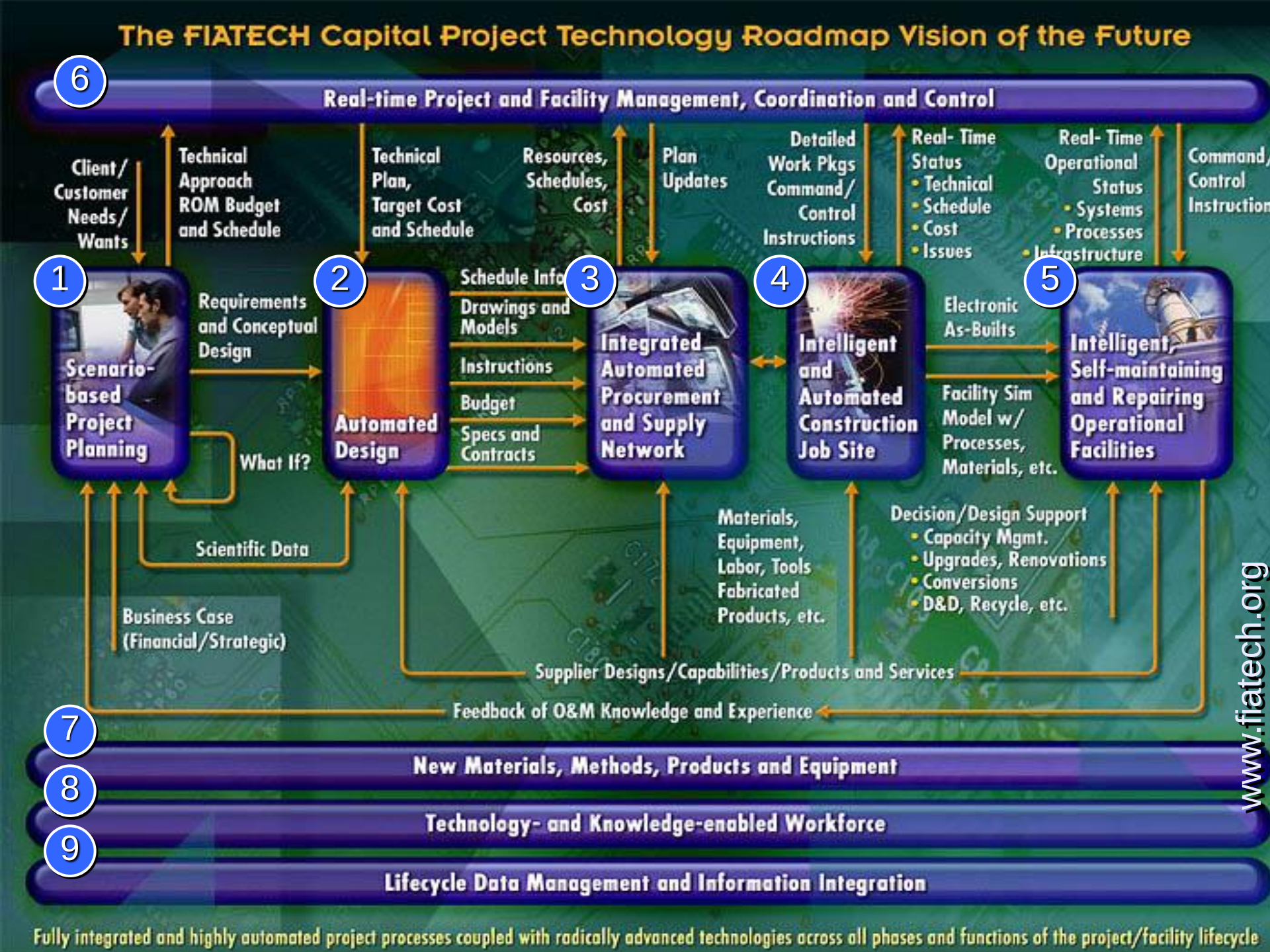
Construction management
-Scheduling
-Logistics, 4D



Procurement
-Product databases
-Price databases

Lars Bjørkhaug, SINTEF Byggforsk,
Illustrations: Statsbygg, Arkitektstudio AS.
Olof Granlund, NBLN Stanford University

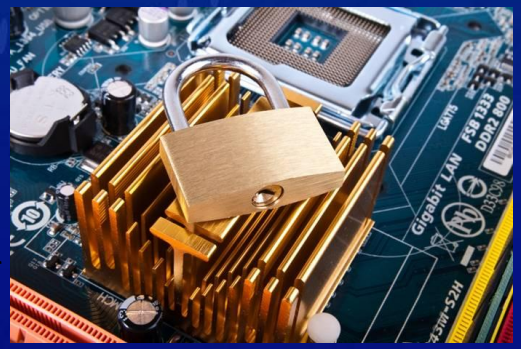
The FIATECH Capital Project Technology Roadmap Vision of the Future



