Workshop: Broer med og uden støbestilladser, 2016

Prefabricated vs. in-situ concrete bridges in a whole life perspective

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Agenda

1. Prefabricated vs. in-situ concrete bridges
2. Tools for Life Cycle Costs (LCC) and Life Cycle Assessment (LCA)
3. Example (comparison)
4. Summary

Prefabricated vs. in-situ concrete bridges

Selected factors that influences the choice (in random order) :

- Contractual setup
- Functional requirements
- Boundary conditions (e.g. location, exposure, soil)
- Execution methods
- Structural design
- Costs
- Execution period
- Risk
- Traffic
- Life Cycle Costs
- Maintenance
- Materials
- Environmental impacts
- Durability, sustainability

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Prefabricated bridges

Pros:	Cons:
› Shorter construction time at site › Traffic disturbance and associate accidents are often minimized › Use of scaffolding is minimized (risk reduction) › Concrete elements are produced in a controlled environment (high quality) › Construction is independent on the weather situation › Large spans are possible	› Every element needs a support (requires bearings and/or cross beams) › Deck height is often higher than when cast-in-situ › More joints are required (larger maintenance costs) › Limited lengths and widths due to transport

In-situ cast bridges

Pros:	Cons:
› Extensive architectural degrees of freedom › Monolithic structures are possible (static advantageous) › No need for cross beams › Interface management is minimized	› Longer period of construction (imposes risks) › Execution require more man-power › Scaffolding is required (imposes risks) › Period of traffic disturbance is longer when compared to prefabricated bridges (imposes risks) › Quality level is dependent on the weather situation › Many site operations at the same time (imposes risks)

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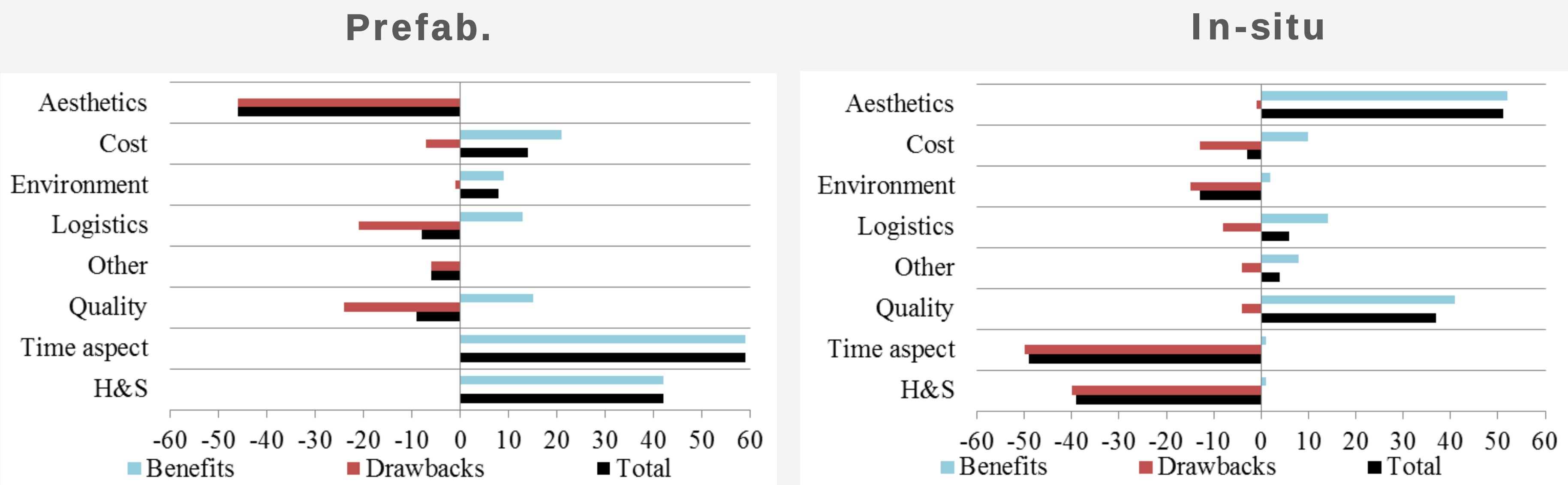
Recent study in Sweden…(Larsson & Simonsson, 2012)



