Future Infrastructure Forum
Scandinavian Points of View

Lennart Elfgren

Professor of Structural Engineering

Luleå University of Technology, Sweden

Cambridge, March 27, 2013

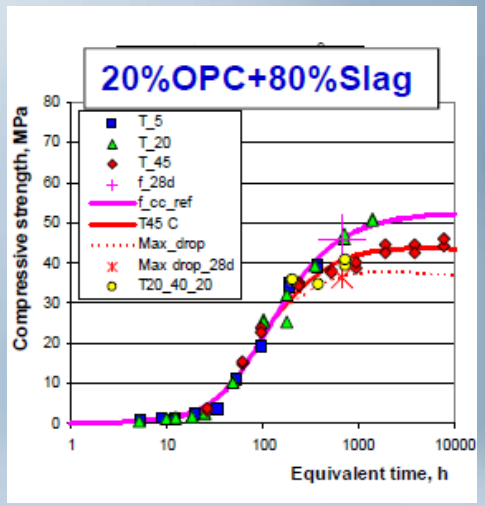
Outline – My journey

- Background
- Swedish Universities of the Built Environment
- EU Projects – Sustainable Bridges & Mainline
- Possible Future Projects
  - Proactive Bridge Strengthening
  - BIM – Building Information Modelling
  - Climate Change, Energy, Ethics & Moral


Luleå
English Civil Engineers of major importance in Sweden
- Telford 1737 - 1834 - Canals
- Stephenson 1781 - 1848 - Railways
- Brunel 1806 - 1859 - Bridges

Division of Structural and Construction Engineering

- Concrete - Low environmental impact (Mats Emborg, Jan-Erik Jonasson, Vladimir Ronin)
- Steel and Timber Structures (Milan Veljkovic, Peter Collin, Lars Stehn, Helena Johnsson)
- Building Production, Industrial Methods (Thomas Olofsson, Martin Nilsson, Ulf Ohlsson)
- Assessment, Health Monitoring, Repair (Björn Täljsten, Thomas Olofsson, Lars Bernspång)
- Ice technology (Lennart Fransson)



