LCC Added-Value Analysis

Equation (1) presents the criterion for evaluating the contractors' D-B bids mathematically.

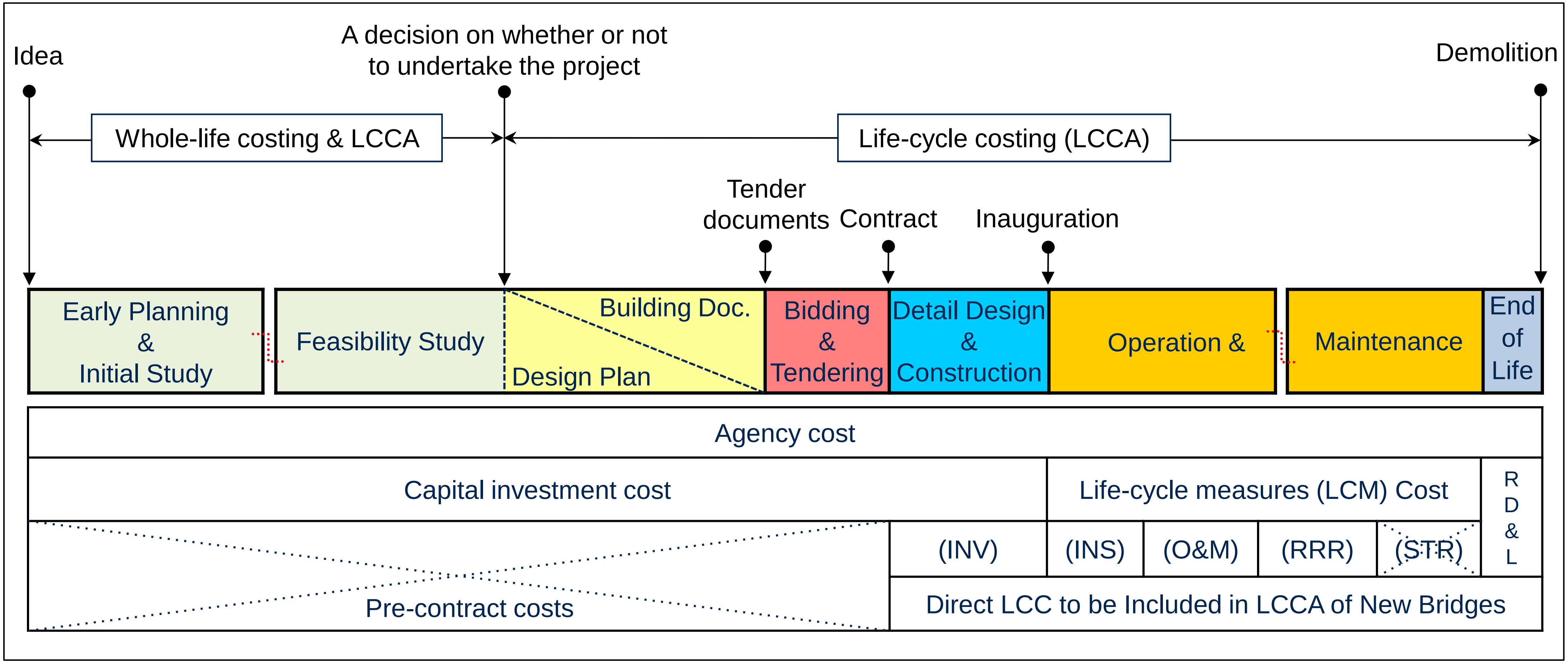
$$LCC^{X,R} = C_{INV}^{X} + LCC_{AV}^{X,R} \qquad \mathbf{(1)}$$

Proposal R is given an LCC added-value of zero, and the LCC added-value for proposal X is calculated using equation (2), with adjustments (if necessary) for differences between them in lifespan and associated LCM costs:

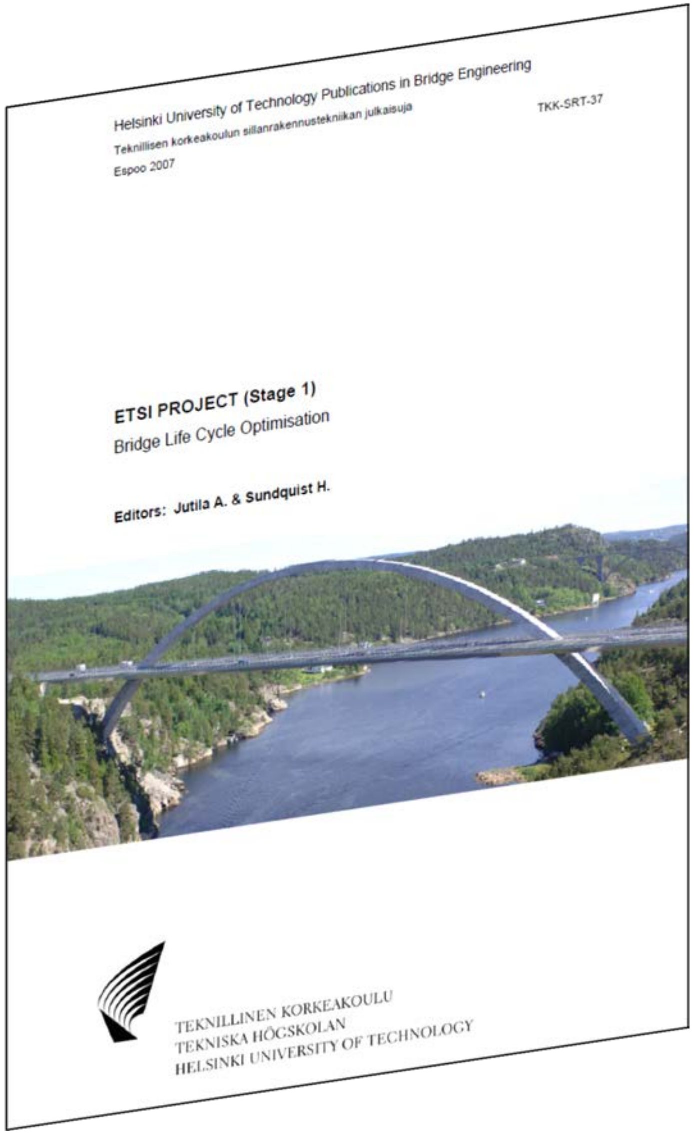
$$LCC_{AV}^{X,R} = \left(\left(EAC_{LCM}^{X} - EAC_{LCM}^{R}\right) \cdot \frac{1-(1+r)^{-L_{min}}}{r}\right) \mp \left(\frac{EAC_{AINV}^{R}}{(1+r)^{L_{min}}} \cdot \frac{1-(1+r)^{-\left|L_R - L_X\right|}}{r}\right) \qquad \mathbf{(2)}$$