NIST's Unique Mission

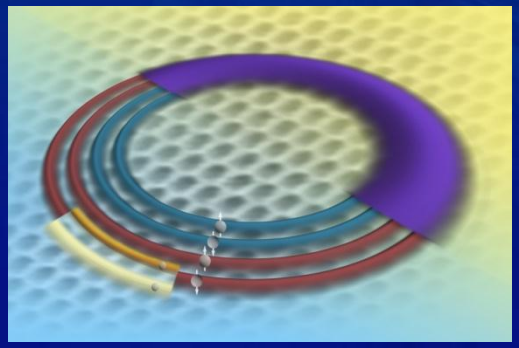
To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.

- 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



Vector.lib/shutterstock.com

Cybersecurity: Improved response to cyber threats



Nanomanufacturing: New measurement tools for advanced materials manufacturing

techibuzz.com/GM Autos

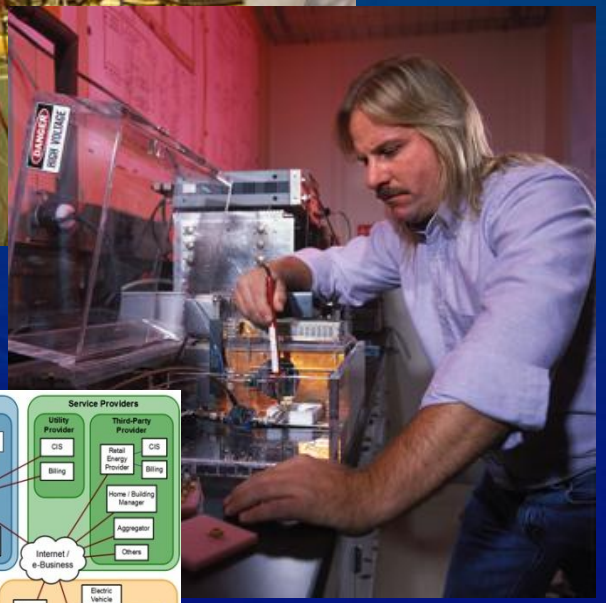
Energy: Measurements and standards for energy security

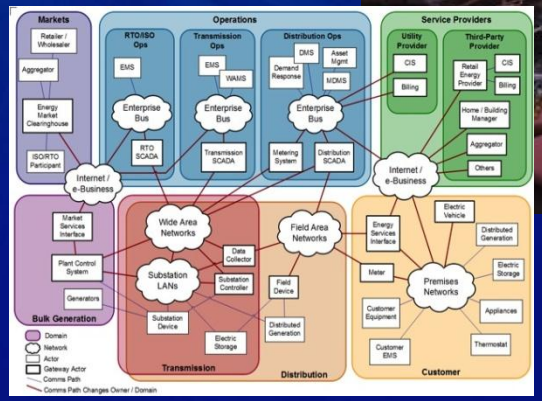
NIST IT-Focused R&D on Construction, Buildings, and Infrastructure

