Closing Seminar
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Malmö

NordFoU

LIFE CYCLE COST CALCULATION OF CONCRETE BRIDGE DECK SURFACE STRUCTURES

M. Sc. Sami Noponen

RAMBØLL

In the life cycle cost analysis

Bridge Life Cycle Optimisation

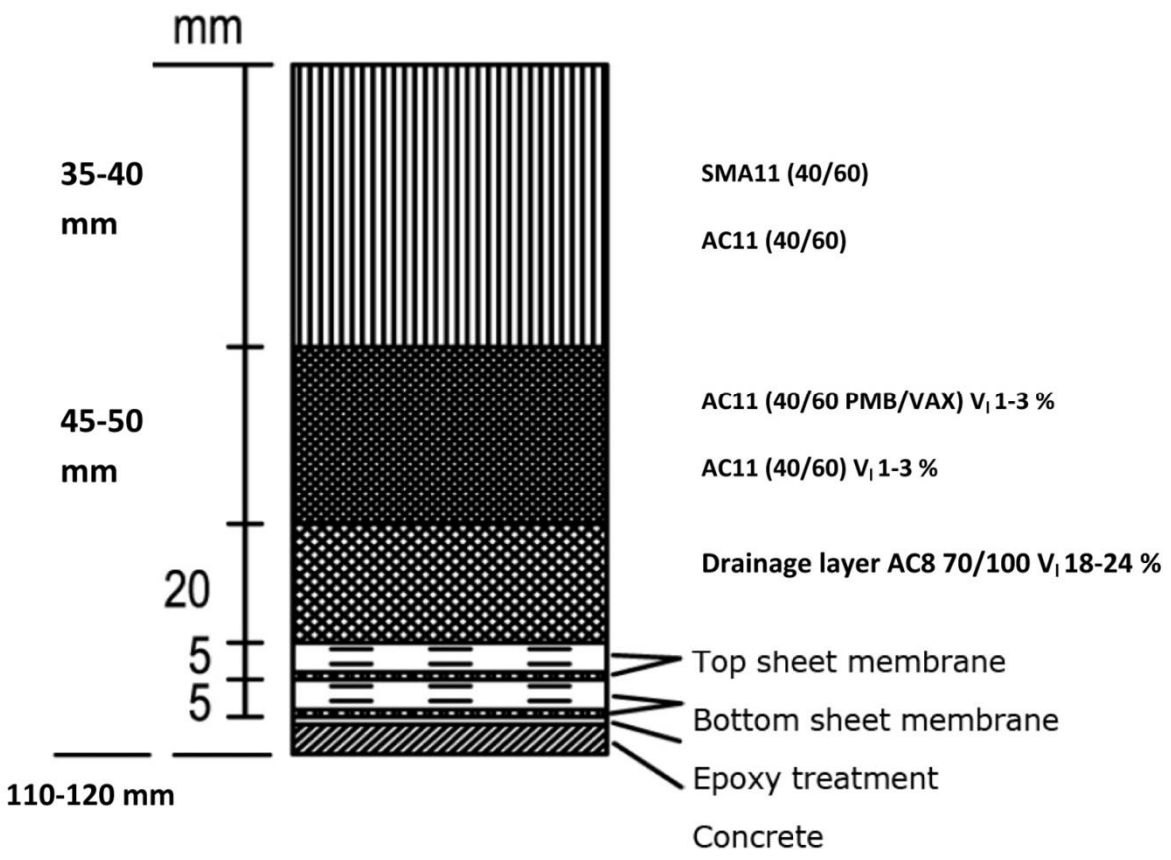
- The essential data is
  - The investment cost
  - Predicted rehabilitation time
  - Rehabilitation costs
- The life of new and already rehabilitated bridge deck depend on the surface structure materials and details
  - Waterproofness
  - Deterioration sensibility
  - Compliance to construction regulations
  - Level of quality control

