



Highway Construction Productivity

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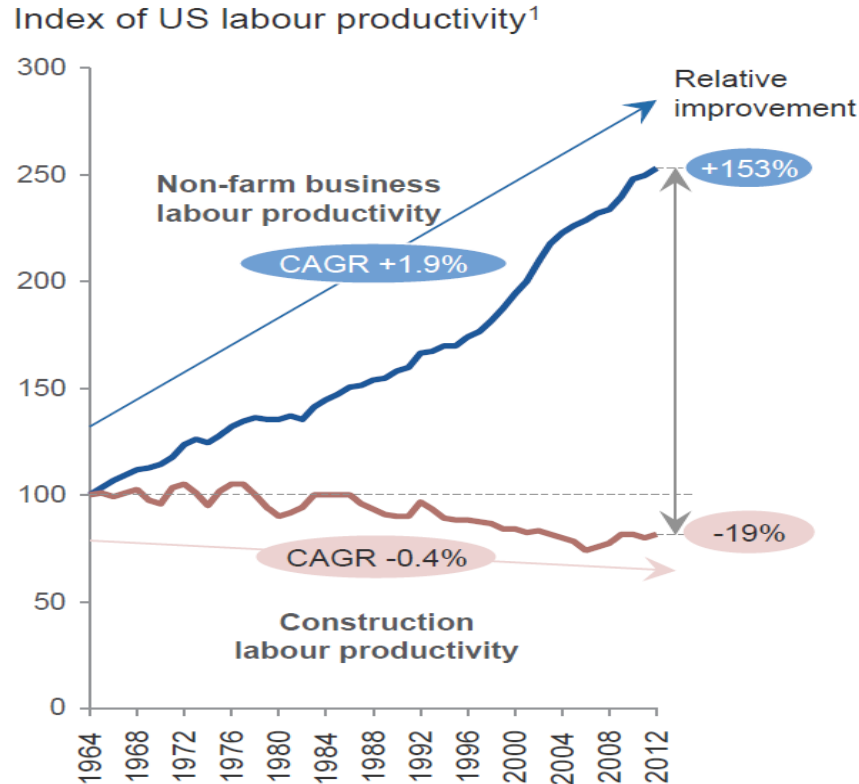
Outline

- Dire news – historical productivity trends
- Points of light – known sources of improvement
- Hope for the Future – promising strategies

Historical Productivity Trends

- Productivity metrics and applications
 - Labor productivity
 - Multi-factor productivity
 - Productivity factor
 - Direct work rate
- Units of construction output definitions
- Cost deflators
- Geographic and sector variability

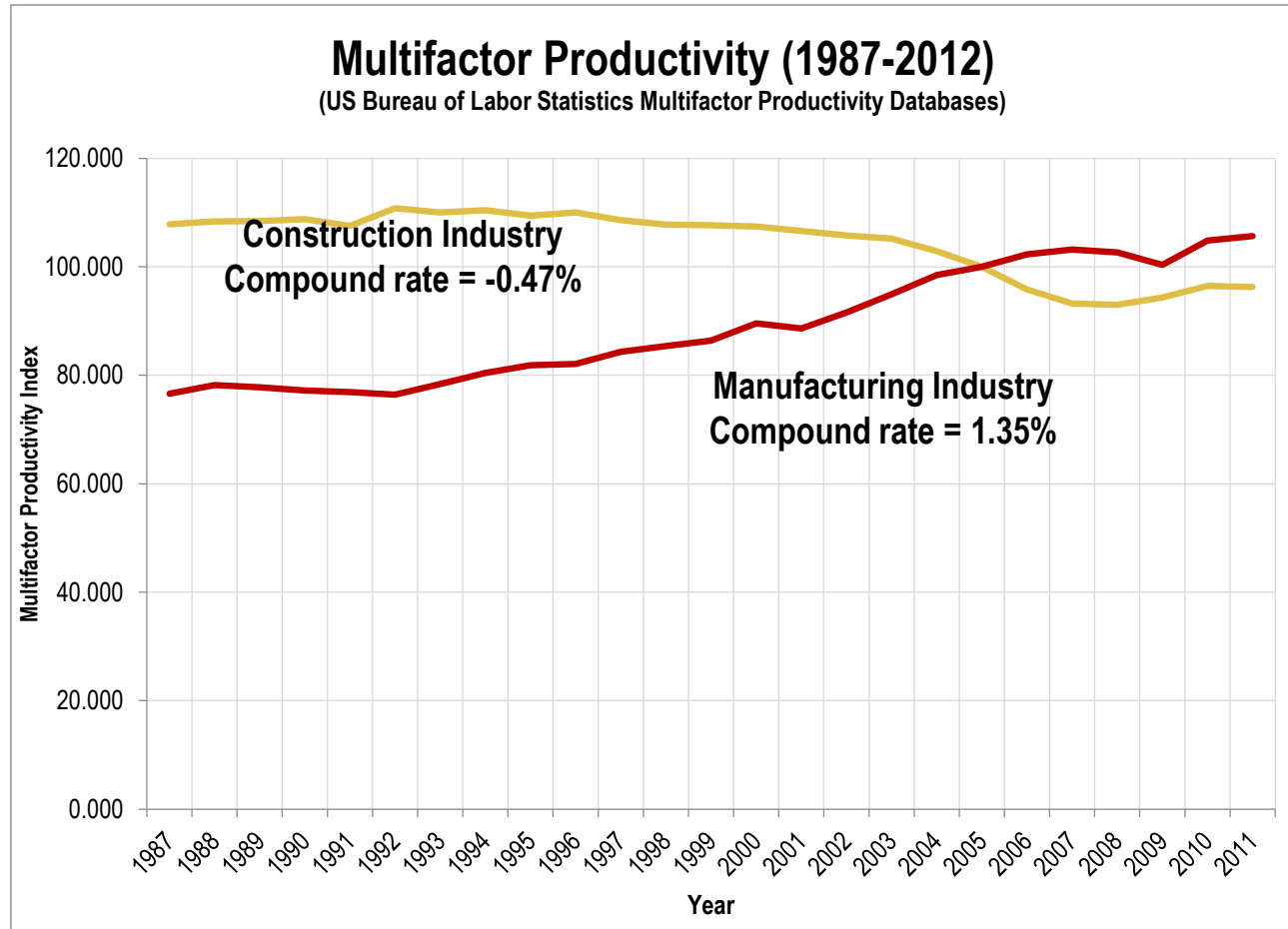
US Industry Labor Productivity and Performance, 1964-2012