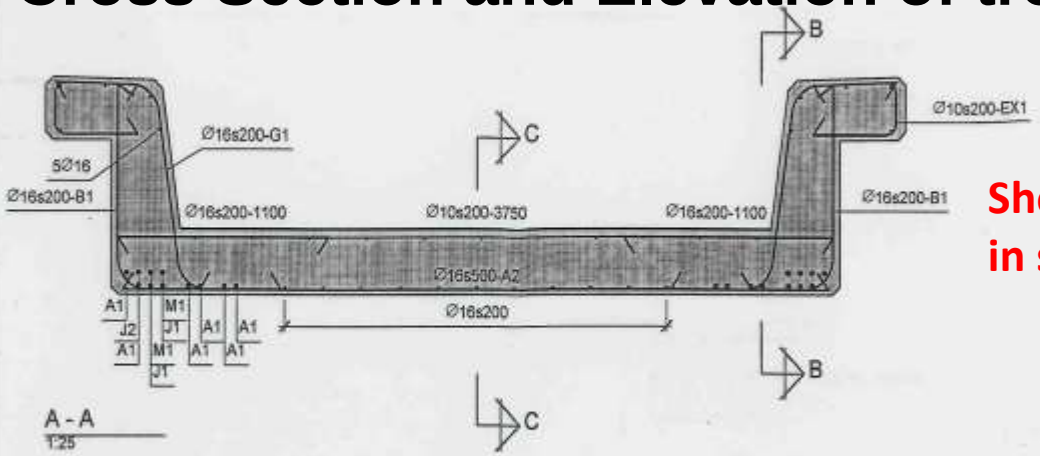
Background

Narvik

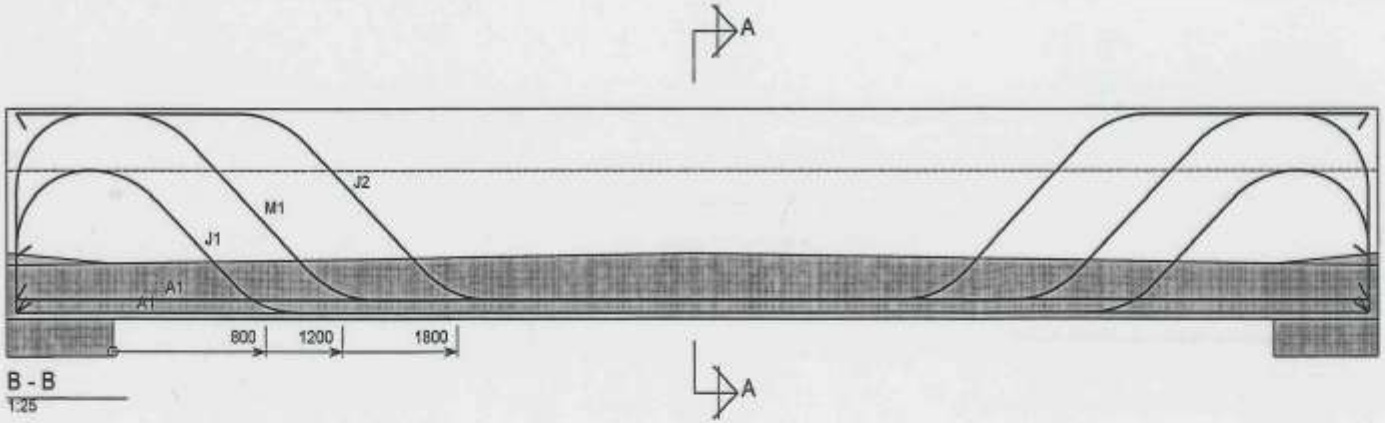
Malmbanan was built around 1900, has a length of about 500 km and has more than 100 bridges.

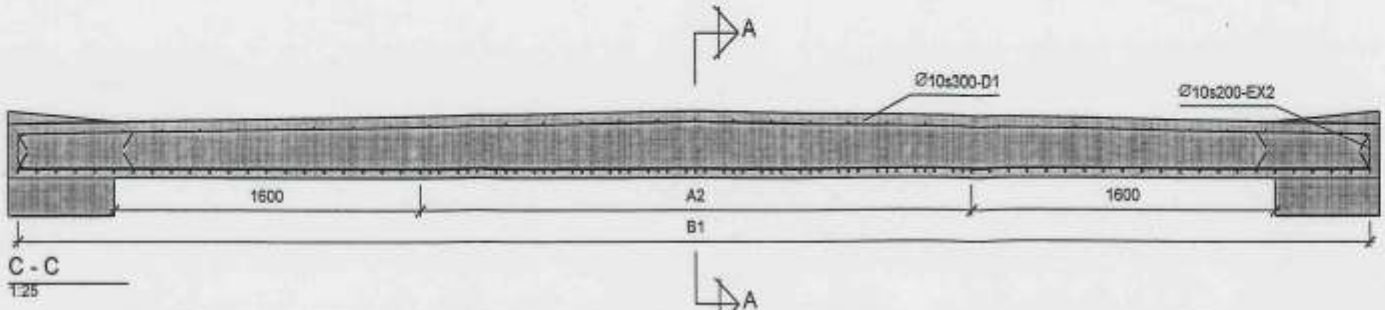
The iron ore producer, LKAB, wanted to minimize its cost for transportation of the ore to the harbours in the Atlantic (Narvik) and the Baltic (Luleå)?

Cross Section and Elevation of trough bridge



Shear Fatigue Capacity in slab-beam connection ?





FÖRKLARINGAR

BETECKNING	ARMERING TYP
A1	6+6 Ø25-7100
J1	2+2 Ø25
J2	1+1 Ø25
M1	2+2 Ø25

FÖRESKRIFTER

BETONG I, STD K40, KONSTRUKTIONS-GRUPP B VATTENTÄT, ARMERING KS40.

HÄNVISNINGAR

VIDSTÅENDE RITNING ÄR ETT UTDRAG UR BANVERKETS BETONGDÄCK ENLIGT STANDARDRITNING B 2447-12 AV ÅR 1972, REV 1974 OCH 1976-12-16.

TRÅGBROAR LÄNGS MALMBANAN

TVÄR- OCH LÄNGDSNITT: ARMERING

We tested a 20 year old bridge. The test showed that we had no shear fatigue problems.

