Steps Toward The Achievement

ETSI
BRIDGE LIFE CYCLE
OPTIMISATION

Life Cycle Costs (Ideas and Remarks)

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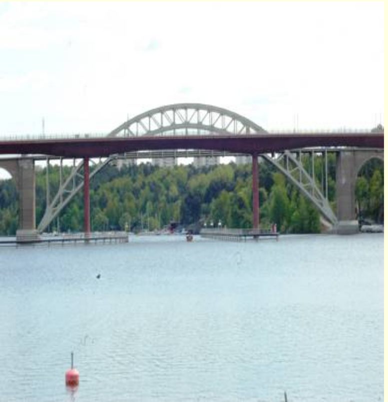
Points and outlines about ETSI

- Now we can say, we are only one step from culminating our progress by wearing the crown of ETSI which is:

  A unified Nordic Methodology & Computer Program for Bridge LCC & LCA Estimation.

- Many things and many interests for each parties, nothing is impossible.
- One great thing is the specifying of the requirements and the interests for each parties.



- *The ideas or the points that I am going to mentioned, may be right or not, all things are subjected to discussion and changes.*

Three Main Steps to Reach the Main Goal of ETSI

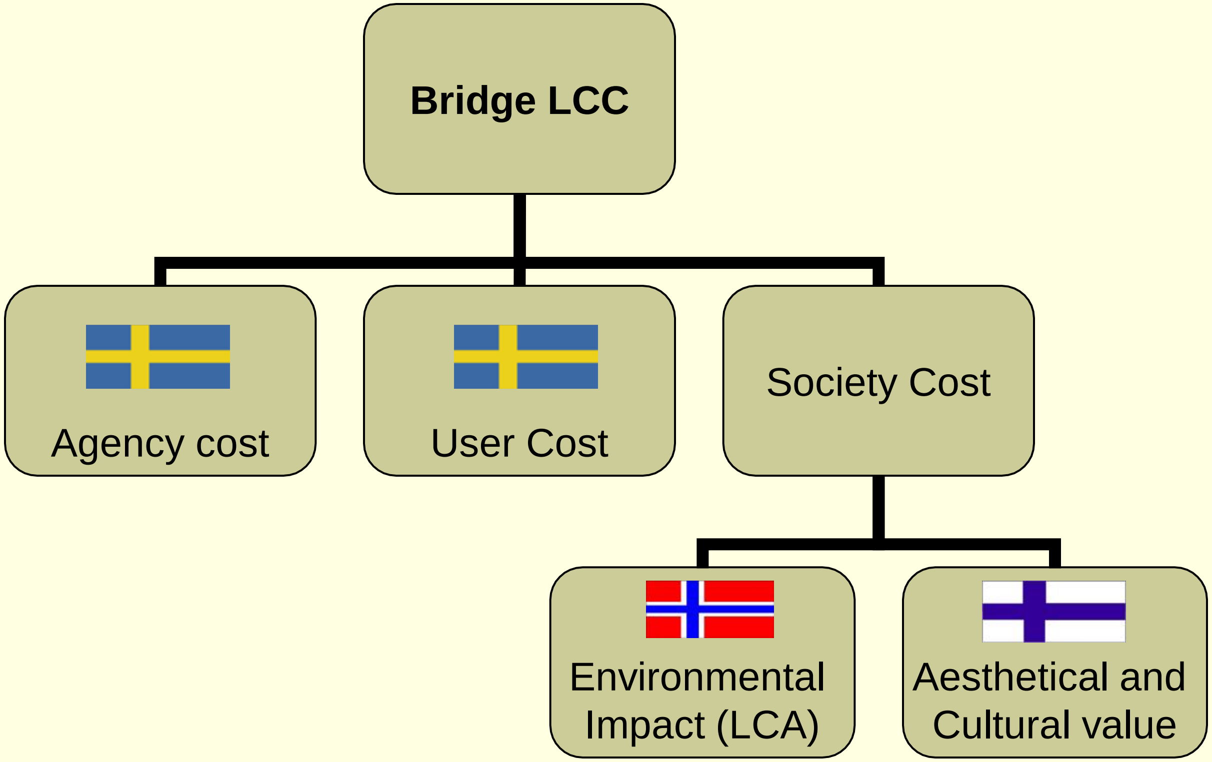
1. Identification of the goals, parameters & assigning methodology for basic calculations **(ETSI Stage1)**
2. Detailed explanation of the interests and the considerations for each ETSI individuals **(ETSI Stage2)**
3. A- Creative ideas and models connecting and transforming the theoretical data and information into simple computer programs, say Excel sheets or others.