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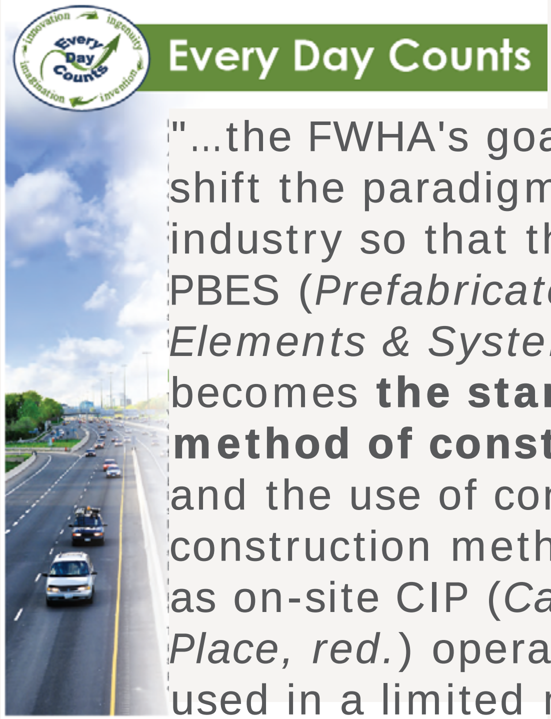
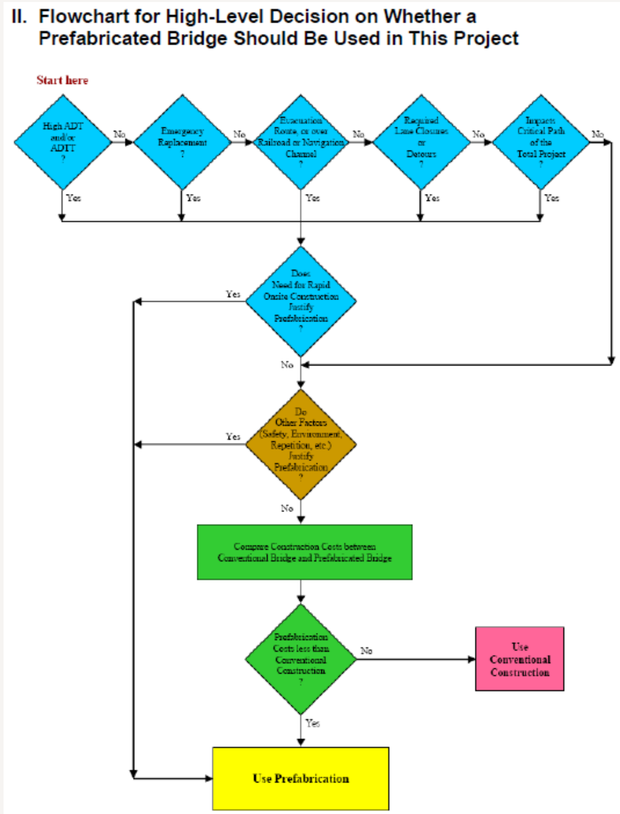
US initiative...(2009-)



"...the FWHA's goal is to shift the paradigm of our industry so that the use of PBES (*Prefabricated Bridge Elements & Systems, red.)* becomes **the standard method of construction** and the use of conventional construction methods, such as on-site CIP (*Cast-In-Place, red.*) operations are used in a limited manner"



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US initiative – some statements…

Accelerated Bridge Construction (ABC) comprise:

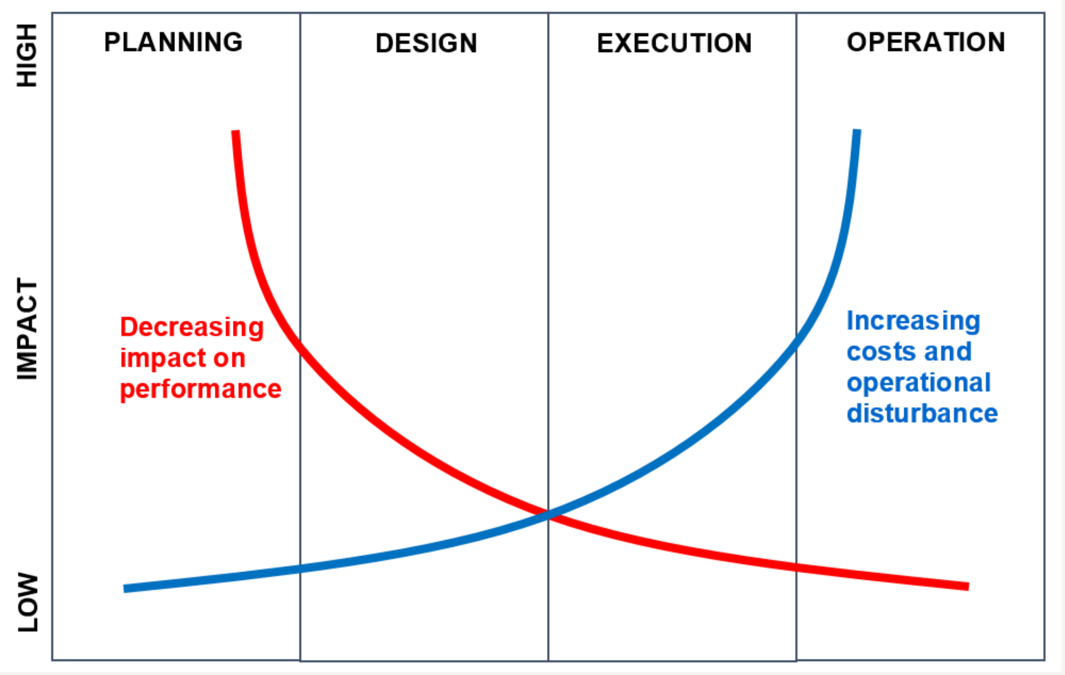
- Slide-in Bridge Construction
- Prefabricated Bridge Elements and Systems
- Geosynthetic Reinforced Soil–Integrated Bridge System.

BENEFITS

Benefits to employing ABC technology include:

- **Mobility impacts on bridge construction or replacement projects can be reduced to 48 to 72 hours with planning and bridge construction reduced by years.** Decreasing construction time directly benefits the public by significantly reducing traffic delays and road closures.
- **Reduced agency costs.** ABC can be the most cost-effective means of construction, especially when total project costs, including right-of-way acquisition, project administration, maintenance of traffic, environmental mitigation utility relocation, escalation or railroad flagging costs are considered.
- **Reduced user costs.** ABC dramatically reduces work zone road user costs associated with bridge construction projects on existing roadways.
- **Improved motorist and worker safety.** Each year 2,000 fatal crashes occur in work zones. Forty-four percent of bridge construction worker injuries involve a vehicle traveling through a work zone and two-thirds of these injuries are fatal. Limiting the duration of traffic impacts reduces the exposure to work zone crashes, increasing safety for both the construction worker and the traveling public.
- **More durable, longer-lasting bridges.** As our Nation faces the prospect of crumbling infrastructure, this innovation is not only effective, but also incredibly important to addressing this serious, time-sensitive challenge.
- **An effective solution to environmentally sensitive areas.** ABC technologies may also be an effective solution or alternative in areas where construction may be constrained or delayed by environmental considerations or limitations.
- **Public support.** Post-construction surveys of residents and businesses indicate high levels of customer satisfaction for ABC projects.

Decisions made early has the greatest impact…



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Contractual setup

Common: Contracts shall support low life cycle costs, stable budgets, right timing and innovation where appropriate.

- **Design and build**
  - functional requirements shall ensure low life cycle costs
  - including other LCC-based requirements can be difficult / requires a robust evaluation model
  - contractors degree of freedom shall be maintained
- **Public-Private-Partnership** (PPP)
  - ex. for a 30 year period, risks are spilt btw. partners
- others...

Tendering – Functional requirements

- Often they concern initial quality because of warranty period
- How to deal with a 10% reduction in service life?

