The Costs and Benefits of Advanced Maintenance in Manufacturing

Douglas Thomas, Economist
National Institute of Standards and Technology

At the Paint Shop in Chrysler Group’s Sterling Heights (Mich.) Assembly Plant, a 2015 Chrysler 200 moves through the Underbody Sealing and Underbody Coating station.

Overview

Estimating national costs/benefits associated with adopting advanced maintenance

- Current literature/data
  - Maintenance costs
  - Benefits of predictive maintenance
  - Barriers to adoption
  - Current maintenance practice
- Data needs
- Feasibility of collecting data


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Douglas S. Thomas

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Maintenance Cost: Data

Chrysler: Robotic welding stations at Windsor Fiat Chrysler Assembly Plant.

- Economic Census
  - Maintenance outsourcing
  - Includes machinery and buildings
- Bureau of Economic Analysis
  - Maintenance outsourcing
  - Machinery only
- Bureau of Labor Statistics
  - Labor only
  - Excludes overhead/materials
- Estimates of cost require making some assumptions

Maintenance Cost: Literature

Total Productive
Productive
Computerized
Preventive
Reactive
Predictive
Reliability Centered
Time Based
Condition Based

- Varying terminology
  - Reactive, Preventive, Predictive
- Cost studies
  - Varying countries (e.g., Sweden, Belgium)
  - Varying economic metrics
  - Case studies with
    - Varying types of machinery
    - Manufacturing and non-manufacturing

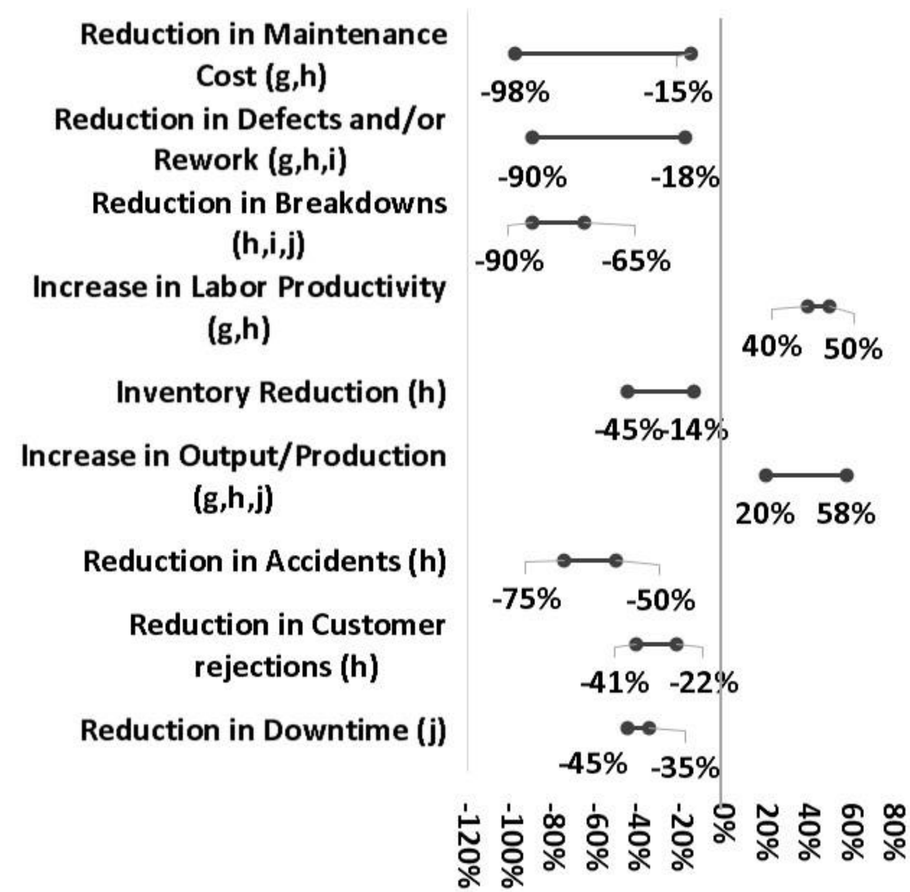
Characteristics of Maintenance Costs from a Selection of Articles, Various Countries/Industries

	Maintenance	
Description	Low	High
Cost of Goods Sold[a,b]	15.0%	70.0%
Sales[c]	0.5%	25.0%
Cost of Ownership[d]	37.5%	
Replacement Value of Plant[e]	1.8%	5.0%
Cost of Manufacturing[f]	23.9%	
Percent of Planned Production Time that is Downtime[f]	13.3%	

