Empirical Study of Life-Cycle Cost Analysis for Bridges

Progress Report

Ahmad Hadavi, PhD, PE

Life-Cycle Cost Analysis Defined

- An economical set of actions and their timing during the life of a bridge to achieve the 50- to 100-year service life that many bridge management professionals feel is an appropriate target for this major public investment (NCHRP Report 483, 2003).

Bridge LCCA Advantages

- Important technique for assisting with investment decisions
- Recent legislative and regulatory requirements call for consideration of such analyses for infrastructure investments

Bridge LCCA Implementation Problems

- Currently, there is no comprehensive methodology for bridge life-cycle cost analysis
- There is a lack of background data

Our Goals

- Determine the achievable useful life for a bridge
- Determine the life-cycle cost of a bridge
- Formulate a cost model for bridge life-cycle cost
- Determine the design practice that leads to the lowest bridge life-cycle cost
- Determine the maintenance and rehabilitation practice that leads to the lowest bridge life-cycle cost

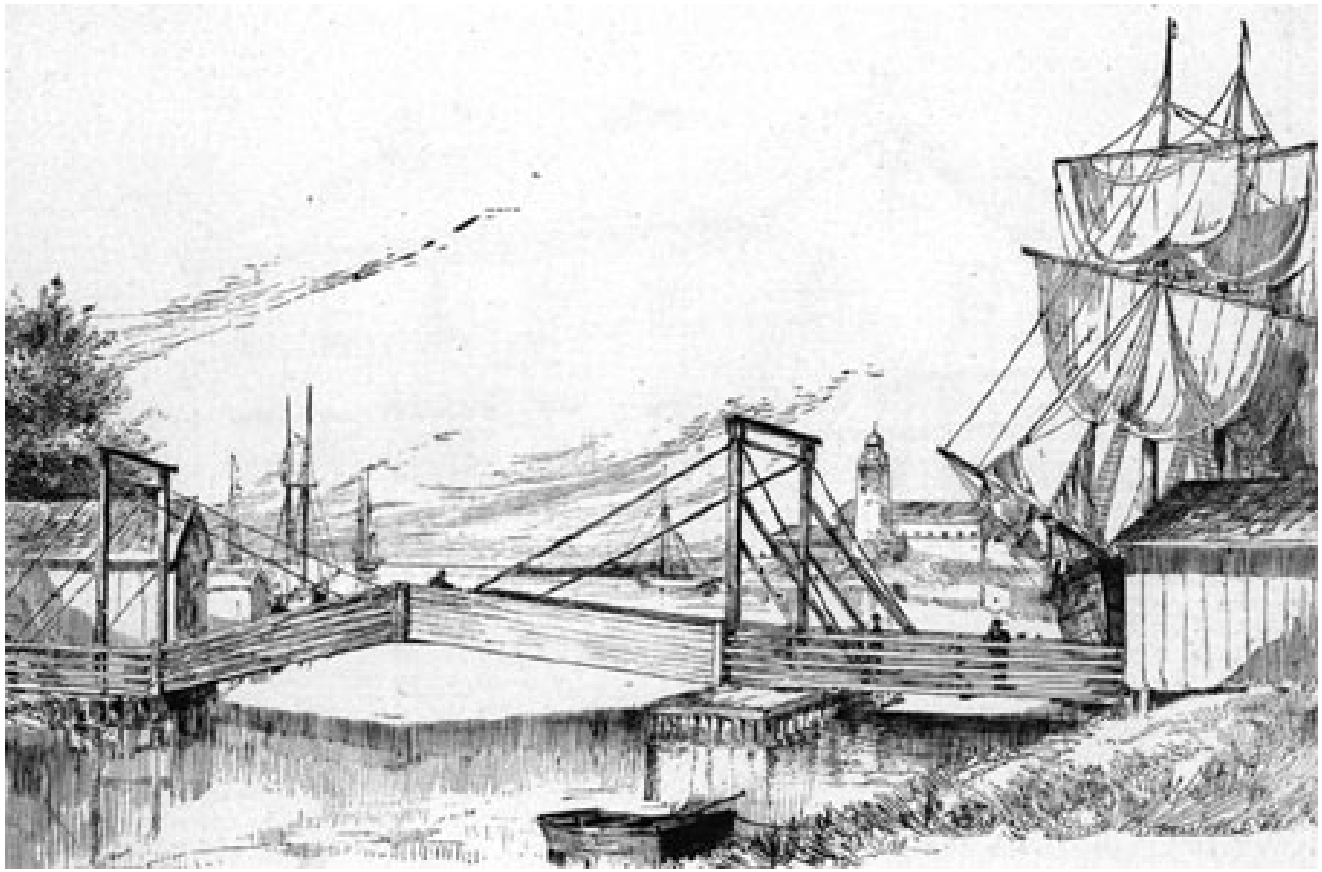
Our Plan

- Step one: Obtain available data from Chicago movable bridges and formulate the overall framework and methodology for the study
- Step two: Obtain data from old urban bridges, such as the Brooklyn Bridge and the Golden Gate Bridge
- Step three: Obtain data from highway bridges of different structural types from different areas of the country

