Closing Seminar
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NordFoU

Service Life Assessment of Structural Parts for Bridge Life Cycle Analysis

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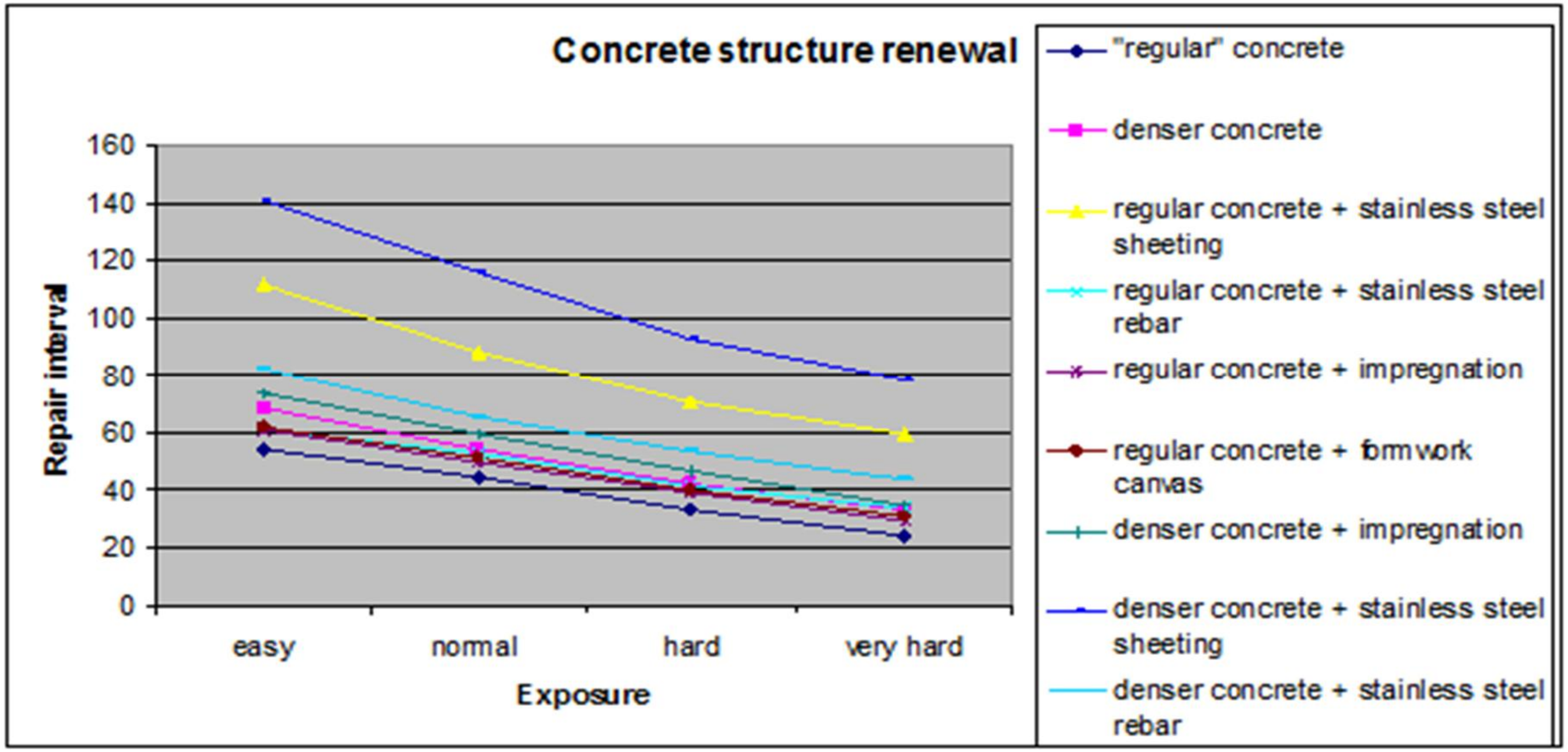
Background of Thesis

Bridge Life Cycle Optimisation

- Background:
  - The time of rehabilitation?
- Goals:
  - To find service life or repair interval estimates for different structural parts of bridge in Finland
  - Concentrate on now used and new structures
  - Test and implement the values with the developed ETSI tools
- Research method
  - Delpi study, expert interview