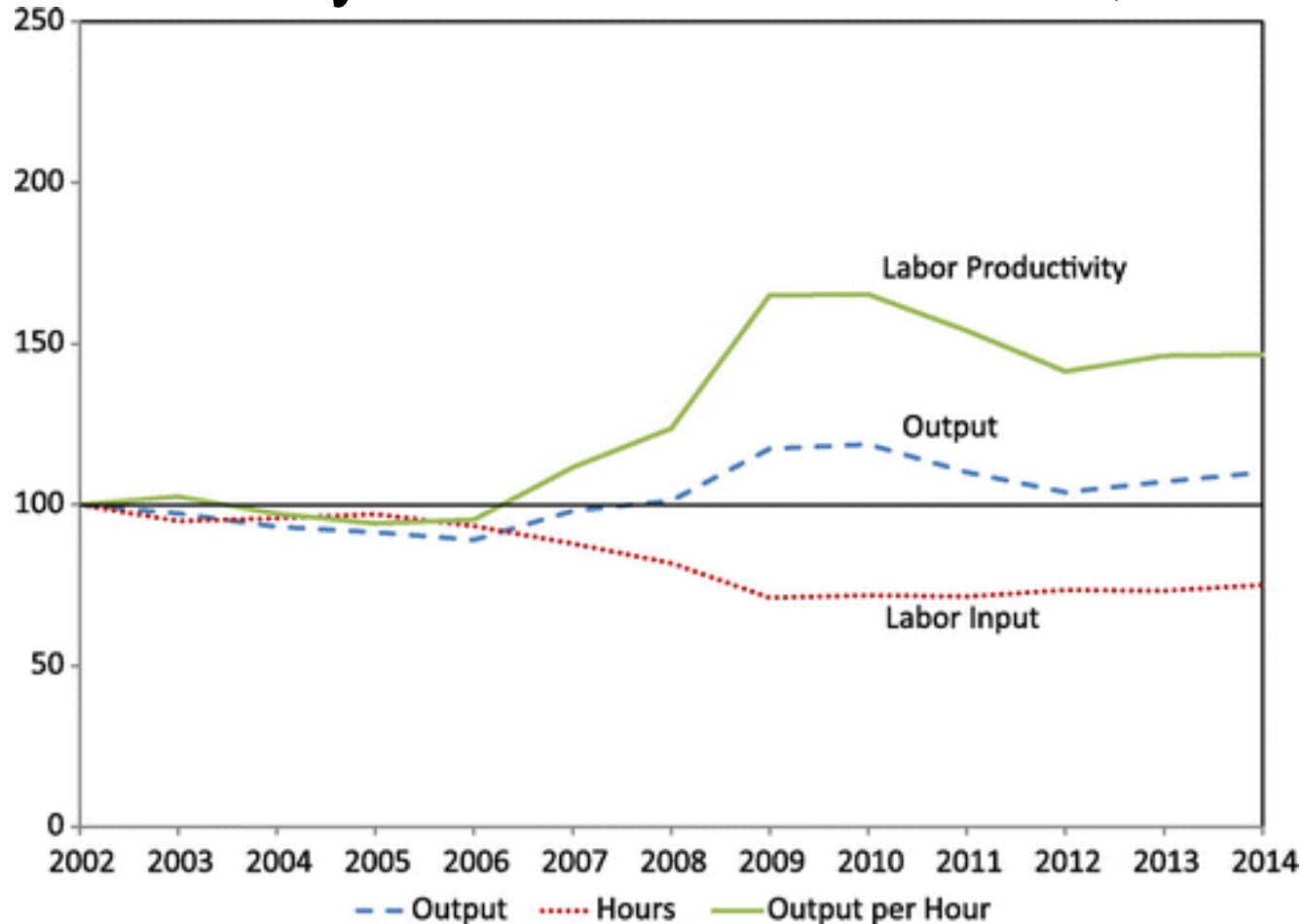
¹ Peer set based on US companies with Engineering, Construction and Services-related Standard Industrial Classification codes. Financials are inflation-adjusted and indexed to 1964; output per working hours. CAGR = compound average growth rate

Source: Global Vantage; Compustat; Bloomberg; www.aecbytes.com/viewpoint/2013/issue_67.html; www.nber.org/papers/w1555.pdf; S&P Capital IQ; BCG ValueScience Center; World Economic Forum

US Industry Multifactor Productivity and Performance, 1987-2012

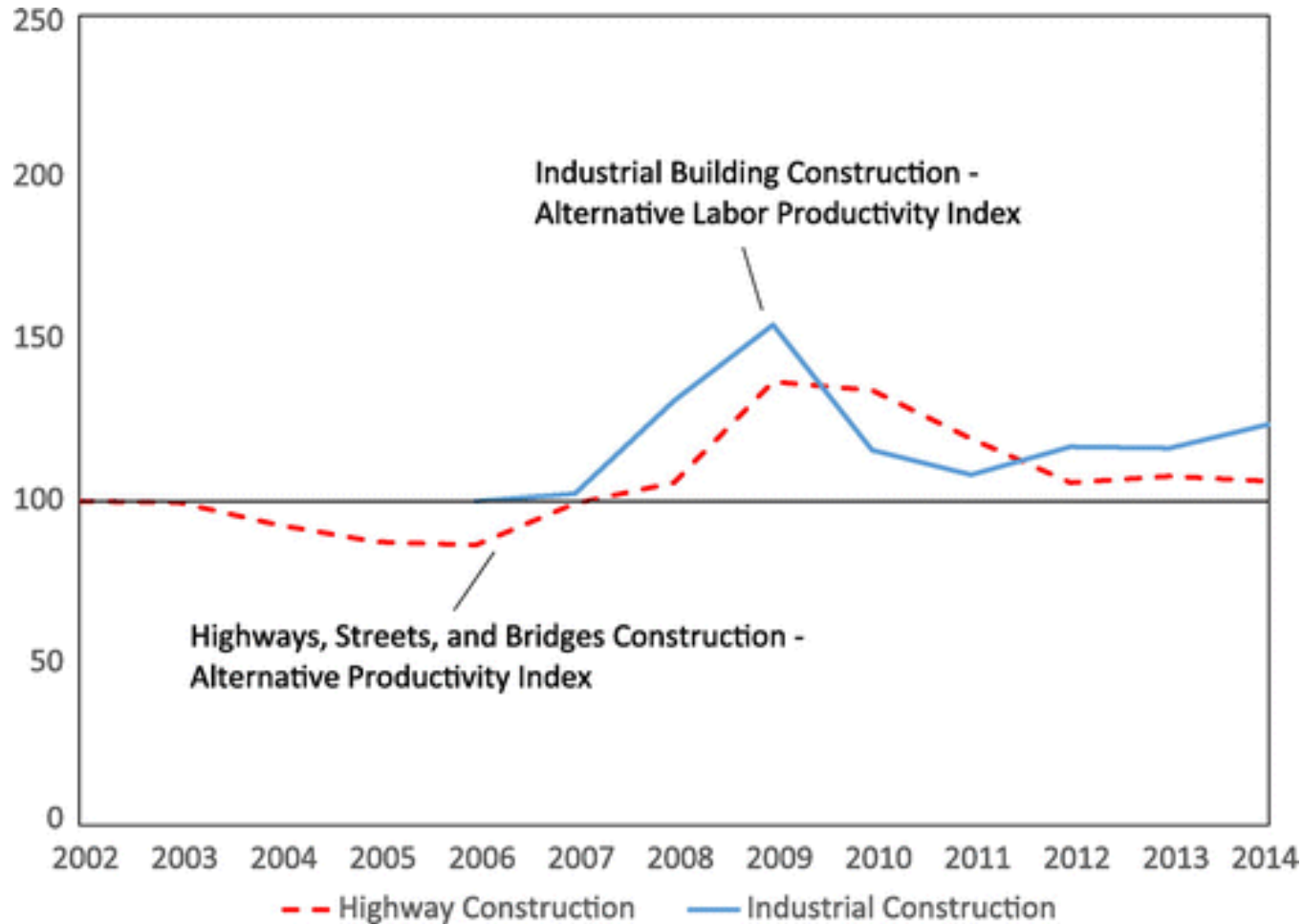


US Highway Construction Labor Productivity and Performance, 2002-2014



Sveikauskas, L., Rowe, S., Mildenerger, J., Price, J., and Young, A. (2016). "Productivity Growth in Construction." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)CO.1943-7862.0001138, 04016045.