Chicago Movable Bridges

- Drawbridge
- Float Bridge
- Swing Bridge
- Lift Bridge
- Bascule Bridge

Dearborn Street Drawbridge

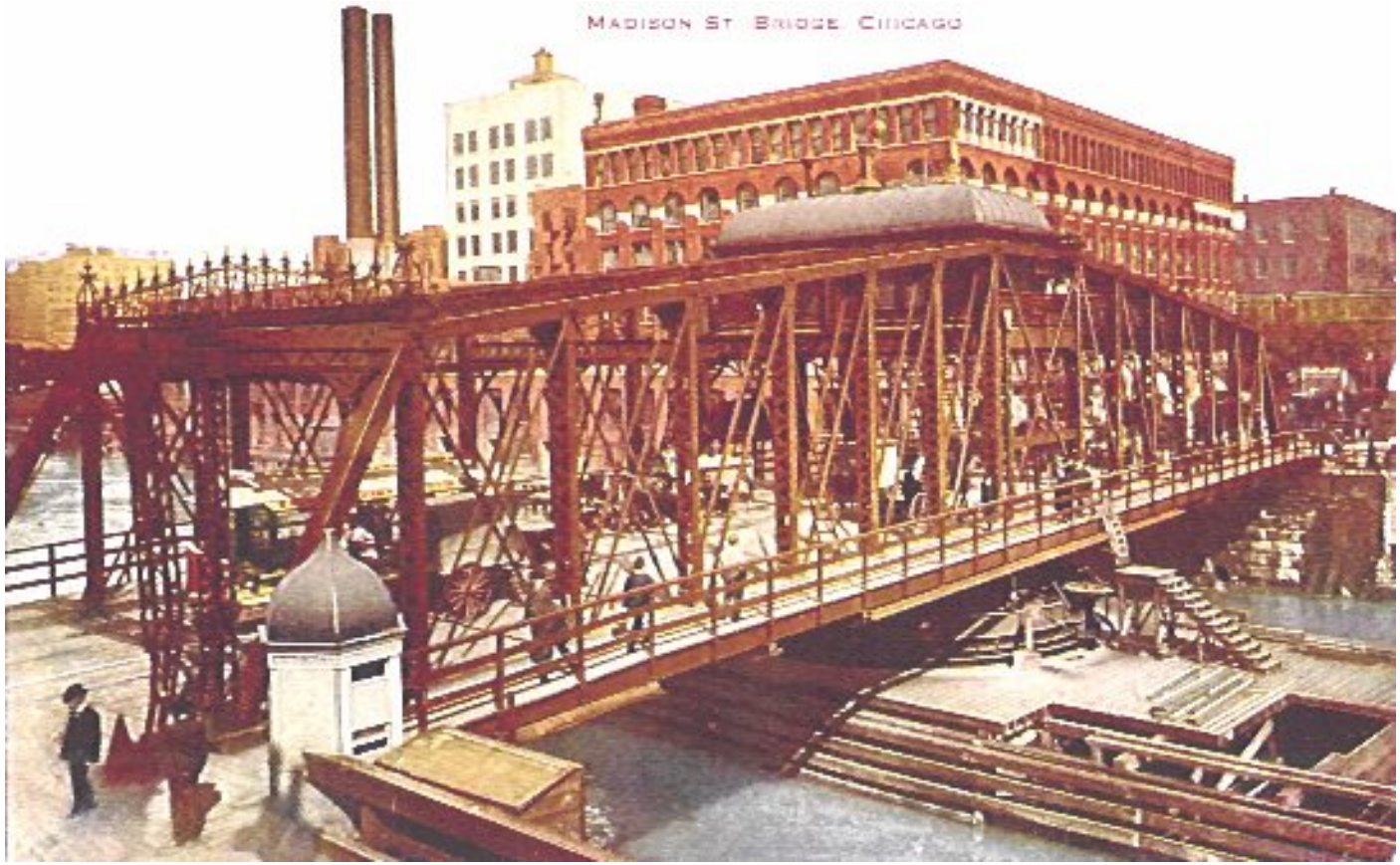


Source: http://www.chipublib.org/003cpl/hf/1830/dearborn.html

Float Bridge

http://www.ci.chi.il.us/CulturalAffairs/PublicArt/RiverwalkGateway/floatbridge.html

