Side-by-Side Box Beam Bridge Life-Cycle Cost Analysis

For Better Investment and Engineering Decisions

By

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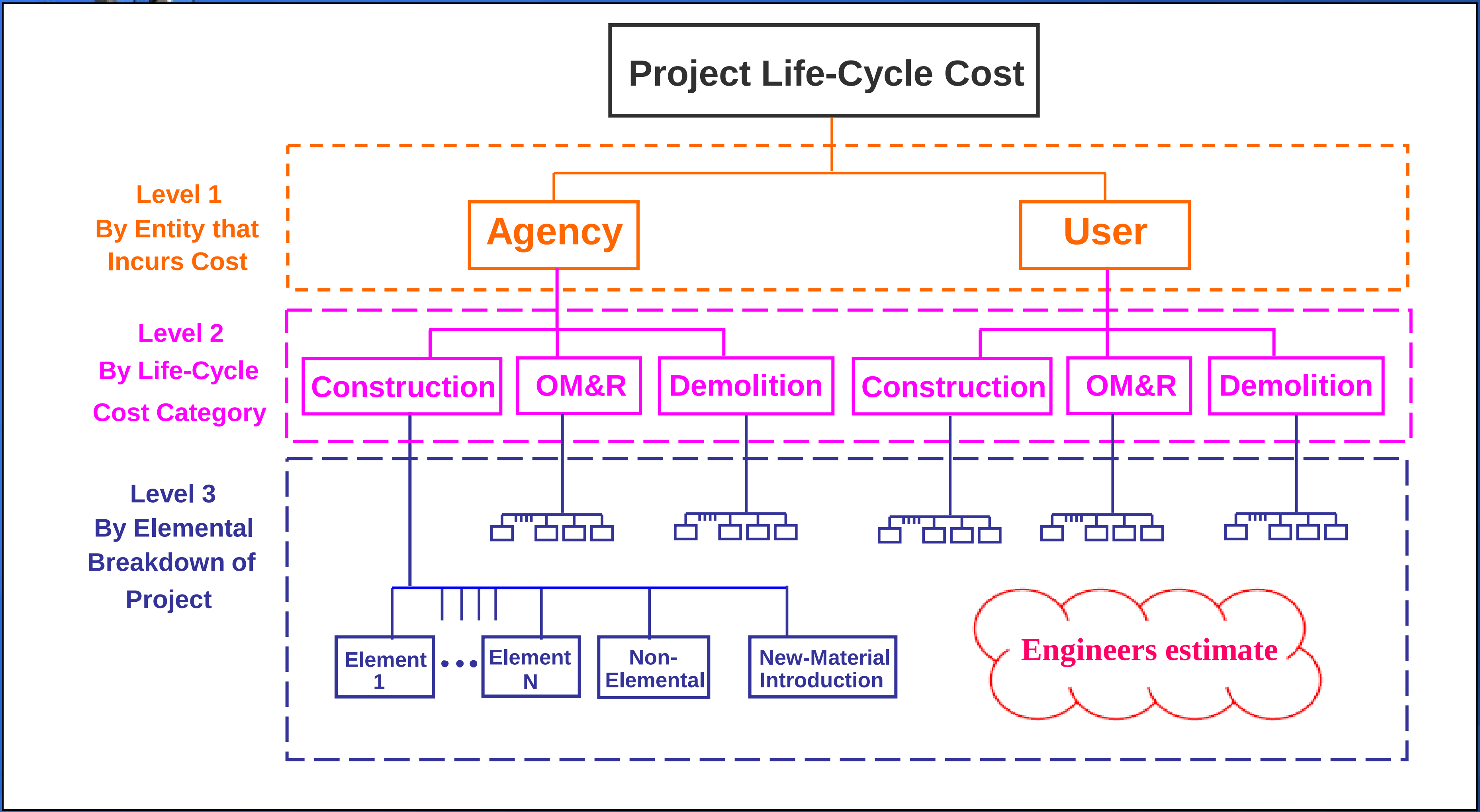
The LCCA Methodology

- Establish design alternatives
- Determine activity timing
- Estimate costs (agency and user)
- Compute life-cycle costs
- Analyze the results

Classification of Project LCC



User Cost

Travel time Costs = $$\left(\frac{L}{S_a} - \frac{L}{S_n}\right) \times AADT \times N \times w$$

L = length of affected roadway over which cars drive;
S_a = traffic speed during bridge work activity;
S_n = normal traffic speed;
$AADT$ = Annual Average Daily Traffic;
N = number of days of road work;
w = hourly time value of drivers;

Vehicle Operating Costs = $$\left(\frac{L}{S_a} - \frac{L}{S_n}\right) \times AADT \times N \times r$$

r = hourly vehicle operating cost;

Crash Costs = $$L \times AADT \times N \times (A_a - A_n) \times c_a$$

A_a = during-construction accident rates per vehicle-mile;
A_n = normal accident rates per vehicle-mile;
c_a = cost per accident.

Inflation and Discounting

The real discount rate (r)

$$r = [(1 + d) / (1 + i)] - 1$$

$$= (d - i) / (1 + i)$$

$$\approx d - i$$

Where: r = real discount rate,

i = inflation rate,

d = nominal discount rate

(also called interest rate, funding rate)

LCC Calculations

$$LCC = \sum_{t=0}^{T} \frac{C_t}{\left(1+r\right)^t}$$

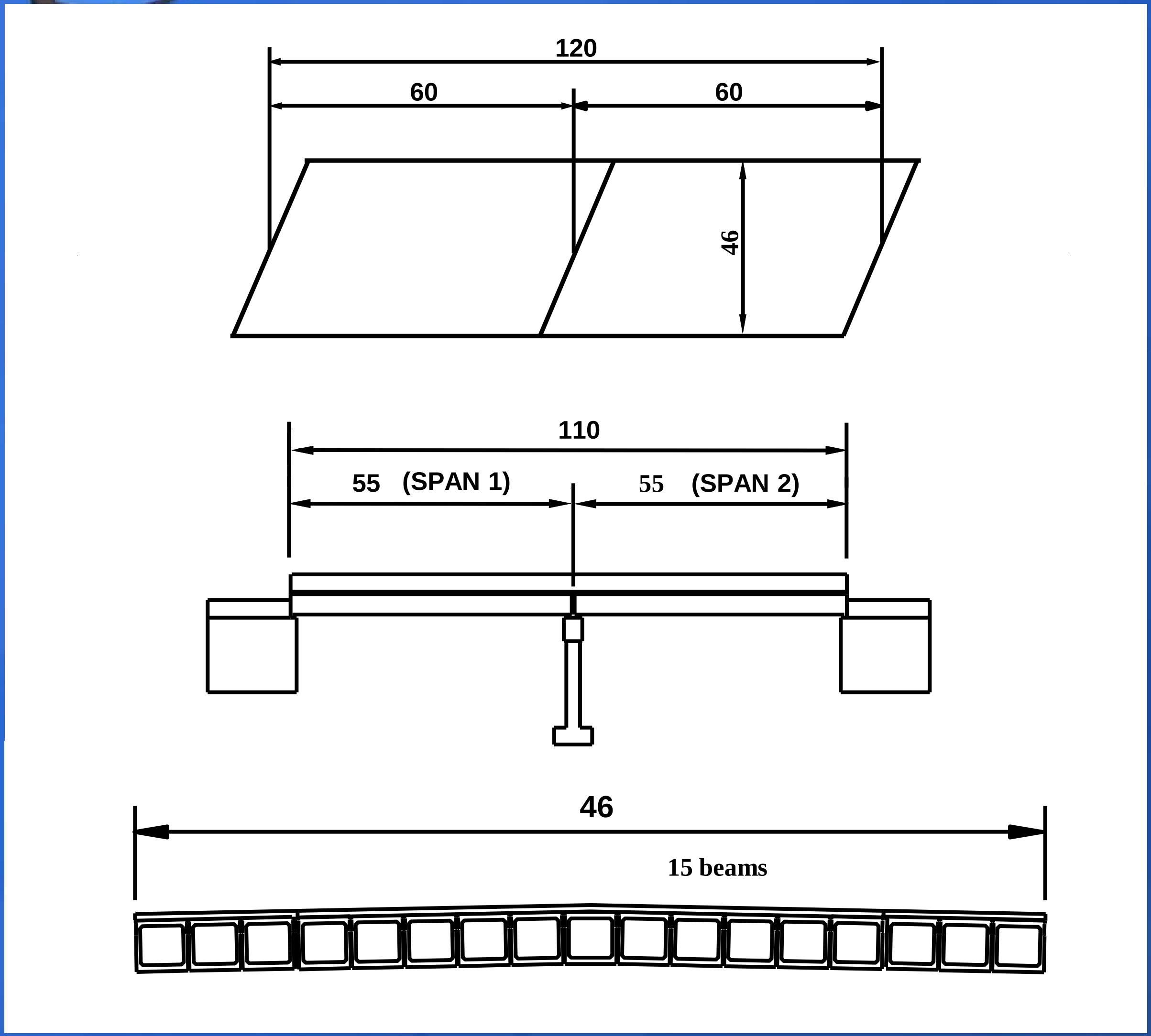
C_t = sum of all costs incurred at time t