   B- Upgrading and development of this simple programs and integrate them in a unified web based program.

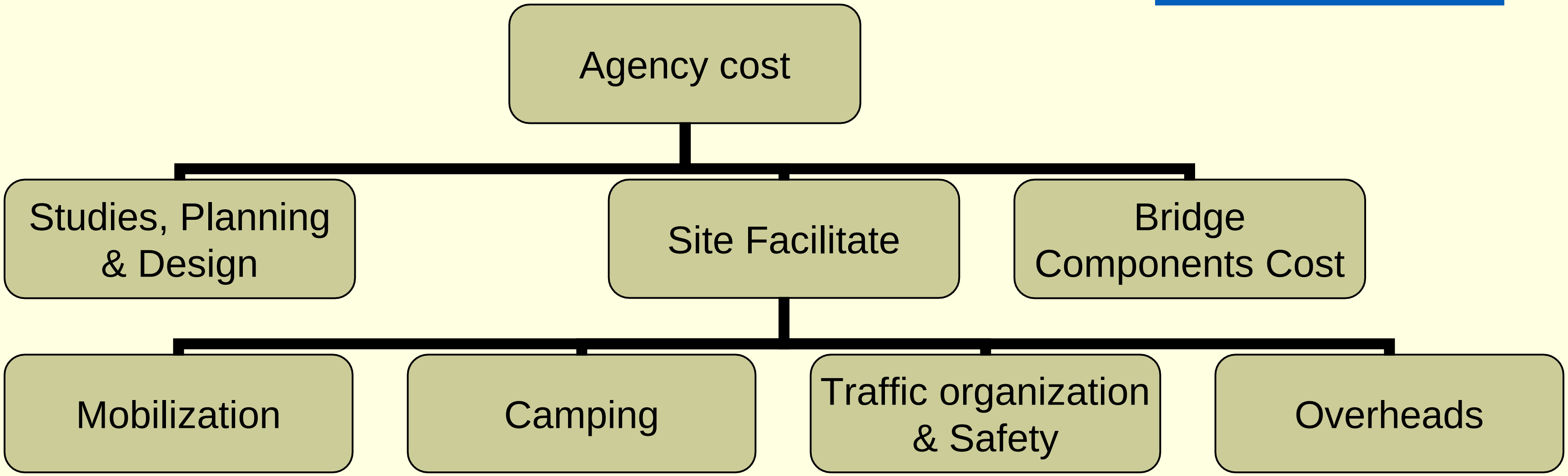
- **(ETSI Stage3)**

Step by Step, Tracking the Proposals Developments

- Bridge life cycle cost components:-



1- Agency Cost



- Before going to the bridge components cost, Three things we have to unify:-

- Unified names of the actions that may take place during the structural element life
- Unified System for bridge components LCC analysis
- Unified degradation curves for bridge components.

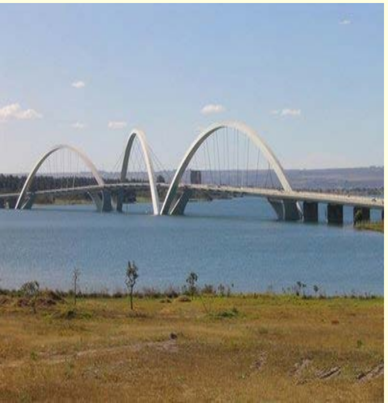
Structural Elements Life Cycle Actions

- Many names and titles with different words describing the action which could take place within the service life of the bridge components like:-

  (investment, initial capital, purchasing and installation, reparation, repair, rehabilitation, operation, maintenance, inspection and investigation, demolition, replacement, and others)

- We agreed in KTH to classify these actions ascending by its occurrence during the life cycle, with these proposed titles.

  - Investment (Purchasing & Installation) Cost
  - Operation & Maintenance Cost
  - Inspection Cost
  - Repair/Replacement & Rehabilitation Cost
  - End of life Management Cost



Two Possible Ways To Analyze The LCC of The Bridge Components.

<u>By the action for all bridge components e.g.,</u>

1-Purchasing and installation cost
- Substructure
- Superstructure
- Bridge equipments
- Etc.

