

\$276 Billion
The United States Cost of Corrosion Study



**NACE**
INTERNATIONAL
THE CORROSION SOCIETY

Cost of Corrosion - Acknowledgement

Amendment to the "Transportation Equity Act for the 21st Century (TEA-21)"
in 1998 led to this project



Cost of Corrosion - Acknowledgement

- Project Funded By:
 - Federal Highway Administration (DOT)
 - Office of Infrastructure Research and Development
 - Project Manager: Y. Paul Virmani, Ph.D.
- In Cooperation With:
 - NACE International – The Corrosion Society
 - Disseminating study finding – raise awareness



Cost of Corrosion – Study Contractor

- CC Technologies
 - Gerhardus H. Koch, Ph.D.
 - Neil G. Thompson, Ph.D.
 - Michael P.H. Brongers
 - Joe H. Payer, Ph.D., Case Western – Reserve University



Cost of Corrosion – Presentation Outline

- Study Goals
- Previous Studies
- Current Study
 - Method 1 – Corrosion Control Methods & Services
 - Method 2 – Industry Sector Analysis
- Highlights of Selected Sectors
- Extrapolation to Total Corrosion Cost
- Preventative Strategies



Cost of Corrosion – Study Goals

- Determines the cost of corrosion control methods and services
- Determines the cost of corrosion for specific industry sectors
- Extrapolate individual sector costs to a national total corrosion cost
- Assess barriers to progress and effective implementation
- Develop strategies for realizing cost savings



Cost of Corrosion – Previous Studies

- 1950 H.H. Uhlig – US Study: 2.1% of GNP
- 1970 T.P. Hoar – UK Study: 3.5% of GNP
- 1974 Japan Study: 1.2% of GNP
- 1975 Battelle/NBS – U.S. Study: 4.5% of GNP



Cost of Corrosion – Method 1 – Methods & Services

- All costs are direct corrosion costs
- Disadvantage: many costs are missed
 - Costs of labor attributed to corrosion management activities
 - Cost of the equipment required because of corrosion-related activities
 - Loss of revenue due to disruption in supply of product
 - Cost of loss of reliability



Cost of Corrosion – Method 1 – Methods & Services

Protective Coatings	B\$	108.6
Corrosion Resistant Alloys	B\$	7.7
Corrosion Inhibitors	B\$	1.1
Engineering Plastics/Polymers	B\$	1.8
Cathodic & Anodic Protection	B\$	1.0
Corrosion Control Services	B\$	1.2
Research & Development	B\$	-
Education & Training	B\$	-
TOTAL:	B\$	121.41



Cost of Corrosion – Method 2 – Industry Sector Analysis

- For each sector, details of analysis are different
 - Government Reports
 - Publicly Available Documents
 - Industry Experts
 - U.S. Department of Commerce Bureau Census
 - Existing Industrial Surveys
 - Trade Organizations
 - Industry Groups
 - Individual Companies



Cost of Corrosion – Method 2 – Industry Sector Analysis

- 26 Sectors in 5 Categories
 - Infrastructure
 - Utilities
 - Transportation
 - Production & Manufacturing
 - Government



Cost of Corrosion – Method 2 – Industry Sector Analysis



Cost of Corrosion – Category: Infrastructure

Highway Bridges	B\$	8.3
Gas & Liquid Transmission Pipelines	B\$	7.0
Waterways & Ports	B\$	0.3
Hazardous Materials Storage	B\$	7.0
Airports	B\$	-
Railroads	B\$	-
TOTAL:	B\$	22.6



Cost of Corrosion – Category: Utilities

Gas Distribution	B\$	5.0
Drinking Water and Sewer Systems	B\$	36.0
Electrical Utilities	B\$	6.9
Telecommunications	B\$	-
TOTAL:	B\$	47.9



Cost of Corrosion – Category: Transportation

Motor Vehicles	B\$	23.4
Ships	B\$	2.7
Aircraft	B\$	2.2
Railroad Cars	B\$	0.5
Hazardous Materials Transport	B\$	0.9
TOTAL:	B\$	29.7



Cost of Corrosion – Category: Production & Manufacturing

Oil & Gas Exploration & Production	B\$	1.4
Mining	B\$	0.1
Petroleum Refining	B\$	3.7
Chemical, Petrochemical, & Pharmaceutical	B\$	1.7
Pulp & Paper	B\$	6.0
Agricultural Production	B\$	1.1
Food Processing	B\$	1.1
Electronics	B\$	-
Home Appliances	B\$	1.5
TOTAL	B\$	17.6