The results of the study are

- The answers of the questionnaire to Nordic bridge experts
  - Of the most typical concrete bridge surface structures
  - On the positive and negative aspects of the surface structure behaviour
- The life cycle cost analysis and comparison of different concrete bridge deck surface structures made from the following wearing coarses and waterproofing materials
  - Asphalt concrete, Stone mastic asphalt and Hot rolled asphalt
  - Sheet membrane, mastic and liquid applied waterproofing
  - Rehabilitation method is either normal or fast

Typical Danish surface structure

Bridge Life Cycle Optimisation



The positive and negative aspects of the typical Danish bridge surface structure

- Positive
  - When the epoxy primer is applied in two consecutive layers, in total 800 g/m^2, it forms a surface free from pores thus preventing any blistering under normal conditions.
  - If any water penetrates the wearing and base coarse it is drained through the drainage layer and let out through drainage channels and pipes placed in the gutter lines
- Negative
  - The 2-layer system is very expensive and rather time-consuming
  - The epoxy primer is very sensitive to ambient conditions

The typical Finnish surface structure

- AC 16/120 50mm, AC11/70 30mm, AC 6/50 20mm, 2 sheet membrane layers, epoxy primer
- Positive
  - The epoxy layer when constructed according to the restrictions prevents blistering.
  - In Finland sheet membrane waterproofing is proven to be the most durable and watertight waterproofing material.
  - Water doesn't flow long distances under the sheet membrane connected to the epoxy treated deck.
- Negative
  - Construction is expensive and time-consuming
  - Recently in hot summers there have been big blistering problems despite epoxy treatment.

The typical Norwegian surface structure

- Wearing coarse >40mm, binder coarse if needed, mastic waterproofing (Topeka 4S) 12mm, Fine sand 0,5-1,5mm, bitumen PmBE60
- Positive
  - Cost effective
  - Simple and fast to apply
  - Robust
  - Local failures don’t affect the whole bridge deck
  - No need for drainage layers and drain pipes
- Negative
  - Blistering has occured a few times on new bridges, but never on old ones

The typical Swedish surface structure

- Asphalt concrete wearing coarse 40mm, combined protection and binder coarse made from polymer modified coarse aggregate mastic asphalt PGJA 50mm, waterproofing of polymer modified flexible sheet 5mm
- Positive
  - PGJA is also included as waterproofing
  - PGJA makes it possible to grind down/repair the wearing coarse many times before having to replace the binder coarse and waterproofing
  - Very safe and durable
- Negative
  - More expensive than some other systems