- **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

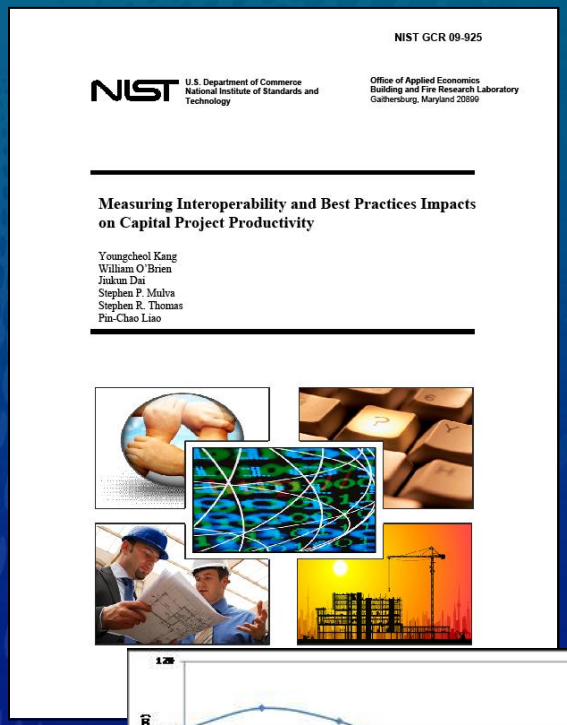




Need for Productivity Metrics

- 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

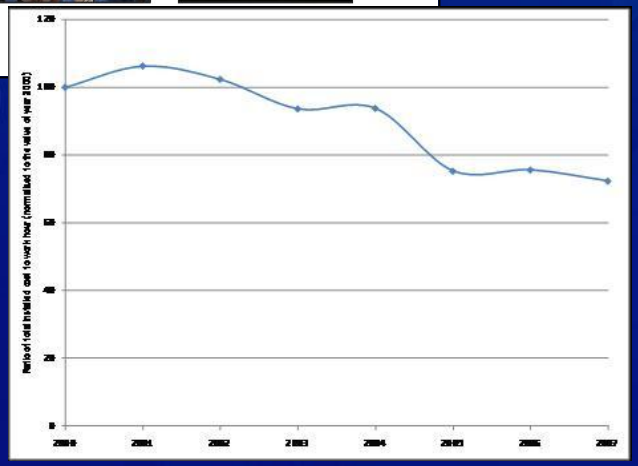

NIST GCR 09-925

NIST U.S. Department of Commerce National Institute of Standards and Technology

Office of Applied Economics Building and Fire Research Laboratory Gaithersburg, Maryland 20899

Measuring Interoperability and Best Practices Impacts on Capital Project Productivity

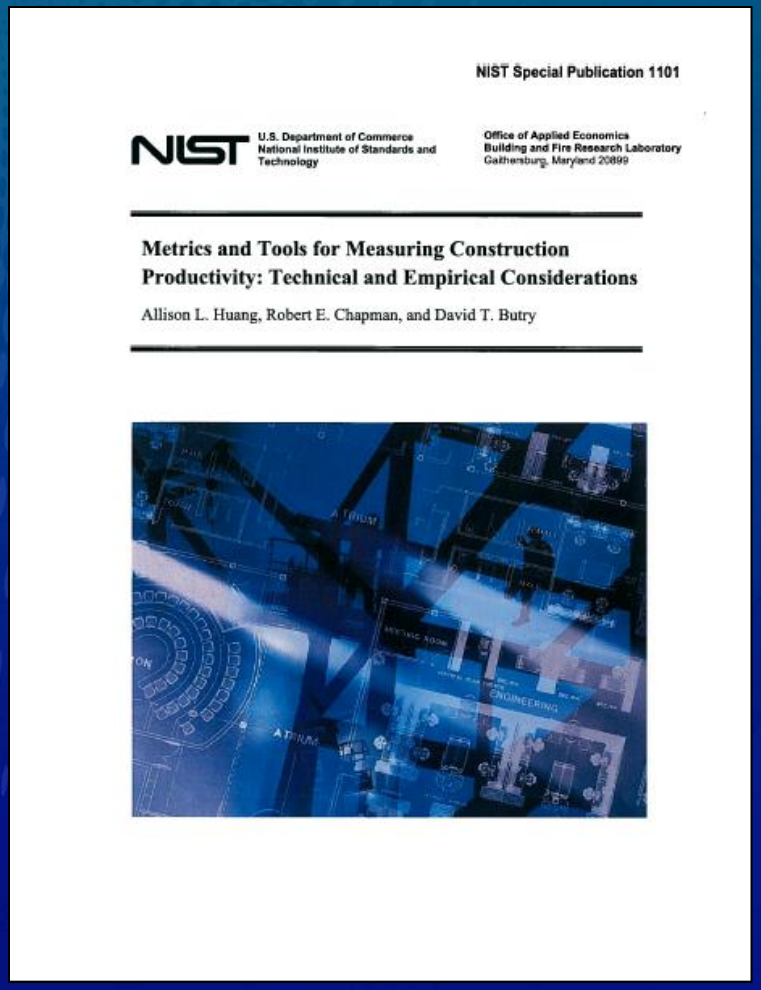
Youngcheol Kang
William O'Brien
Jiukun Dai
Stephen P. Mulva
Stephen R. Thomas
Pin-Chao Liao



- 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



NIST Special Publication 1101

NIST U.S. Department of Commerce
National Institute of Standards and Technology

Office of Applied Economics
Building and Fire Research Laboratory
Gaithersburg, Maryland 20899

Metrics and Tools for Measuring Construction Productivity: Technical and Empirical Considerations

Allison L. Huang, Robert E. Chapman, and David T. Butry

- 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

(Conceived by CII and NIST in 1999)

Contact Info

Shyam Sunder
Director

301 975 5900
sunder@nist.gov

Engineering Laboratory
National Institute of Standards and Technology
100 Bureau Drive
Gaithersburg, MD 20899-8600

www.nist.gov/el