Government

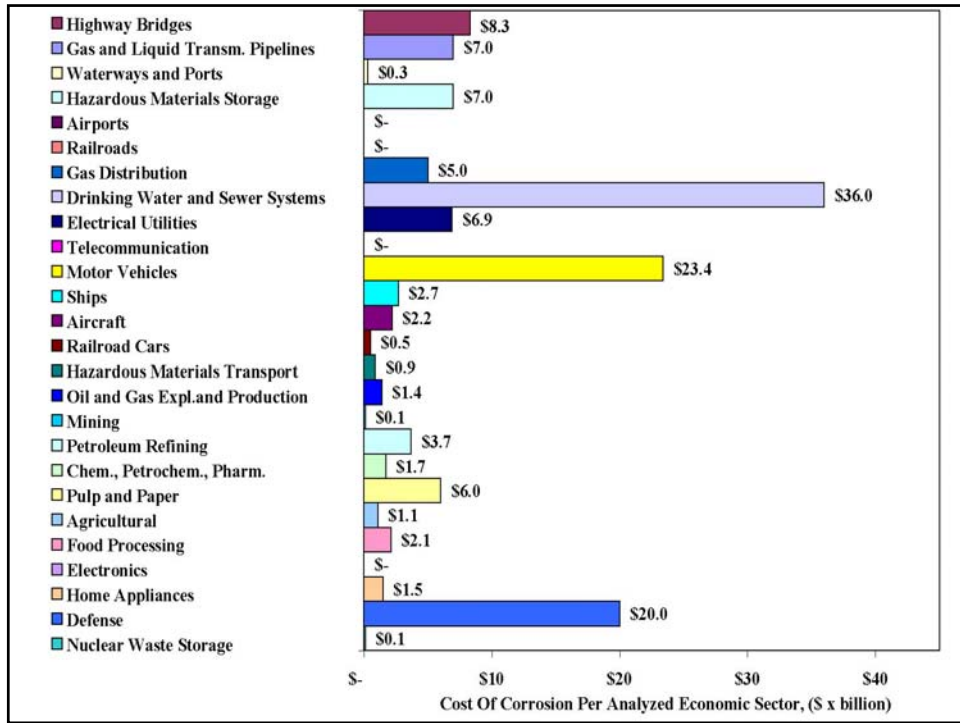
Defense	B\$	20.0
Nuclear Waste Storage	B\$	0.1
TOTAL	B\$	20.1



Cost of Corrosion – Summary of Sector Analyses

Infrastructure	B\$	22.6
Utilities	B\$	47.9
Transportation	B\$	29.7
Production & Manufacturing	B\$	17.6
Government	B\$	20.1
TOTAL	B\$	137.9





Highlights of Selected Sectors

Highways & Bridges
Transmission Pipelines
Drinking Water & Sewer Systems
Oil & Gas Exploration & Production



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Highways & Bridges

\$8.3 Billion Per Year



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National Bridge Inventory Database

- Approximately 600,000 bridges in the U.S
Half were built between 1950 and 1994

- The materials of construction
Concrete, steel, timber, masonry,
timber/steel/concrete combinations, & aluminum

- This sector focused on reinforced concrete and steel bridges; they make up the vast majority of highway bridges



Highway Bridges – Trends

- Reported downward trend in the % structurally deficient bridges - decrease from 18 % to 15 % between 1995 to 1999
- However, costs to replace aging bridges increased by 12 % during the same period.
- In addition, there has been a significant increase in the required maintenance of the aging bridges



Sector Summary: Highway Bridges

Replace structurally deficient bridges	B\$ 3.79
Maintenance and capital cost	
For concrete bridge decks	2.00
For concrete sub- and superstructures	2.00
Maintenance painting cost for steel bridges	.5
Total :	B\$ 8.29



Highway Bridges - Findings

Indirect corrosion costs:

- Estimated from life-cycle analysis
- Costs to user due to traffic delays & lost productivity
- More than ten times the direct cost of corrosion