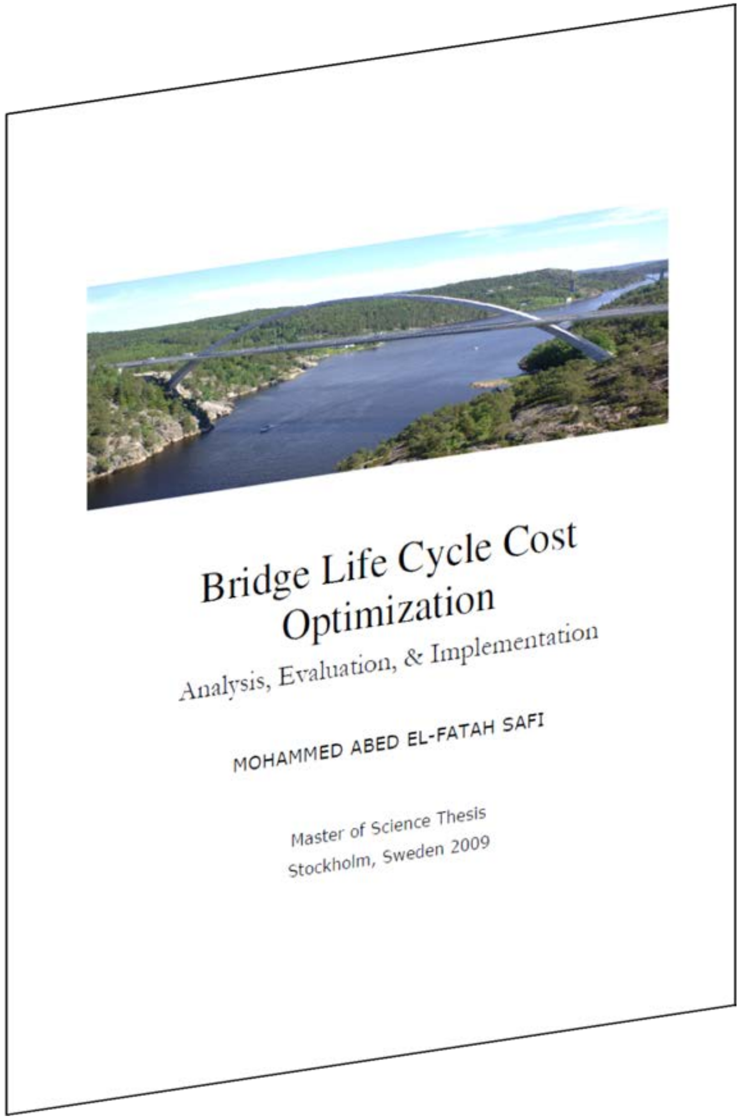
The second part of equation (2) will have a positive sign if $L_X < L_R$ and vice versa.