r = real discount rate for converting time t costs

T = number of time periods in the analysis period

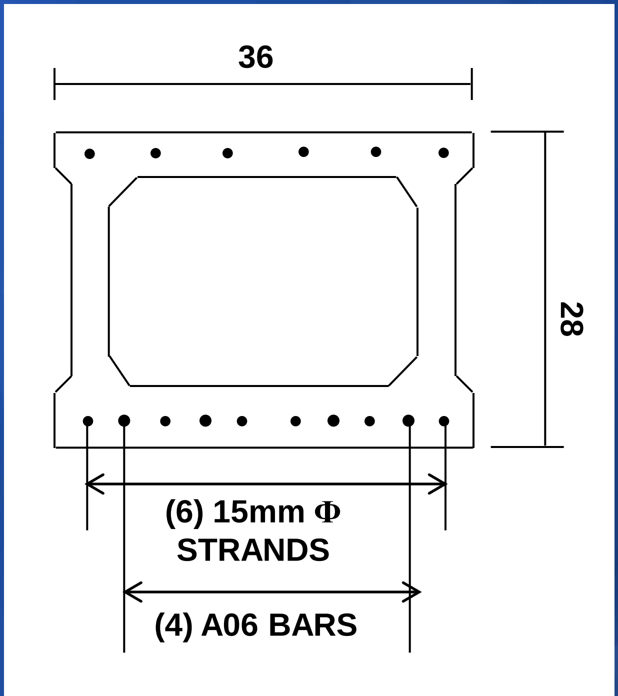
General Plan of Bridge

Case Study



Bridge dimensions are in ft.

Dimensions are in inch



Establish Design Alternatives

- Bridge with black steel reinforcement and with cathodic protection
- Bridge with epoxy-coated steel reinforcement
- Bridge with CFRP reinforcement

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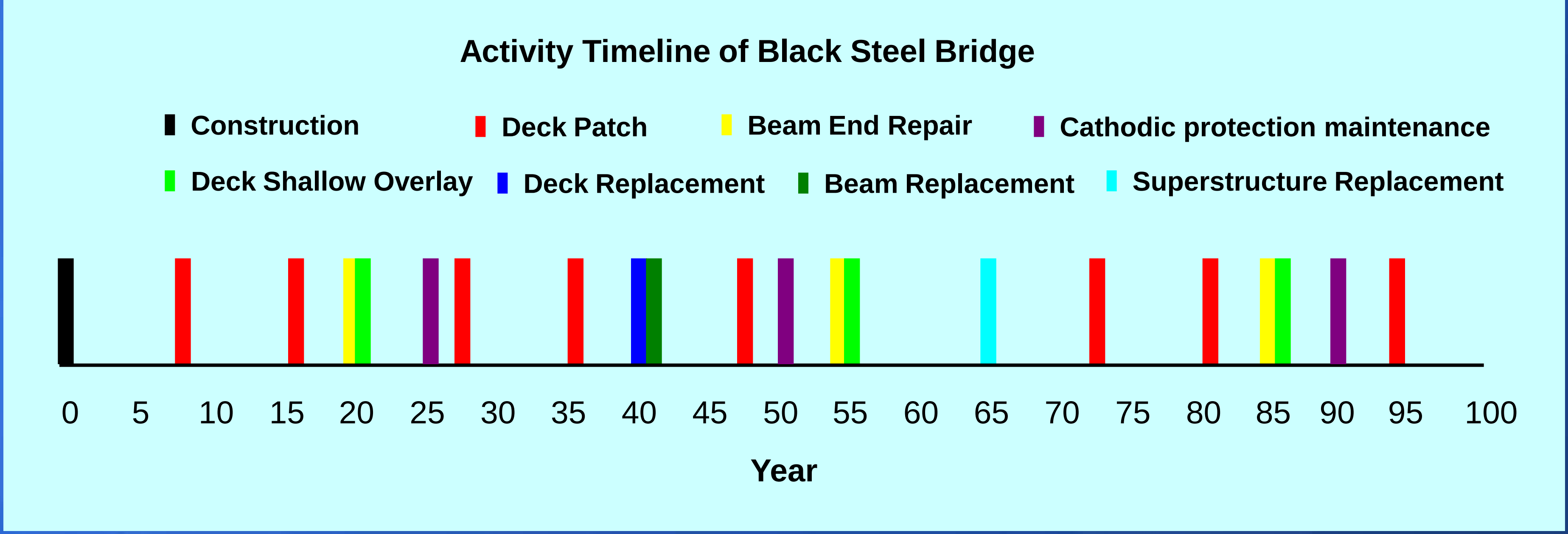
Determine Activity Timing