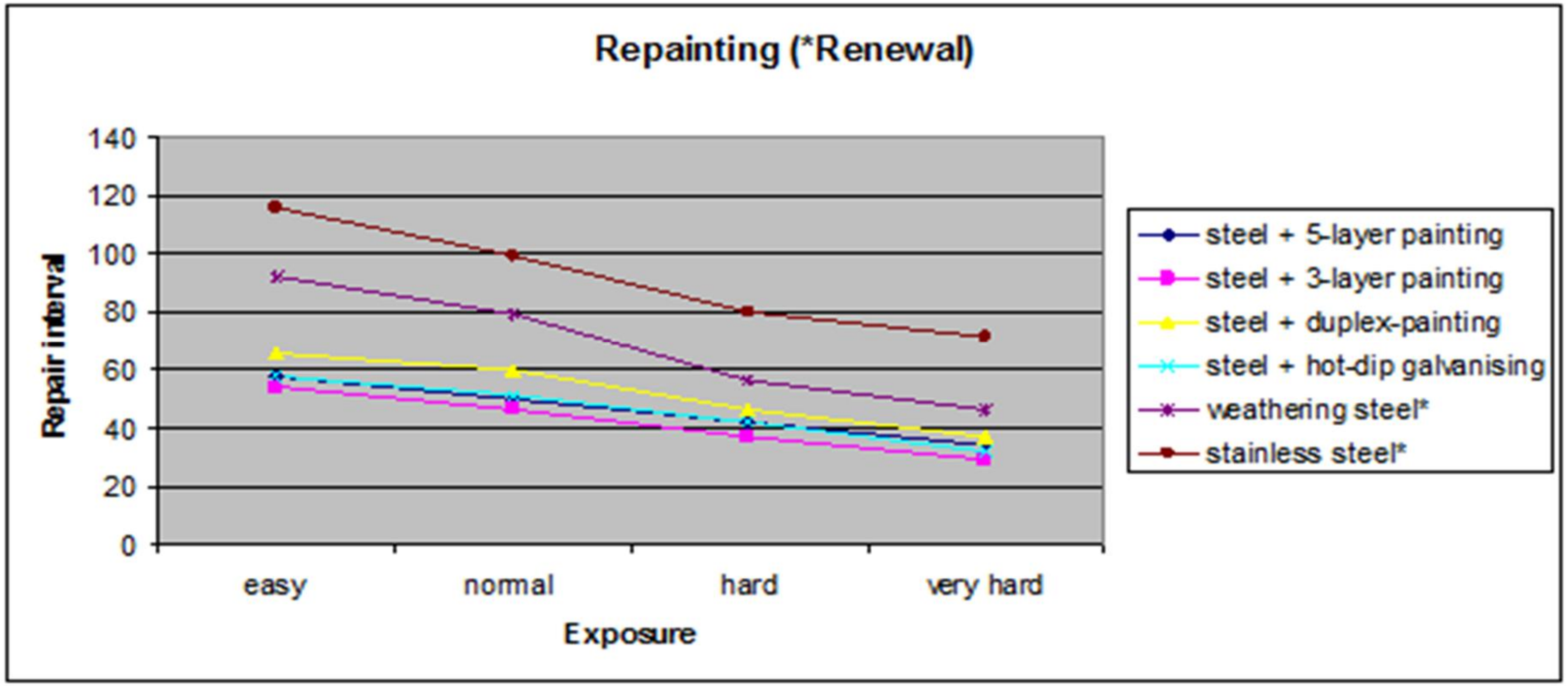
Results –example of interview results (2/3)

Bridge Life Cycle Optimisation



Results –example of interview results (3/3)

Bridge Life Cycle Optimisation



Results –suggestion (1/6)