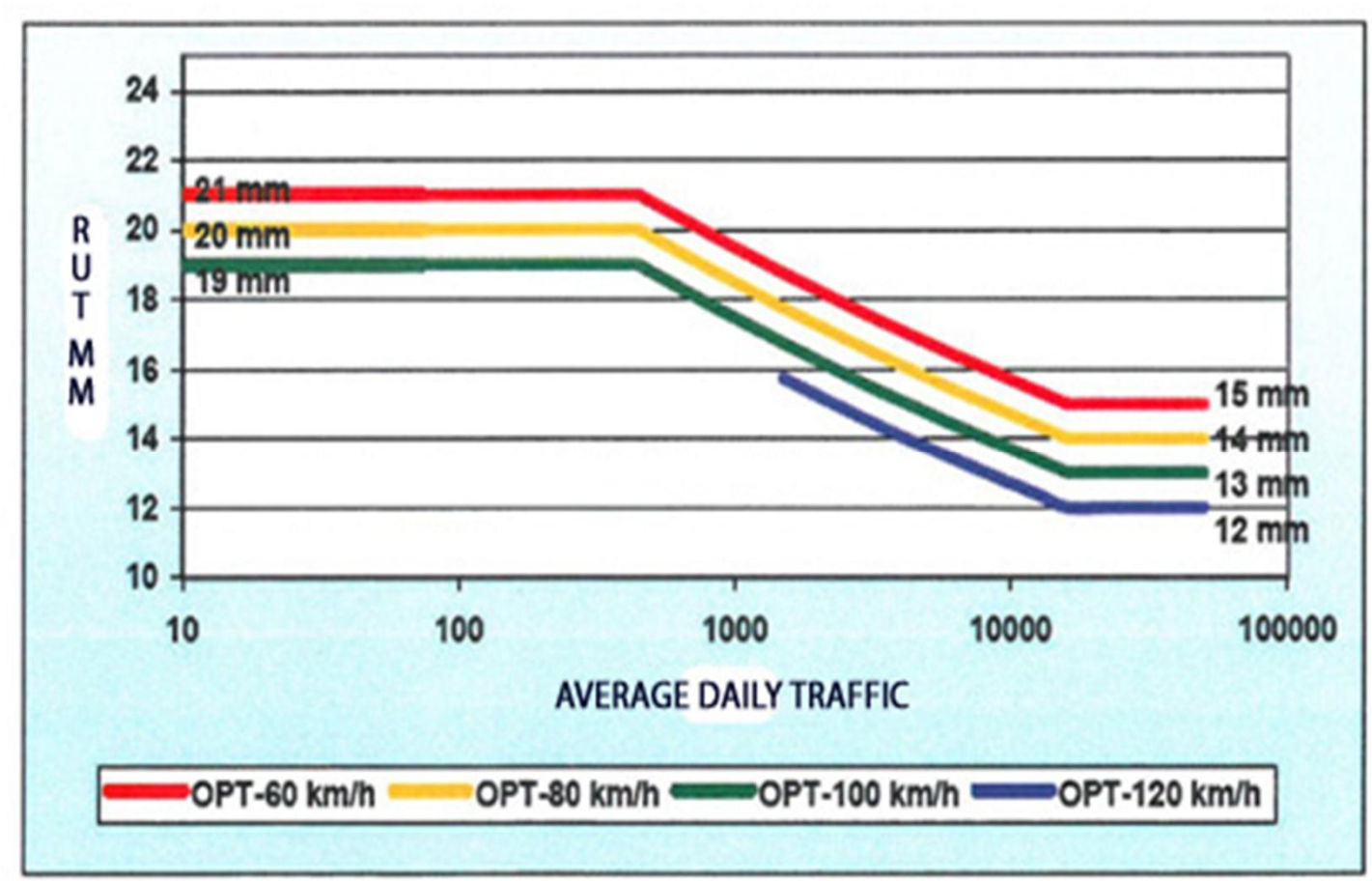
The initial data of the LCC has been received from the following sources

Bridge Life Cycle Optimisation

- The initial unit costs from the Finnish Transport Agency's bridge cost quide
- The cost information of insulation-free bridges is from research named Isoleringsfrie broer
- The renewal costs of the surface structure are from the 'Bridge Inspector's Quide'
- Some quidelines on rehabilitation work timeframes are taken from the Finnish research publication, 'Speeding up bridge rehabilitation'
- The rutting speed and other kind of deterioration is taken from researches 'The rutting of different bridge coarses' and from 'The Finnish bridge life cycle cost calculation instruction manual'