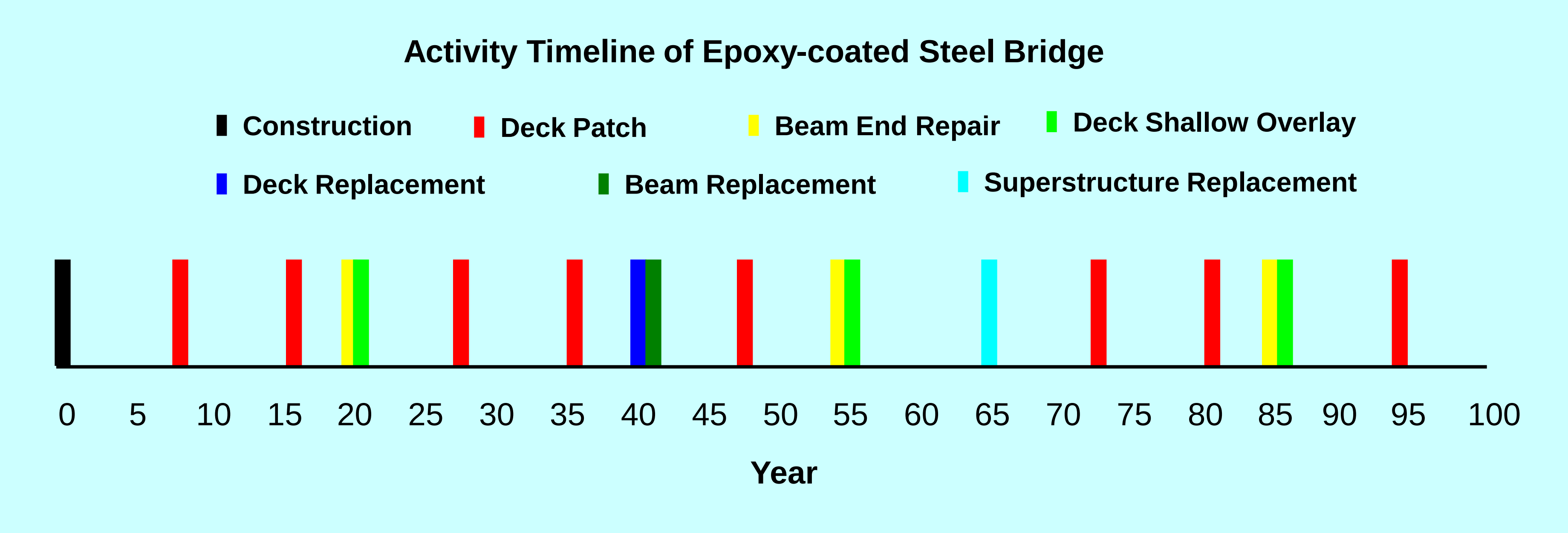
Routine inspection every two years

Detailed inspection every five years

Cathodic protection maintenance every year

Determine Activity Timing

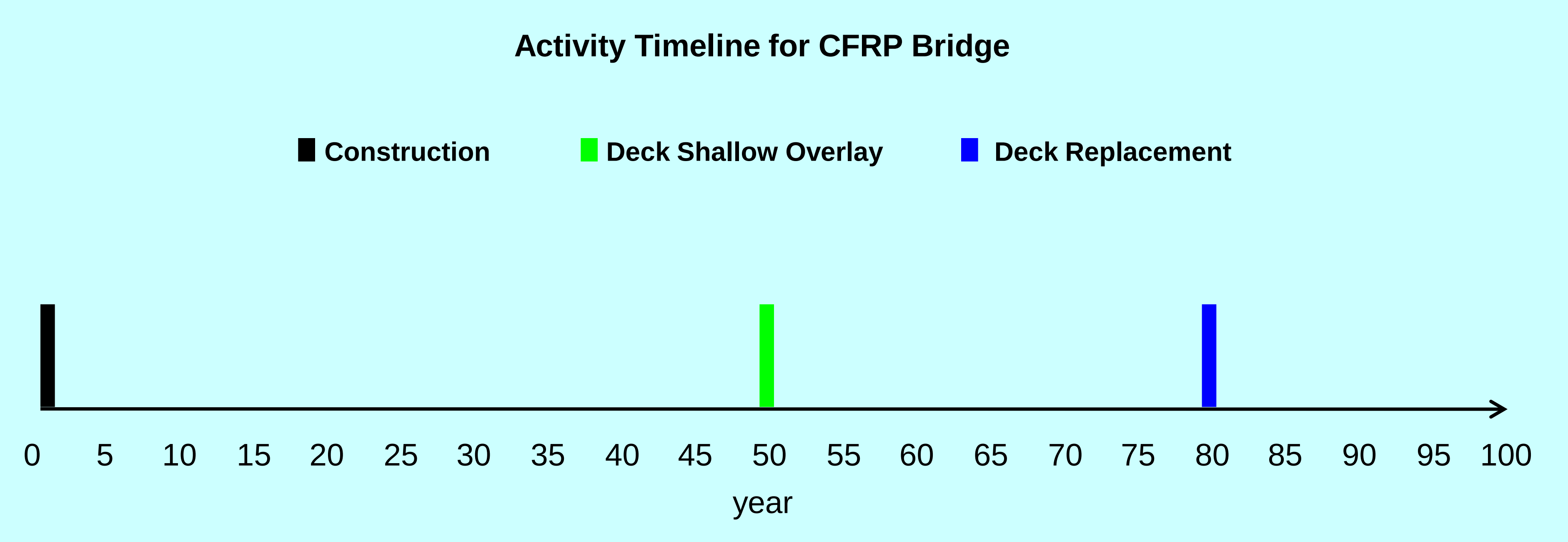
The same activity timing with black steel bridge except cathodic protection activity