The allowable axle loads could be increased from 25 to 30 tons

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Swedish Universities of the Built Environment

A collaboration between four major Swedish universities of technology:

- Luleå University of Technology, LTU
- Royal Institute of Technology in Stockholm, KTH
- Chalmers University of Technology in Göteborg, CTH
- Lund University in Lund, LTH

Swedish Universities of the Built Environment

CHALMERS

KTH VETENSKAP OCH KONST

LULEÅ TEKNISKA UNIVERSITET

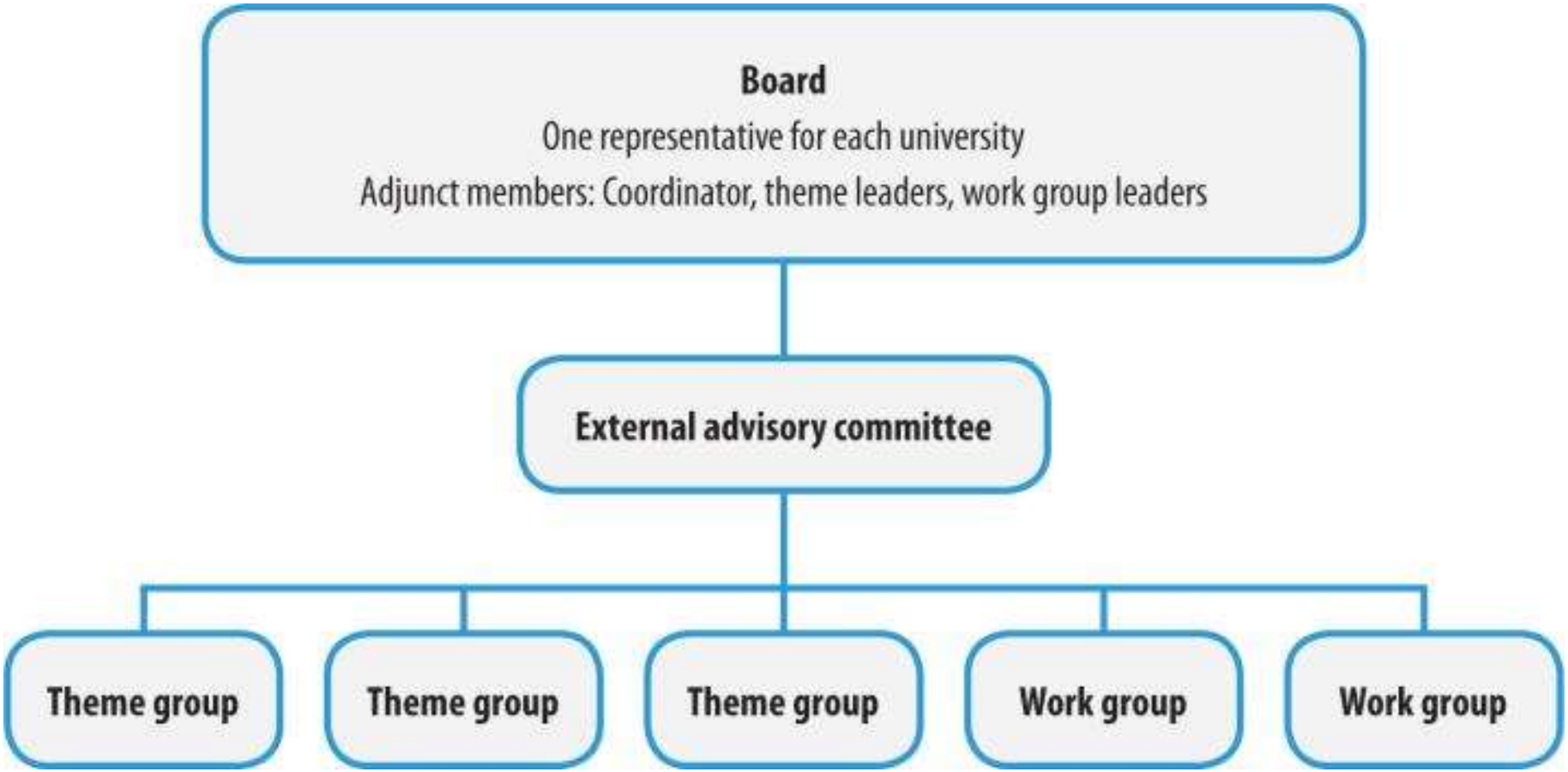
LUNDS UNIVERSITET

Background and purposes

- Small research groups and decline in funding
- Low research volume in relation to sector size
- Strengthen by collaboration: attain critical mass and increase international funding
- 2009-2010 Start up project
- 2011- 2013 Collaboration agreement, basic financial support for coordinator and expenses.