Cost categories to be Included in LCCA of New Bridges



Paper V: Origin if the Idea





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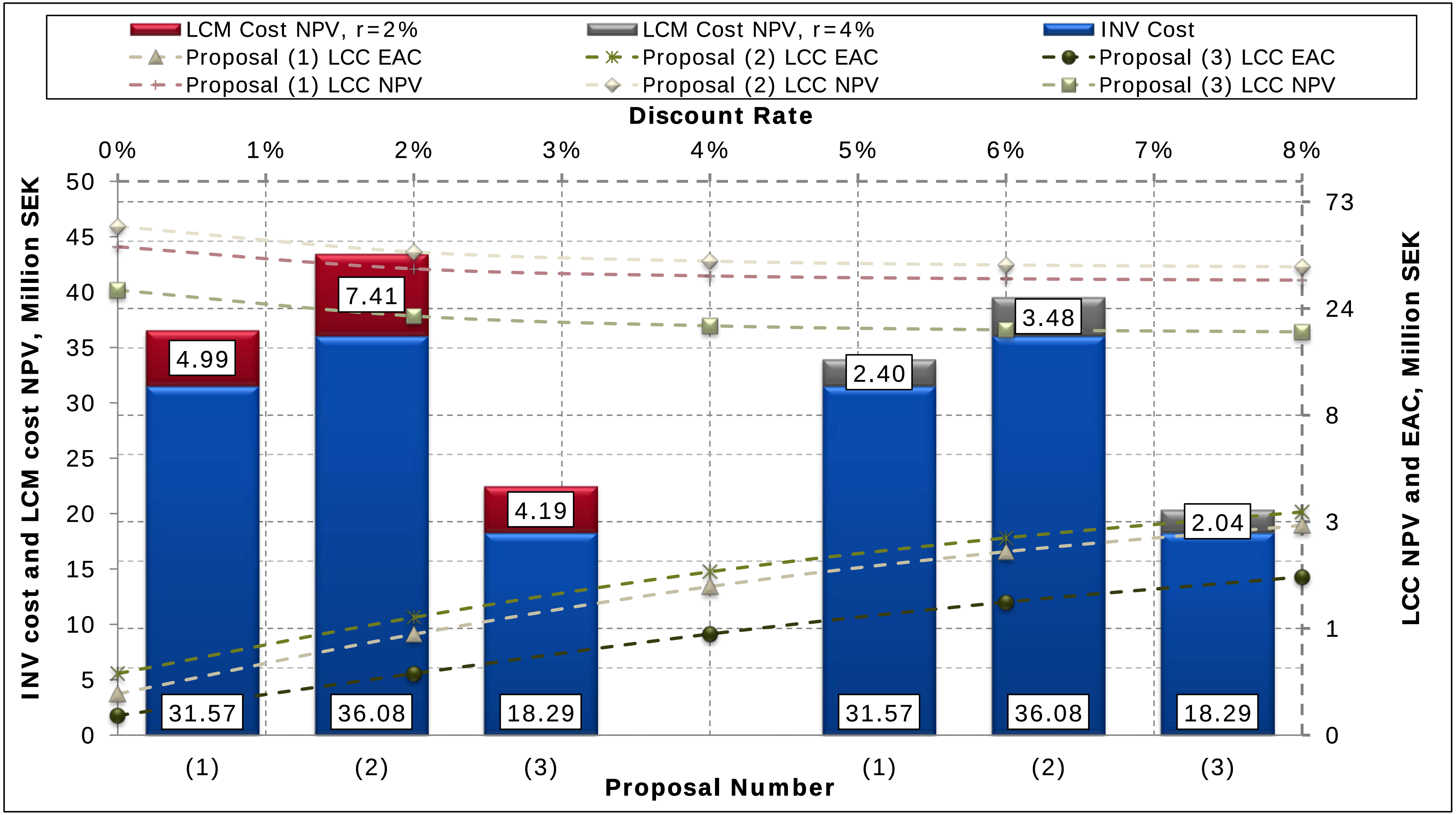
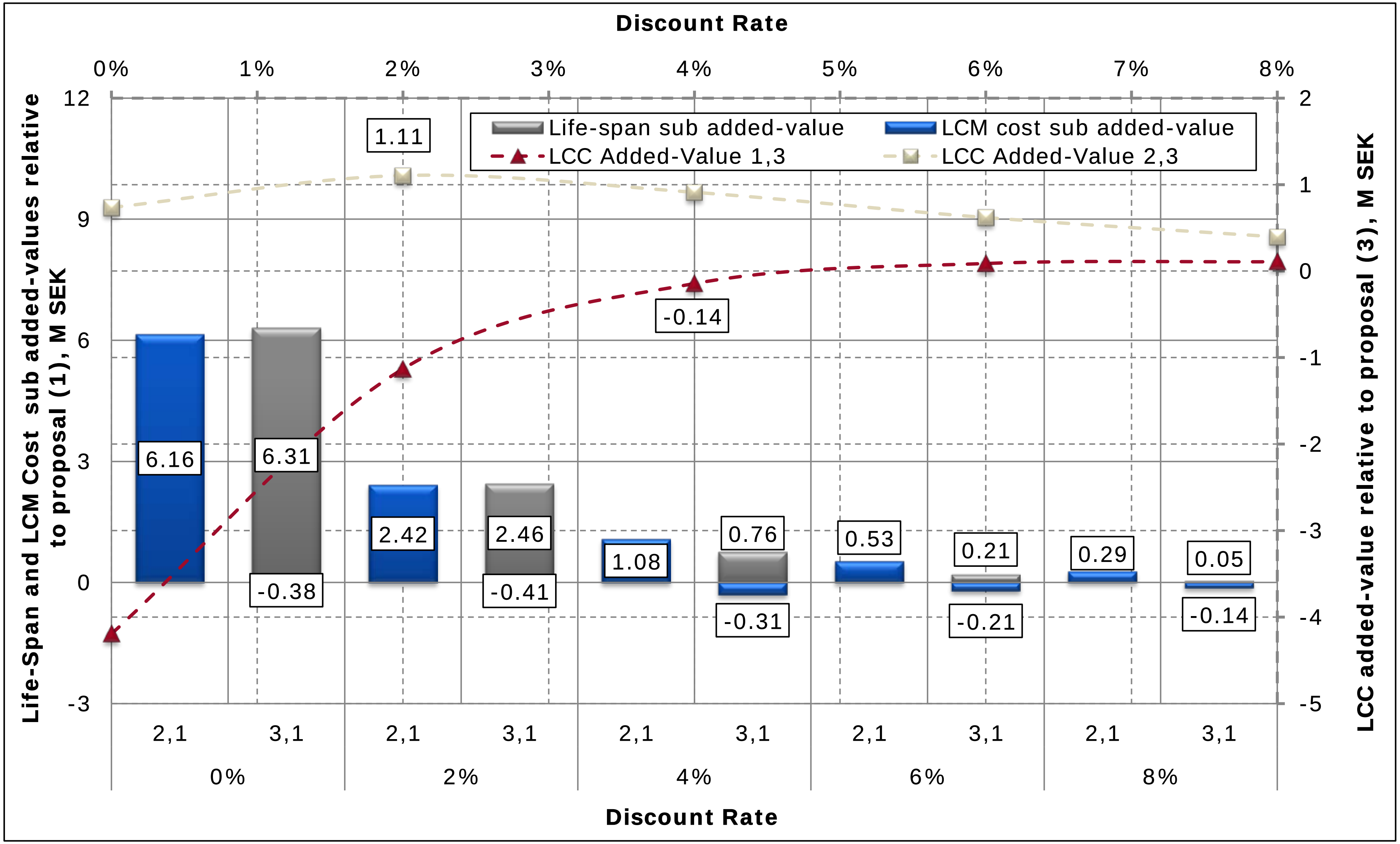
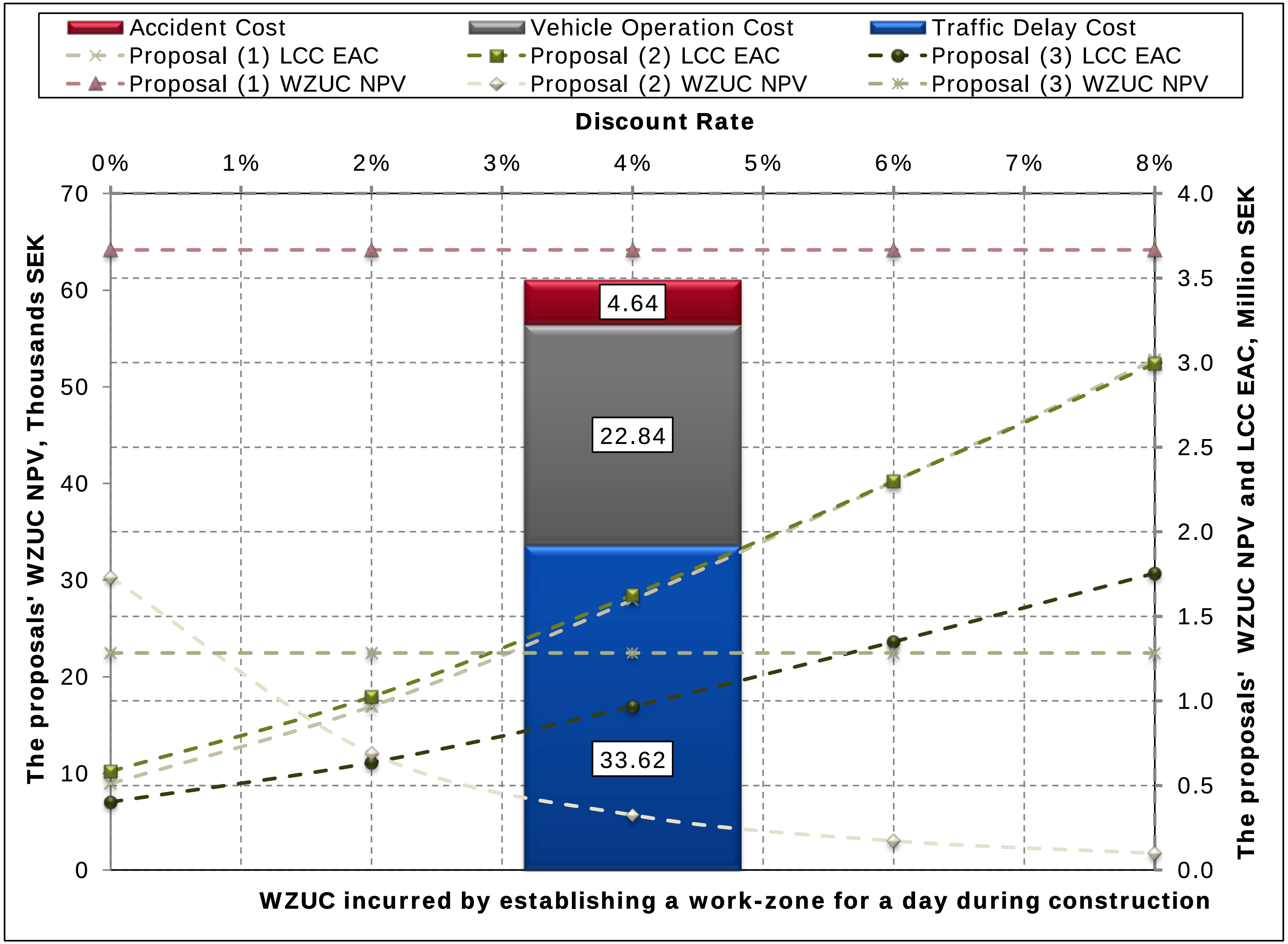
LCCA