2-Operation & maintenance cost
- Substructure
- Superstructure
- Bridge equipments
- Etc.

3-Reparation &rehabilitation cost
- Substructure
- Superstructure
- Bridge equipments
- Etc.

4-Etc.
- Etc

<u>By the bridge component for all actions e.g.,</u>

1-Substructure
- Purchasing and installation cost
- Operation & maintenance cost
- Reparation & Rehabilitation cost
- Etc.

2-Superstructure
- Purchasing and installation cost
- Operation & maintenance cost
- Reparation & Rehabilitation cost
- Etc...

3-Bridge Equipments
- Purchasing and installation cost
- Operation & maintenance cost
- Reparation & Rehabilitation cost
- Etc.

4-Etc.
- Etc

- **In KTH we agreed to use the first system (which is the same system used in the WEBLCC program)**

❖ Many proposals of breaking down the bridge into components, which are as following:-

A- LCA group proposal
B- 3 proposals from Håkan Sundquist
C- 1 proposal from Arne Juttila

❖ What is the main requirement from the unified proposal?

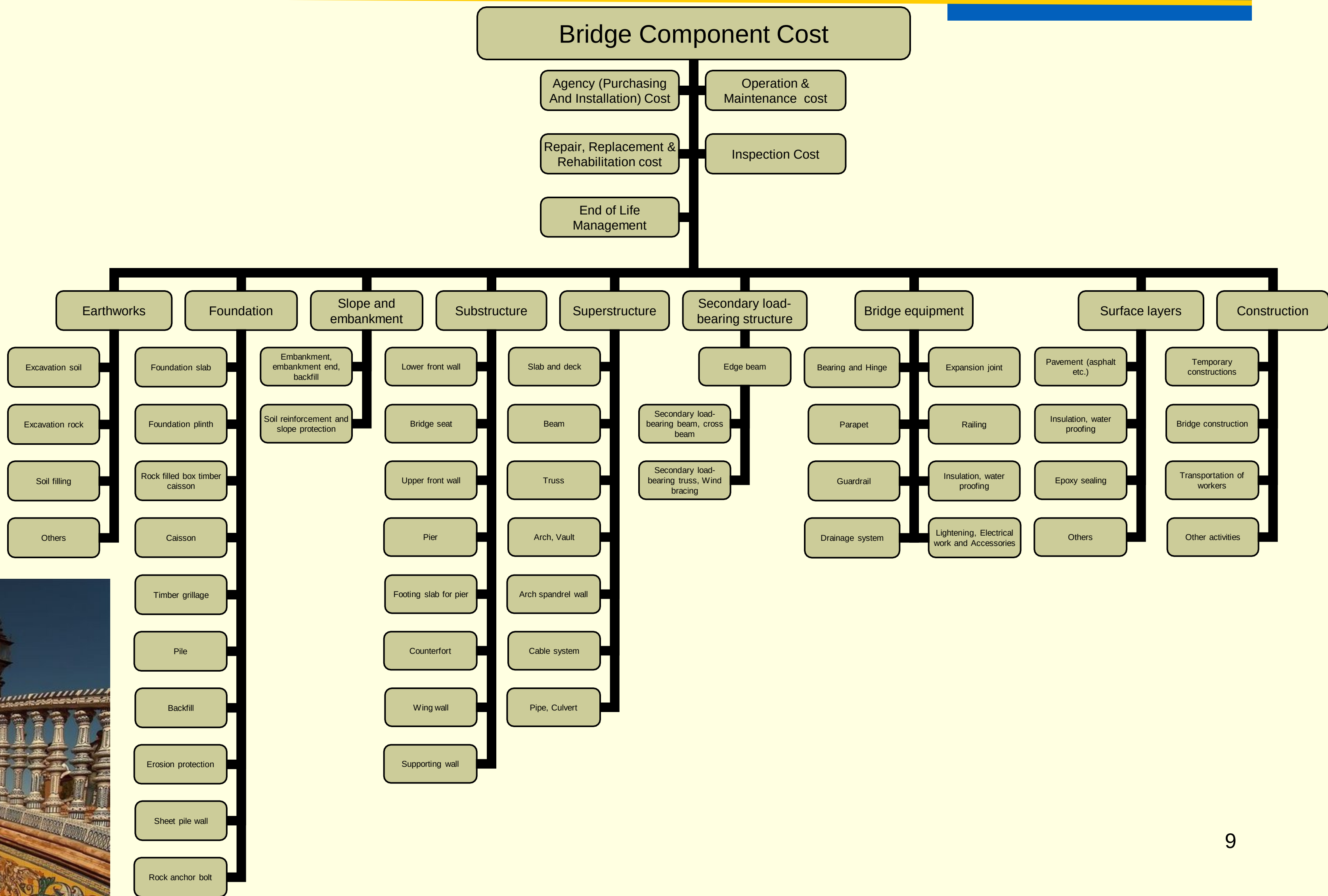
➢ Include the LCA required parameters within the parameters of LCC calculation. So in this case we don't have to import any external Excel sheets to LCCWEB program to calculate LCA