Swedish Universities of the Built Environment
CHALMERS
KTH VETENSKAP OCH KONST
LULEÅ TEKNISKA UNIVERSITET
LUNDS UNIVERSITET

Organisation



Swedish Universities of the Built Environment

CHALMERS

KTH VETENSKAP OCH KONST

LULEÅ TEKNISKA UNIVERSITET

LUNDS UNIVERSITET

Organisation

Board

Representatives from CTH, KTH, LTH and LTU

Coordinator

External advisory committee

Representatives from companies

Theme groups

- Structural Engineering
- Building Performance Design
- Construction and Facilities Management
- Geotechnology
- Water and Environmental Technology
- Highway Infrastructure and Transport Systems
- Education

Swedish Universities of the Built Environment

CHALMERS

KTH VETENSKAP OCH KONST

LULEÅ TEKNISKA UNIVERSITET

LUNDS UNIVERSITET

Activities

Internal/operative

- Cooperate in PhD, graduate and undergraduate education
- Submit joint research proposals
- Joint publications

External/strategic

- Represent built environment research
- Function as a network
- Collaborate with external actors in industry, society and other countries.

Swedish Universities of the Built Environment

CHALMERS

KTH VETENSKAP OCH KONST

LULEÅ TEKNISKA UNIVERSITET

LUNDS UNIVERSITET

http://www.sverigesbygguniversitet.se/pages/?pg=about_us

Sveriges Bygguniversitet

Startsida | Om oss | Nyheter | Publikationer | Kontakt

Nu startar bygginnovationen

2011-09-16

Det övergripande syftet med Bygginnovationen är att utveckla en stark och uthållig innovationsmiljö för svensk byggsektor. Det ska bland annat ske genom att brygga över gapet till högskole- och universitetssektorn och därigenom främja kommersialisering av kunskap, lösningar och forskningsresultat samt förbättra samverkan mellan byggsektorn, instituten och samarbetsorganisationen Sveriges bygguniversitet.

Läs mer »

Sveriges Bygguniversitet

2011-06-21

Den grundläggande driften av Sveriges bygguniversitet finansieras av de fyra högskolorna. Övrig verksamhet genomförs i projektform med hjälp av egeninsatser och bidrag från samarbetspartners, forskningsfinansiärer och övriga intressenter.

Läs mer »

Sveriges Bygguniversitet

Sveriges Bygguniversitet är en samarbetsorganisation som omfattar de forsknings- och utbildningsenheter på Chalmers, KTH, LTH och LTU som är knutna till utbildning av civilingenjörer V eller motsvarande.

Organisationens syfte är att verka för att den bygginriktade forskningen och utbildningen får bättre möjligheter att fylla det behov av ny och tvärdisciplinär kunskap och kompetens som utvecklingen mot ett mer hållbart samhälle skapar. Verksamheten är organiserad i sju temagrupper.

- Tema Byggkonstruktion
- Tema Byggprocess och förvaltning
- Tema Byggnadens tekniska funktion
- Tema Geoteknologi
- Tema Vatten och miljö
- Tema Väg- och trafikteknik
- Grundutbildningsgruppen

För mer information om Sveriges Bygguniversitet:
Koordinator: Anna Kadefors, Chalmers
Styrelseordförande: Thomas Olofsson, LTU