Benefits of Adoption

- Similar challenges
  - Varying countries
  - Varying metrics
  - Varying industries
  - Varying terminology
- Case studies
  - Limits to extrapolating
- Wide range of impacts

Range of Impacts Identified in Various Publications for Implementing Advanced Maintenance Techniques



Maintenance Cost Characterization, by Type

	Maintenance Type		
	Reactive	Preventive	Predictive
Frequency	On Demand	Scheduled, Timed, or Cycle Based	Condition Based
Labor Cost	High	High	Low
Labor Utilization	High	Low	Low
Parts Cost	High	Medium	Medium
Throughput Impact	High	Medium	Very Low
Urgency	High	Low	Low
ROI	Low	Medium	High
Initial Investment	Low	Medium	High
Profitability	Not cost effective	Satisfactory cost-effectiveness	Significant cost savings
Cost effectiveness	Labor intensive	Costly due to potential over maintenance or ineffective & inefficient maintenance	Cost-effective due to extended life and less failure-induced costs

Barajas and Srinivasa, 2008; Jin et al., 2016

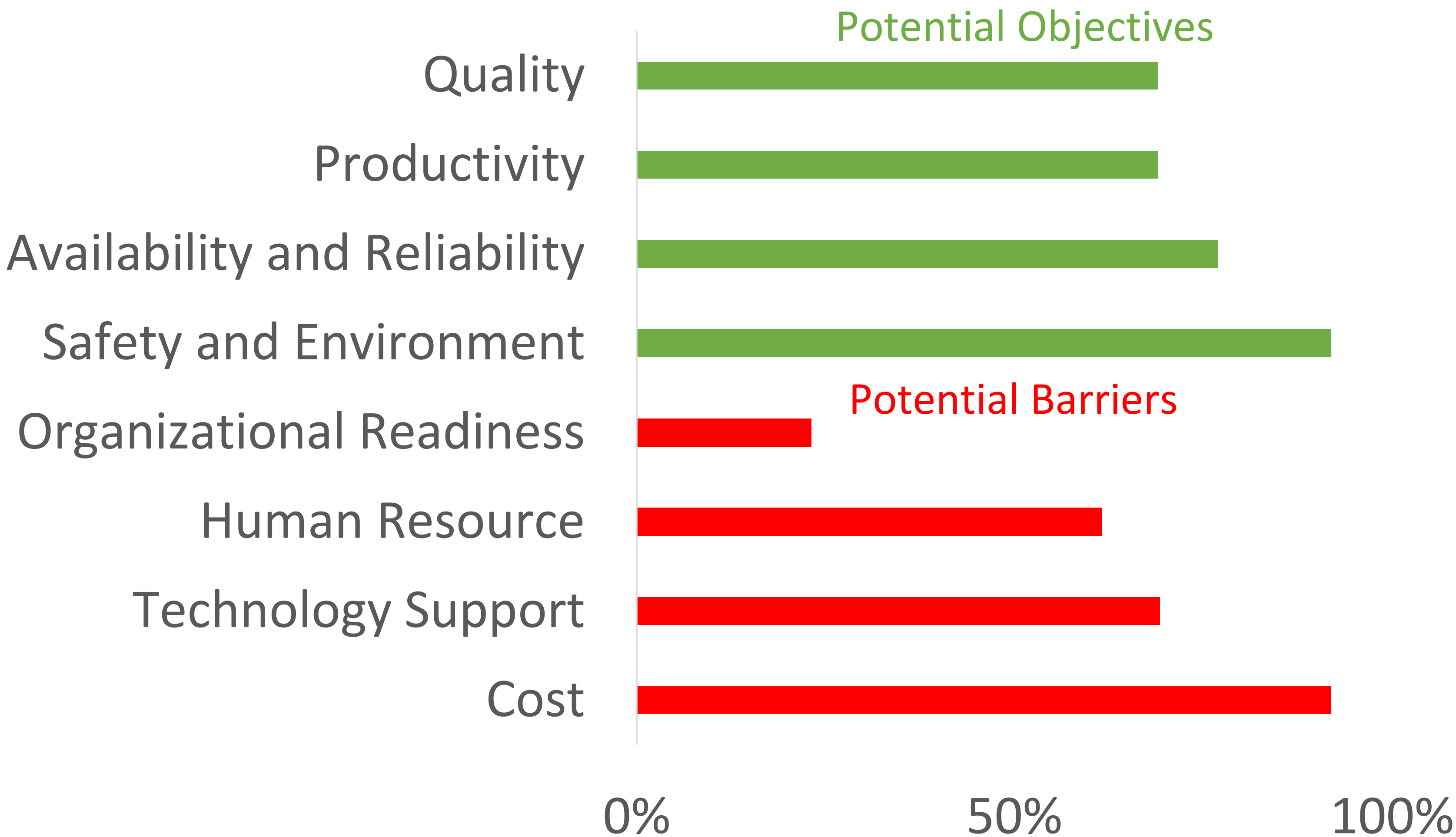
Current Maintenance Practice

- Studies have varying factors (e.g., country)
- Firm competition
  - Cost comp. – higher reactive
  - Quality comp. – higher predictive
- Swedish study – 50% of maintenance time is planned tasks
  - 13% planning
  - 37% unplanned

Alsyouf, 2009

Chrysler Group's Sterling Heights (Mich.) Assembly Plant

Objectives and Prevalent Barriers to the Adoption of Advanced Maintenance Techniques



Sources: Jin et al., 2016

Assessing the costs and benefits

- To assess costs/benefits at National level
  - Identify data needs
  - Develop a data collection strategy
  - Develop a scaling strategy
  - Assess the minimum sample size

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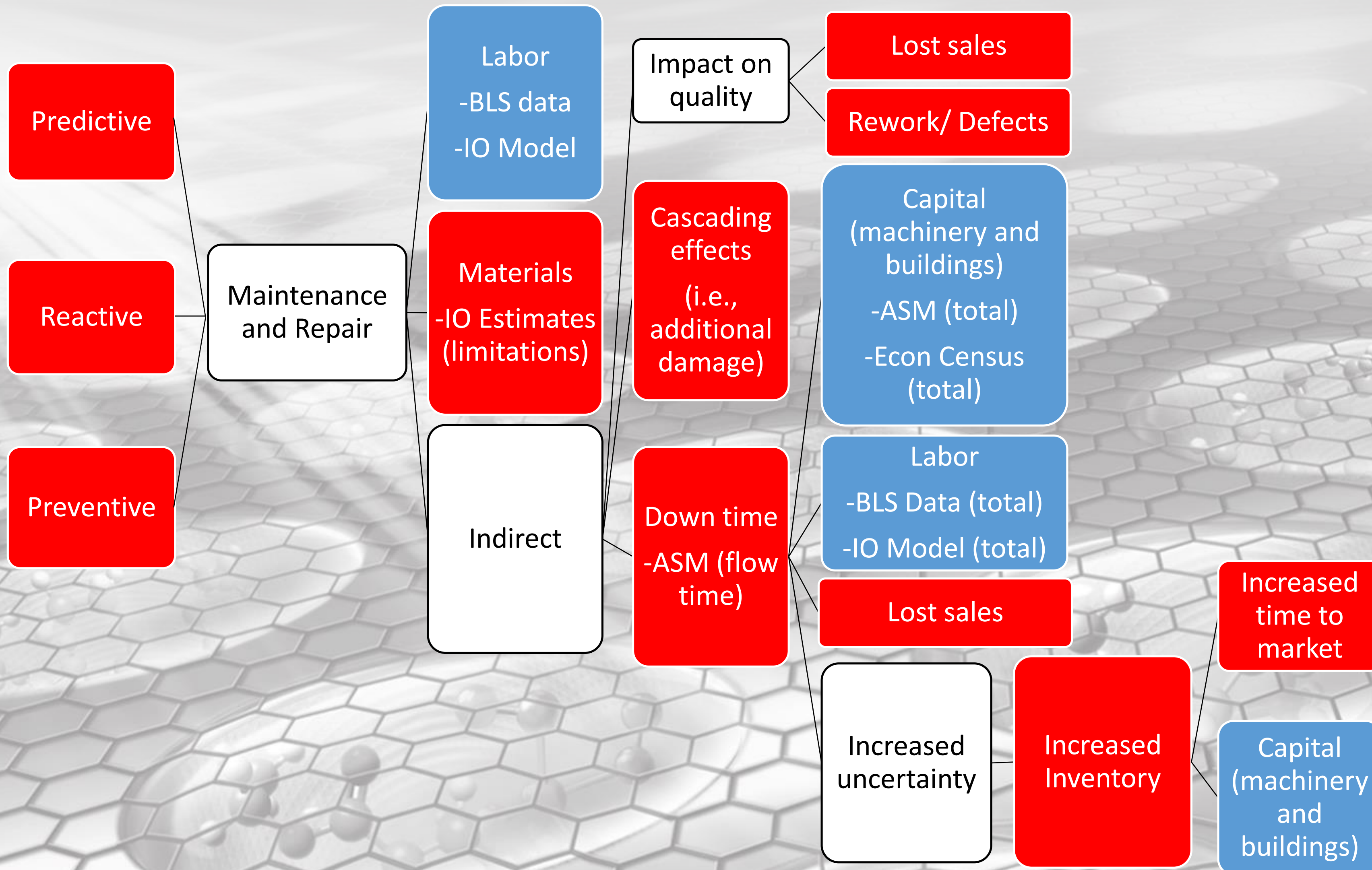
Data Needs Map