❖ In KTH, we achieve this target by preparing a proposal which include all of the required parameters in LCC & LCA (and now we are working with creating a model for this purpose)

Bridge breaking down components.

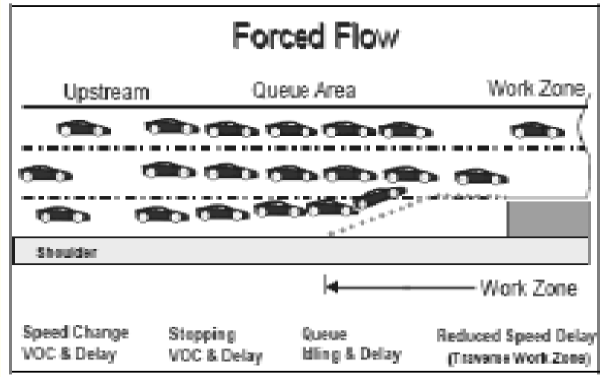
LCA Grope Proposal	łakan Proposal (1	Hakan Proposal (2	Hakan Proposal (3)	SAs Proposal	attebos Propo	Safi Proposal
Material transportation						**1. Material transportation**
Truck transportation [km]						Truck transportation [km]
Boat transportation [km]						Boat transportation [km]
Ship transportation [km]						Ship transportation [km]
Train transportation [km]						Train transportation [km]
				1. Earthworks		**2. Earthworks**
				1.1 excavation soil		Excavation soil
				1.2 excavation rock		Excavation rock
				1.2 soil filling		Soil filling
				1.3 others		Others
Foundation	**Foundation**	**Foundation**	**Foundation**	**2. Foundation**	**1. Foundation**	**3. Foundation**
Foundation, plinth, pile cap	Foundation slab	Foundation slab (base slab), plinth, pile cap	Foundation slab, plinth, pile cap	2.1 piles	1.1 Groundwork	Foundation slab
Pile	Foundation plinth	Excavation, soil	Caisson	2.2 base slab (foundat	1.2 Piles	Foundation plinth
Erosion protection	Rock filled box timber caisson	Excavation, rock	Excavation, soil	2.3 others		Rock filled box timber caisson
	Caisson	Pile	Excavation, rock			Caisson
	Timber grillage	Erosion protection	Pile			Timber grillage
	Pile		Erosion protection			Pile
	Backfill					Backfill
	Erosion protection					Erosion protection
	Sheet pile wall					Sheet pile wall
	Rock anchor bolt					Rock anchor bolt
Slope and embankment	**Slope and embankment end**	**Slope and embankment**	**Slope and embankment**	**7. Road works at bridge place**		**4. Slope and embankment**
Embankment, Embankment end, backfill	Slope	Embankment, embankment end, backfill	Embankment, embankment end, backfill	7.1 embankment material		Embankment, embankment end, backfill
Soil reinforcement and slope protection	Embankment end	Soil reinforcement and slope protection	Soil reinforcement and slope protection	7.2 embankment piling		Soil reinforcement and slope protection
	Embankment			7.3 embankment slab		
	Pile			7.4 revetment		
	Pile cap			7.5 pavement (asphalt etc)		
	Pile deck			7.6 others		
	Chalk-cement column					
Abutments and piers	**Abutments and piers**	**Abutments and piers**	**Abutments and piers**	**3. Substructure**	**2. Substructure**	**5. Substructure**
All concrete structures belonging to the substructure (excl. foundation and including the found-ation slabs)	Lower front wall	All concrete structures belonging to the sub-struc-ture excl. foundation and including the found-ation slabs	Front wall, counterfort	3.1 abutment (end su	2.1 Abutment	Lower front wall
	Bridge seat		Bridge seat	3.2 piers, columns, gr	2.2 Intermediate support (columns, gravity constructions, piers)	Bridge seat
	Upper front wall		Pier	3.3 others		Upper front wall
	Pier		Wing wall			Pier
	Footing slab for pier					Footing slab for pier
	Counterfort					Counterfort
	Wing wall					Wing wall
	Supporting wall					Supporting wall
Main load bearing structure	**Main load bearing structure**	**Main load bearing structure**	**Main load bearing structure**	**4. Superstructure**	**3. Superstructure**	**6. Superstructure**
Slab and deck	Slab	Slab / deck	Slab and deck	4.1 main load carrying	3.1 Main load carr	Slab and deck
Beam, girder	Beam	Beam, girder	Beam	4.2 bridge deck	3.2 Bridge deck (n	Beam
Truss	Truss	Truss	Truss	4.3 edge beams	3.3 Surface layers	Truss