CHALMERS | KTH | LUNDS UNIVERSITET

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Sustainable Bridges

EC project within FP6

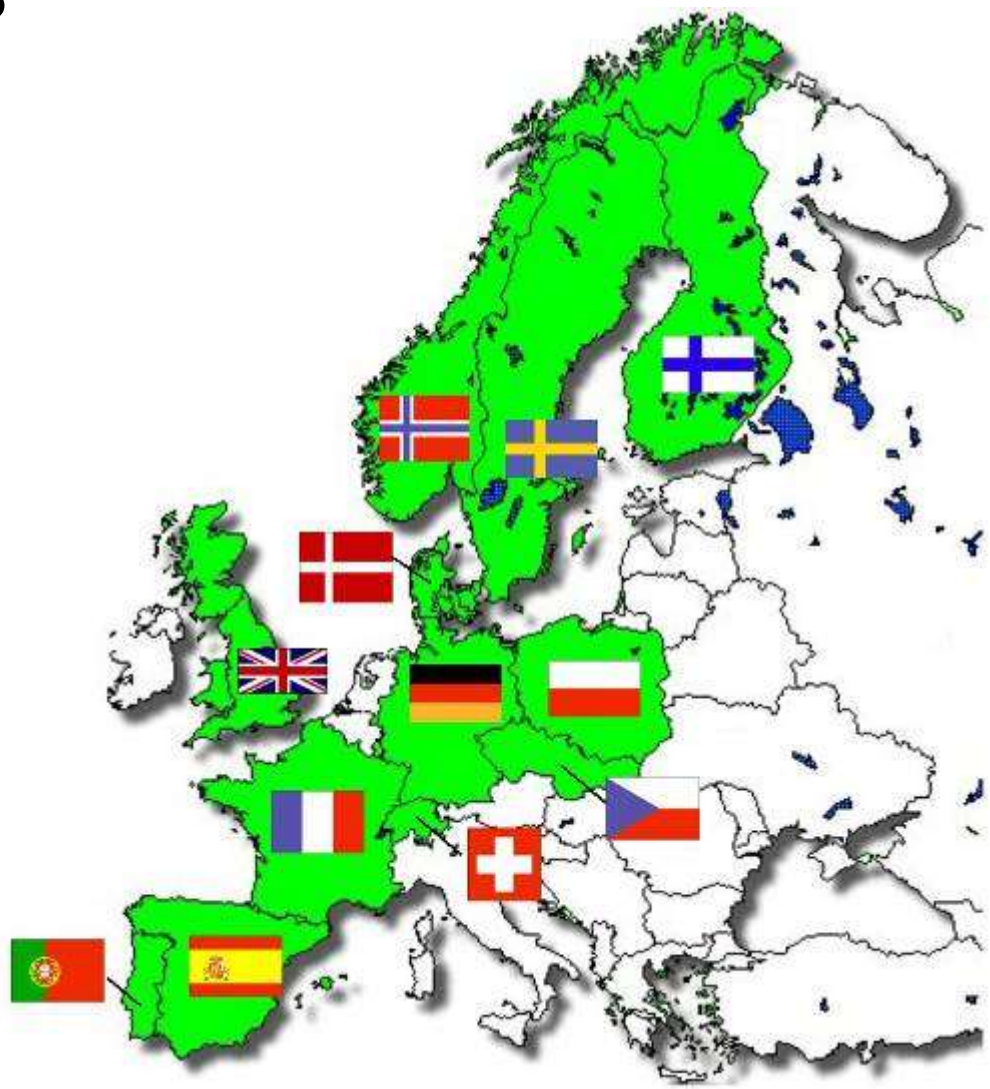
Started on December 1, 2003
Ended on November 30, 2007

Total budget (official)
10,2 million € of which
6,9 million € as EC contribution

Jan Olofsson, Skanska
Coordinator

Lennart Elfgren, LTU
Scientific Leader

New follow up Project
MAINLINE 2011-2014



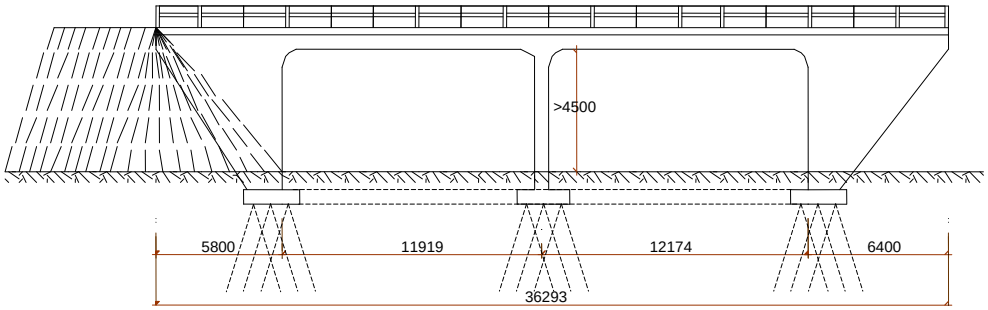
www.sustainablebridges.net
www.mainline-project.eu/