Gas & Liquid Transmission Pipelines

\$7 Billion Per Year



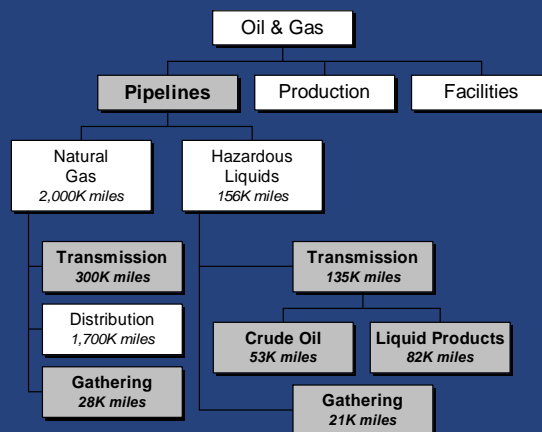
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Gas & Liquid Transmission Pipelines

- Over 480,000 Miles of Gas and Liquid Transmission Pipelines
 - Gas Transmission
 - Natural Gas Lines – 328,000 Miles
 - Liquid Transmission Lines
 - Crude Oil Lines – 74,000 Miles
 - Liquid Product Lines – 82,000 Miles
- 60% of These Lines Are Over 40 Years



Gas & Liquid Transmission Pipelines



Gas & Liquid Transmission Pipelines

- **Typical Corrosion Related Costs**

- Annual ICCP System Investment - \$40 Million
- Annual Sacrificial CP Investment - \$9 Million
- Annual O&M Costs - \$2.4 Billion - \$4.8 Billion

- **Certification**

- 30% of Companies has personnel dedicated to Corrosion Control
- Regulations require Certification of Corrosion Control Staff
- Annual Cost \$32.4 Million



Sector Summary: Transmission Pipelines

	Low Estimate	High Estimate	Average	
	(\$ x M)	(\$ x M)	(\$ x M)	%
Cost of Capital	2,500	2,840	2,670	38
Operations & Maintenance (O&M)	2,420	4,840	3,630	52
Cost of Failures (Non-Related O&M)	471	875	673	10
TOTAL COST DUE TO CORROSION	5,391	8,555	6,973	100



Drinking Water & Sewer Systems

\$36 Billion Per Year



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Drinking Water & Sewer Systems

- **Two Separate Systems**
 - Drinking Water
 - Sewage Water
- Costs in Operation, Maintenance, Finance, Capital Investments
- Maintenance crews find and repair leaks, but the number of leaks increases with system age.



Drinking Water & Sewer Systems

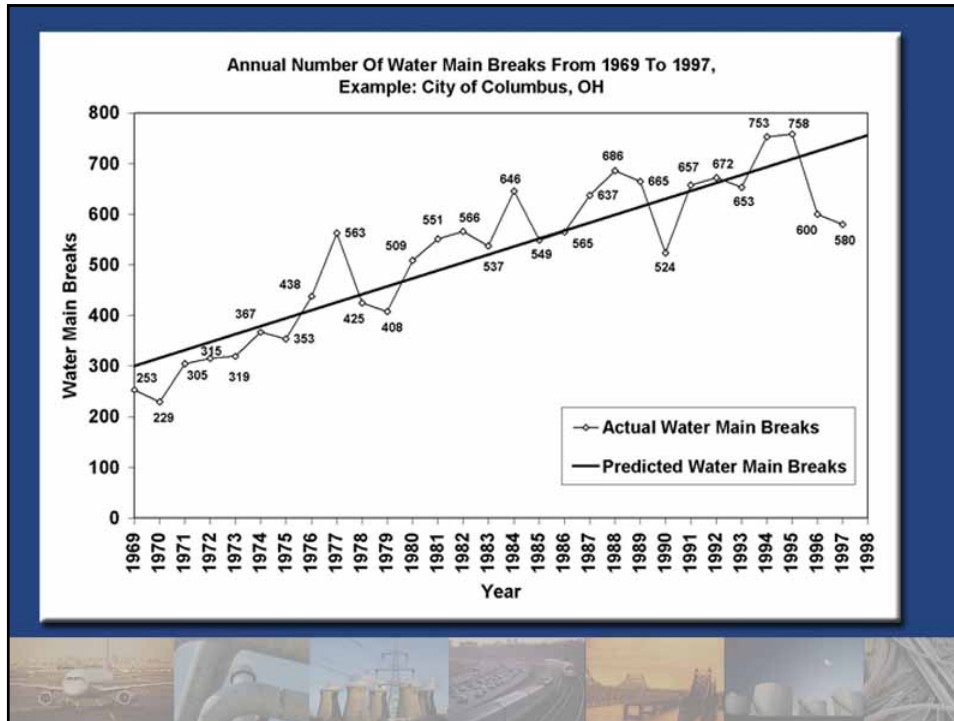
- **System Size**
 - 550 liters of water consumption per person per day
 - 56.7 Billion m³ / year in the U.S.
 - 1.4 Million km of municipal water pumping
- A major barrier to progress in corrosion management is the absence of complete and up-to-date information on all water systems.