- A LCC model as part of the tender evaluation could supplement functional requirements, on component level it could favor:
  - low initial cost
  - low maintenance and replacement costs
  - low quantity (very transparent)
  - high service life

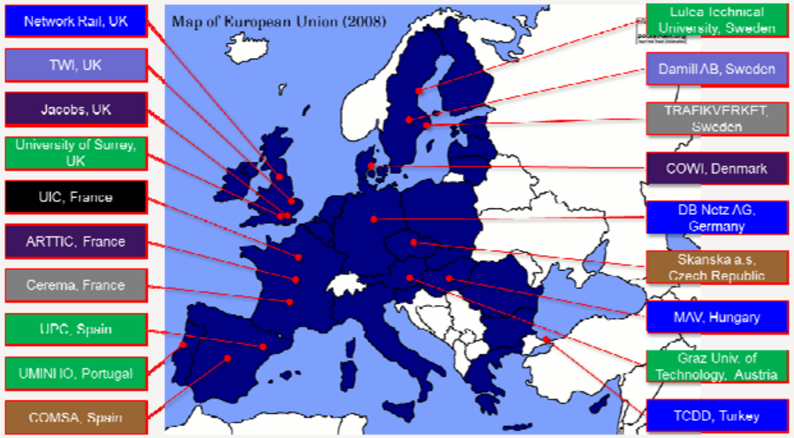
LCC in a tender framework

- Contractors job (objectivity)?
- Owners job (robust and transparent model as part of tender)?
- Step-wise procedure:
  - LCC (Owner) of Conceptual Design
  - LCC (Contractor) as part of the offer (model as part of tender)
  - LCC (Owner) comparison of offers
  - LCC (Owner) during construction as a reality check
- Requires country specific and realistic O&M costs
- Keeping Contractors degrees of freedom

Tools for LCC and LCA … for bridges

ETSI
BRIDGE LIFE CYCLE OPTIMISATION

MAIN LINE



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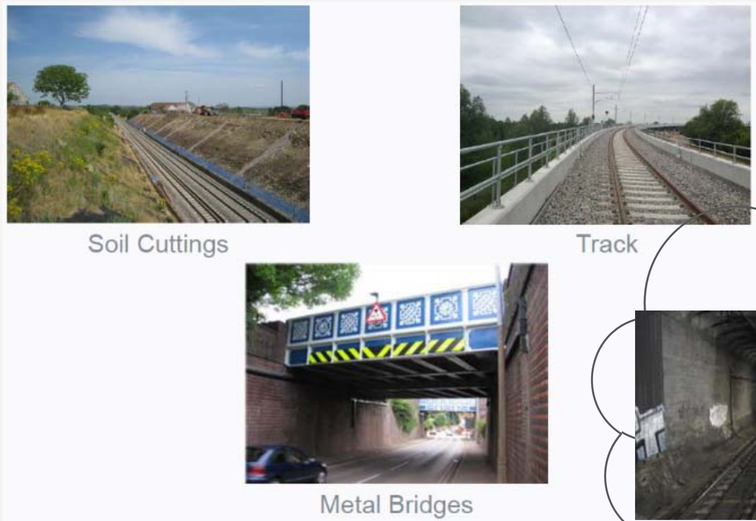
ETSI

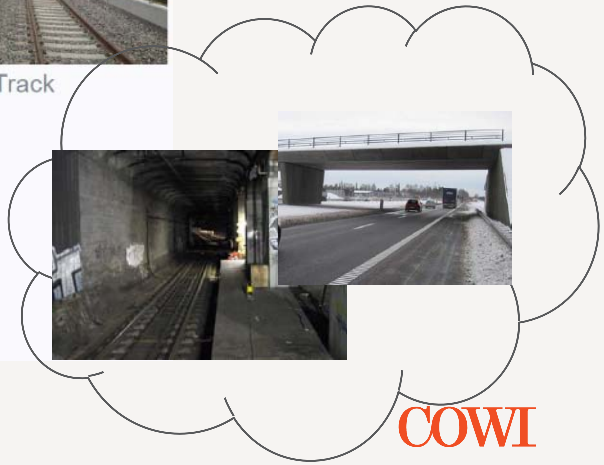

Choosing the Best Bridge Alternative
ETSI
Compromise
LCC
LCA
"LCE"