Cost Equivalent of the Lifespan and LCM cost difference



Work-Zone User Cost



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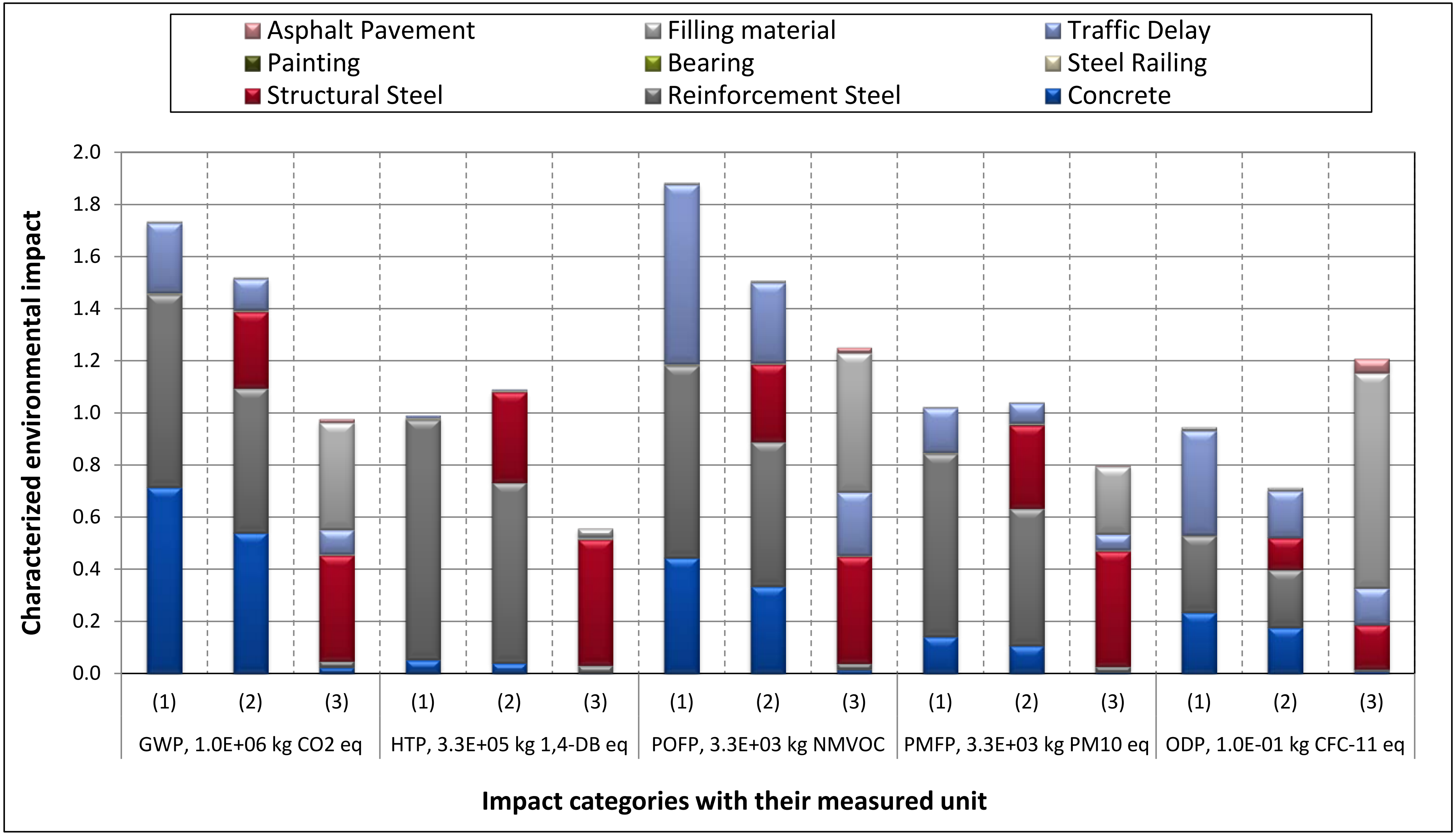
Integration and Evaluation of Aesthetic Aspects

Items considered for evaluation				Weight factors w_j (out of 100)	Average evaluation points p_j for Proposal no.		
					1	2	3
Structure simplicity and integration with the site				10	1	-1	2
Structure honesty and visibility from the underpass traffic perspective				10	1	1	-2
Bridge view from above				10	1	-1	2
Bridge form as a whole	Symmetry, order & rhythm			5	1	1	2
	Unity of design and harmony of spans			5	0	-1	2
	Proportion	Depth to span ratio		5	1	1	2
		Deck to parapet depth ratio		2	0	0	1
		Span to parapet depth ratio		2	0	0	1
Structural-members	Superstructure	Parapet design & shape		5	1	0	2
		Girder	Elevation	5	0	0	2
			Cross-section	4	-1	-2	2
	Substructure	Headstock and pier combination		5	0	-2	2
		Piers	Longitudinal pier spacing	4	-1	-1	-2
			Pier cross-section	4	1	-1	-2
			Pier short elevation	2	0	0	-2
			Pier long elevation	2	0	0	-2
	Abutments	Visible size		4	1	1	2
		Placement		2	1	1	1
		Shape		4	1	1	2
	Details	Joints and connections		3	0	0	1
		Barriers & railings		3	1	1	1
		Lighting, color & embellishments		4	1	1	2
Aesthetic coefficient: k^{X}_{AES}					-0.29	0.07	-0.50
Willingness-to-pay-extra for the bridge's aesthetic appeal: $WTPE_{ACE}$, (Million SEK)					3.66		
Cost equivalent of the aesthetic merit: $CEAM^{X}$, (Million SEK)					-1.06	0.26	-1.83
Aesthetic rank					2nd	3rd	1st