Operation & Management Costs

- **There are only 2 reasons why utilities replace or change water systems:**
 - Pipes are considered broken,
 - Leaking water
 - Corrosion products in the water
 - Capacity too small for the area
- Assume 50% of all operation and maintenance costs are corrosion-related





Three Reports on Water System Costs

- 1997 EPA: B\$6.9 per year
 - Drinking water system maintenance only
- 1998 AWWA: B\$16.3 per year
 - Drinking water transmission – maintenance only
- 2000 WIN: B\$51 per year for Drinking Water
B\$45 per year for Sewer Systems
- Includes Operation, Maintenance, Finance, Capital



Cost of Lost Water

- Nationwide, 15% of treated water is lost
- Loss of revenue: B\$3.0 per year
- More than 90% of lost-water cost is corrosion-related, because of leaking systems
- Underground leaks go unnoticed: Therefore low cost awareness



Sector Summary: Drinking Water & Sewer Systems

• Operation, Maintenance, Finance, Capital	
• Drinking water systems	B\$19.25
• Sewer systems	B\$13.75
• Cost of Lost water	B\$3.0
TOTAL	B\$36.0



Oil & Gas Exploration Production

\$1.4 Billion Per Year



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Background

- Significant available onshore oil & gas reserves have been explored
- U.S. 1998 Oil Production – 3.04 Billion Barrels
- Recoverable Reserves
 - Deep Waters Offshore
 - Remote Arctic Locations
 - Reservoirs with Unconsolidated Sands



Background

- Relative High Costs of Oil & Gas Production in the U.S.
 - Maintenance Costs Must be Kept to a Minimum
 - Emphasis on Controlling Internal Corrosion with Corrosion Inhibitors



Sector Summary: Oil & Gas

- Operation, Maintenance, Finance, Capital

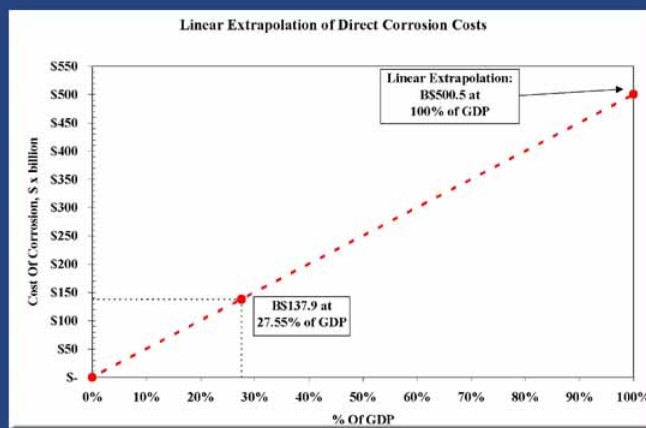
• Surface Piping & Facility Costs	M\$589
• Downhole Tubing Expenses	M\$463
• Capital Expenses	M\$320
TOTAL	B\$1.36