Arch, Vault	Arch	Arch, vault	Arch, Vault	4.3 others	3.4 Others	Arch, Vault
Cable system	Arch spandrel wall	Cable system	Arch spandrel wall			Arch spandrel wall
Pipe, Culvert	Vault	Pipe, culvert	Cable system			Cable system
	Cable suspension system		Pipe, Culvert			Pipe, Culvert
	Pipe					
Secondary load bearing structure	**Secondary load bearing system**	**Secondary load bearing sstructures**	**Secondary load bearing system**			**7. Secondary load-bearing structure**
Secondary load-bearing beam, cross beam	Secondary load-bearing beam	Secondary load-bearing beam, cross beam	Secondary load-bearing beam, cross beam			Secondary load-bearing beam, cross beam
Secondary load-bearing truss, Wind bracing	Cross beam	Secondary load-bearing truss, wind bracing	Secondary load-bearing truss, Wind bracing			Secondary load-bearing truss, Wind bracing
	Secondary load-bearing truss					Edge beam
	Wind bracing					
Bridge equipment		**Equipment**		**4. Bridge equipment**	**4. Bridge equipme**	**8. Bridge equipment**
Bearing and Hinge	**Edge beam**	Bearing and hinge	**Edge beam**	5.1 Bearings	4.1 Bearings	Bearing and Hinge
Edge Beam	**Insulation**	Edge beam	**Insulation, Water**	5.2 Parapets	4.2 Parapets	Expansion joint
Insulation, Water proofing	**Parapet**	Insulation, water proofing	**Surfacing**	5.3 Expansion joints	4.3 Expansion joint	Parapet
Surfacing	**Expansion joint**	Surfacing	**Parapet, Railing**	5.4 Others	4.4 Others	Railing
Parapet, Railing	**Drainage system**	Parapet, railing	**Expansion joint**			Guardrail
Expansion joint	Bearing	Expansion joint	**Drainage system**			Insulation, water proofing
Drainage system	Hinge steel	Drainage system	Bearing and Hinge			Drainage system
	Hinge concrete					Lightening, Electrical work and Accessories
	Surfacing			**5. Surfacelayers**		**9. Surfacelayers**
	Wearing course			4.1 pavement (asphalt etc.)		Pavement (asphalt etc.)
	Spreader course			4.2 waterproofing		Insulation, water proofing
	Protection course			4.3 epoxy sealing		Epoxy sealing
				4.4 others		Others
Construction				**6. Construction**	**5. Construction**	**10. Construction**
Temporary constructions				6.1 Temporary constr	5.1 Temporary con	Temporary constructions
Excavation, soil				6.2 Bridge constructio	5.2 Bridge constru	Bridge construction
Excavation, rock				6.3 Transportation of	5.3 Transportation	Transportation of workers
Bridge construction				6.4 Other activities	5.4 Other activities	Other activities
Transportation of workers						
Other activities						
Operation, repair and maintenance				**8. Operation, repair**	**6. Operation, rep**	**11. Operation, repair & maintenance**
Year 1 - 10				Year 1 - 10	Year 1 - 10	Year 1 - 10
Year 11 - 20				Year 11 - 20	Year 11 - 20	Year 11 - 20
Year 21 - 30				Year 21 - 30	Year 21 - 30	Year 21 - 30
Year 31 - 40				Year 31 - 40	Year 31 - 40	Year 31 - 40
Year 41 - 50				Year 41 - 50	Year 41 - 50	Year 41 - 50
Year 51 - 60				Year 51 - 60	Year 51 - 60	Year 51 - 60
Year 61 - 70				Year 61 - 70	Year 61 - 70	Year 61 - 70
Year 71 - 80				Year 71 - 80	Year 71 - 80	Year 71 - 80
Year 81 - 90				Year 81 - 90	Year 81 - 90	Year 81 - 90
Year 91 - 100				Year 91 - 100	Year 91 - 100	Year 91 - 100
EOL management				**9. End of Life Mana**	**7. End of Life Ma**	**12. End of Life Management**
Demolition				9.1 Demolition	7.1 Demolition	7.1 Demolition
Land scaping				9.2 Landscaping	7.2 Landscaping	7.2 Landscaping
Waste management				9.3 Waste manageme	7.3 Waste manag	7.3 Waste management (incl. recycling and recovery)