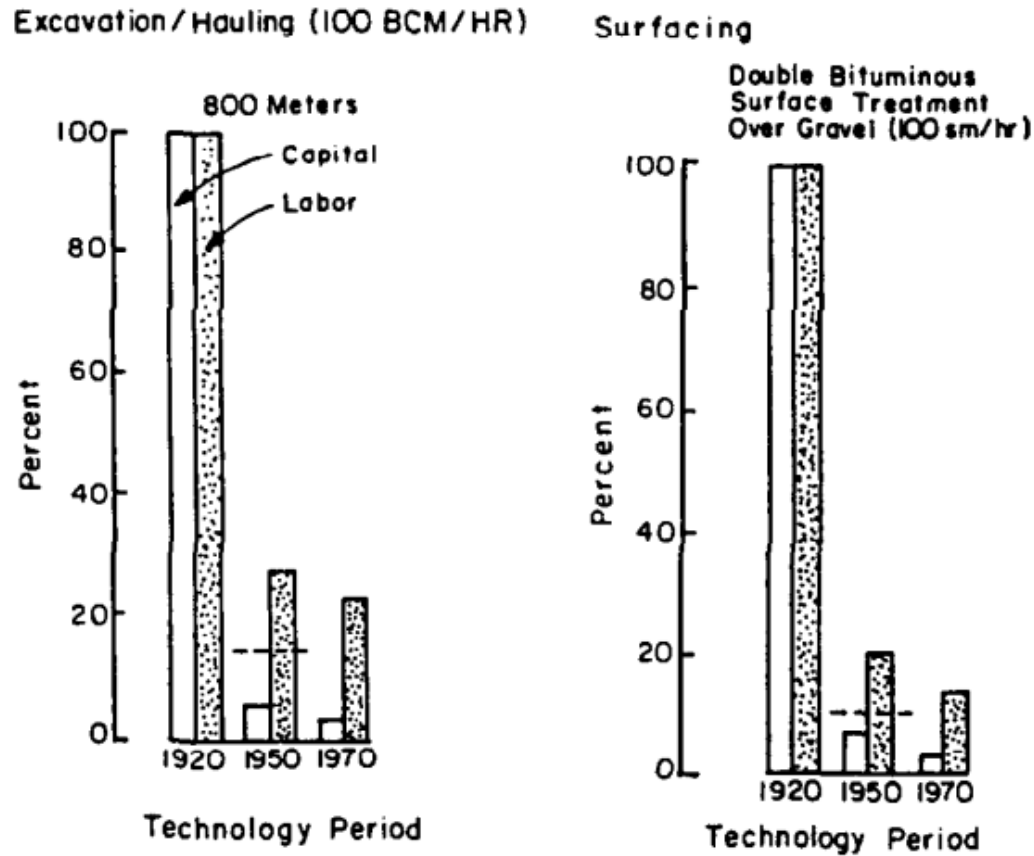
US Highway and Industrial Construction Productivity, 2002-2014



Sveikauskas, L., Rowe, S., Mildenerger, J., Price, J., and Young, A. (2016). "Productivity Growth in Construction." J. Constr. Eng. Manage., 10.1061/(ASCE)CO.1943-7862.0001138, 04016045.

US Road Construction Productivity and Performance, 1920-1970

F. MOAVENZADEH

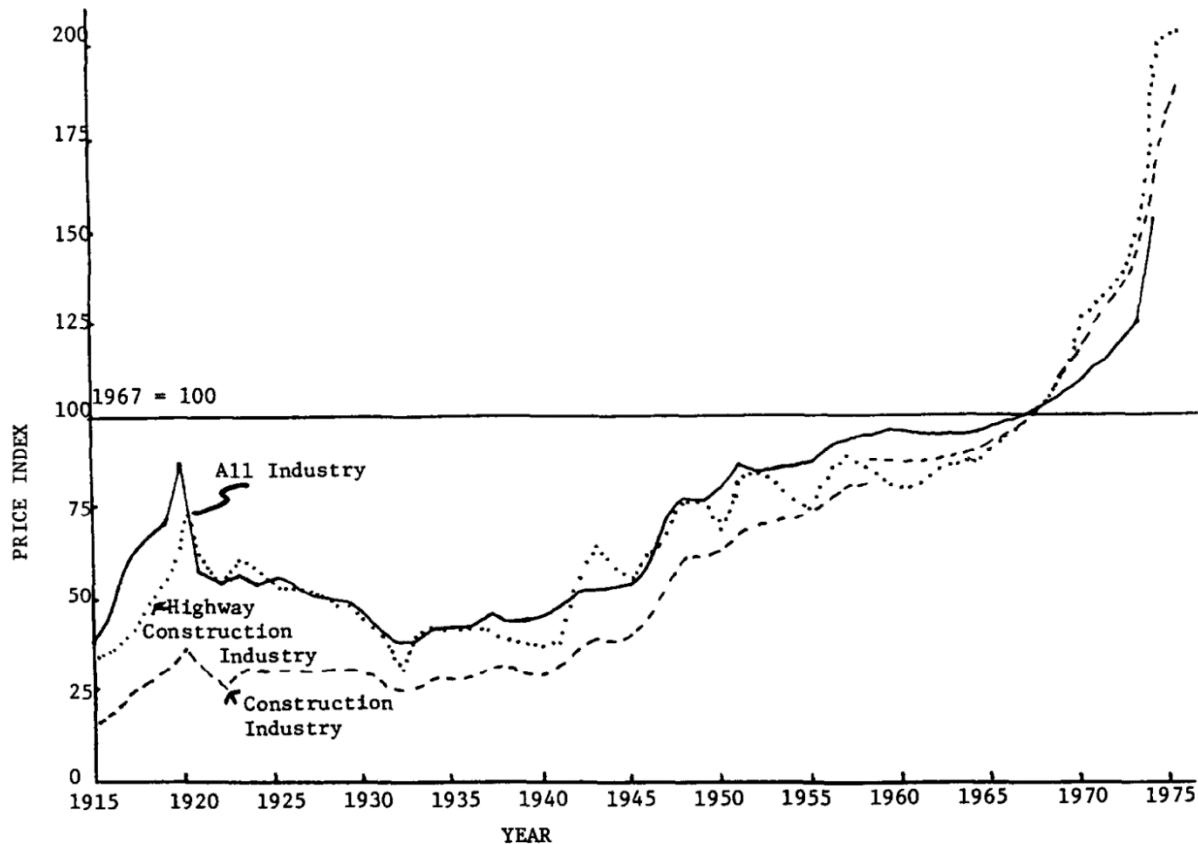


Transportation Research Part A: General Volume 19, Issues 5-6, September-November 1985, Pages 497-509
Special Issue Transportation Research: The State of the Art and Research Opportunities, Research needs in transportation facilities: guideway technology and materials research, Fred Moavenzadeh

Why did it happen?