Swing Bridge

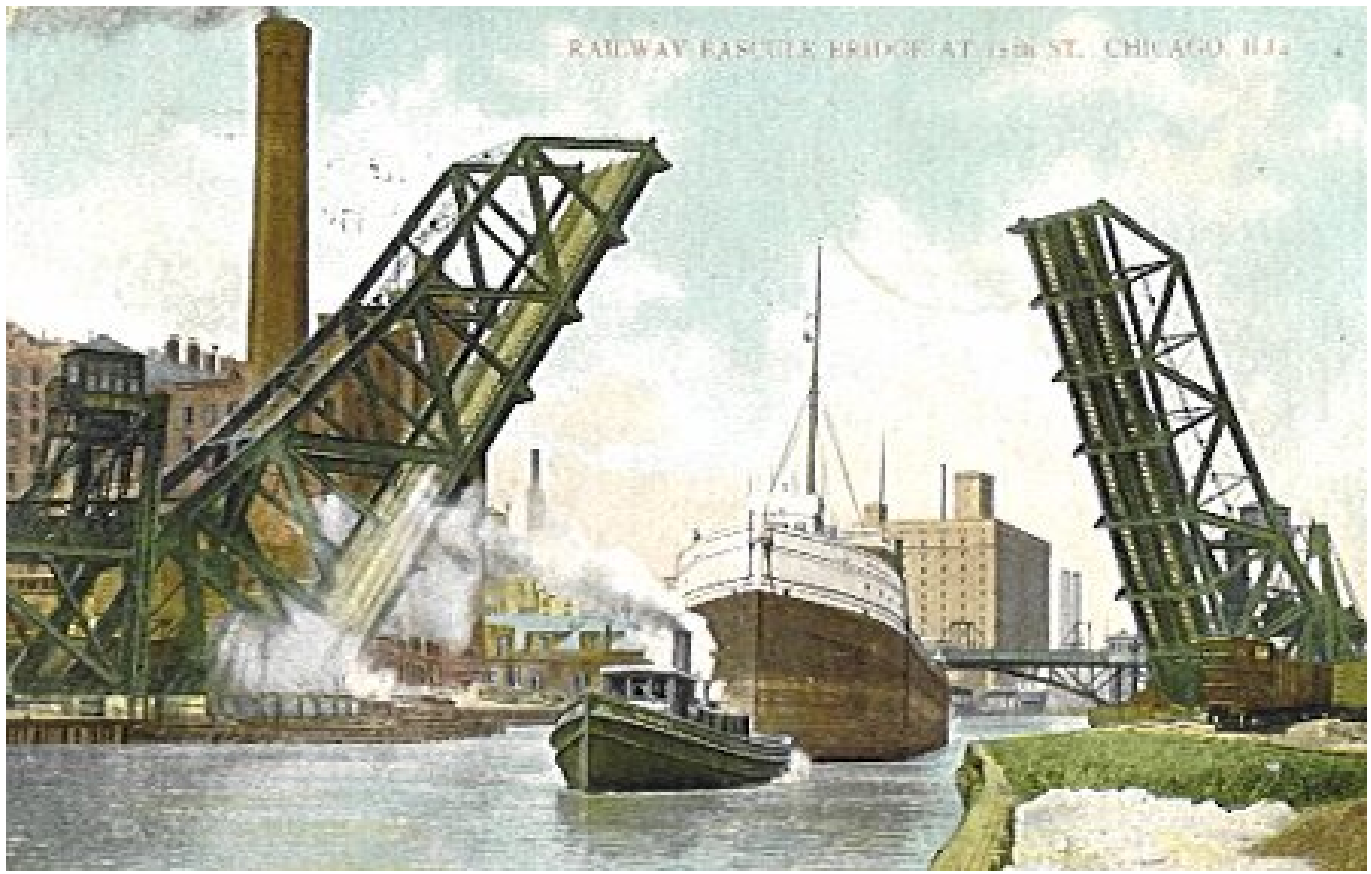


Source: http://www.geocities.com/boc2400/bridges2.html

Halsted Street Lift Bridge

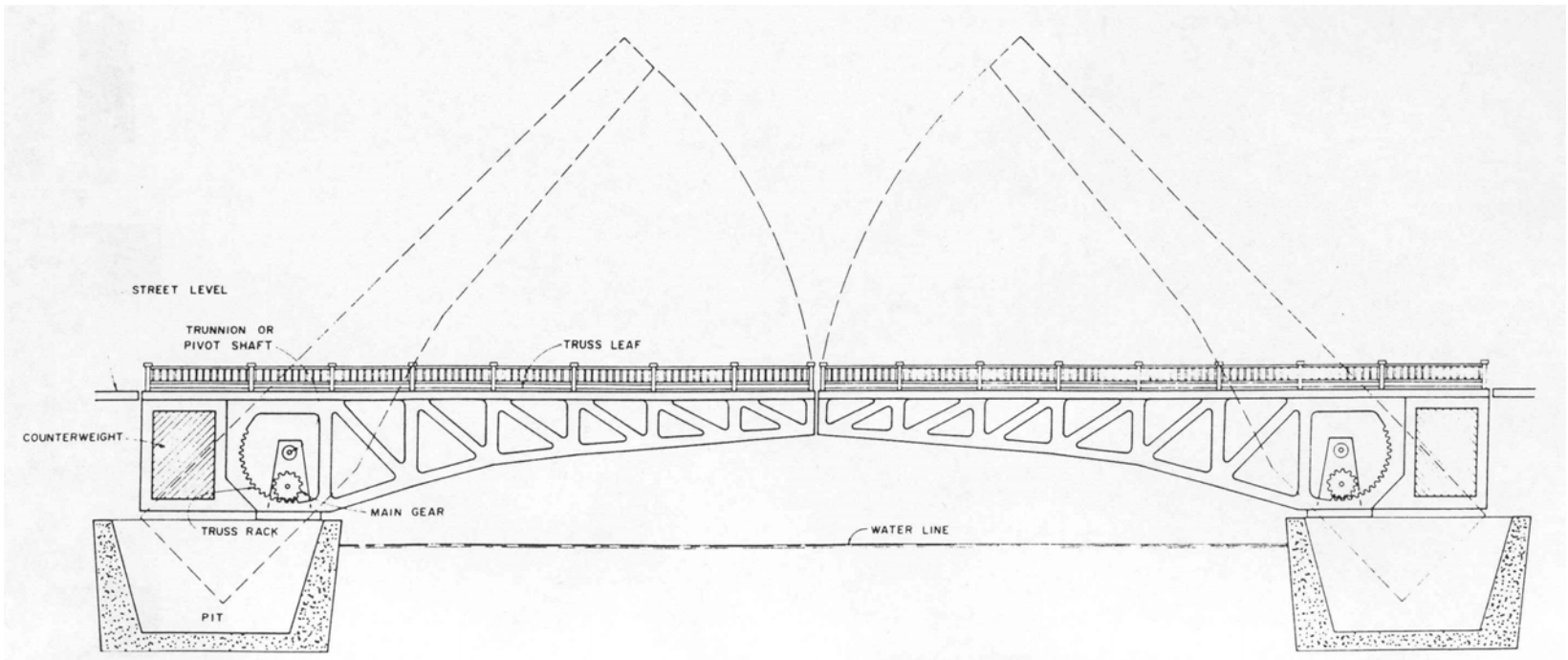
Source: http://patsabin.com/illinois/HalstedBridge.htm