LCA Results

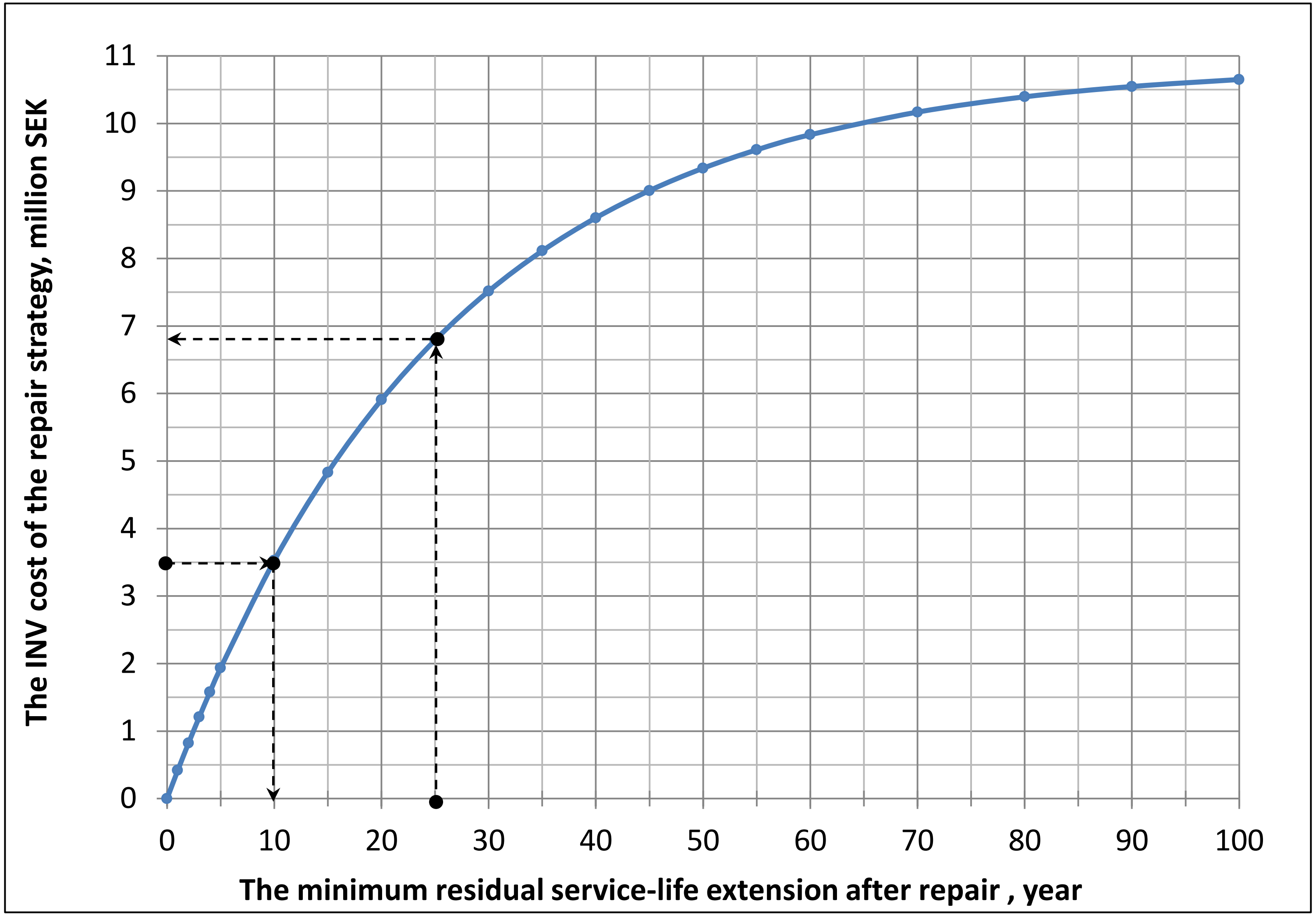


Asphalt Pavement
Filling material
Traffic Delay
Painting
Bearing
Steel Railing
Structural Steel
Reinforcement Steel
Concrete
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Characterized environmental impact
(1)
(2)
(3)
GWP, 1.0E+06 kg CO2 eq
HTP, 3.3E+05 kg 1,4-DB eq
POFP, 3.3E+03 kg NMVOC
PMFP, 3.3E+03 kg PM10 eq
ODP, 1.0E-01 kg CFC-11 eq
Impact categories with their measured unit

Monetary weighting of the LCA Results

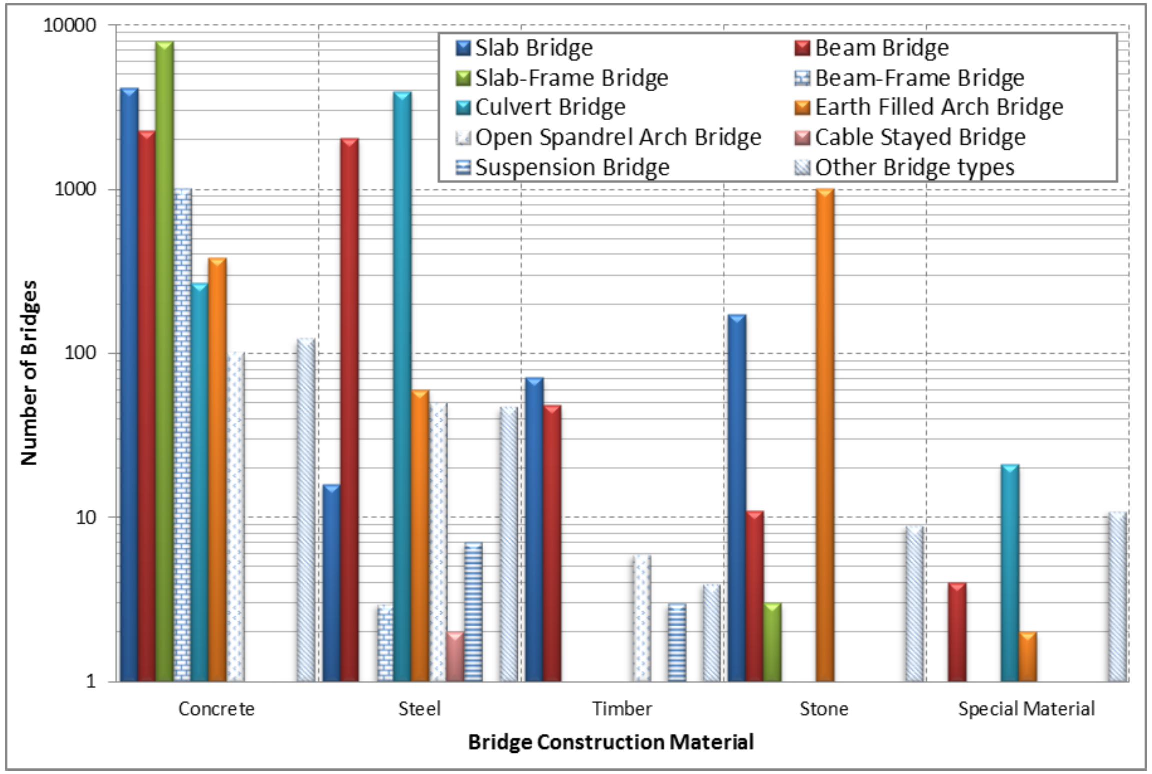
Impact category	Unit	Monetary weighting factor (SEK/Unit)	Proposal 1		Proposal 2		Proposal 3	
			Total impact	Monetary impact cost (kSEK)	Total impact	Monetary impact cost (kSEK)	Total impact	Monetary impact cost (kSEK)
GWP	kg CO2 eq	2.85	1.9E+06	5,422	1.6E+06	4,548	1.0E+06	2,949
ODP	kg CFC-11 eq	--	1.2E-01	--	8.2E-02	--	1.3E-01	--
HTP	kg 1,4-DB eq	2.81	3.3E+05	934	3.6E+05	1,026	1.9E+05	525
POFP	kg NMVOC	15.97	6.6E+03	106	5.2E+03	83	4.3E+03	68
PMFP	kg PM10 eq	273	3.5E+03	960	3.5E+03	960	2.7E+03	736
IRP	kg U235 eq	--	7.1E+04	--	7.0E+04	--	1.3E+05	--
TAP	kg SO2 eq	30	5.3E+03	158	4.5E+03	135	5.0E+03	150
FEP	kg P eq	670	4.5E+01	30	5.7E+01	38	3.5E+01	23
MEP	kg N eq	90	2.1E+02	19	1.6E+02	14	1.5E+02	13
TETP	kg 1,4-DB eq	--	1.4E+02	--	1.3E+02	--	7.9E+01	--
FETP	kg 1,4-DB eq	--	5.3E+02	--	4.5E+02	--	3.4E+02	--
METP	kg 1,4-DB eq	12	1.3E+03	16	1.5E+03	18	1.1E+03	13
Total monetary impact cost (kSEK)			7,645		6,821		4,478	
Total monetary impact cost/year, (kSEK)			76		68		56	
Total monetary impact cost for 80 years (kSEK)			6,116		5,457		4,478	
Environmental rank			3rd		2nd		1st	
k_{EI}^{X}			100%		89%		73%	
$WTEP_{EI}$, **(kSEK)**			2,744					
$CEEI^{X,R}$ **(kSEK)**			2,744		2,448		2,009	