US Price Trends in General and Highway Construction, 1915-1975



SOURCE: Rossow, Janet Ann Koch and Moavenzadeh, Fred. Technology and Productivity in Highway Construction, Cambridge, Massachusetts: MIT/TDP Report No. 77-1, Spring 1977.

Fig. 4. Price trends exhibited by industry, in general, and the construction and highway construction sectors over the past 60 years.

US Construction (Non-uniform) Productivity Growth by Division, 1976-1998

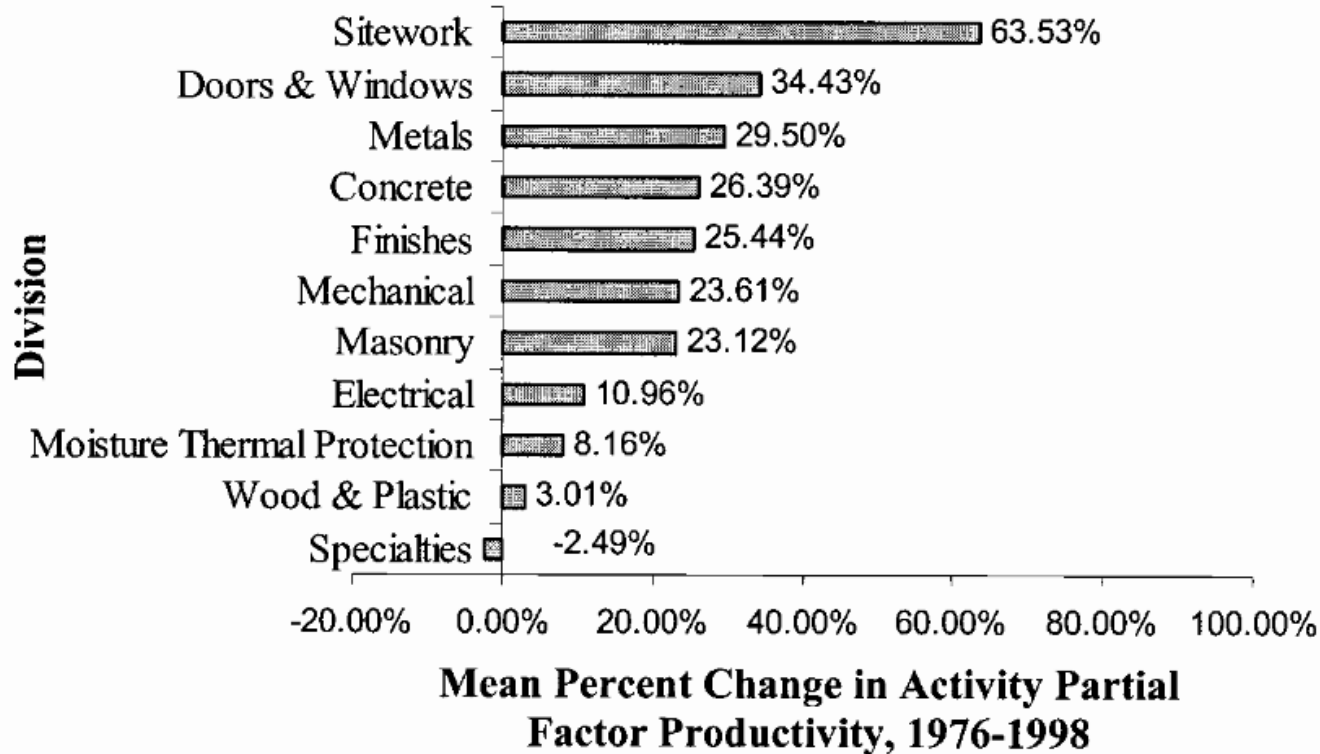
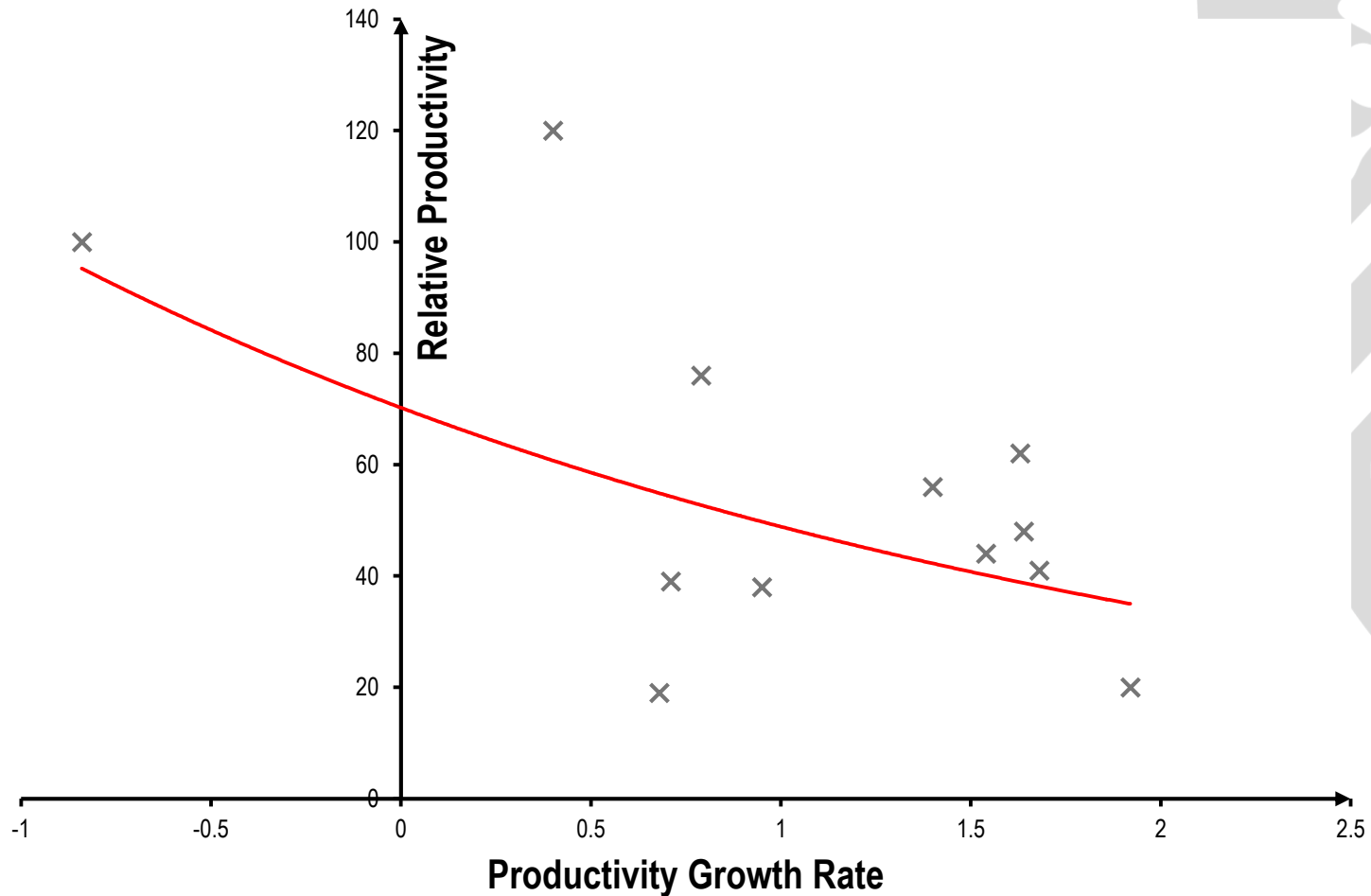