Bridge Life Cycle Optimisation

Concrete structures

Repair: concreting / shotcreting

Average effect on the repair interval of the structural part	Exposure				Important bridge site
	easy	normal	hard	very hard	
"regular" concrete (C30/37; w/c = 0,45)	45	35	25	20	-3
denser concrete (1	55	45	30	25	-3
concrete shell	35	30	25	20	-2
regular concrete + stainless steel sheeting	70	60	50	40	-4
regular concrete + stainless steel rebar	47	40	32	25	-4
regular concrete + impregnation (2	47	40	30	22	-3
regular concrete + coating	50	40	30	25	-3
regular concrete + epoxy-coated rebar	45	40	30	22	-4
regular concrete + hot-dip galvanised rebar	45	40	30	22	-4
regular concrete + formwork canvas	47	40	30	25	-3
denser concrete + impregnation	57	45	35	30	-3
denser concrete + coating	57	45	37	32	-3
denser concrete + stainless steel sheeting	85	75	57	45	-4
denser concrete + epoxy-coated rebar	57	50	37	30	-4
denser concrete + stainless steel rebar	60	55	42	32	-4
denser concrete + hot-dip galvanised rebar	57	50	37	30	-4
regular concrete + stainless steel rebar + impregnation	57	50	37	30	-3
regular concrete + epoxy-coated rebar + impregnation	55	45	35	30	-3
regular concrete + hot-dip galvanized rebar + impregnation	55	45	35	30	-3
concrete shell + impregnation	35	32	27	22	-2
concrete shell + stainless steel rebar	37	35	30	25	-2
concrete shell + epoxy-coated rebar	37	35	30	25	-2
concrete shell + hot-dip galvanised rebar	37	35	30	25	-2
denser concrete + stainless steel rebar + impregnation	60	55	42	32	-3
denser concrete + epoxy-coated rebar + impregnation	57	50	37	30	-3
denser concrete + hot-dip galvanised rebar + impregnation	57	50	37	30	-3

1) denser concrete ~ lowering w/c -ratio 0,45 -> 0,40; curing requirements are taken into account when defining unit costs and durations
2) Hydrofobic and repeated impregnation

Results –suggestion (2/6)

ETSI

Bridge Life Cycle Optimisation

Repair: Renewing the structural part (edge beams)

Average effect on the repair interval of the structural part	Exposure easy	normal	hard	very hard	Important bridge site
"regular" concrete (C30/37; w/c = 0,45)	47	40	30	25	-5
denser concrete (1	55	50	37	30	-4
concrete shell	32	25	22	20	-4
regular concrete + stainless steel sheeting	95	75	60	50	-4
regular concrete + stainless steel rebar	55	50	40	30	-5
regular concrete + impregnation (2	55	45	35	25	-5
regular concrete + coating	55	45	35	30	-5
regular concrete + epoxy-coated rebar	52	47	37	30	-5
regular concrete + hot-dip galvanised rebar	52	47	37	30	-5
regular concrete + formwork canvas	55	45	35	27	-5
denser concrete + impregnation	65	55	45	32	-5
denser concrete + coating	65	55	45	35	-5
denser concrete + stainless steel sheeting	105	95	80	65	-4
denser concrete + epoxy-coated rebar	65	57	47	35	-5
denser concrete + stainless steel rebar	70	60	50	40	-5
denser concrete + hot-dip galvanised rebar	65	57	47	35	-5
regular concrete + stainless steel rebar + impregnation	67	60	47	35	-5
regular concrete + epoxy-coated rebar + impregnation	67	57	45	35	-5
regular concrete + hot-dip galvanized rebar + impregnation	67	57	45	35	-5
concrete shell + impregnation	40	35	27	22	-4
concrete shell + stainless steel rebar	45	40	32	27	-4
concrete shell + epoxy-coated rebar	42	37	30	25	-4
concrete shell + hot-dip galvanised rebar	42	37	30	25	-4
denser concrete + stainless steel rebar + impregnation	70	60	50	40	-4
denser concrete + epoxy-coated rebar + impregnation	65	57	47	35	-4
denser concrete + hot-dip galvanised rebar + impregnation	65	57	47	35	-4

Results –suggestion (3/6)

Bridge Life Cycle Optimisation

Steel structures

Beams and trusses (1/2)

the material of the load-bearing member (+ protection)

Repair: Patching the paint

Average effect on the repair interval of the structural part	Exposure easy	normal	hard	very hard	Important bridge site
steel + 5-layer painting (EPZn(R)EPPUR 310/5-FeSa2½)	35	30	25	20	-3
steel + 3-layer painting	35	30	25	20	-3
steel + duplex-painting (1	40	35	27	22	-3
steel + hot-dip galvanising	35	30	22	17	-4

Beams and trusses (2/2)

*The service life of load-bearing member manufactured of stainless steel or weathering steel are inputted here

Repair: Repainting

Average effect on the repair interval of the structural part	Exposure easy	normal	hard	very hard	Important bridge site
steel + 5-layer painting (EPZn(R)EPPUR 310/5-FeSa2½)	55	50	40	32	-5
steel + 3-layer painting	55	50	40	32	-5
steel + duplex-painting (1	62	60	45	35	-6
steel + hot-dip galvanising	55	50	40	32	-6
weathering steel *	95	85	70	50	-8
stainless steel (2 *	110	100	85	75	-8

1) duplex-painting system = thermal spraying (zinc) + painting

2) austenitic (e.g. 1.4301, 1.4401) and austenitic-ferritic (duplex) -steels (e.g. 1.4162, 1.4462) have been used in load-bearing members