Data needed
Some data availability
Descriptive Grouping



Data Collection via Survey

- Collect data through survey
  - Direct maintenance costs
  - Downtime
  - Defects/rework
  - Separate costs into predictive, preventive, and reactive
  - Separate planned maintenance from repair
  - Lost sales → quality
- Scale using payroll data by industry by establishment size

FCA Chrysler – Brampton Assembly Plant (2016). This image was used in accordance with Fiat Chrysler Automobile's editorial use policy. http://media.fcanorthamerica.com

Data Collection via Survey

- Disproportional amount of small firms
- Scale by establishment size
  - Census data
- Anonymous survey
- Short survey
  - Target: 1 Page

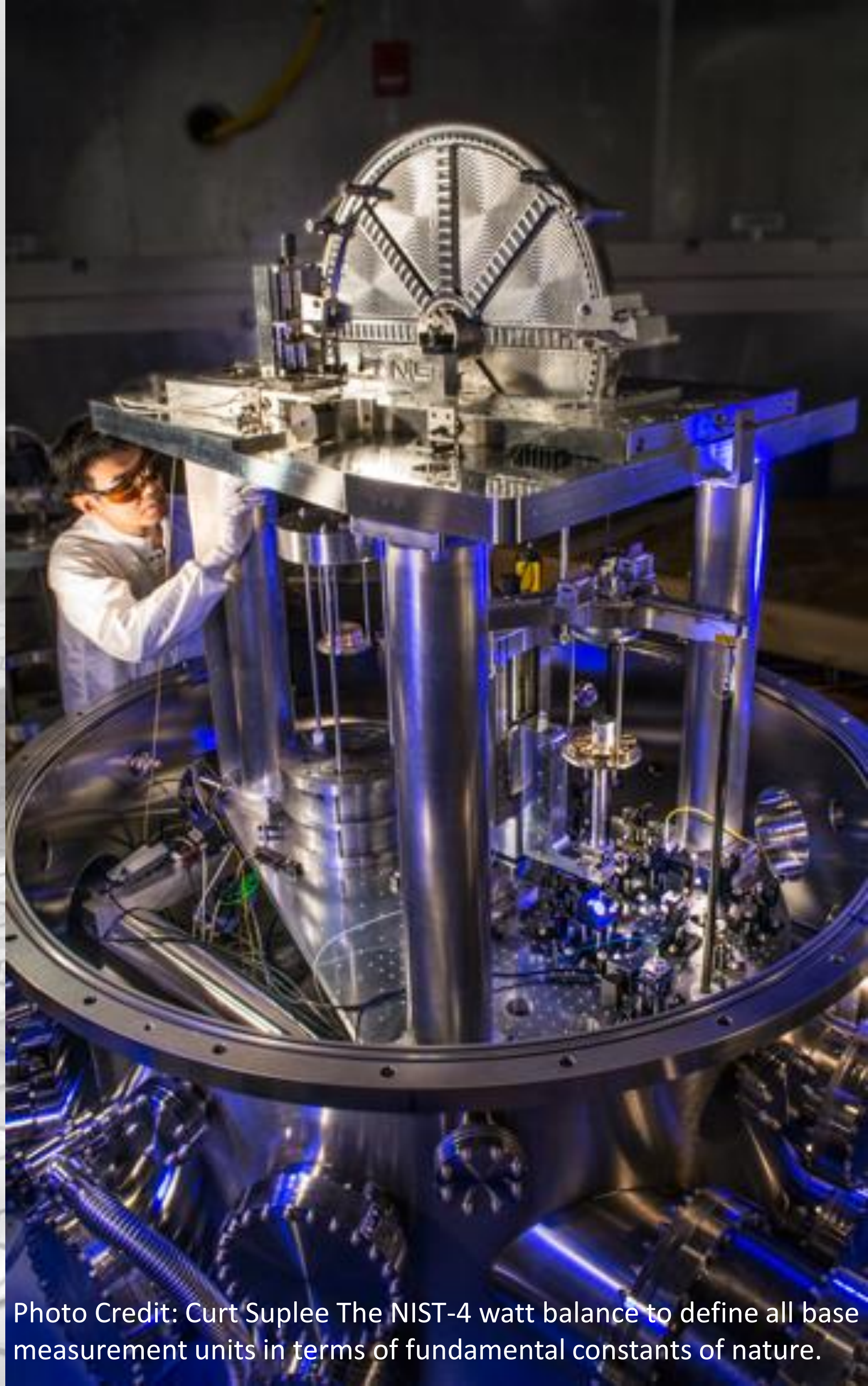