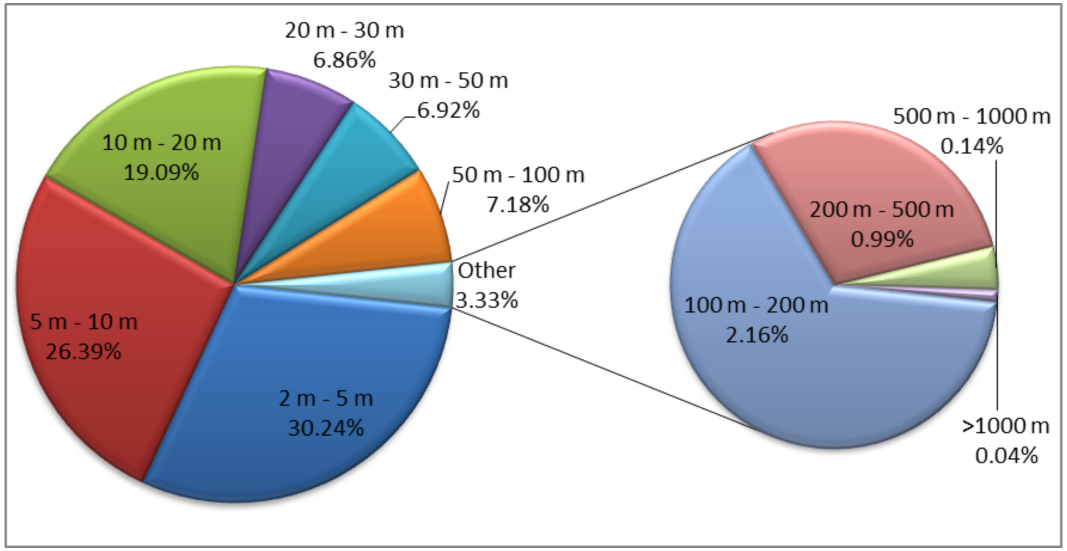
Relation between the INV cost of the repair strategy and the minimum required residual service life extension



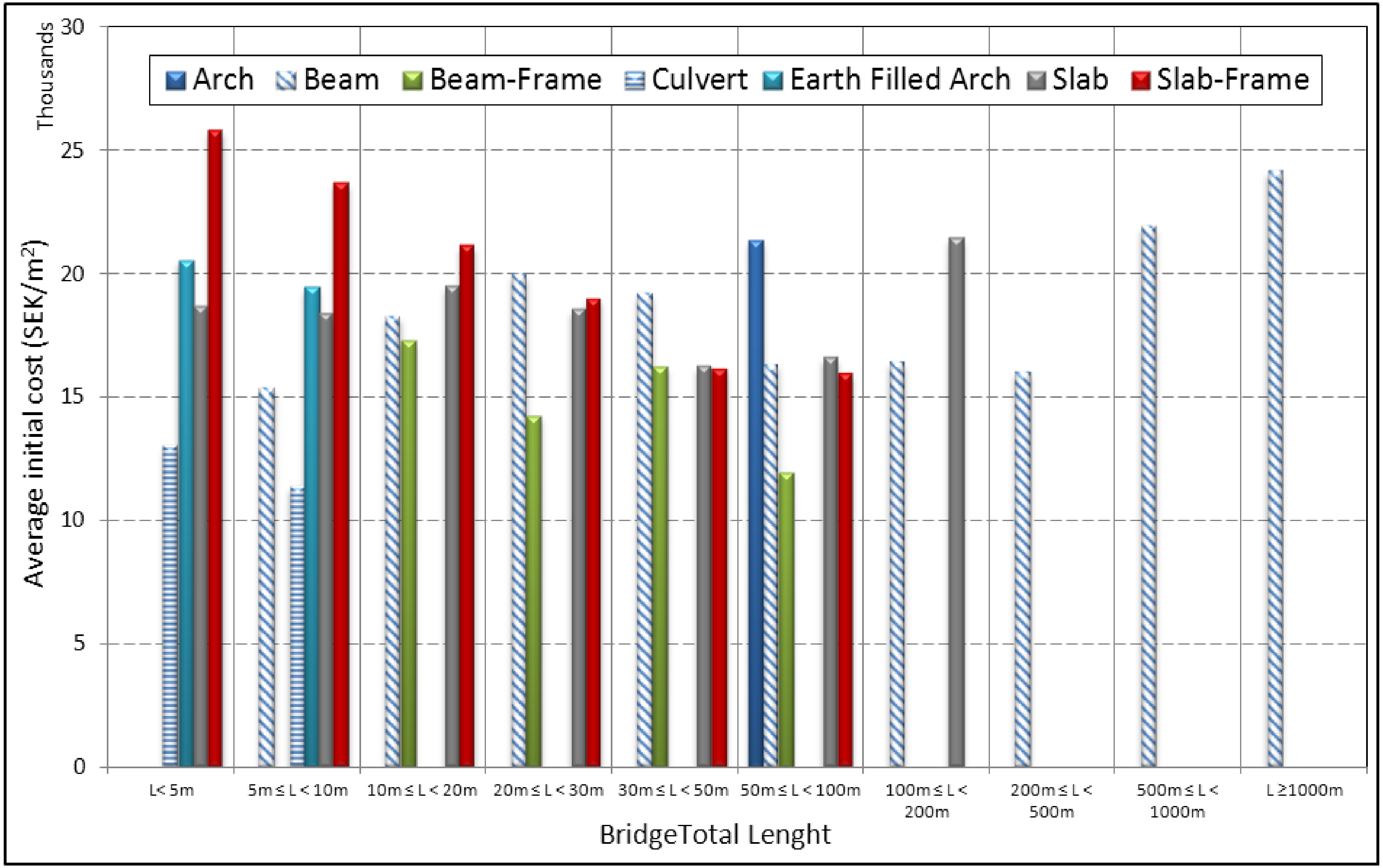
The Swedish Bridge Stock

	Bridge Function Type				Total No. Of Bridges	Bridge Total Area (m^2)	Bridge Total Length (m)
	Roadway	Railway	Pedestrian & Bicycle	Other			
BaTMan's Bridges	23,848	4,411	1,619	251	**30,129**	7,644,208	668,381
Trafikverket's Bridges in BaTMan	20,050	3,179	207	14	**23,450**	5,858,570	528,905