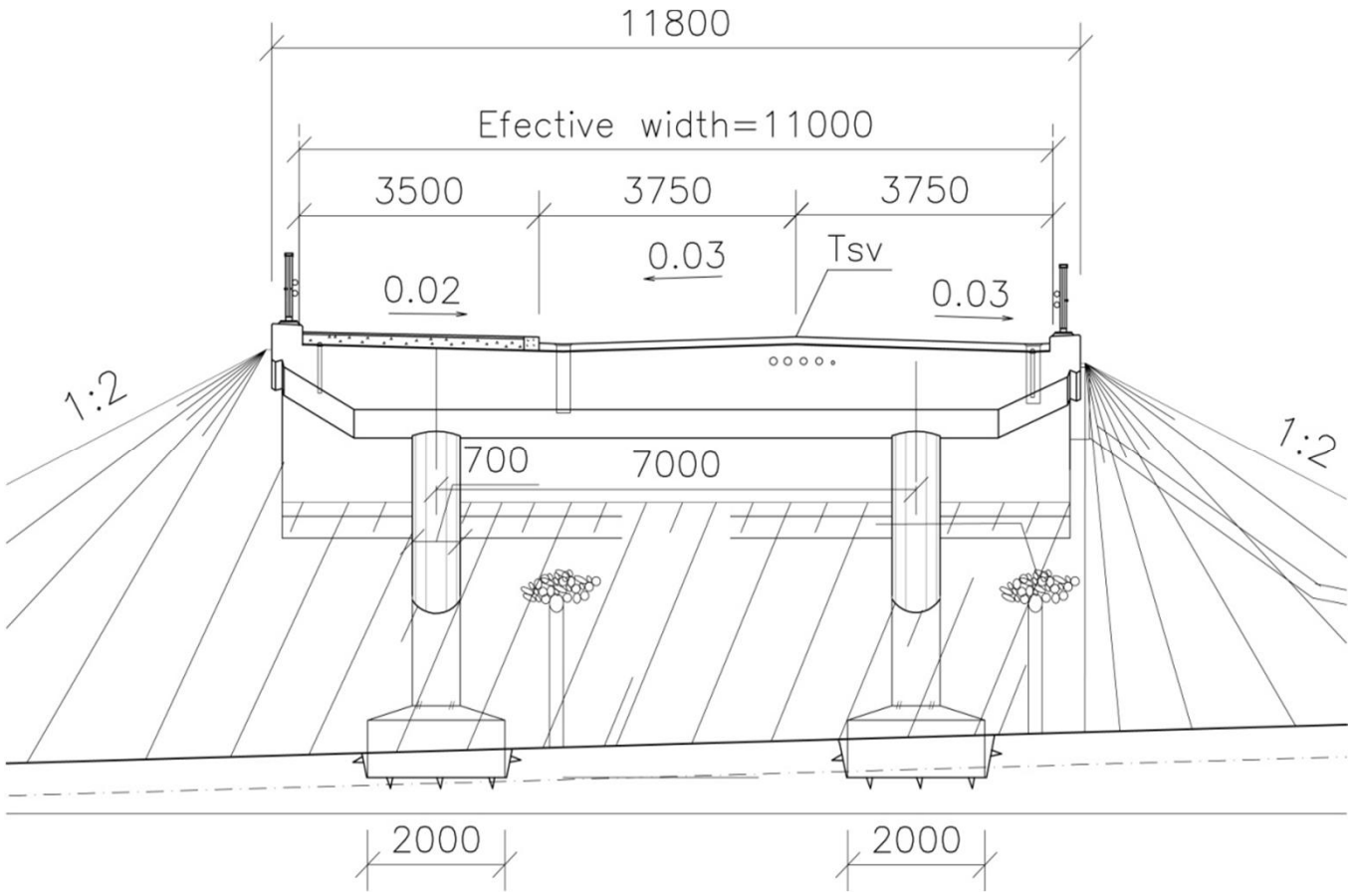
The rutting limits for rehabilitation actions

Bridge Life Cycle Optimisation



The LCC example bridge with 11 metre effective width and 23 metre length (250 m^2)