Chicago Bascule Bridge



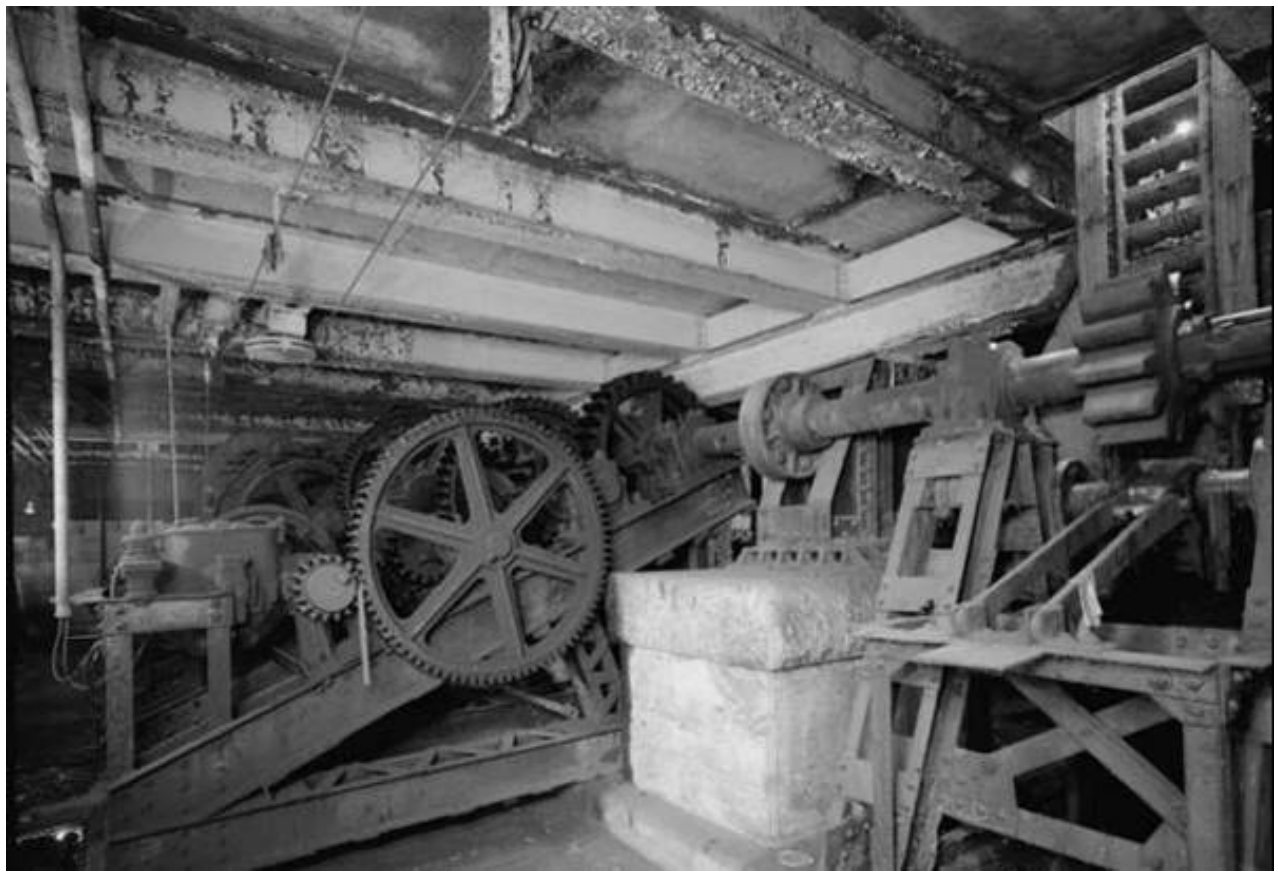
http://www.geocities.com/boc2400/bridges2.html