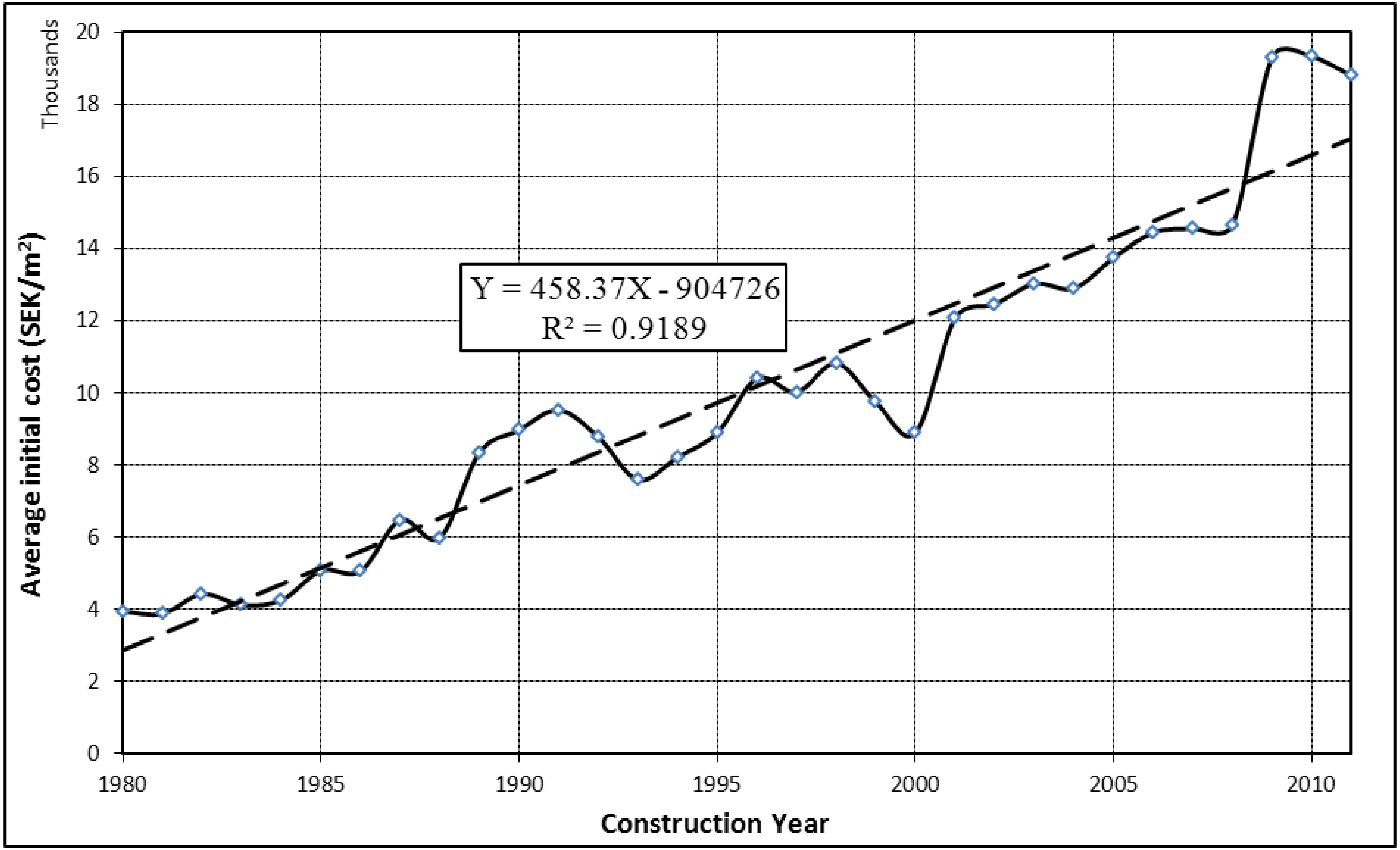


The Average Real INV cost/m²

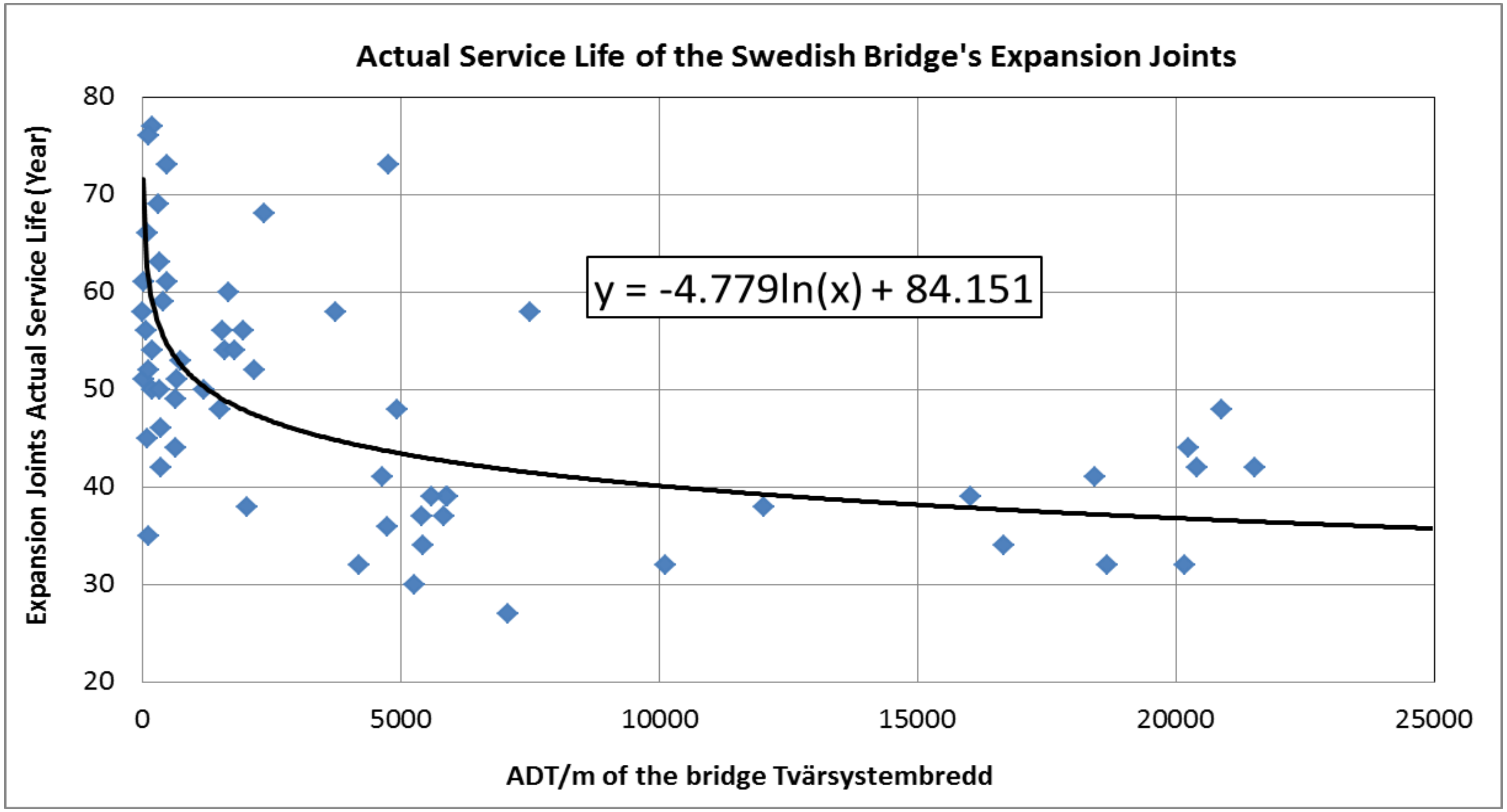


Based on cost data for 2,508 bridges constructed between 1980 and 2011.