Bridge Life Cycle Optimisation

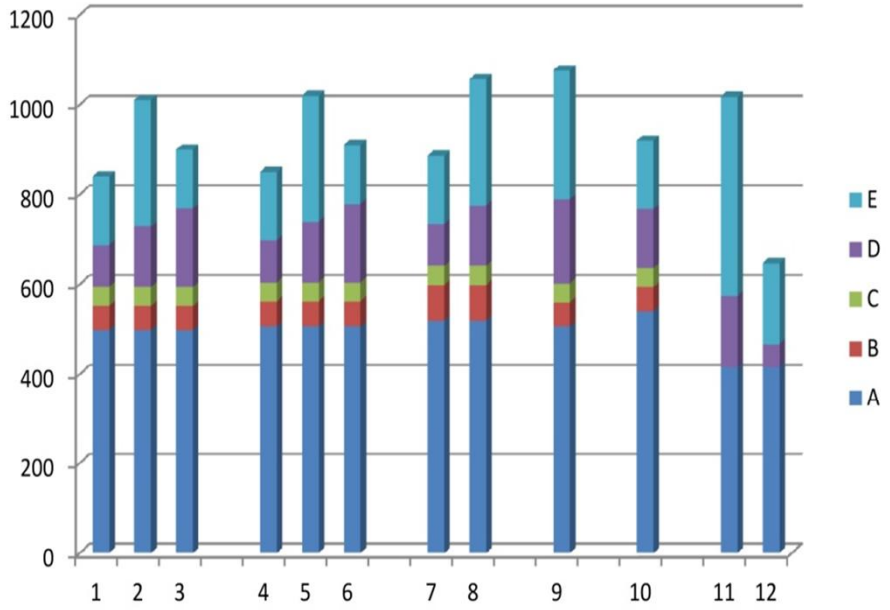


LCC distribution of different concrete bridge deck surface structure alternatives for 500 ADT per lane

Bridge Life Cycle Optimisation

Alternatives:

AC+sheet membrane
1 -norm. 45 y. rehabilitation
2 -rehabilitation max. 60 y.
3 -fast rehabilitation 60 y.
SMA+sheet membrane
4 -norm. 45 y. rehabilitation
5 -rehabilitation max. 60 y.
6 -fast rehabilitation 60 y.
HRA+sheet membane
7 -norm. 45 y. rehabilitation
8 -rehabilitation max. 60 y.
9 AC+mastic waterp. (rehab. 30+60 y.)
10 AC+liquid aplied waterp. (rehab. 45 y.)
11 Concrete slab , insulation free, scen. 1
12 Concrete slab , insulation free, scen. 2



Distribution of discounted life cycle costs:

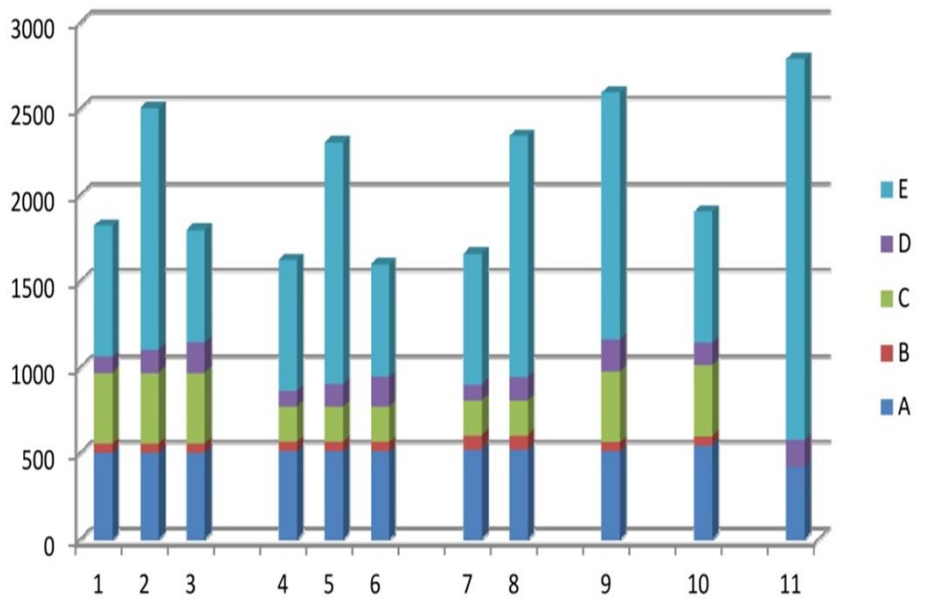
A	Initial costs of bridge surface and superstructure construction
B	Rehabilitation of bridge asphalt layers
C	Driver delay cost due asphalt layer rehabilitations
D	Rehabilitation of deteriorated waterproofing
E	Driver delay cost due waterproofing rehabilitations

