INNOVATIVE ASSET MANAGEMENT

RELIABILITY BASED OPTIMAL SOLUTION FOR REHABILITATION OF EXISTING BRIDGE STRUCTURES

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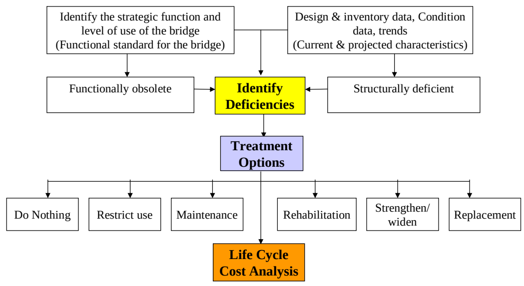
Decision support tools for rehabilitation of concrete Infrastructure

Challenges in Bridge Maintenance and Rehabilitation

- Bridges in the world are ageing
- loads, vehicles and legal load limits for bridges are increasing
- In USA
  - 125,000 deteriorated bridges
  - At least US$90 billion is needed
- In Australia
  - over 60% of bridges for local roads are over 50 years old
  - 55% of highway bridges are over 20 years old

Management are seeking a tool for fund allocation for bridge rehabilitation and the best solution for rehabilitation

Proposed Decision Support Framework



Rehabilitation Strengthening / Widening

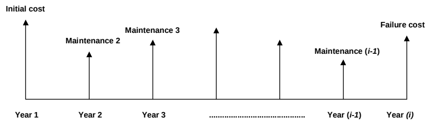
- Conventional rehabilitation methods
  - Post tensioning
  - Steel plate bonding
- Innovative method
  - FRP strengthening

The Challenge in Life cycle costing

- Method adopted for estimating current value
- Identify input parameters
- Integrate all the input parameters
- Allow for uncertainty of the estimation of the input parameters
- Population of the cost elements
- Cost and probability of failure – should we incorporate it ?
- Present the decision maker with a useful comparison

Economic analysis

- Whole of life cycle cost analysis



  - Costs
  - Timing of the costs over analysis period
  - Convert costs to a base date time value
  - Net Present Value (NPV)- evaluation method

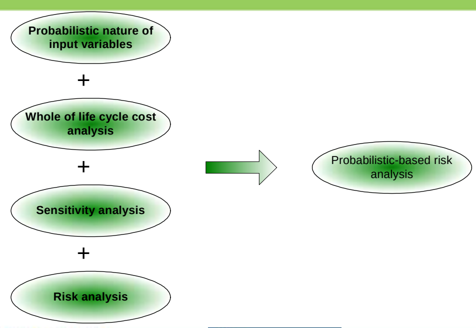
Whole of life cycle cost analysis

- Costs
- Study period
  - For bridges normally greater than 40 years
- Residual value
  - For projects of 30 year study period, this is zero
- Discount rate and inflation
  - Influenced by social, economic and political factors
  - Australia 7%, US 2-3%, UK Department of Transport 8%, Sweden 4% and Finland 6%
- Net Present Value (NPV)
  - Constant dollar excludes rate of general inflation

WLCCA -costs

- Initial cost
  - Design cost
  - Material cost
  - Labor cost
- Maintenance, monitoring and repair cost
  - Material cost
  - Labor cost
  - Traffic control cost
- Costs associated with traffic delays or reduced travel time (Extra user cost)
- Expected failure cost

WLCCA -costs



WLCCA-probabilistic nature

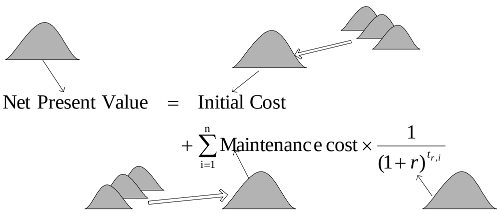
LCCA component	Input variable	Source
Initial and future costs	Preliminary engineering	Estimate
	Construction	Estimate
	Maintenance	Assumption
Timing of costs	Bridge performance	Projection
User costs	Current traffic	Estimate
	Future traffic	Projection
	Hourly demand	Estimate
	Vehicle distributions	Estimate
	Dollar value of delay time	Assumption
	Work zone configuration	Assumption
	Work zone hours of operation	Assumption
	Work zone duration	Assumption
	Work zone activity years	Projection
	Crash rates	Estimate
	Crash cost rates	Assumptions
NPV	Discount rate	Assumption

Variables and Ranges

- Variables and ranges (Austroads, 1996)

Variable	Suggested minimum value	Suggested maximum value
Capital cost (final costing)	-10% of estimate	+10 to 20% of estimate
Operating and maintenance cost	-10% of estimate	+10% of estimate
Total traffic volume	-10 to 20% of estimate	+10 to 20% of estimate
Normal traffic growth rate	-2% pa (absolute) of the forecast rate	+2% pa (absolute) of the forecast rate
Traffic generated or diverted by project	-50% of estimate	50% of estimate
Traffic speed changes	-25% of estimated change in speed	+25% of estimated change in speed
Accident changes	-50% of estimated change	+50% of estimated change