Routine inspection every two years

Detailed inspection every five years

Determine Activity Timing



Detailed inspection every ten years

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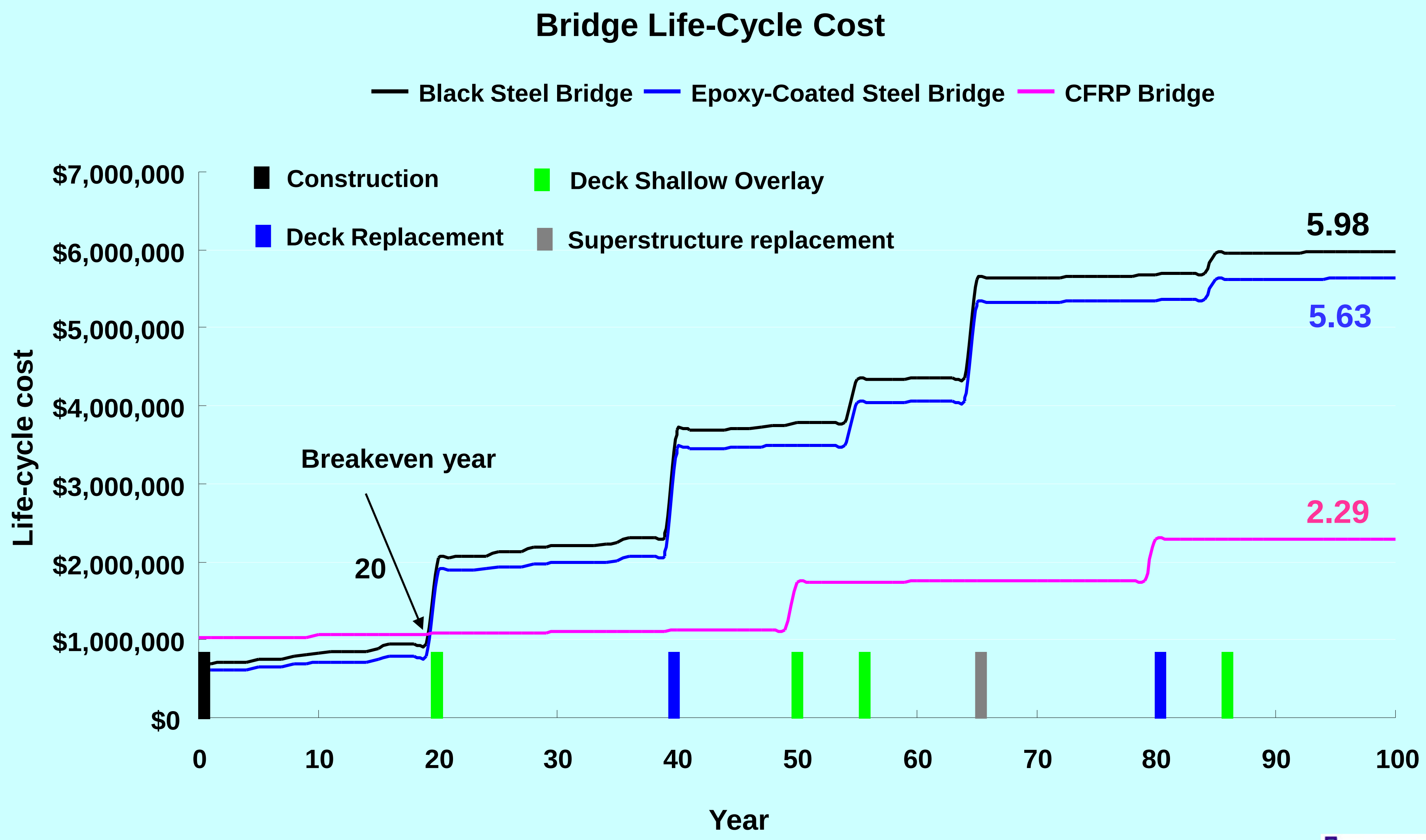
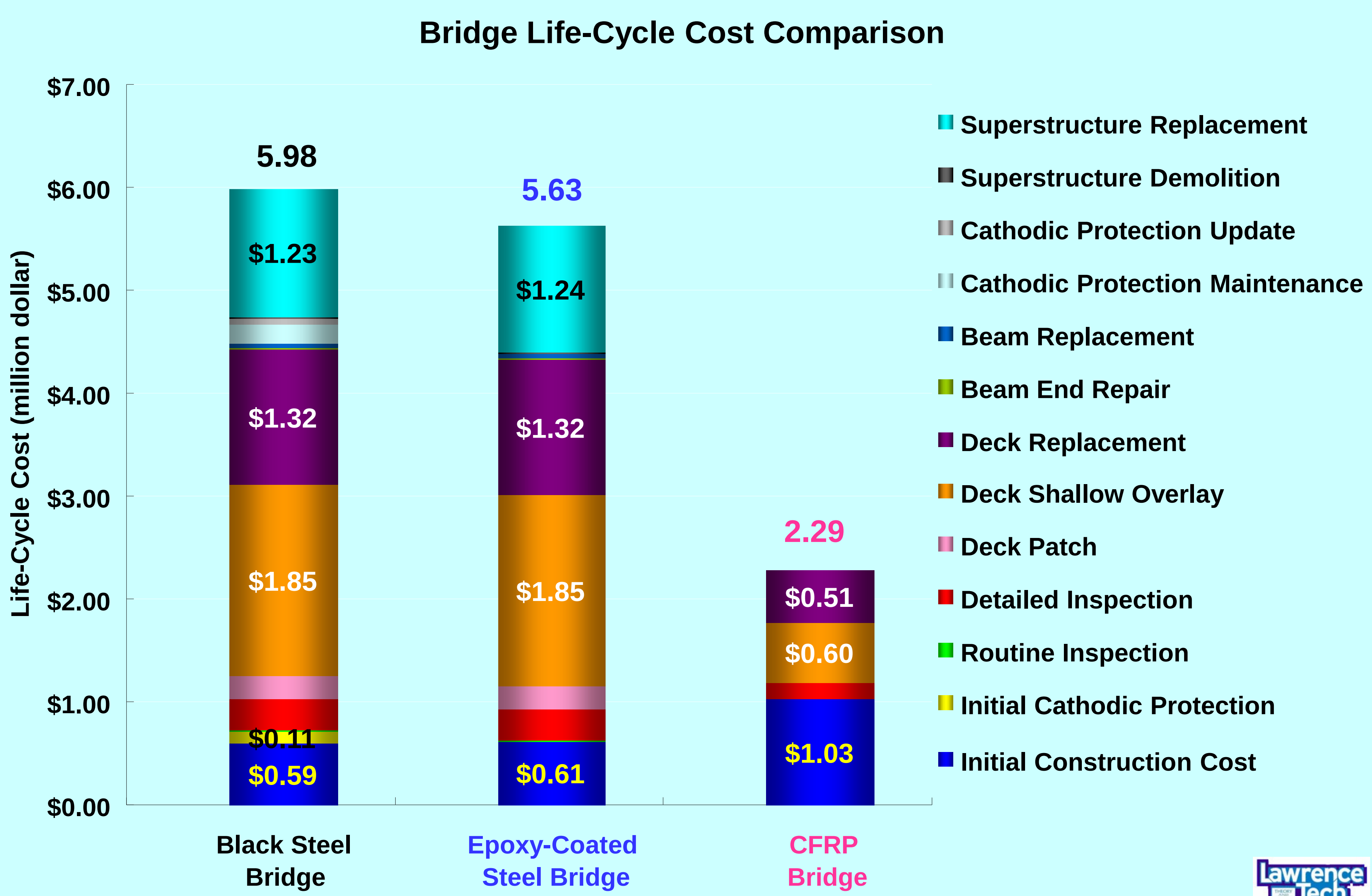
Medium span bridge with High-traffic-below and High-traffic-above



Medium span bridge with High-traffic-below and High-traffic-above



Sensitivity Analysis

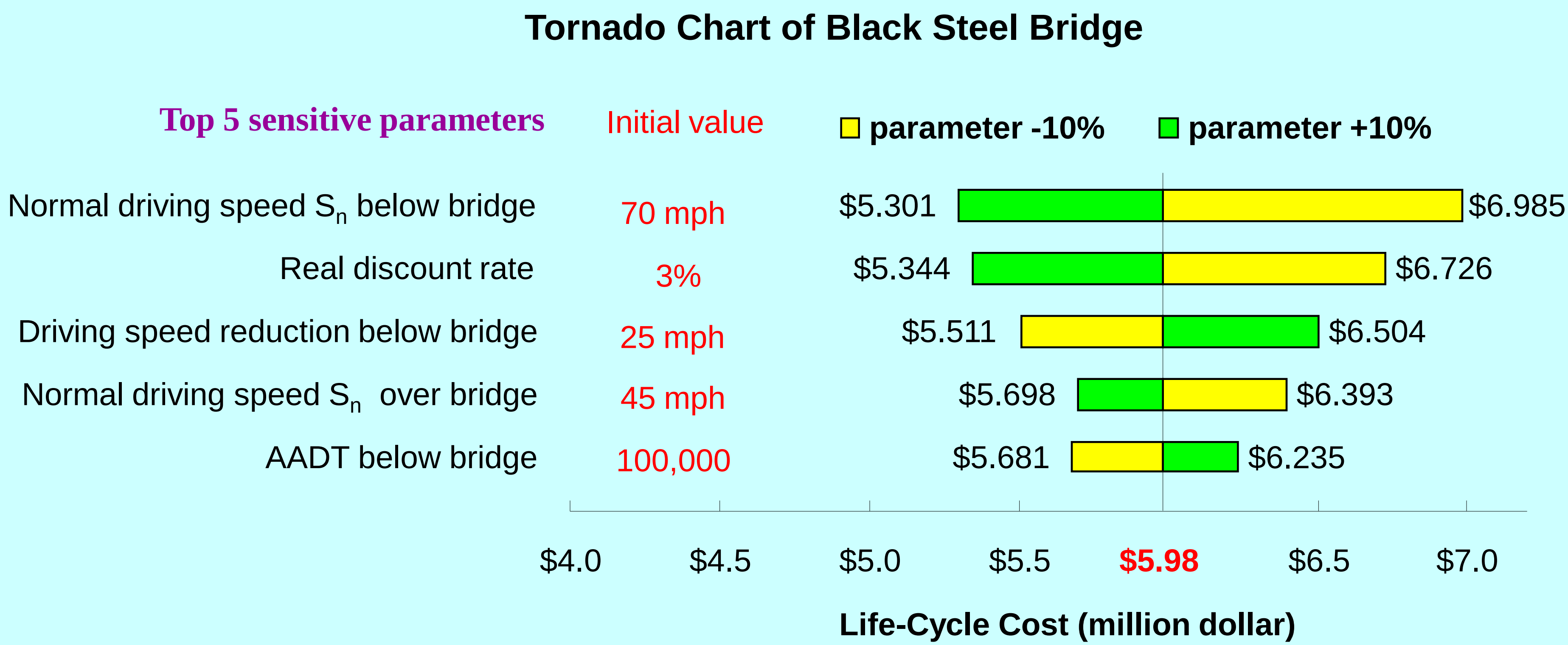
- Sensitivity analysis studies the manner of how the most optimal target solution or function (Output), would be affected by changes in the value of one or more parameters (Input) of a model, while the rest of them remain unchanged.