Results –suggestion (4/6)

Bridge Life Cycle Optimisation

Wood structures (1/2)

Repair: repairing

Average effect on the repair interval of the structural part	Exposure				Important bridge site
	easy	normal	hard	very hard	
glue-laminated wood + creosote impregnation	32	30	20	17	
glue-laminated wood + salt impregnation	30	25	17	15	
glue-laminated wood + salt impregnation + structural protection	35	32	22	17	
wood deck	22	18	15	10	
stress laminated wood deck	22	20	15	10	

Wood structures (2/2)

Repair: Renewing

Average effect on the repair interval of the structural part	Exposure				Important bridge site
	easy	normal	hard	very hard	
glue-laminated wood + creosote impregnation	57	50	40	35	
glue-laminated wood + salt impregnation	52	45	32	27	
glue-laminated wood + salt impregnation + structural protection	60	52	40	35	
wood deck	40	32	30	20	
stress laminated wood deck	40	35	32	22	

Results –suggestion (5/6)

Bridge Life Cycle Optimisation

Expansion joints and bearings (1/2)

Repair: Repairing/maintenance

Average effect on the repair interval of the structural part	Exposure				Important bridge site
	easy	normal	hard	very hard	
elastomeric bearings	22	20	17	15	
pot bearings	22	20	15	12	
steel bearings	27	25	22	17	
flexible plug expansion joint	20	17	12	10	
expansion joint mechanism	25	20	15	10	

Expansion joints and bearings (2/2)

Repair: Renewing

Average effect on the repair interval of the structural part	Exposure				Important bridge site
	easy	normal	hard	very hard	
elastomeric bearings	50	45	40	32	
pot bearings	52	50	42	35	
steel bearings	55	50	45	37	
flexible plug expansion joint	42	40	30	22	
expansion joint mechanism	45	40	30	25	

Results –suggestion (6/6)

Bridge Life Cycle Optimisation

Waterproofing

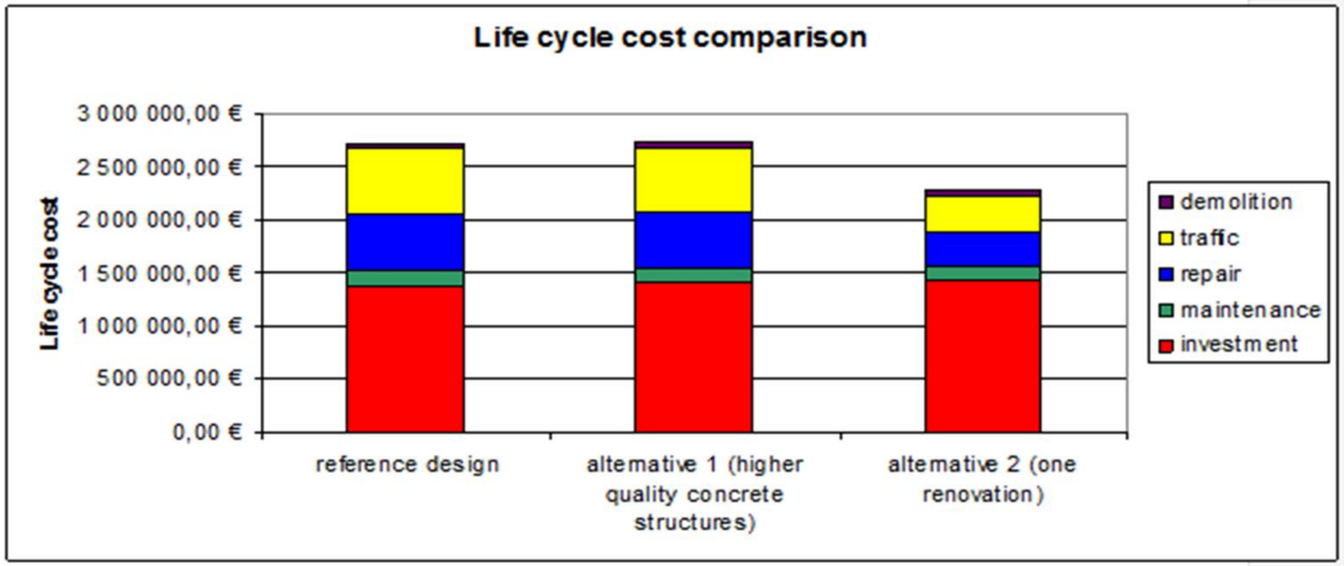
Repair: Renewing the surface structure (and waterproofing)