WLCCA-probabilistic nature II



$$\text{Net Present Value} = \text{Initial Cost} + \sum_{i=1}^{n} \text{Maintenance cost} \times \frac{1}{(1+r)^{t_{r,i}}}$$

r = discount rate
tr,i = year of maintenance
n = number of maintenance

Formulation of Whole of life Cycle Cost

Optimal bridge rehabilitation can be found based on following formulations:

$$W = Benefit_{\ life\ cycle} - Cost_{\ life\ cycle}$$

$$Cost_{\ life\ cycle} = Cost_{\ initial} + Cost_{\ repair} + Cost_{\ life\ users} + Cost_{\ failure}$$

$$C_{maintenace}(t_{r,i}) = C_1(t_{r,i}) + C_2(t_{r,i}) + C_3(t_{r,i})$$

$$C_{repair} = \sum_{i=1}^{n} \left(1 - P_f(t_{r,i})\right) C_{maintenance}(t_{r,i}) \frac{1}{(1+r)^{t_{r,i}}}$$

$$C_{user} = \sum_{i=1}^{n} C_{user}(t_{r,i}) \frac{1}{(1+r)^{t_{r,i}}}$$

$$Expected\ Cost\ of\ Failure = \sum_{j=1}^{M} p_{f,j} C_{f,j}$$

Case study - Identify structure and logic of problem

- Identify basic elements
- Organize them in an analytical model using

$$NPV = \text{Initial Cost} + \sum \text{Future Costs} \left[\frac{1}{1+i}\right]^n$$

- Tools for modeling – existing software

Include uncertainty using probability

- Define probability distributions for uncertain input variables based on previous research
- normal distribution (mean, std. dev.)
  - Initial Dept. cost
  - Future rehabilitation cost
- Triangular distribution (min, most likely, max)
  - Service life (initial)
  - Service life (rehabilitation)
  - Discount rate

Existing Software for probabilistic analysis

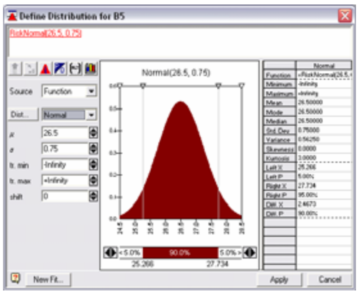
- Crystal ball
- Anthill
- @Risk

@Risk was observed to be most user friendly and has the advantage of the ability to work with a spreadsheet such as Excel.

User Interface

- Complexity of defining the input and simulation requirement
- Need to customize the tool for decision making in bridge asset management
- Generation of user friendly reports with capability of extracting information

Probability distribution - example

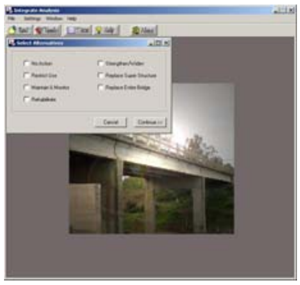


Simulation - adopted

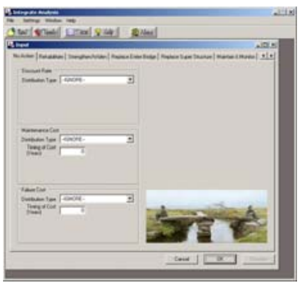
- Select different random sets of values from the input probability distributions
- Calculate discrete result for each set
- Make an array of results in form of distribution covering all possible outcomes
- Monte Carlo simulation
  - Each iteration gives a possible scenario of outcome
  - Each iteration result is captured, compiled and subjected to statistical analysis
  - Sampling process continues until simulation process converges
  - Large number of iterations required

Software Tool

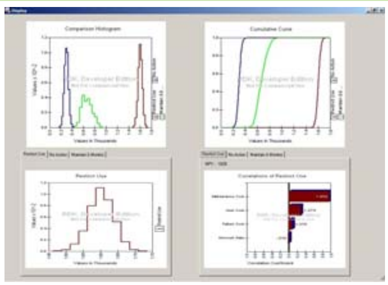
User Interface



Input Screen



Output



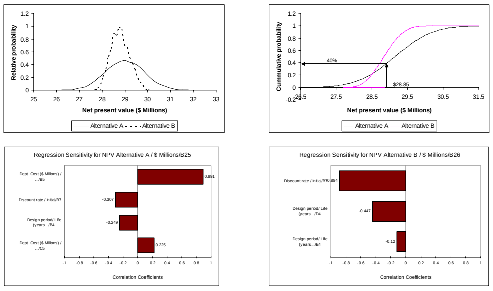
Typical comparison of two alternatives

- Alternative A

  Initial cost- estimated = 29.15 million
- Alternative B

  Initial cost-estimated = 28.85 million

Output



Current research challenges

- Overall calibration of the methodology
- Establishing user cost
  - Time of day, duration of closure etc.
- Establishing failure cost:

  Probability of failure X Cost of failure
  - Estimation of probability of failure
    - Assume if the design capacity is reached 5% probability of failure ?
    - Cost of failure: cost of loss of life to be included ?

THANK YOU