Fig. 2. Mean percent change for activity partial factor productivity by division, 1976–1998

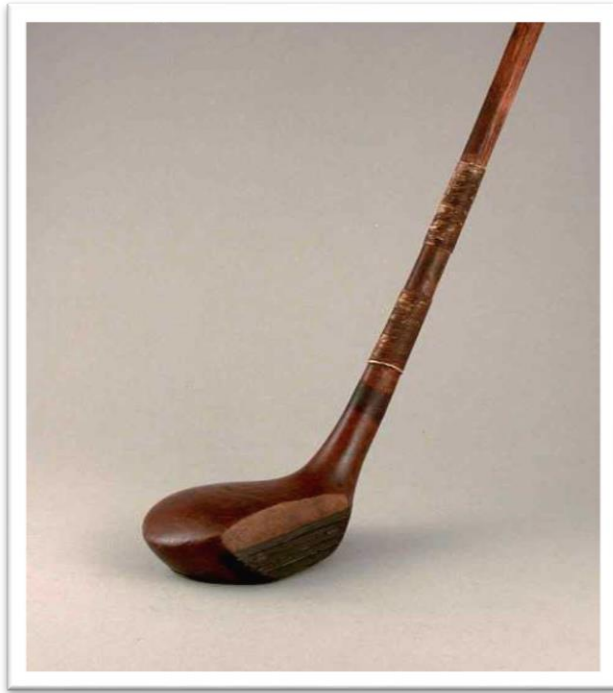
Nations' Construction Productivity vs Productivity Growth Rate



Advancing the Competitiveness and Efficiency of the U.S. Construction Industry, Kennedy, T., et al, The National Academies Press, Washington, D.C., ISBN – 13:978-0-309-14191-8, "Appendix C: An International Perspective on Construction Competitiveness and Productivity", by C. Haas, pp. 55-75, 2009.

Sources of Improvement

Tools for Productivity Improvement



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US Construction Productivity Drivers, 1976-1998

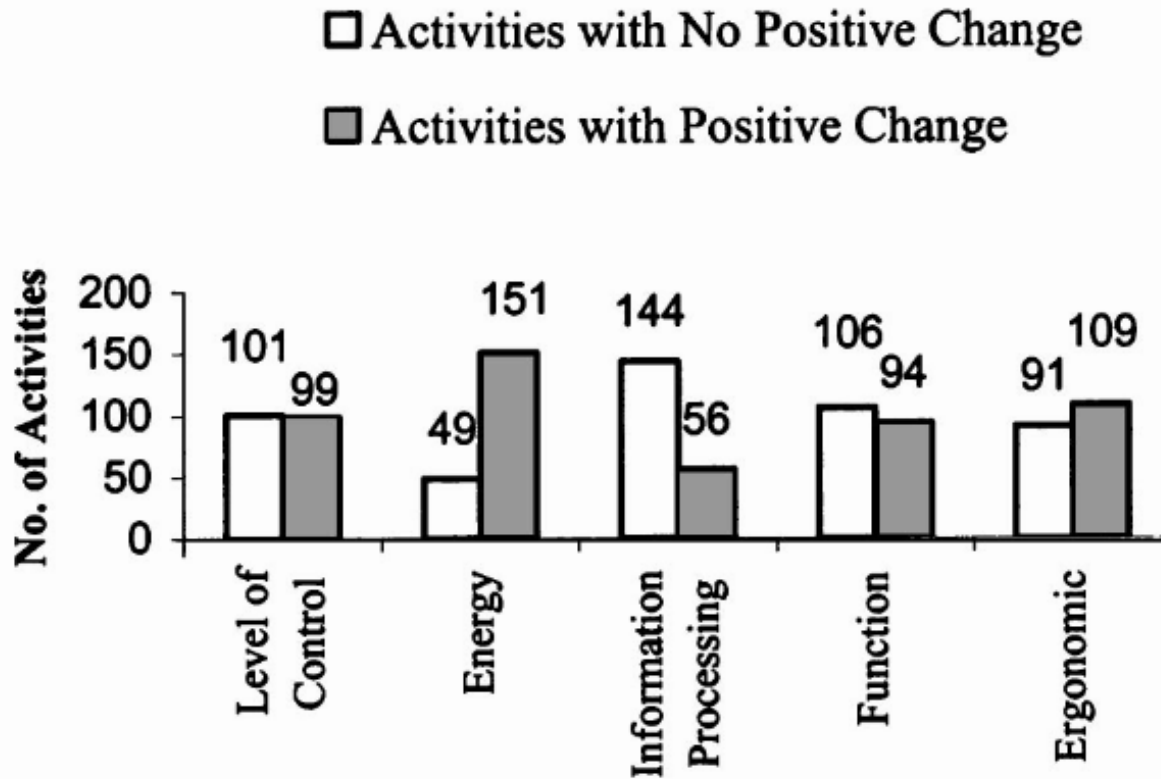
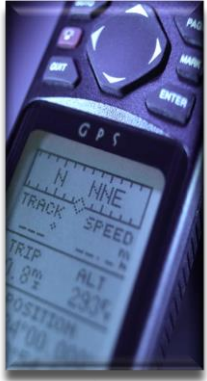


Fig. 3. Positive changes in equipment technology by technology factor, 1976–1998

Goodrum, P., and Haas, C., "The Long Term Impact of Equipment Technology on Labor Productivity in the U.S. Construction Industry at the Activity Level," ASCE Journal of Construction Engineering and Management, vol. 130, no. 1, Jan/Feb 2004, pp. 124-133.