Trunnion Bascule Bridge Schematic Diagram



Cortland Street Bridge

Cortland Street Bridge



Source: http://www.structurae.net/en/photos/index.cfm?JS=6608

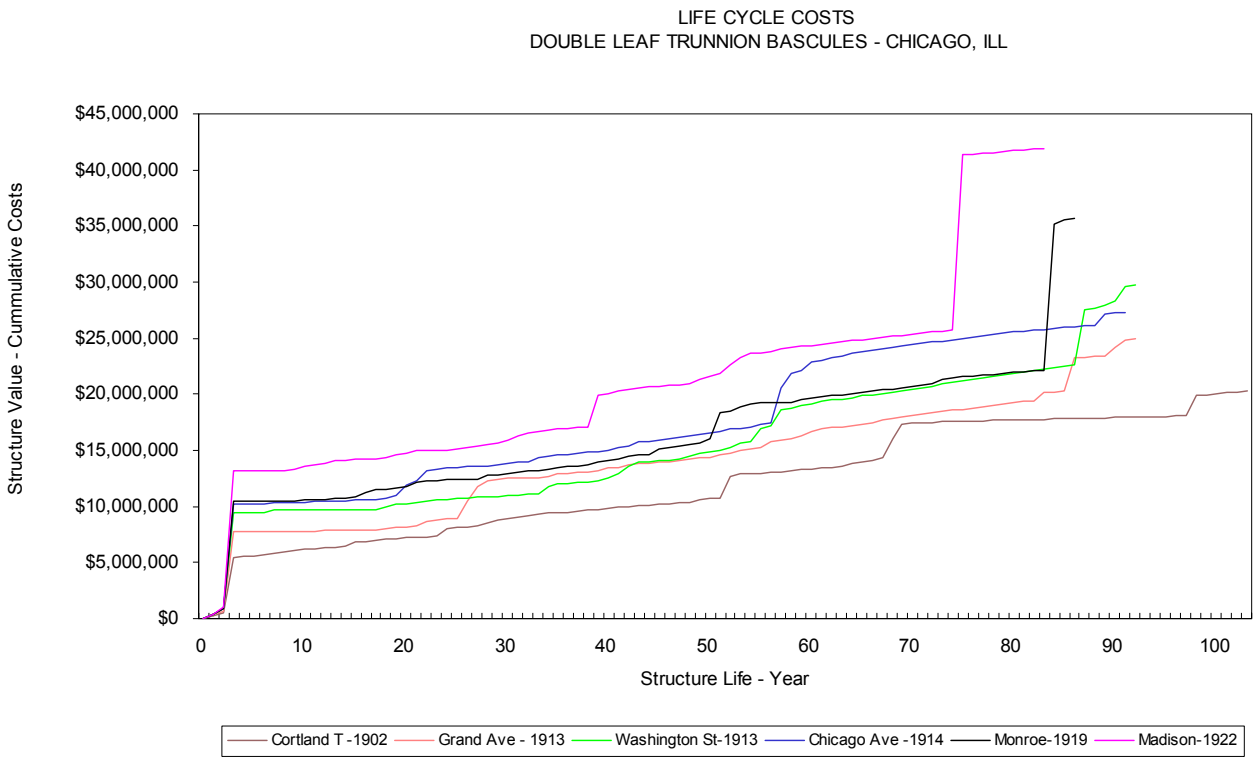
State Street Bascule Bridge