Photo Credit: Curt Suplee The NIST-4 watt balance to define all base measurement units in terms of fundamental constants of nature.

Credit: Fran Webber - Custom designed and built at NIST, the very small angle neutron scattering (vSANS) instrument at the Center for Neutron Research

Feasibility of Data Collection

- Discussions with manufacturers suggest
  - It is reasonable to expect manufacturers to be willing and able to share data
- However,
  - Apprehensiveness from a few in sharing some of the variables
  - A number of variables are not tracked → approximations

Required Sample Size for Survey

It’s complicated

$$Sample\ Size = \left(\frac{z\sigma}{e}\right)^2$$

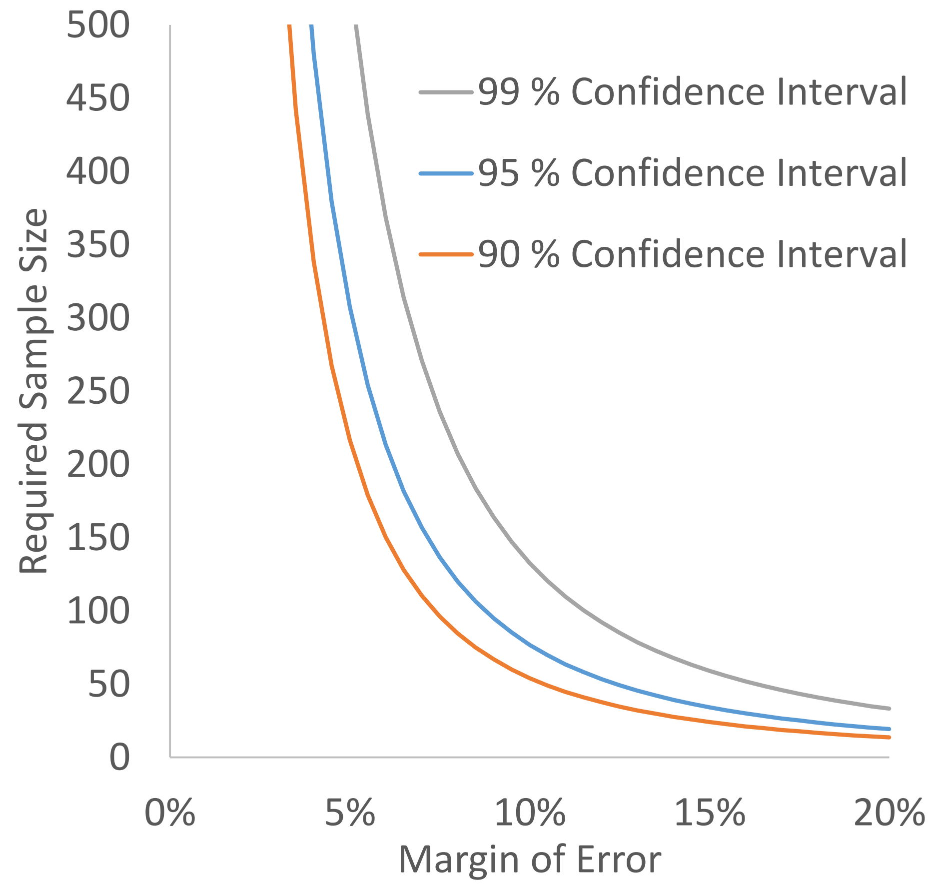
where
σ = Standard deviation
e = Margin of error
z = z-score