Automation and Integration



- Automation

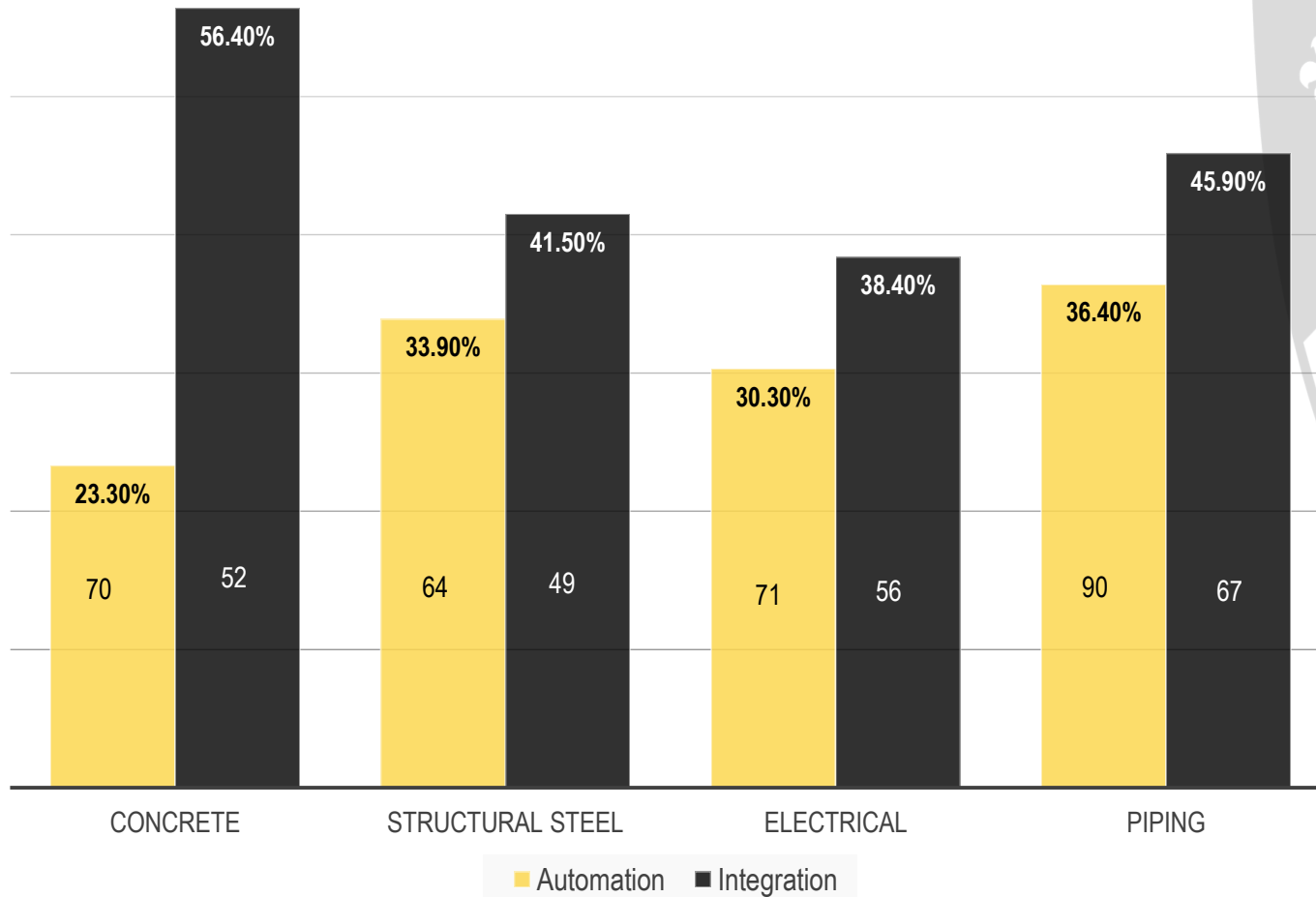
- The use of an electronic or computerized tool by a human being to manipulate data or produce a product



- Integration

- The sharing of information between project participants or melding of information sourced from separate systems

The Percentage Difference in Productivity due to Advanced Information Systems



Zhai, D., Goodrum, P., Haas, C., and Caldas, C. (2009). "Relationship between the Automation and Integration of Construction Information Systems and Productivity." *ASCE Journal of Construction Engineering and Management*, 135(8). pp 746-753.