Source: http://patsabin.com/illinois/BasculeBridge.htm

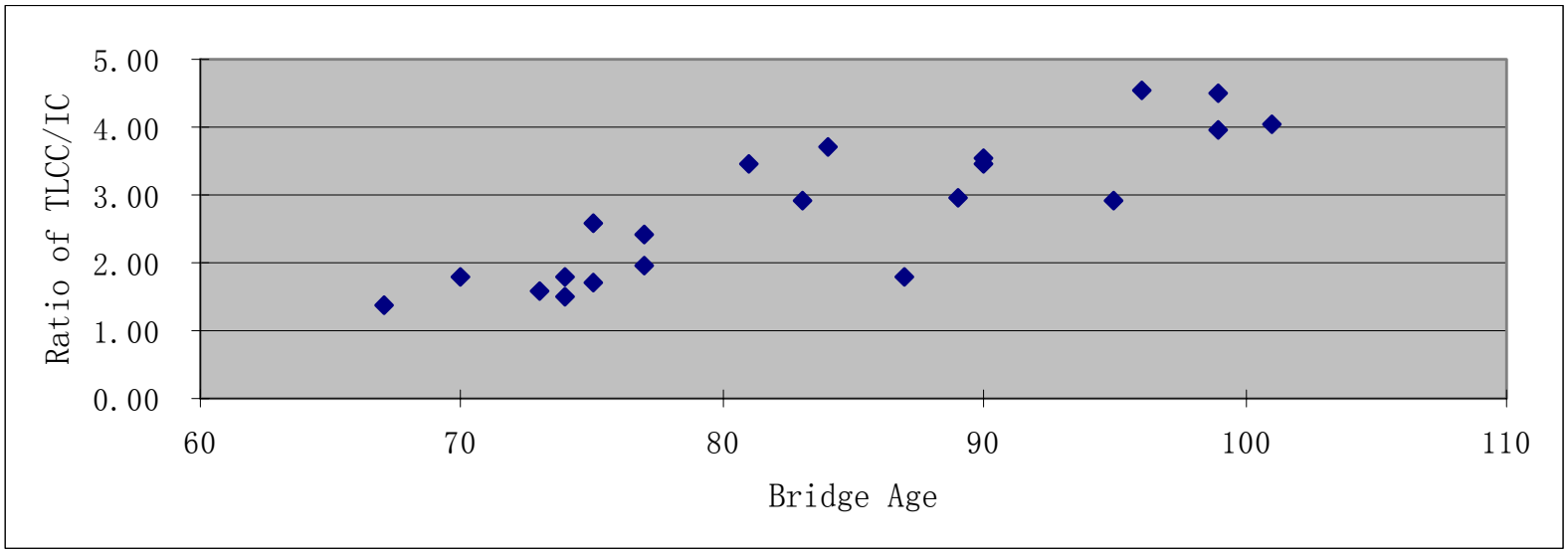
Washington Street Bridge

Source: http://patsabin.com/illinois/WashStBridge.htm

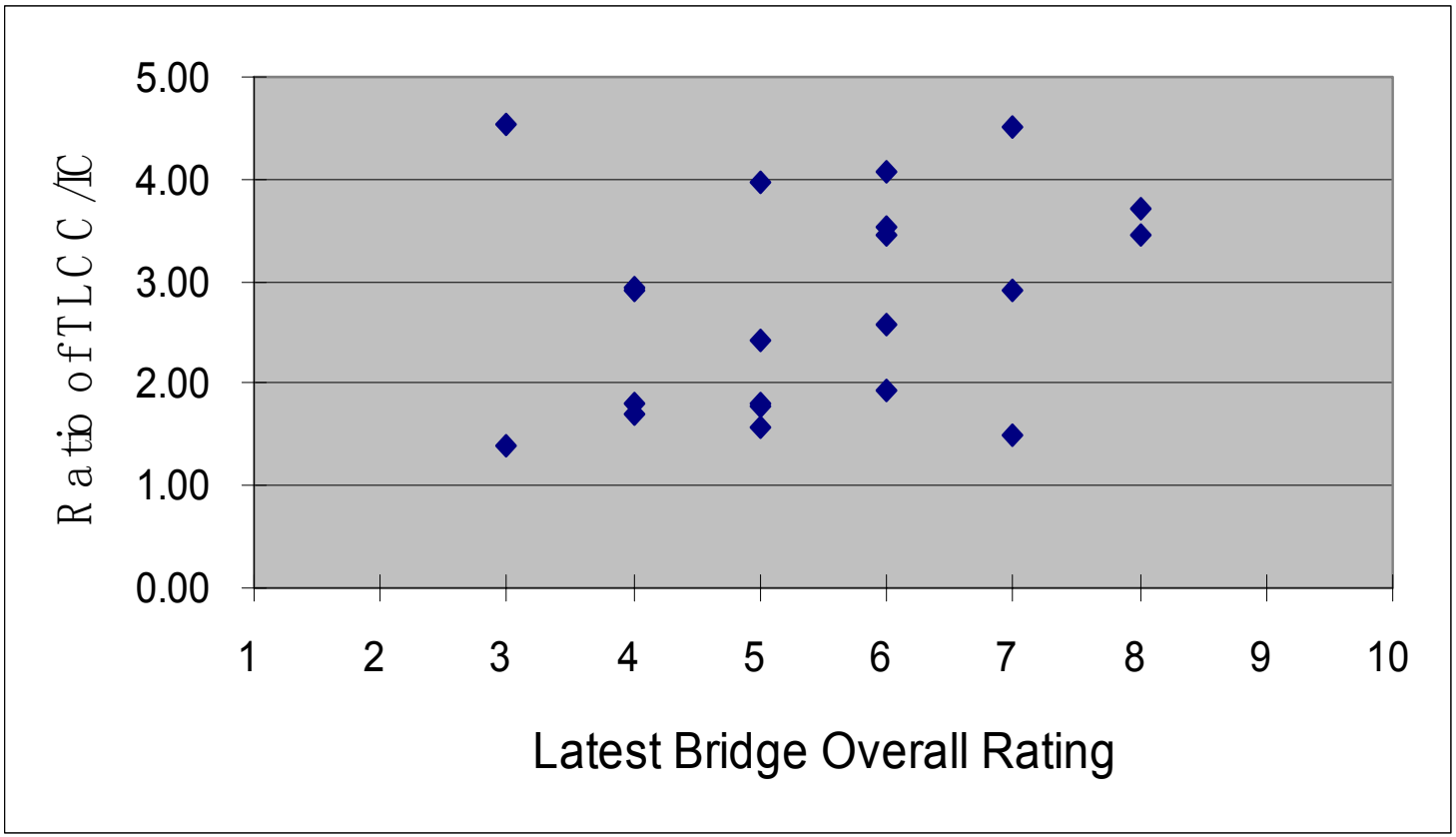