LCC distribution of different concrete bridge deck surface structure alternatives for 2,000 ADT per lane

Bridge Life Cycle Optimisation

Alternatives:

AC+sheet membrane
1 -norm. 45 y. rehabilitation
2 -rehabilitation max. 60 y.
3 -fast rehabilitation 60 y.
SMA+sheet membrane
4 -norm. 45 y. rehabilitation
5 -rehabilitation max. 60 y.
6 -fast rehabilitation 60 y.
HRA+sheet membane
7 -norm. 45 y. rehabilitation
8 -rehabilitation max. 60 y.
9 AC+mastic waterp. (rehab. 30+60 y.)
10 AC+liquid aplied waterp. (rehab. 45 y.)
11 Concrete slab , insulation free, scen. 1



Distribution of discounted life cycle costs:

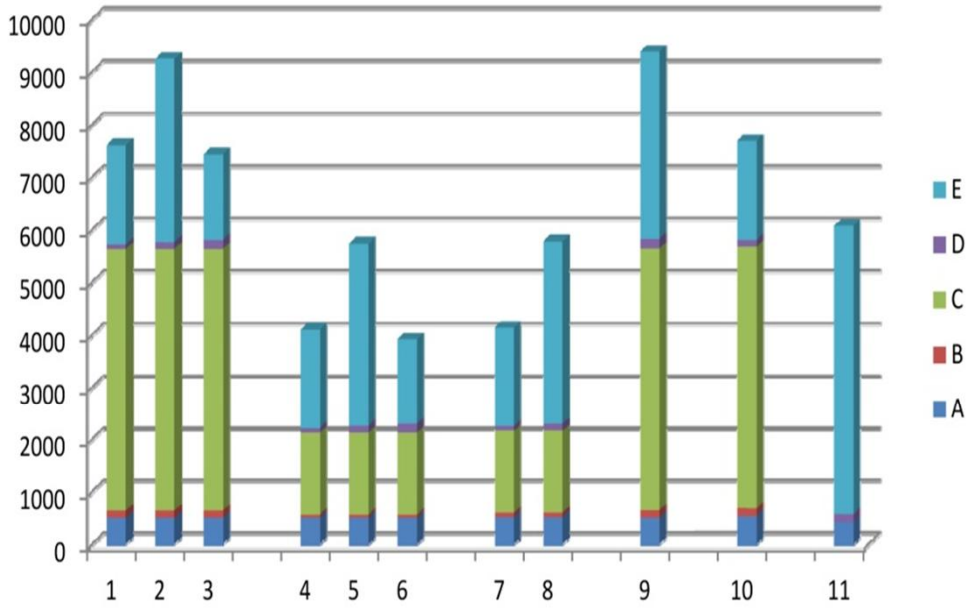
A	Initial costs of bridge surface and superstructure construction
B	Rehabilitation of bridge asphalt layers
C	Driver delay cost due asphalt layer rehabilitations
D	Rehabilitation of deteriorated waterproofing
E	Driver delay cost due waterproofing rehabilitations

LCC distribution of different concrete bridge deck surface structure alternatives for 5,000 ADT per lane

Bridge Life Cycle Optimisation

Alternatives:

AC+sheet membrane
1 -norm. 45 y. rehabilitation
2 -rehabilitation max. 60 y.
3 -fast rehabilitation 60 y.
SMA+sheet membrane
4 -norm. 45 y. rehabilitation
5 -rehabilitation max. 60 y.
6 -fast rehabilitation 60 y.
HRA+sheet membane
7 -norm. 45 y. rehabilitation
8 -rehabilitation max. 60 y.
9 AC+mastic waterp. (rehab. 30+60 y.)
10 AC+liquid aplied waterp. (rehab. 45 y.)
11 Concrete slab , insulation free, scen. 1



Distribution of discounted life cycle costs:

A Initial costs of bridge surface and superstructure construction
B Rehabilitation of bridge asphalt layers
C Driver delay cost due asphalt layer rehabilitations
D Rehabilitation of deteriorated waterproofing
E Driver delay cost due waterproofing rehabilitations

LCC distribution of different concrete bridge deck surface structure alternatives for 10,000 ADT per lane

Bridge Life Cycle Optimisation

Alternatives:

AC+sheet membrane
1 -norm. 45 y. rehabilitation
2 -rehabilitation max. 60 y.
3 -fast rehabilitation 60 y.
SMA+sheet membrane
4 -norm. 45 y. rehabilitation
5 -rehabilitation max. 60 y.
6 -fast rehabilitation 60 y.
HRA+sheet membane
7 -norm. 45 y. rehabilitation
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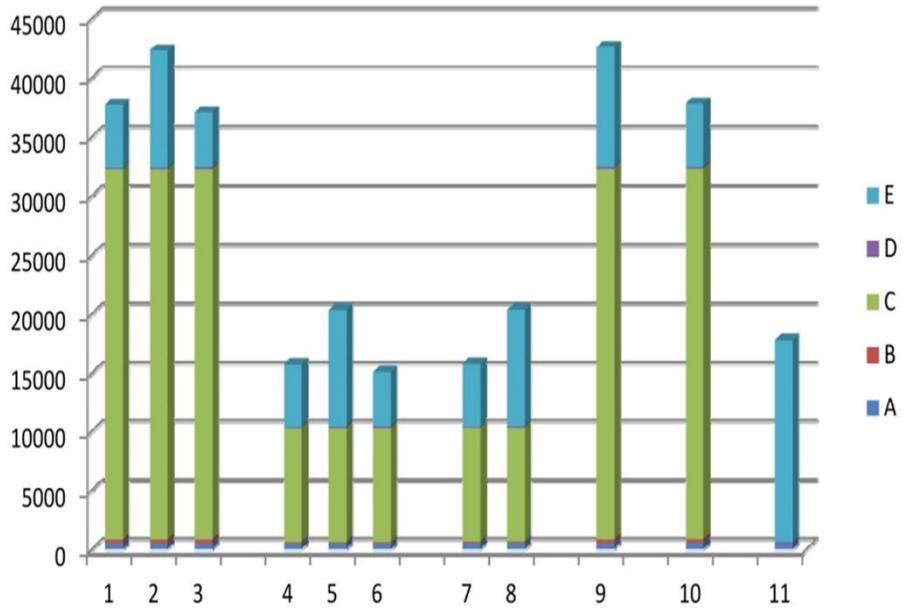

Distribution of discounted life cycle costs:

A Initial costs of bridge surface and superstructure construction
B Rehabilitation of bridge asphalt layers
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In the forthcoming research, it is desirable to consider

Bridge Life Cycle Optimisation

- Are Finnish bridge construction and rehabilitation costs at the correct level in the cost quides?
- How does the watertight mastic asphalt affect the waterproofness of the waterproofing in comparison with the other wearing coarses?
- What is the bridge wearing coarse rutting speed for different traffic volumes, and should Finnish instructions be updated?
- What is the correct way to minimise the epoxy sealing faults in hot summer weather, so that blistering problems occur as infrequantly as possible?

To decrease LCC of the bridge deck surface structure it is essential to develop

Bridge Life Cycle Optimisation

- Better deterioration procedure understanding
- Surface structures and their construction methods
- Quality-control requirements and better work supervision

Thank you!

Bridge Life Cycle Optimisation