Practices for Productivity Improvement



Materials
Management



Equipment
Logistics



Craft Information
Systems



Human Resource
Management



Construction
Methods

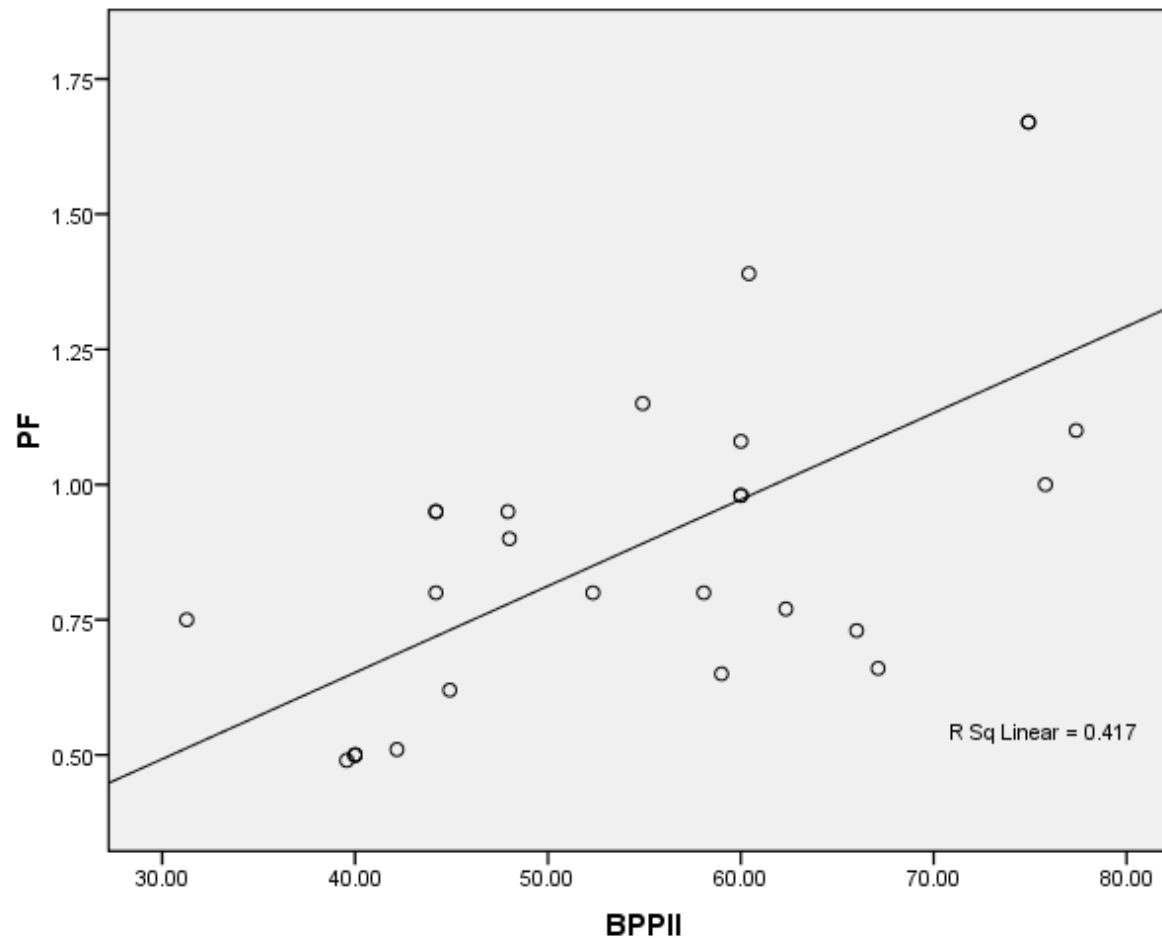


Environmental
Safety and Health

Methodology and Procedure

- Productivity Normalization
- Divide the practices into low and high level practice use groups
 - Low-level
(Practice Use Index $<$ (Median - 5%))
 - High-level
(Practice Use Index $>$ (Median + 5%))

Preliminary Results for Infrastructure BPPII (Best Productivity Practices Implementation Index)

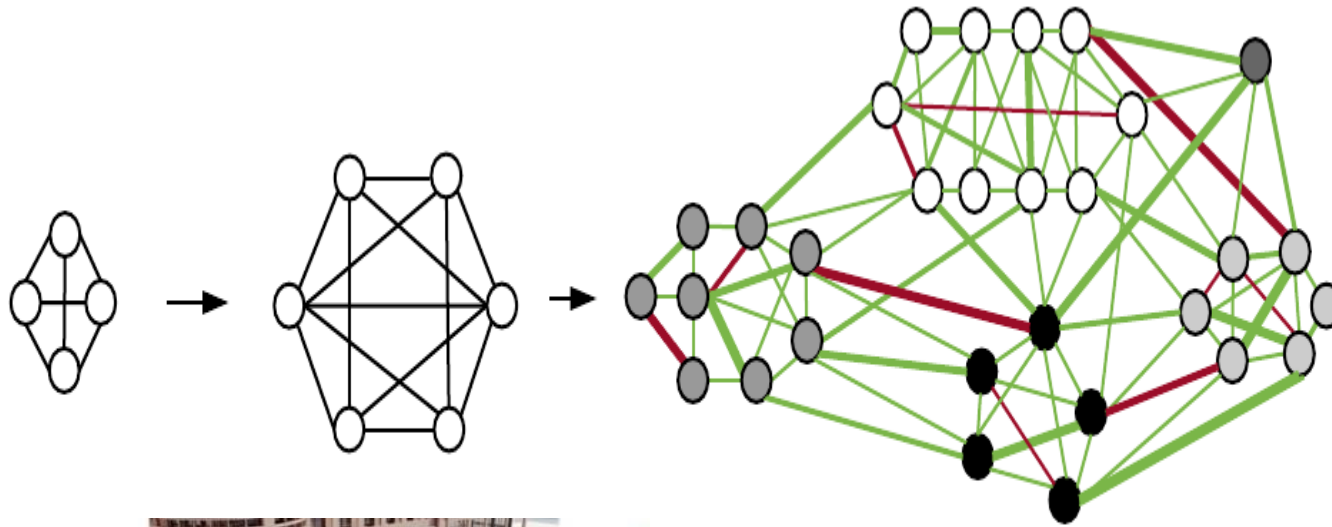


Nasir, H., Haas, C., Caldas, C., and Goodrum, P., "An Integrated Productivity Practices Implementation Index for Infrastructure Projects Execution Planning," ASCE Journal of Infrastructure Systems, 2016.

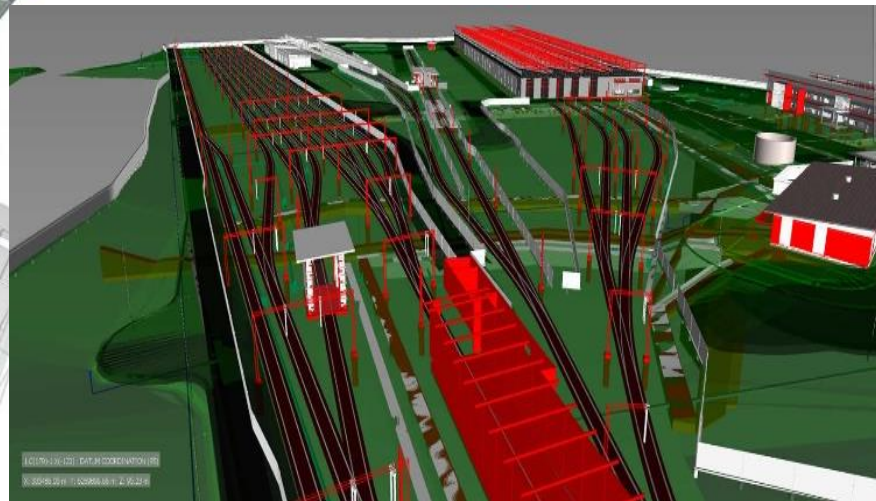
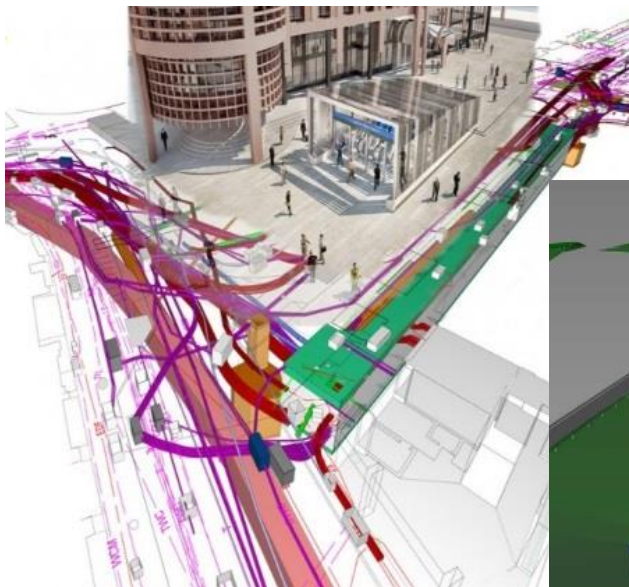
Promising Strategies