Sensitivity Analysis

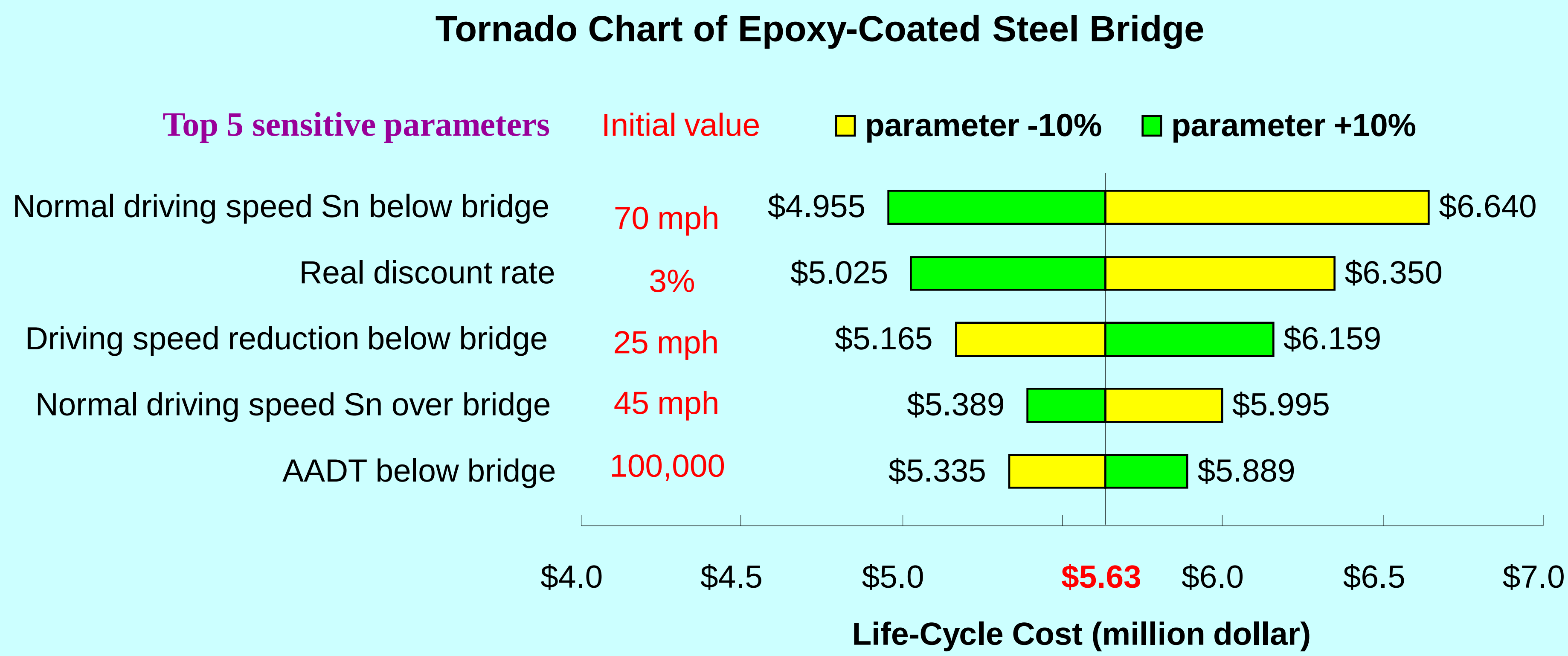
Tornado chart

- Tornado chart shows a graphical representation of the changes produced in the target optimal solution or function whenever a specific quantity or value in a model's parameters changes.