Bridge Components Life Cycle Costs Tree



2- User Costs

- User Cost
  - Construction & Installation
  - Operation & Maintenance
  - Inspection
  - Repair, Replacement & Rehabilitation
  - End of life management
    - Traffic Delay Cost
    - Vehicle operation Cost
    - Increase Risk & Accident
    - Discomfort



3- Society Cost

Environmental Impact LCA

Used Materials for every component during the life cycle

- ADP
- GWP
- ODP
- HTP
- FAETP
- MATEP
- TETP
- PCOP
- AP
- EP

An effective model combining the agency costs, the user costs & LCA impact at the same time

Investment (Purchasing & Installation) Cost

Bridge Component, Activites	Used Materials		Material Transportation			User Cost		Other Total Price
	Blasting [kg] ☑ Add	Quantity	Truck transportation	Distance [km]	Weight [ton],[person]	Days of Work	Affected Length (Km)	
1-Foundation			Truck transportation					
Caisson ☐ Add								
2-Slope and embankment								
Embankment, embankment end, backfill ☐ Add								
3-Substructure								
Bridge seat ☐ Add								
4-Superstructure								
Arch, Vault ☐ Add								
5-Secondary load-bearing structure								
Edge beam ☐ Add								
6-Bridge equipment								
Railing ☐ Add								
7-Surfacelayers								
Others ☐ Add								
8. Earthworks								
Excavation soil ☐ Add								
9. Construction								
Transportation of workers ☐ Add								
10. End of Life Management								
7.3 Waste management (incl. recycling and recovery) ☐ Add								

Operation & Maintenance Cost

Bridge Component, Activites	Used Materials		Material Transportation			User Cost		Other Total Price
	Blasting [kg] ☑ Add	Quantity	Truck transportation	Distance [km]	Weight [ton],[person]	Days of Work	Affected Length (Km)	
1-Foundation			Truck transportation					
Caisson ☐ Add								
2-Slope and embankment								
Embankment, embankment end, backfill ☐ Add								
3-Substructure								
Bridge seat ☐ Add								
4-Superstructure								
Arch, Vault ☐ Add								
5-Secondary load-bearing structure								
Edge beam ☐ Add								
6-Bridge equipment								
Railing ☐ Add								
7-Surfacelayers								
Others ☐ Add								
8. Earthworks								
Excavation soil ☐ Add								
9. Construction								
Transportation of workers ☐ Add								
10. End of Life Management								
7.3 Waste management (incl. recycling and recovery) ☐ Add								

Repair/Replacement & Rehabilitation Cost

An effective model combining the agency costs, the user costs & LCA impact at the same time

- *With doing some updates and little changes in the WEBLCC model we can include LCA , as proposed in the next slide.*
  - Including the used materials in LCA model by a build up list of material.
  - Perfectly specifying the transportation of each bridge component
  - Using the used material column we can compute the prices for LCC and the amounts for LCA

LCA Excel Program

The used Materials ⟺ The Emissions amounts

3- Society Cost

Aesthetical & Cultural Value

- Evaluation of the Bridge Site
  - Bridge Site Location
  - Landscape Value
  - Bridge Cultural Value
  - Bridge Aesthetics al Demands
- Evaluation of the Considered Items
  - Integration between the bridge and the site
  - Horizontal and Vertical geometry
  - Superstructu re
    - Harmony of Span
    - Type and Shape
    - Simplicity, slendernes s and transparenc y
  - Abutments
    - Placement
    - Shape
    - Visible size
  - Column, piers and Pylons
    - Placement
    - Shape
  - Railings
  - Embellishm ents,colour s and textures
  - Lighting
  - Others

SP3 Unique, Systematic Way for Evaluating the Aesthetical Value of the Bridge

We tried to convert this theoretical system into a simple Excel program and applied this to some cases.