Sample BLCC Curves for Chicago Bridges



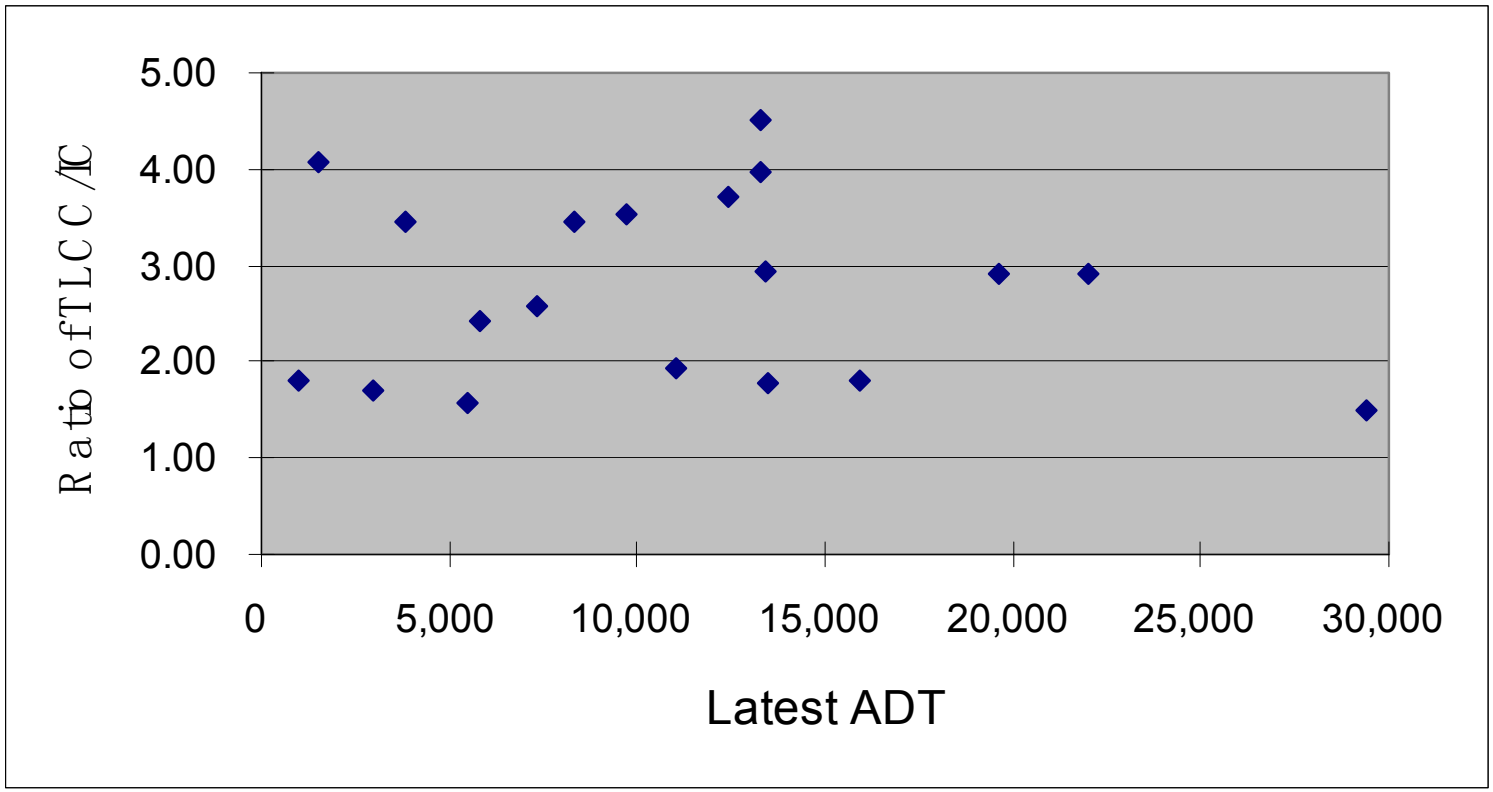
Bridge Age vs. TLCC/IC



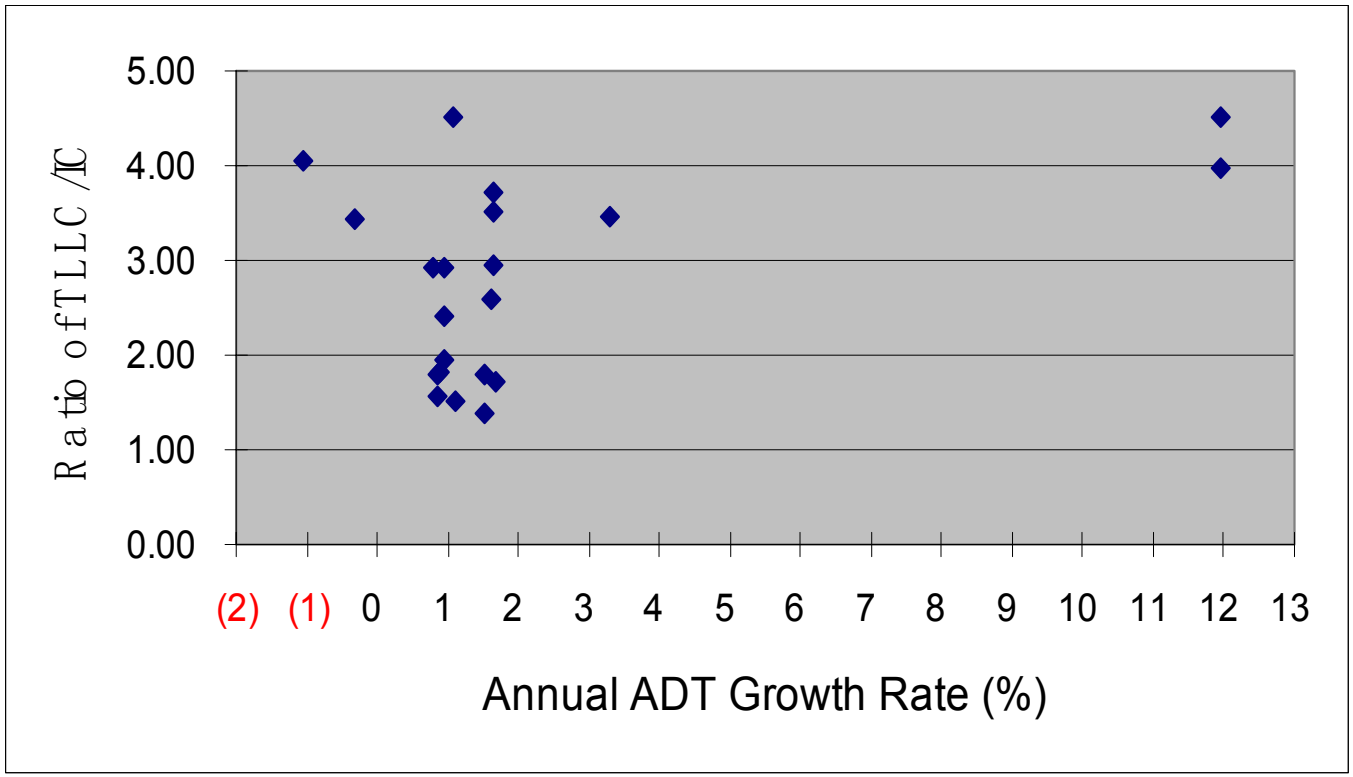
Latest Bridge Overall Rating vs. TLCC/IC