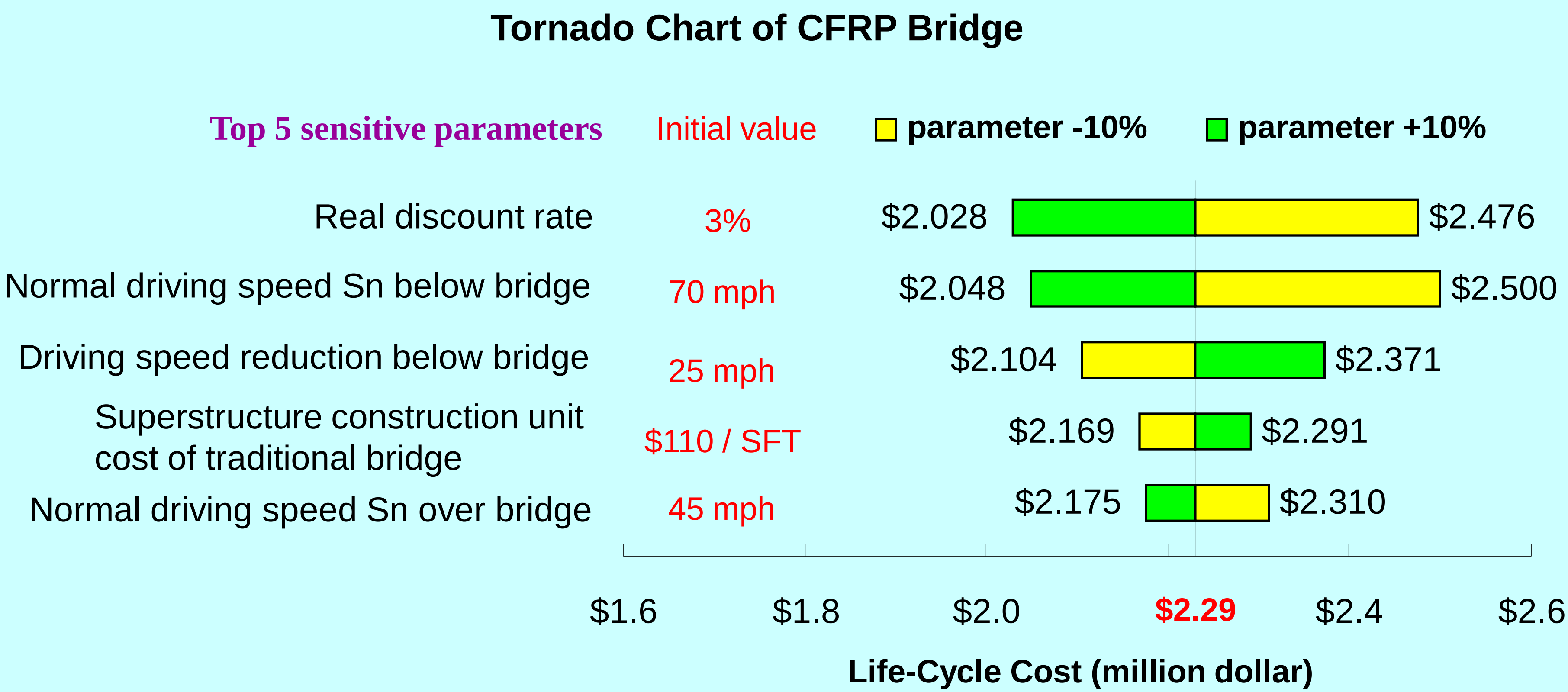
Sensitivity Analysis



Sensitivity Analysis



Sensitivity Analysis

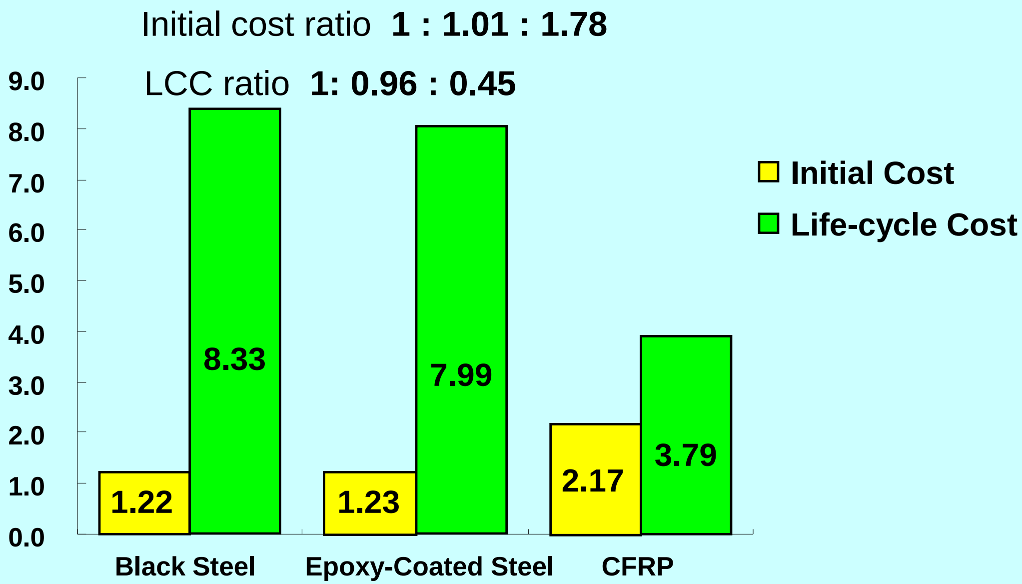


Parameter Study

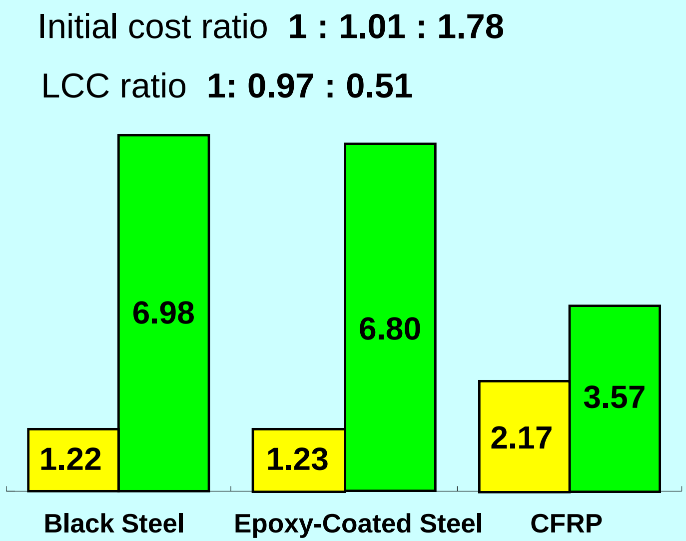
Parameter Matrix		Short-span bridge (30ft - 60ft) Double span (45ft)	Medium-span bridge (60ft - 110ft) Double span (60ft)	Long-span bridge (110ft -) Double span (122ft)
Low traffic below Bridge	Low traffic above bridge	C	C	N/C
	High traffic above bridge	C	C	N/C
Medium traffic below bridge	Low traffic above bridge	C	C	C
	High traffic above bridge	N/C	C	C
High traffic Below bridge	Low traffic above bridge	N/C	C	C
	High traffic above bridge	N/C	C	C

C: Considered　　N/C : Not considered (Not so common)

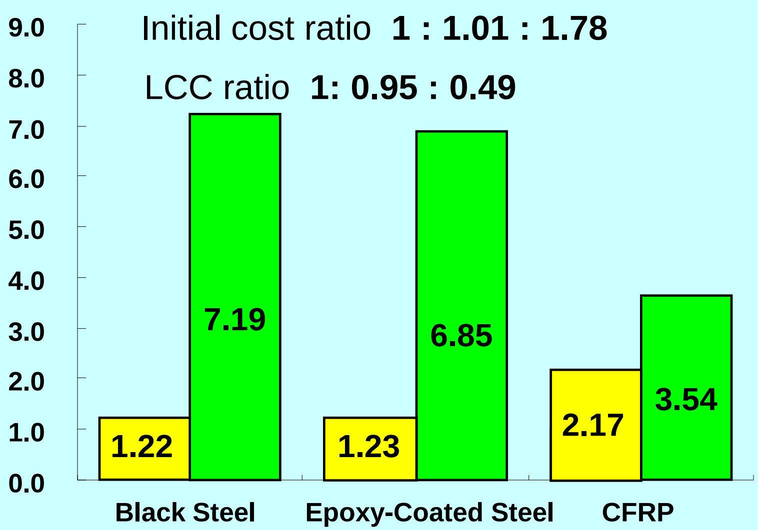
Long span Box Beam Bridge (122 ft span)