Estimate standard deviation using census data on maintenance cost

Chrysler 200 Factory, Sterling Heights Assembly Plant

Sample Size to Estimate Maint. Cost

- Graph sample size
- Standard deviation from Census
- Different confidence intervals
- 10% margin of error w/95% confidence interval: 77
- 20% margin of error w/90% confidence interval: 14



Summary

- Current maintenance cost data has limitations
  - Outsourcing only
  - Includes buildings + machinery
- Literature has
  - Varying metrics
  - Varying countries
  - Wide range of values
- Feasibility of data collection
  - Firms are willing/able
  - Approximations
  - Minimum sample size: 14-77 needed

Tesla Autobots. Steve Jurvetson (Flickr: Tesla Autobots) [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons

How You Can Help

- Your participation would be appreciated
- What's in it for you?
  - Receive a copy of the report
  - See how you compare with others
  - Develop the business case for advanced maintenance

How to participate in Survey

Contact Douglas Thomas

douglas.thomas@nist.gov

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Thank You

Sources

- [a]Mobley, R. Keith. An Introduction to Predictive Maintenance. (Woburn, MA: Elsevier Science, 2002). 1.
- [b]Bevilacqua, M. and M. Braglia. "The Analytic Hierarchy Process Applied to Maintenance Strategy Selection." Reliability Engineering and System Safety. 70, no 1 (2000): 71-83.
- [c]Komonen, Kari. "A Cost Model of Industrial Maintenance for Profitability Analysis and Benchmarking." International Journal of Production Economics. 79 (2002): 15-31.
- [d]Herrmann, C., S. Kara, S. Thiede. "Dynamic Life Cycle Costing Based on Lifetime Prediction." International Journal of Sustainable Engineering. 4, no 3 (2011): 224-235.
- [e]Eti, M.C., S.O.T. Ogaji, and S.D. Probert. "Reducing the Cost of Preventive Maintenance (PM) through Adopting a Proactive Reliability-Focused Culture." Applied Energy. 83 (2006): 1235-1248.
- [f]Tabikh, Mohamad. "Downtime Cost and Reduction Analysis: Survey Results." Master Thesis. KPP321. Mälardalen University. (2014). http://www.diva-portal.org/smash/get/diva2:757534/FULLTEXT01.pdf
- [g]Nakajima, S. Introduction to Total Productive Maintenance (TPM). (Portland, OR: Productivity Press, 1988).
- [h]Ahuja, I.P.S. and J.S. Khamba. "Total Productive Maintenance: Literature Review and Directions." International Journal of Quality and Reliability Management. 25, no 7 (2008): 709-756.
- [i]Chowdhury, C. "NITIE and HINDALCO give a new dimension to TPM." Udyog Pragati, Vol. 22 No. 1, (1995): 5-11.
- [j]Federal Energy Management Program. Operations and Maintenance Best Practices: A Guide to Achieving Operational Efficiency. (2010). https://energy.gov/sites/prod/files/2013/10/f3/omguide_complete.pdf

Other Sources

- Barajas, Leandro and Narayan Srinivasa. “Real-Time Diagnostics, Prognostics and Health Management for Large-Scale Manufacturing Maintenance Systems” Proceedings of the 2008 International Manufacturing Science and Engineering Conference. October 7-10, 2008. Evanston IL.
- Jin, Xiaoning, David Siegel, Brian A. Weiss, Ellen Gamel, Wei Wang, and Ni Jun. “The Present Status and Future Growth of Maintenance in US Manufacturing: Results from a Pilot Survey.” Manufacturing Review. 3 (2016): 1-10.
- Jin, Xiaoning, Brian A. Weiss, David Siegel, Jay Lee, Jun Ni. “Present Status and Future Growth of Advanced Maintenance Technology Strategy in US Manufacturing. 7, Issue 12 (2016): 1-18.
- Jin, Xiaoning, Brian Weiss, David Siegel, and Jay Lee. “Present Status and Future Growth of Advanced Maintenance Technology and Strategy in US Manufacturing.” International Journal of Prognostics and Health Management. Special Issue on Smart Manufacturing PHM. 7, no 12 (2016).

- Jin, Xiaoning, David Siegel, Brian A. Weiss, Ellen Gamel, Wei Wang, and Ni Jun. “The Present Status and Future Growth of Maintenance in US Manufacturing: Results from a Pilot Survey.” Manufacturing Review. 3 (2016): 1-10.

- Alsyouf, Imad. “Maintenance Practices in Swedish Industries: Survey Results.” International Journal of Production Economics. 121 (2009): 212-223.