Average effect on the repair interval of the structural part	Exposure				Important bridge site
	easy	normal	hard	very hard	
sheet membrane waterproofing	50	45	37	32	
mastic waterproofing	37	32	25	20	
liquid applied membranes	47	40	35	30	
no waterproofing	30	22	17	12	

Example calculations – Highway viaduct

Bridge Life Cycle Optimisation

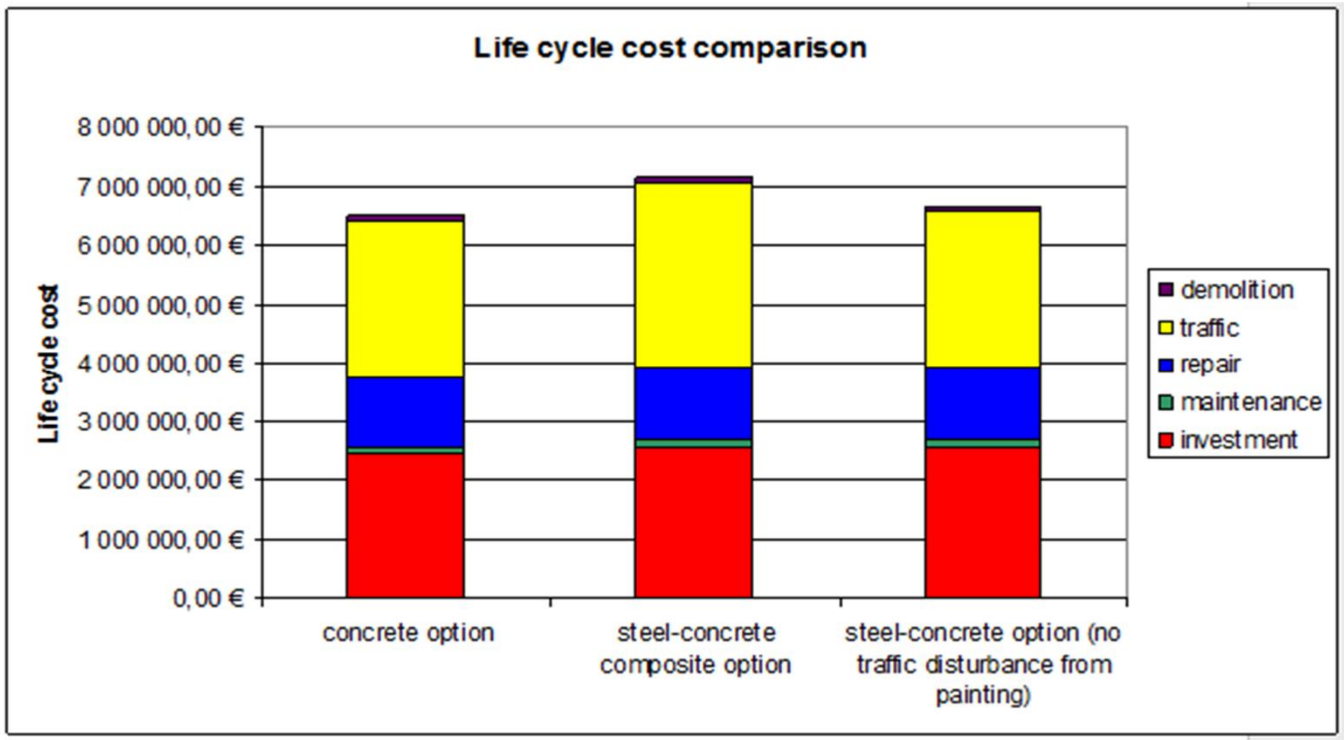
- Reference design: ”normal” structures
- Alt 1: higher quality concrete structures
- Alt 2: long-lasting structures -> cycle of one renovation



Example calculations – Highway bridge over a river

Bridge Life Cycle Optimisation

- Alt 1: Prestressed concrete girder
- Alt 2: steel concrete composite girder



Conclusions

Bridge Life Cycle Optimisation

- Estimates are preliminary
  - With these comparison throughout the life cycle can be done
  - Estimates must be updated
  - Register data should be used in updating the values
- Life cycle costs are reduced if one renovation cycle can be achieved
  - Risks concerning the waterproofing rises
- Suggestions for future research:
  - Comparison to other sources
  - The effect of traffic disturbance on the life cycle costs and environmental impacts