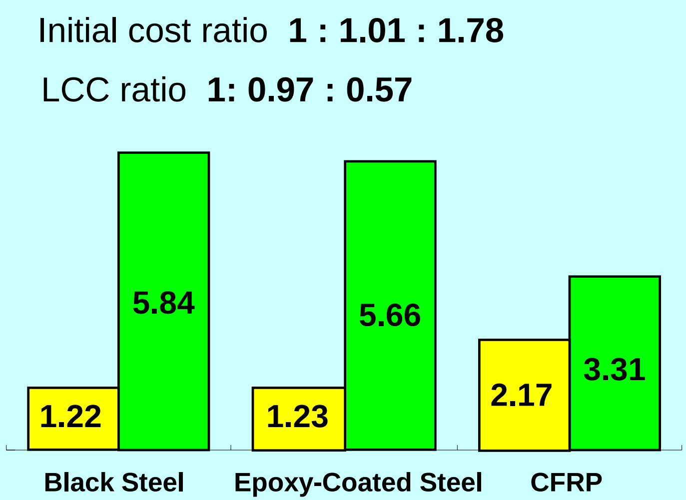
High-traffic-below & High-traffic-above



High-traffic-below & Low-traffic-above

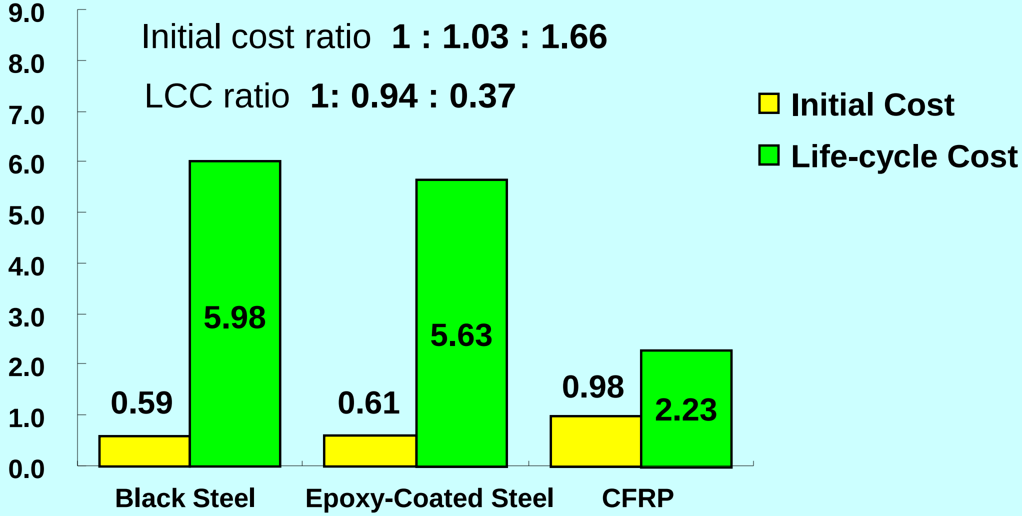


Medium-traffic-below & High-traffic-above

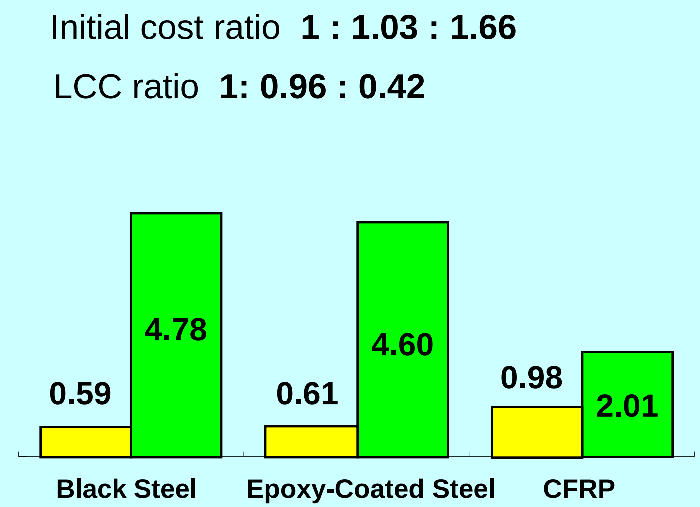


Medium-traffic-below & Low-traffic-above

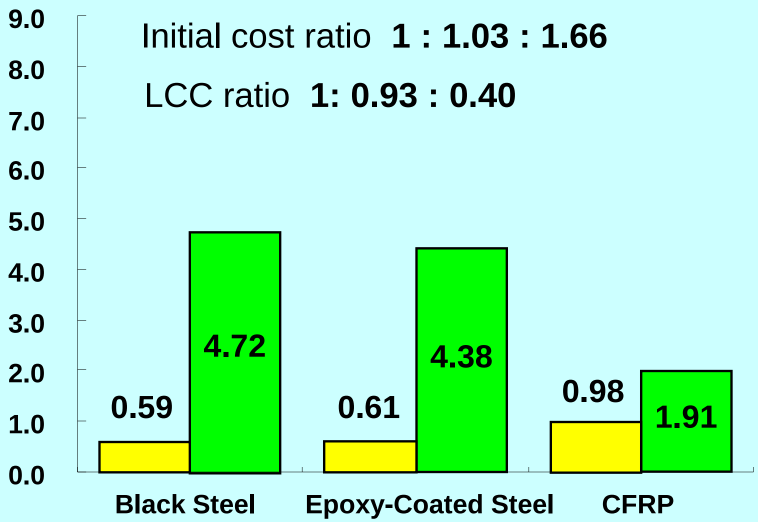
Medium span Box Beam Bridge (60 ft span)