The real inflation rate of the INV cost/m^2



BSMs' LCPs based on Real repair Records

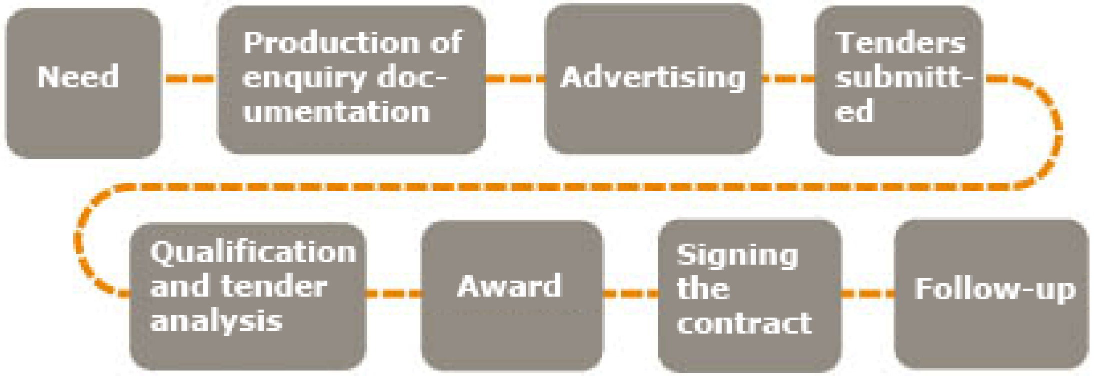


Based on 288 Replacement actions performed between 1980 and 2010

Appendix B introduces rough life-cycle plans (LCPs) for the various bridge structural members (BSMs) of Swedish bridges.

Procurement within Public Agencies

Public Procurement Act, based on EU Procurement Directives.



Enquiry documentation is the collective documentation that:

- Describes what is to be procured,
- What requirements are placed on the tenderer
- and the subject of the procurement,
- as well as how the tenders will be evaluated.

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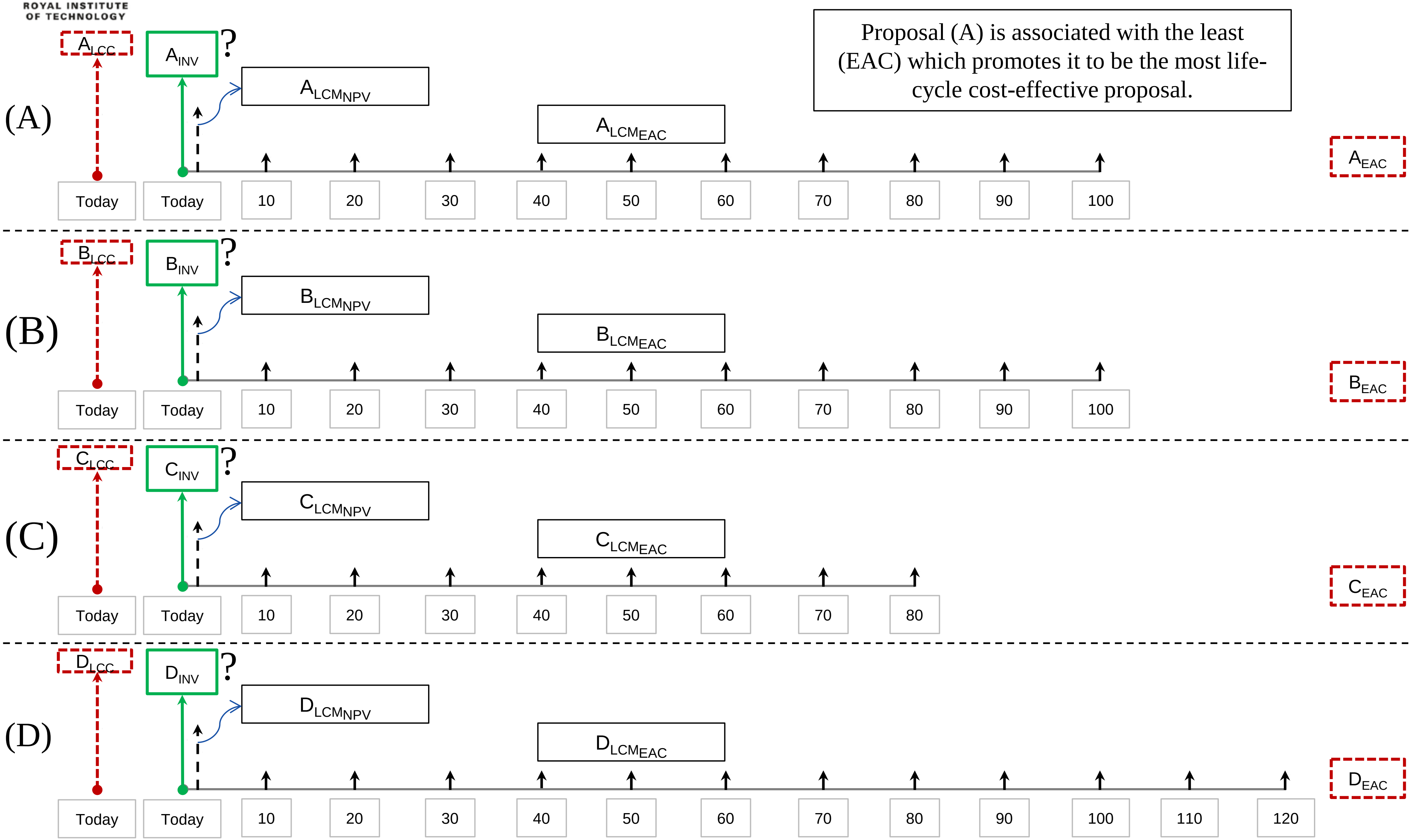
The Concept of the Lowest LCC Bid

- The lowest LCC bid should be used as the contract award criterion under D-Bs, instead of the lowest INV bid
- Two inappropriate ways to apply the lowest LCC bid award criterion.

1. Request contractors to supplement bids with life-cycle plans (LCPs) and LCM cost calculations:
   A. Some contractors may underestimate LCM costs of their designs because they will not usually be obligated in the long run.
   B. Most contractors are not familiar with actual LCM costs of designs, since they are usually incurred by the bridge procurers.
   C. The LCP and LCM costs for a proposal prepared by a contractor could be strongly questioned by other contractors.
2. The other inappropriate way is for the agency to analyze LCCs of contractors’ bids and use the results to select a contractor,
   A. The results may easily be adjusted to provide a desired answer and
   B. Different analysts might generate different results.


Proposal (A) is associated with the least (EAC) which promotes it to be the most life-cycle cost-effective proposal.
(A)
A_{LCC}
A_{INV}
?
A_{LCMNPV}
A_{LCMEAC}
A_{EAC}
Today
Today
10
20
30
40
50
60
70
80
90
100
(B)
B_{LCC}
B_{INV}
?
B_{LCMNPV}
B_{LCMEAC}
B_{EAC}
Today
Today
10
20
30
40
50
60
70
80
90
100
(C)
C_{LCC}
C_{INV}
?
C_{LCMNPV}
C_{LCMEAC}
C_{EAC}
Today
Today
10
20
30
40
50
60
70
80
(D)
D_{LCC}
D_{INV}
?
D_{LCMNPV}
D_{LCMEAC}
D_{EAC}
Today
Today
10
20
30
40
50
60
70
80
90
100
110
120