MAINLINE

› **MAIN**TENANCE, RENEWA**L** AND **I**MPROVEMENT OF RAIL TRANSPORT **IN**FRASTRUCTURE TO REDUCE **E**CONOMIC AND ENVIRONMENTAL IMPACT

&





Example (comparison)

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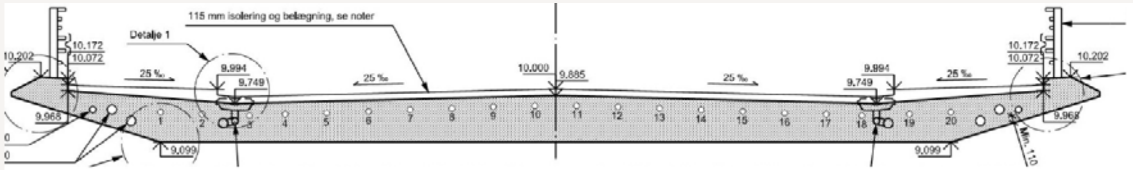
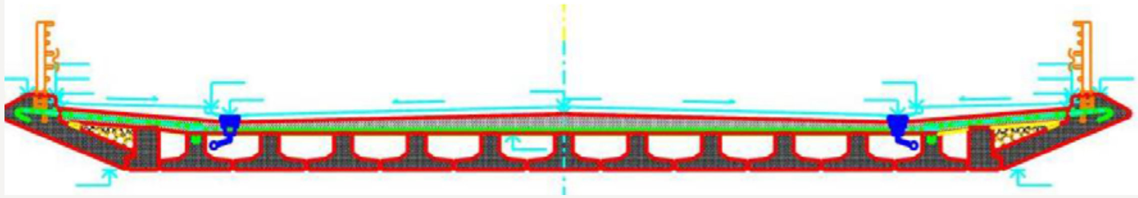
Example (comparison)

- Construction costs:
  - In-situ: 11.4 mio. DKK.



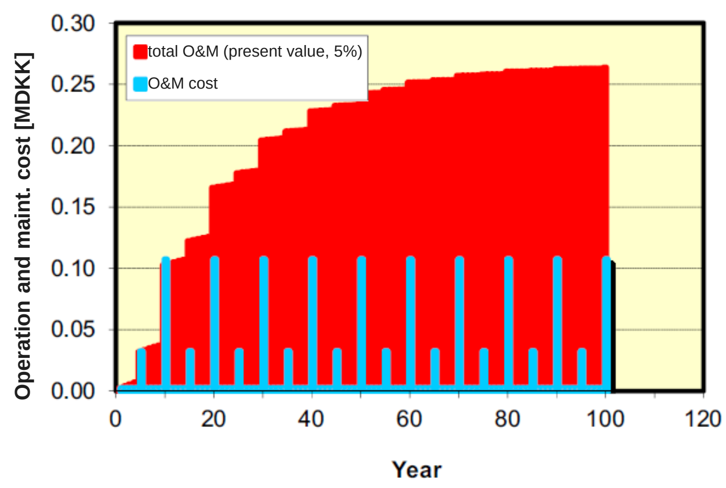
  - Prefab: "same level"

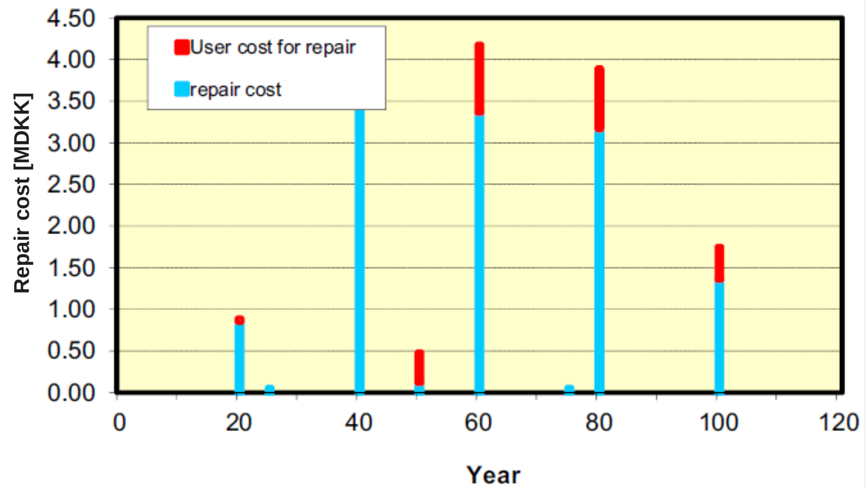


Recent study from Netherlands support this for "typical" bridges (Bakker, 2014) +/- 10%