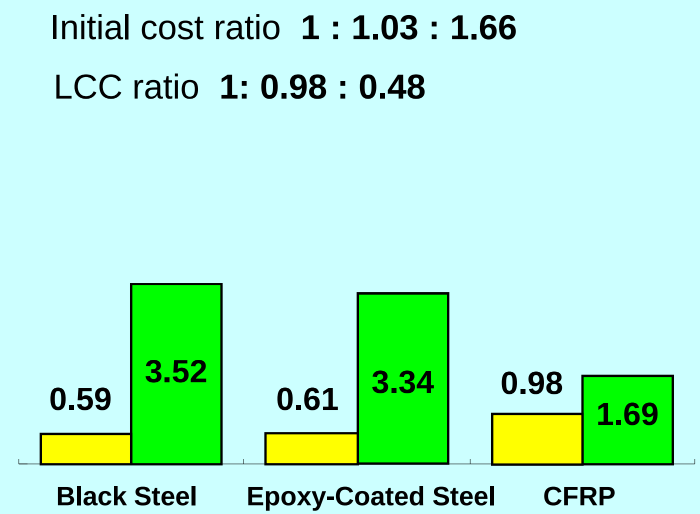
High-traffic-below & High-traffic-above



High-traffic-below & Low-traffic-above

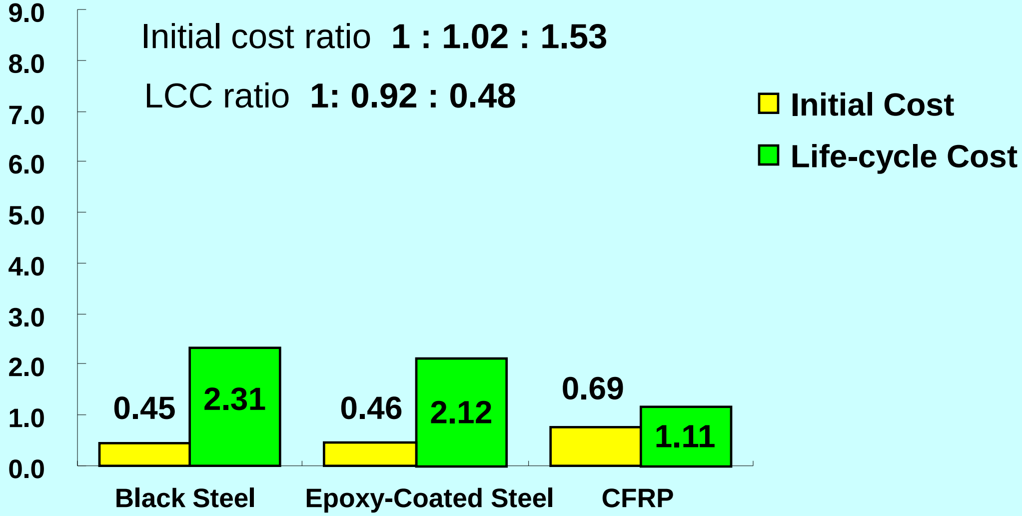


Medium-traffic-below &High-traffic-above

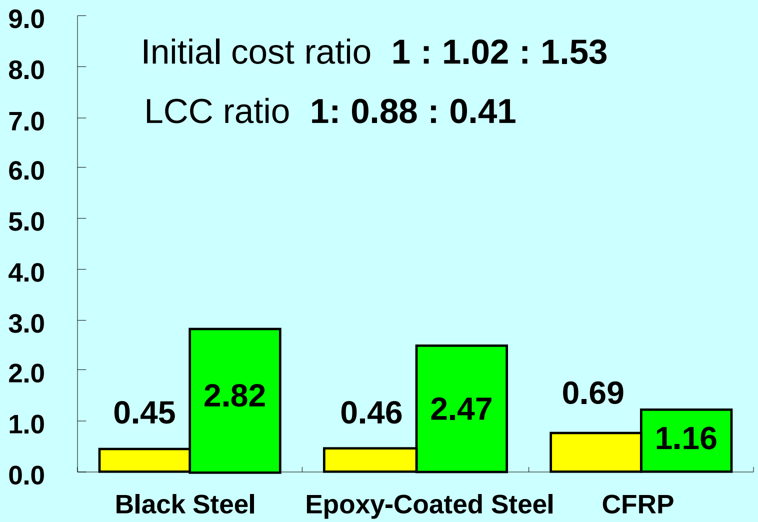


Medium-traffic-below & Low-traffic-above

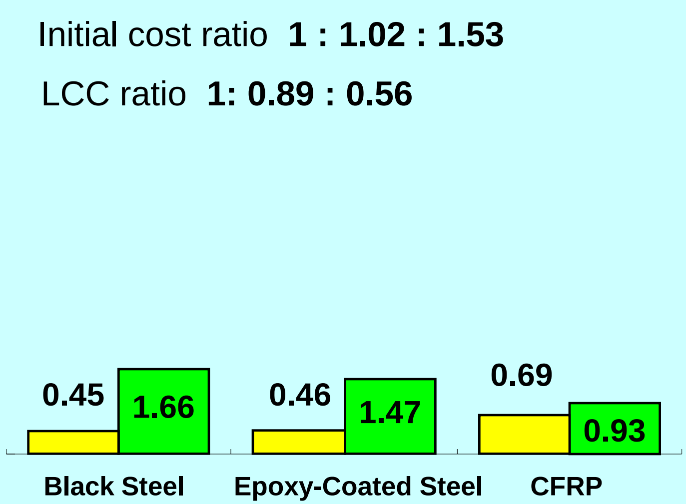
Short span Box Beam Bridge (45 ft span)



Medium-traffic-below & Low-traffic-above

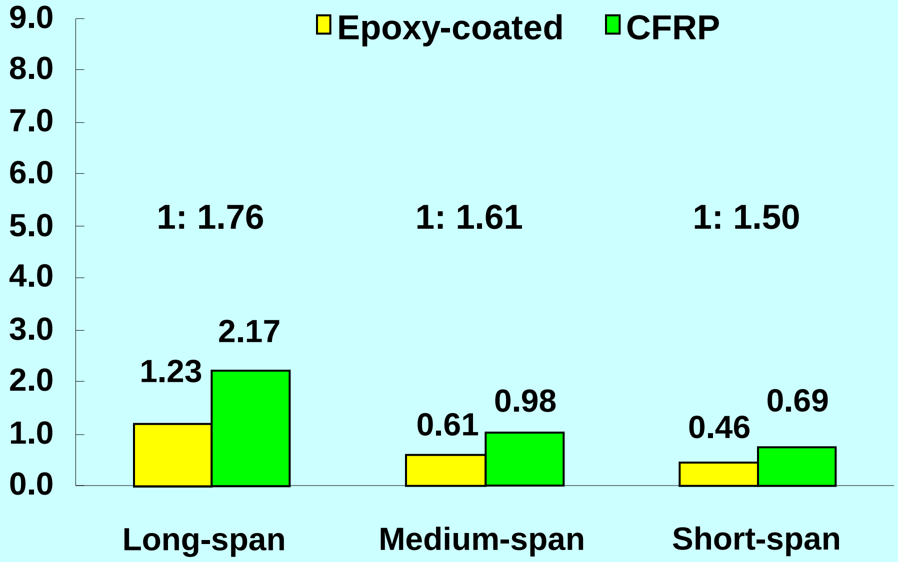


Low-traffic-below & High-traffic-above

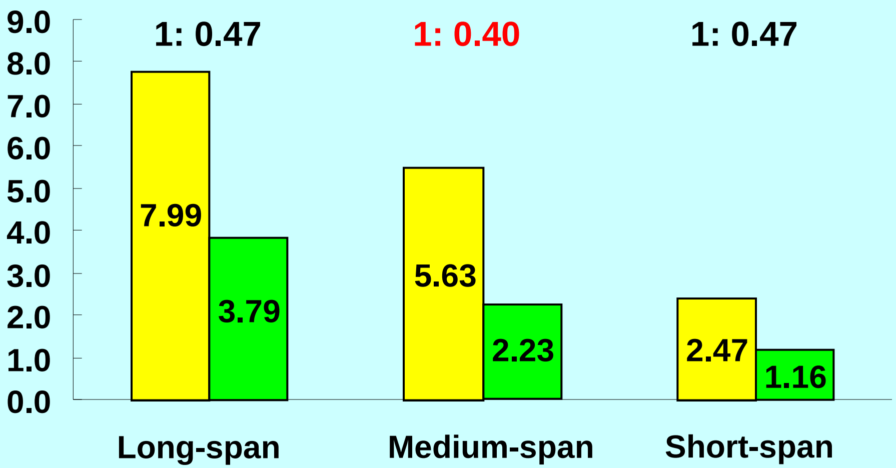


Low-traffic-below & Low-traffic-above

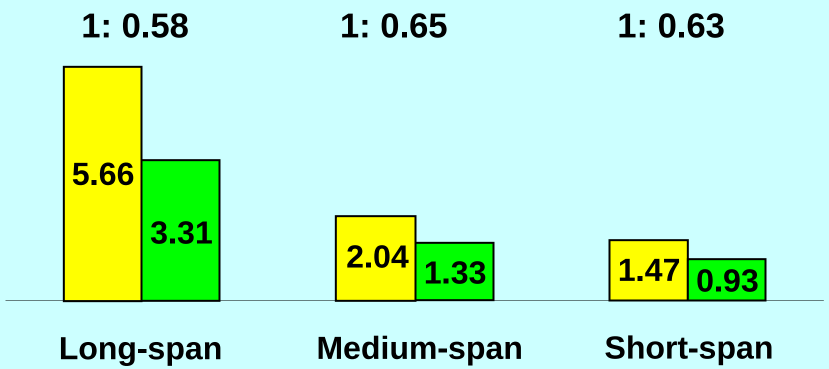
Initial Cost Comparison



LCC Comparison (Most traffic)



LCC Comparison (Least traffic)



Conclusions

With the results of the completed analysis of all the thirteen side-by-side box beam bridges, the following conclusions have been drawn:

- Bridges built with CFRP reinforcement are ***more economical*** than traditional bridges for LLC

- **Medium-span bridge is the most cost-efficient** on initial construction cost when CFRP reinforcement is used

- Among these thirteen bridges, “Medium-span with High-traffic-below & High-traffic-above” is the most cost-efficient one when CFRP reinforcement is integrated in the design

THANK YOU!