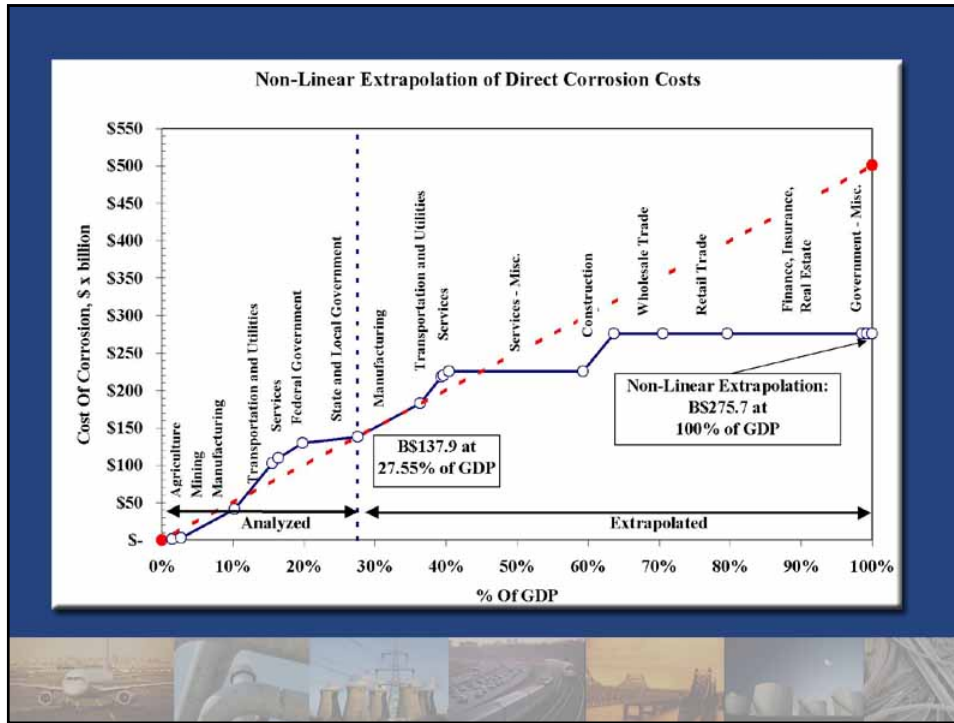


How to Extrapolate the Total Cost of Corrosion



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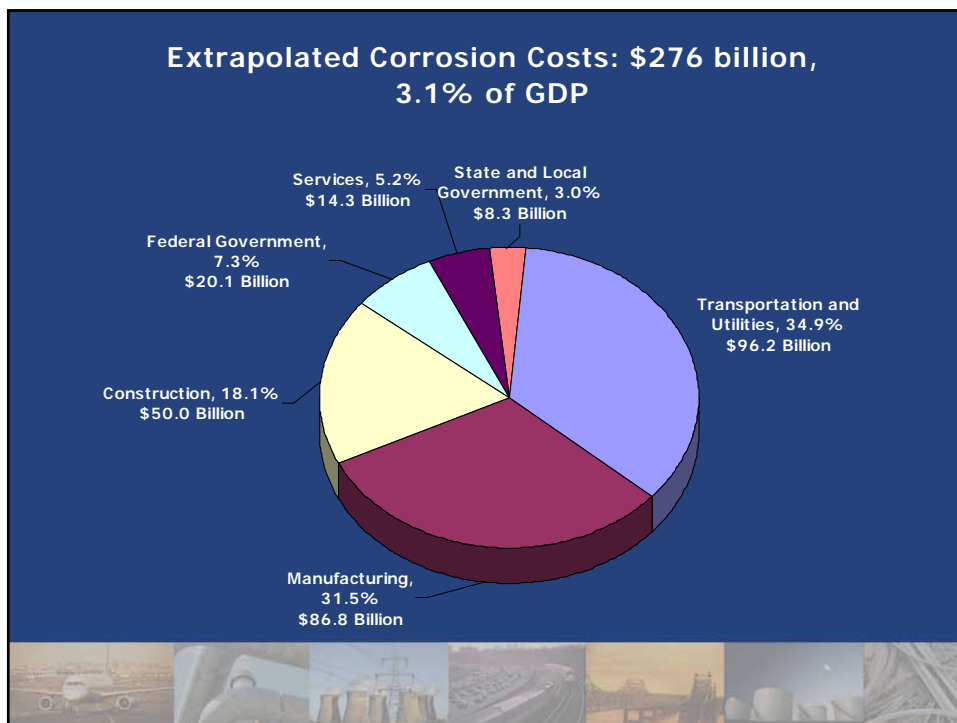
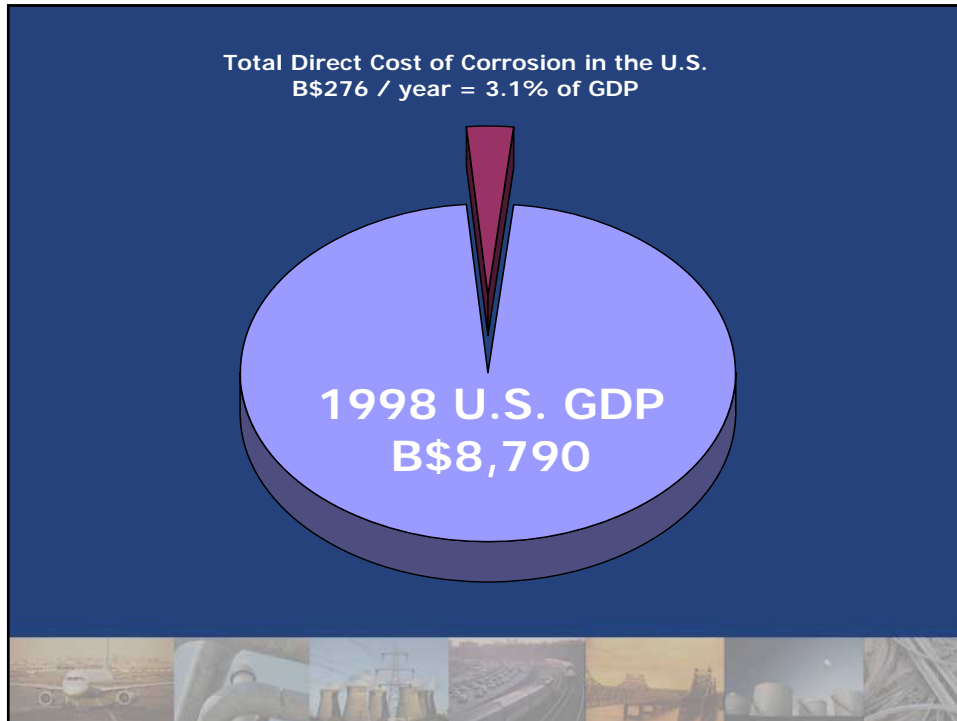