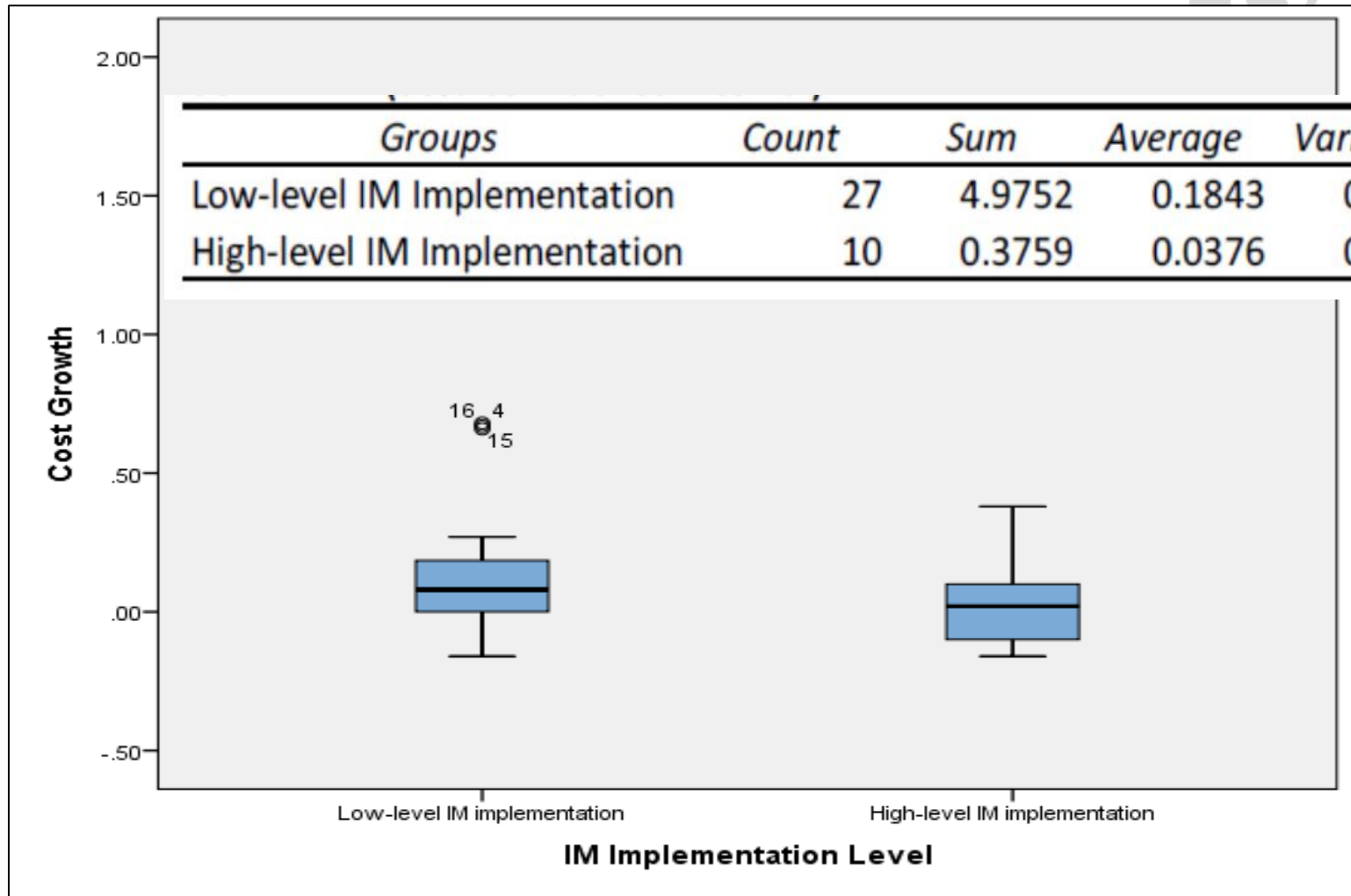
Interface Management (IM) + BIM



- Consultants
- Constructors
- Environmental Report generators
- Public
- Owners
- 1-5 Interfaces
- 6-14 Interfaces
- 15-30 Interfaces
- Low Project Health
- High Project Health



IM Level of Implementation vs Cost Growth



Stakeless earth moving

- <https://www.youtube.com/watch?v=3cWZCPJccvM>



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Complete Interoperability (e.g. Infrakit)

- <https://www.youtube.com/watch?v=99bQxNpasu0>
- Infrakit <http://infrakit.com/en/what-is-infrakit/>
- http://www.cat.com/en_US/support/operations/technology/earth-moving-solutions/accugrade-grade-control-system.html



“Future of Construction” website

- A central platform to exchange best practices and ideas guiding the infrastructure and urban development industry in its transformation, and helping it to address its key challenges.
- <https://futureofconstruction.org/blog/>
- World Economic Forum
- The Boston Consulting Group
- The University of Waterloo

Summary

- Productivity growth is becoming harder
- Sources of improvement include:
 - **Interoperability** of information and control systems
 - Automated and more powerful equipment
 - Implementation of known best practices
 - Development of new materials (such as warm asphalt) that use less energy to work and set
 - Contracting strategies to incentive collaboration, innovation and best practices

References

- Teicholz, P., Goodrum, P., and Haas, C. (2001). "U.S. Construction Labor Productivity Trends, 1970–1998." *J. Constr. Eng. Manag.*, 10.1061/(ASCE)0733-9364(2001)127:5(427), 427-429.
- Transportation Research Part A: General
Volume 19, Issues 5–6, September–November 1985, Pages 497-509
Special Issue Transportation Research: The State of the Art and Research Opportunities
Research needs in transportation facilities: guideway technology and materials research
Fred Moavenzadeh
- Goodrum, P., and Haas, C., "Partial Factor Productivity and Equipment Technology Change at the Activity Level in the U.S. Construction Industry," *ASCE Journal of Construction Engineering and Management*, Vol. 128, no.6, pp 463-472, Nov/Dec, 2002.
- Goodrum, P., and Haas, C., "The Long Term Impact of Equipment Technology on Labor Productivity in the U.S. Construction Industry at the Activity Level," *ASCE Journal of Construction Engineering and Management*, vol. 130, no. 1, Jan/Feb 2004, pp. 124-133.
- Sveikauskas, L., Rowe, S., Mildenerger, J., Price, J., and Young, A. (2016). "Productivity Growth in Construction." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)CO.1943-7862.0001138, 04016045.
- Zhai, D., Goodrum, P., Haas, C., and Caldas, C. (2009). "Relationship between the Automation and Integration of Construction Information Systems and Productivity." *ASCE Journal of Construction Engineering and Management*, 135(8). pp 746-753.
- Nasir, H., Haas, C., Caldas, C, and Goodrum, P., "An Integrated Productivity Practices Implementation Index for Infrastructure Projects Execution Planning," *ASCE Journal of Infrastructure Systems*, 2016.
- Shokri, S., Ahn, S., Lee, S., Haas, C., and Haas, R., "Current Status of Interface Management in Construction: Drivers and Effects of Systematic Interface Management," published online in *Journal of Construction Engineering and Management*, October 2015.
- *Advancing the Competitiveness and Efficiency of the U.S. Construction Industry*, Kennedy, T., et al, The National Academies Press, Washington, D.C., ISBN – 13:978-0-309-14191-8, "Appendix C: An International Perspective on Construction Competitiveness and Productivity", by C. Haas, pp. 55-75, 2009.