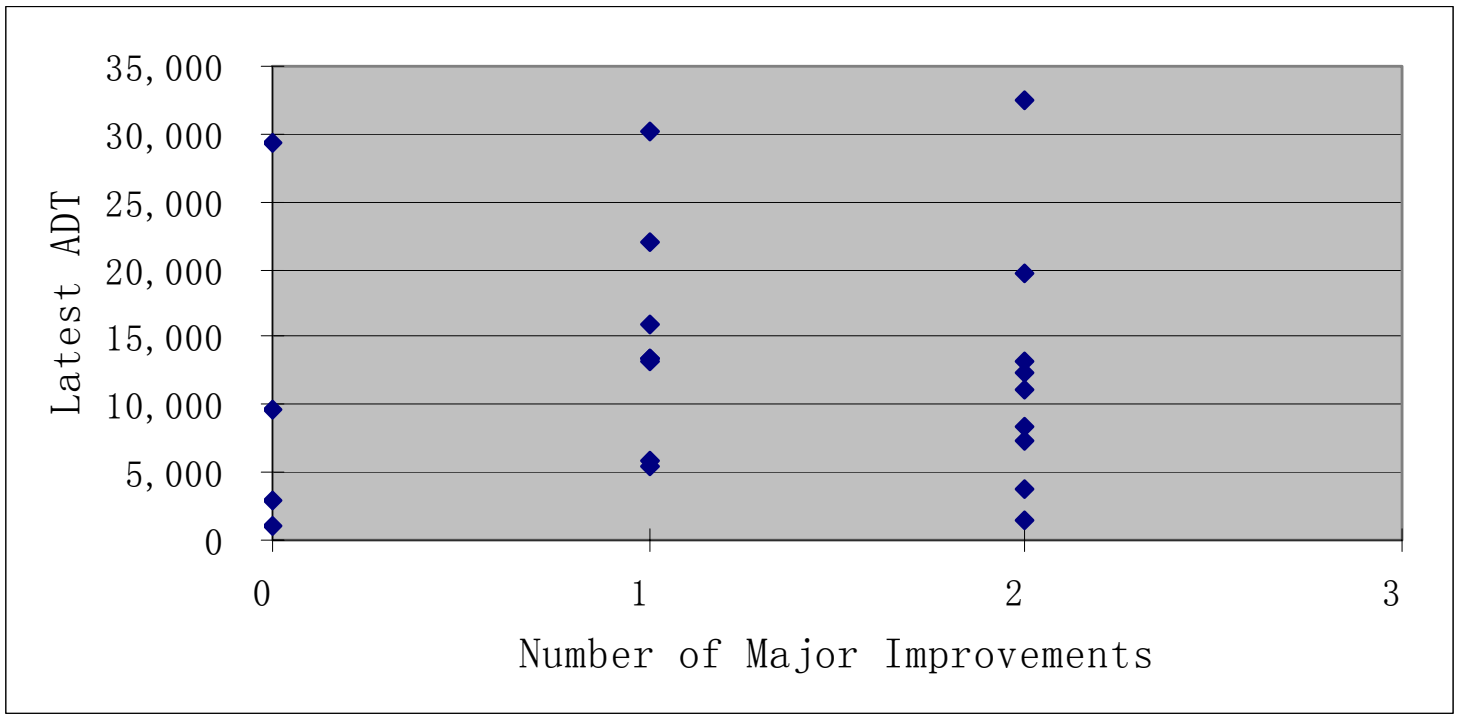
Latest ADT vs. TLCC/IC



Annual ADT Growth Rate vs. TLCC/IC



Frequency of Major Improvements vs. Latest ADT



Chicago Double Leaf Trunnion Bascules

- Basic findings
  - Useful life can be more than 100 years
  - Older bridge have higher TLCC/IC ratios, as expected
  - Bridges in better condition have higher TLCC/IC ratios
  - ADT has little impact on frequency of major capital improvements
  - Major MRR cost items are deck overlays, structural repairs, painting, sidewalks, bridge house, machinery, and electrical equipment

Chicago Double Leaf Trunnion Bascules

- Initial costs and MRR costs
  - Many factors may influence MRR costs, so it is inappropriate to conclude that higher initial costs should result in lower MRR costs, because higher initial costs might be attributed to various other causes, such as traffic volume or the frequency of bridge openings

Chicago Double Leaf Trunnion Bascules

- Attempts are currently being made to determine the distribution of MRR costs among
  - Structural including deck
  - Painting
  - Machinery
  - Electrical equipment

Bridges from IDOT

- Basic data from Springfield
- Supplemental data from Schaumburg
- Many bridges were reconstructed at ages between 40 to 60 years old
- For most of the older bridges, maintenance costs were not readily available
  - Maintenance costs for several bridges were combined
  - No records were kept
  - Data are in a “secret file”

Bridges and Tunnels from New York City

Name		Year Built	Age as of 2002	Total Length (ft)	Roadway Width (ft)	Initial Cost (IC) ($)	Cost as of Dec.31,2002 (TC) ($)	TC/IC	Total Traffic Volume in 2002
Outerbridge Crossing		1928	74	8,800	42	9,600,000	189,256,000	19.71	14,356,000
Goethals bridge		1928	74	7,100	42	7,200,000	150,798,000	20.94	15,682,000
Bayonne bridge		1931	71	5,780	40	13,000,000	166,873,000	12.84	3,837,000
George Washington Bridge		1931	71	4,760	90	59,000,000	844,248,395	14.31	54,764,000
Holland Tunnel	North tube	1927	75	8,558	21.5	48,000,000	400,238,000	8.34	15,764,000
	South tube			8,371					
Lincoln Tunnel	North tube	1945	57	7,482	20	75,000,000	672,870,000	8.97	20,931,000
	Center tube	1937	65	8,216					
	South tube	1957	45	8,006					

Bridges in California

- Data sources:
  - Reports on Completed Contracts
  - Inspection Reports: Maintenance Division
  - Bridge Files
- Procedure for pursuing useful data:
  - Setting criteria: built before 1940, without reconstruction
  - Screening from inventory: resulted in 332 bridges
  - Searching for bridges with initial cost from Reports on Completed Contracts: resulted in 48 bridges
  - Searching for MRR history and costs for these 48 bridges from Inspection Reports and Bridge Files

Bridges in California

- 48 candidate bridges:
  - Bridge types: R.C. arch, R.C. girder, R.C. box girder, steel
  - Historical significance: rating of 1 to 5, with one being the most significant
  - Sample: Bixby Creek Bridge
    - Built in 1932
    - 330-foot open spandrel deck arch span and nine 40-foot deck girder approach spans
    - 260 feet above the stream bed
    - Longest and tallest concrete arch bridge in California

Bixby Creek Bridge

Source: CalTrans

Bridges in California

- Notable differences
  - Different climate in California compared to the Midwest. No salt is necessary on decks.
  - In addition to deterioration, scour and seismic action are big issues in California.
  - In California, 70% of the bridges are replaced due to earthquake and scour vulnerability rather than deterioration.
  - Every year, five or so bridges fail due to scour.

Bridge Profile: California vs. Illinois

Structural Type

	Slab	Stringer /Multi-Beam or Girder	Girder& floor beam System	Tee Beam	Box Beam or Girders (Multiple)	Truss-Thru	Channel Beam	Other	Total
CALIFORNIA									
AS OF 12/2002	5,470	3,993	66	3,217	6,922	253	34	237	20,192
AS OF 12/1997	5,360	4,095	41	3,305	6,553	275	0	112	19,741
ILLINOIS									
AS OF 12/2002	2,480	7,777	239	739	7,715	461	1,498	526	21,435
AS OF 12/1997	2,743	7,966	289	874	6,868	642	1,364	604	21,350

Bridge Profile: California vs. Illinois

Material Type

State	Concrete	Concrete Continuous	Steel	Steel Continuous	Pre-stressed Concrete	Pre-stressed Concrete Continuous	Wood	Masonry	Aluminum / Iron	Other	Total
CALIFORNIA											
AS OF 12/2002	6,229	8,956	2,511	336	2,574	2,262	814	41	3	14	23,740
AS OF 12/1997	6,157	8,832	2,514	341	2,351	2,018	907	40	0	24	23,184
ILLINOIS											
AS OF 12/2002	6,880	1,869	3,517	4,099	8,814	239	128	10	15	25	25,596
AS OF 12/1997	7,032	1,736	4,133	4,057	7,876	185	152	11	13	19	25,214

Bridges in California

- Follow-up plan:
  - MRR history and costs for 48 candidate bridges
  - Condition history for these 48 bridges, if possible
  - Cost information on Pre-stressed R.C. box girder bridges
    - First built in 1960s
    - Designed for less maintenance
  - Timber bridges

Pre-Stressed R.C. Box Girder Bridge

Source: CalTrans

Thank You

Questions?