Then we have found some questions that need to be clarified.

$$C_{rel} = k_{rel} C_{LCC}$$

$$C = C_{rel} + C_{LCA}$$

- Where is the user cost?!

AESTHETICS AND CULTURAL VALUE OF THE BRIDGE

Assumption: a = 0.2 That means that in the extreme cases the reduction coefficient k_{rel} varies between . 0.8 and 1.2

1- Evaluation of Bridge Site

Class	Explanation
Class I	Very demanding
Class II	Demanding
Class III	Remarkable
Class IV	Ordinary

Evaluated items:-

Location of the bridge site	Value of the landscape	Cultural value of the bridge site	Aesthetical demands of the bridge
Class I	Class II	Class II	Class II

Bridge Site Class ***II***

2- Evaluation of Bridge Items

Category	Explanation
-2	Poor
-1	Modest
0	Medium
1	Good
2	Excellent

Considered Items:-		Evaluation	Proposed weight factors for the considered items			
			Class I	Class II	Class III	Class IV
Integration between the bridge and the site		-2	6	4	2	0
Horizontal and vertical geometry		-2	3	2	1	0
Superstructure	harmony of spans	-2	2	2	1	0
	type and shape	-2	4	3	2	0
	simplicity, slenderness and trans.	-2	3	2	1	0
Abutments	placement	-2	2	1	1	0
	shape	-2	1	1	1	0
	visible size	-2	1	1	1	0
Columns, piers and pylons	placement	-2	1	1	1	0
	shape	-2	3	2	1	0
Railings		-2	2	2	1	0
Embellishments, surface colors and textures		-2	2	2	1	0
Lighting		-2	2	2	1	0
Others		-2	0	0	0	0
		Σ	32	25	15	0

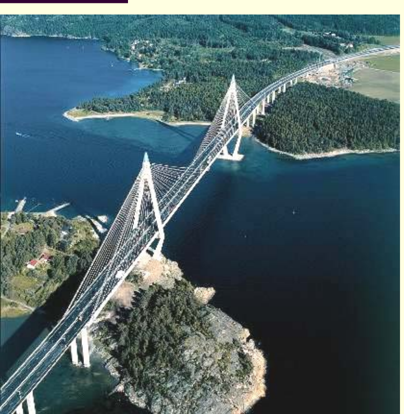
K_{rel} = **1.156**

a= 2	Class I	Class II	Class III	Class IV
K_{rel} max	1.2	1.156	1.094	1
K_{rel} min	0.8	0.844	0.906	1

SP3 Unique, Systematic Way for Evaluating the Aesthetical Value of the Bridge

- questions need to be clarified.

$$k_{rel} = 1 - a\frac{\sum_{i=1}^{n} w_i p_i}{p_{\max}\sum_{i=1}^{n} w_i} = 1 - 0{,}2\frac{\sum_{i=1}^{n} w_i p_i}{2\sum_{i=1}^{n} w_i} = 1 - 0{,}1\frac{\sum_{i=1}^{n} w_i p_i}{\sum_{i=1}^{n} w_i}$$



AESTHETICS AND CULTURAL VALUE OF THE BRIDGE

Assumption: a = 0.2 — That means that in the extreme cases the reduction coefficient k_{rel} varies between 0.8 and 1.2

1- Evaluation of Bridge Site

Class	Explanation
Class I	Very demanding
Class II	Demanding
Class III	Remarkable
Class IV	Ordinary

Evaluated items:-

Location of the bridge site	Value of the landscape	Cultural value of the bridge site	Aesthetical demands of the bridge
Class I	Class II	Class II	Class II