Example (comparison)

› O, M and R budget (in-situ):





Routine Maintenance (yearly)
Principal Inspection (every 5th year)
Special Inspection (every 10th year)
Road user disturbance not included

Primarily: Wearing course, surfacing+ waterproofing, conc. rep., railings and edge-beams

Example (comparison)

- We do not have sufficient data...
- However, construction joints in prefab. bridges increase O&M costs
- But Net Present Values during a 100 year period are expected to be roughly the same.

Example (comparison)

› Road user disturbance cost (NPV, 5%):

	ADT	Speed (km/h)	Detour
Overpass	10.000	50 -> 30	1 km
Underpass	40.000	110 -> 70 (6 -> 4 lanes)	-

⇩

	Duration (years)		Cost (MDKK)		Remark	Reference
	In-situ	Prefab	In-situ	Prefab		
Execution	1	7/12	37	22	No queuing	DRD
Operation	100	100	0.27	~0.27	No queuing	ETSI

Example (comparison)

- Other society cost, ex. accidents:
  - 1 death: ~20 MDKK.
  - Risk = Probability x Consequence
  - In-situ (1 year):
    - Execution: 24.000 kr.
  - Prefab (7 month):
    - Execution: 14.000 kr.
  - Additional risk due to scaffolding and other effects

Activity	Number of deaths per hour per 10^8 persons
Mountaineering (int.)	2700
Travel by plane (int.)	120
Travel by car	56
Construction sites	7.7
Accidents at home	2.1
Structural failure	0.002

~2.5 (DK 2003-2008), recent numbers for constuction sites are smaller

UK, 1970'ies
(Thoft Christensen et al, 1982)

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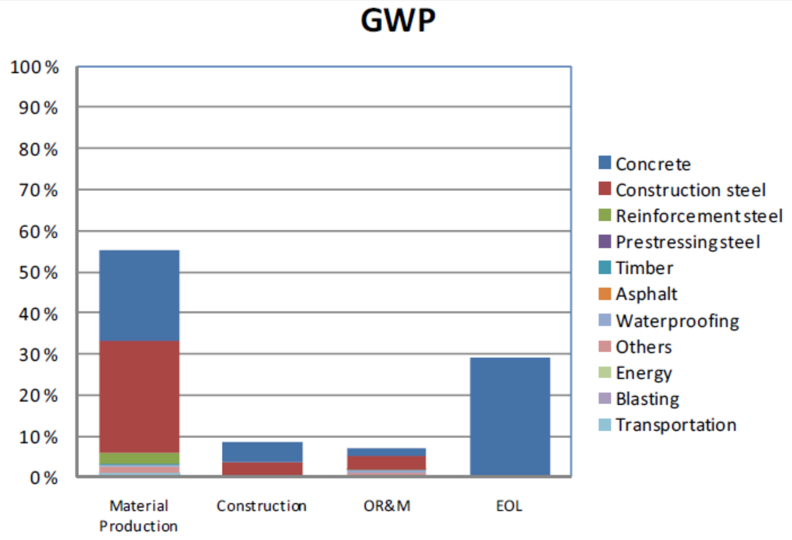
Environment – (How) do we take this into consideration?

According to MAINLINE investigation, it is limited due to:

- Bridge projects consist of many different elements
- Long service life
- Significant uncertainties
- Complexity (not only CO_2 and waste)
- Lack of local data
- Lack of rules for monetization (balancing discount rate, tax etc.)

Global Warming Potential – Overpass Vindingevej (ETSI, 2013)



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Summary

- We see a growth in number of prefabricated bridges
- Growth is primarily driven by society costs (road user disturbance)
- Some reservations related to aesthetics
- Tools and data for LCC and LCA are needed
- Tendering and contractual setup shall support the above
- Gathering of data/experience is needed from all partners and especially for infrastructure managers

Thank you

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