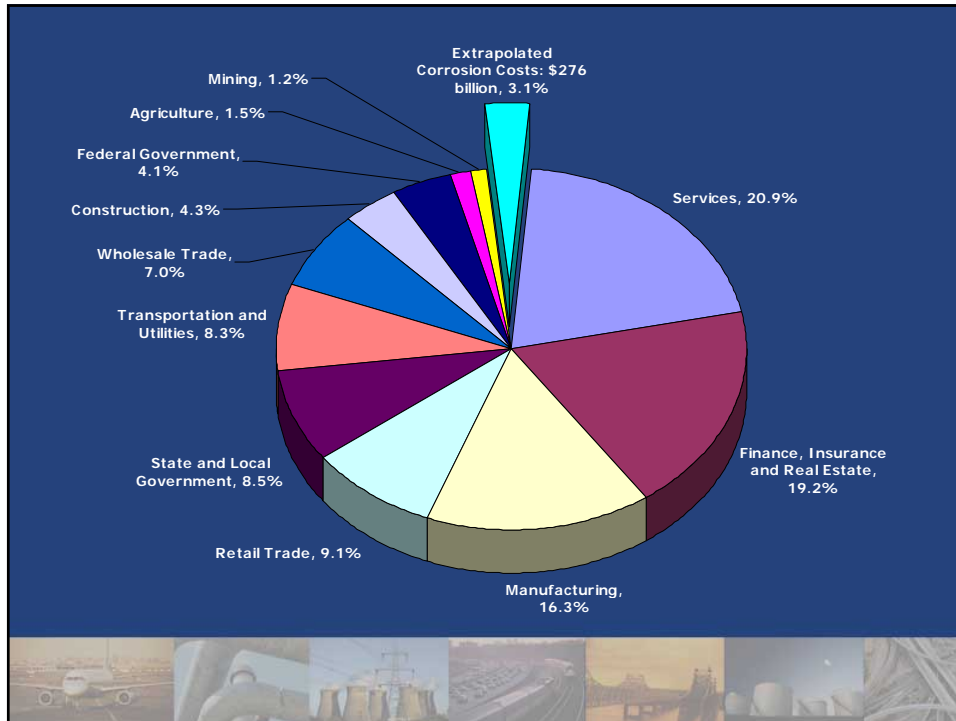


Total Cost of Corrosion

- Estimated Cost B\$138
- Extrapolated Cost B\$276
- Actual Cost >B\$550

- Bridges >5 times
- Electric Utilities >3 times





Non-Technical Preventive Strategies (4)

- Increase awareness of the large corrosion costs and potential savings
- Change the misconception that nothing can be done about corrosion
- Change policies, regulations, standards, and management practices to increase corrosion savings
- Improve education and training of staff

Technical Preventive Strategies (3)

- Advance design practices for better corrosion management
- Advance life prediction and performance assessment methods
- Advance corrosion technology through research, development, and implementation



Further Information

- FHWA – RD-01-156 – Full Report
- FHWA – RD-01-157 – Tech Brief
- Contact:
 - Federal Highway Administration
 - Y. Paul Virmani (202) 493-3052
- Web Site:
 - <http://www.corrosioncost.com>



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