Bridge Site Class *II*

2- Evaluation of Bridge Items

Category	Explanation
-2	Poor
-1	Modest
0	Medium
1	Good
2	Excellent

Considered Items:-		Evaluation	Proposed weight factors for the considered items: Class I	Class II	Class III	Class IV
Integration between the bridge and the site		-2	6	4	2	0
Horizontal and vertical geometry		-2	3	2	1	0
Superstructure	harmony of spans	-2	2	2	1	0
	type and shape	-2	4	3	2	0
	simplicity, slenderness and trans.	-2	3	2	1	0
Abutments	placement	-2	2	1	1	0
	shape	-2	1	1	1	0
	visible size	-2	1	1	1	0
Columns, piers and pylons	placement	-2	1	1	1	0
	shape	-2	3	2	1	0
Railings		-2	2	2	1	0
Embellishments, surface colors and textures		-2	2	2	1	0
Lighting		-2	2	2	1	0
Others		-2	0	0	0	0
		Σ	32	25	15	0

K_{rel} = 1.156

a= 2	Class I	Class II	Class III	Class IV
K_{rel} max	1.2	1.2	1.2	1.2
K_{rel} min	0.8	0.8	0.8	0.8

Two Possible Ways to Include & Assess the Bridge Environmental Impacts (LCA)

1- By transforming the amount of emissions & the environment distortion due to the usage of unrenewable materials from

Unit Quantity to Unified Standard Unit Price. eg.

A unit of Global Warming Potential (GWP) will cost me (xxx $)

- and then add this prices of the emissions to LCC cost.

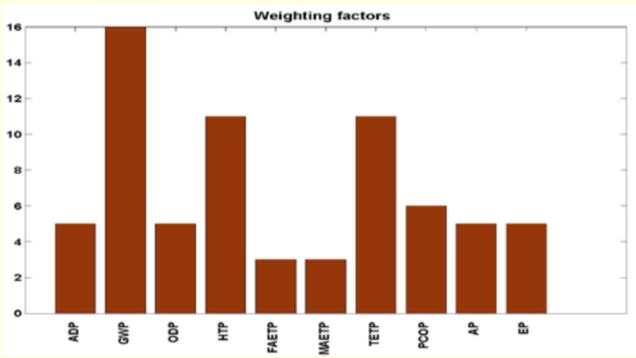
- (May this is not applicable due to differences in the environmental policy).

2- Follow the suggestions which was mentioned in SP3 with same procedures with little changes to concise the demand of the environments

- (Need help from the Norwegian team to propose the parameters to be considered and its weight factors)

A model suggesting how to include and translate LCA–values into LCC calculations will be presented in the next slide

Proposed Model to include LCA in LCC calculations



- Need adoption and confirmation from the Norwegian team

ENVIRONMENTAL IMPACTS OF THE BRIDGE

Assumption: a = 0.25 — That means that in the extreme cases the enviromental coefficient K_{env} varies between . 1 and 1.25

1- Evaluation of Bridge & Environment Friendships Demands

Class	Explanation
Class I	Very demanding
Class II	Demanding
Class III	Remarkable
Class IV	Ordinary

Evaluated items:-

Location of the bridge	Partners pollutions sensitivity	location environmental regulations	Demands of the bridge
Class I	Class II	Class II	Class II

Bridge Site Class *II*

2- Evaluation of Harmful & Hazard Materials & Emissions

Category	Explanation
-2	Poor
-1	Modest
0	Medium
1	Good
2	Excellent

Considered Items:-		Used Amount	Evaluation	Proposed weight factors for the considered items			
				Class I	Class II	Class III	Class IV
abiotic depletion	ADP		-2	6	4	2	0
global warming (GWP100)	GWP		-2	3	2	1	0
ozone layer depletion (ODP)	ODP		-2	2	2	1	0
human toxicity	HTP		-2	4	3	2	0
fresh water aquatic ecotox.	FAETP		-2	3	2	1	0
marine aquatic ecotoxicity	MAETP		-2	2	1	1	0
terrestrial ecotoxicity	TETP		-2	1	1	1	0
photochemical oxidation	PCOP		-2	1	1	1	0
acidification	AP		-2	1	1	1	0
eutrophication	EP		-2	3	2	1	0
Others			-2	2	2	1	0
Others			-2	2	2	1	0
Others			-2	2	2	1	0
Others			-2	0	0	0	0
			Σ	32	25	15	0

K_{env} = 1.195

a= 2	Class I	Class II	Class III	Class IV
K_{env}	1.2	1.156	1.094	1

K_{env} must be bigger than one for all cases

Thank You

Questions?