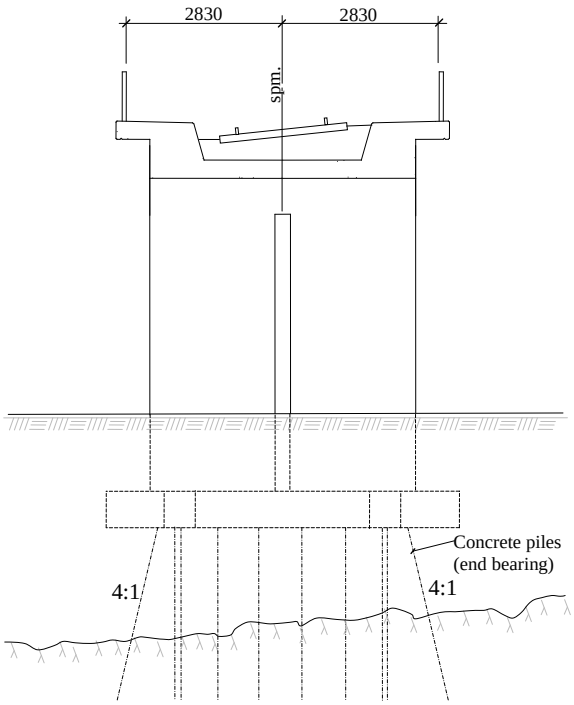
Objectives

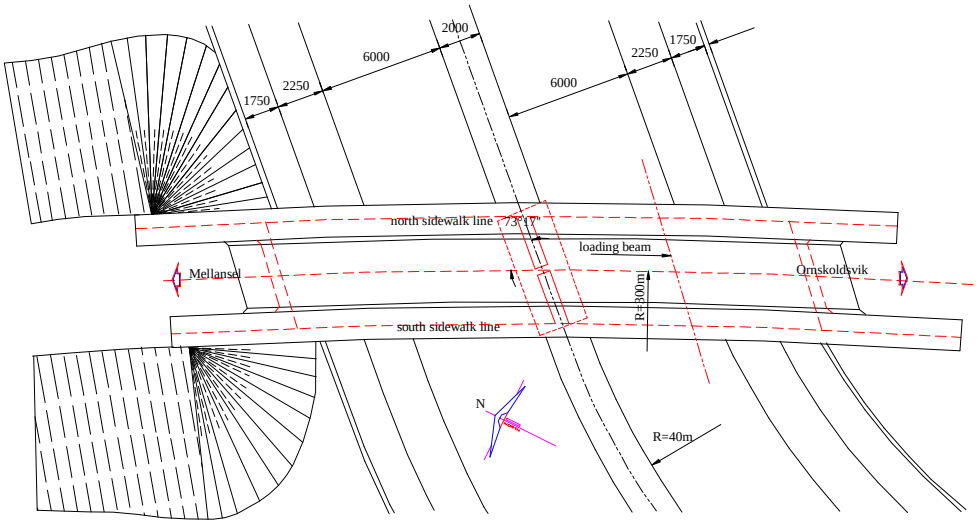
- **Increase the transport capacity** of existing bridges
  by allowing higher axle loads (up to 33 tons)
  or by allowing higher speeds (up to 350 km/hour)
- **Increase the residual service lives** of existing bridges
  with up to 25 %
- **Enhance management, strengthening, and repair systems**.
- **4 guidelines and 53 reports** available at
  www.sustainablebridges.net

Testing of a strengthened R C Bridge 2006 in Örnsköldsvik

Overview – Boundary Conditions







Built 1955
Axle Load 250 kN

The bridge was strengthened in bending in order to get a shear failure

We are all optimists

Sawing for Strengthening with
Near Surface Mounted CFRP Rods

Strengthening procedure
Björn Täljsten et al






Final test
July 6, 2006


11.07.2006

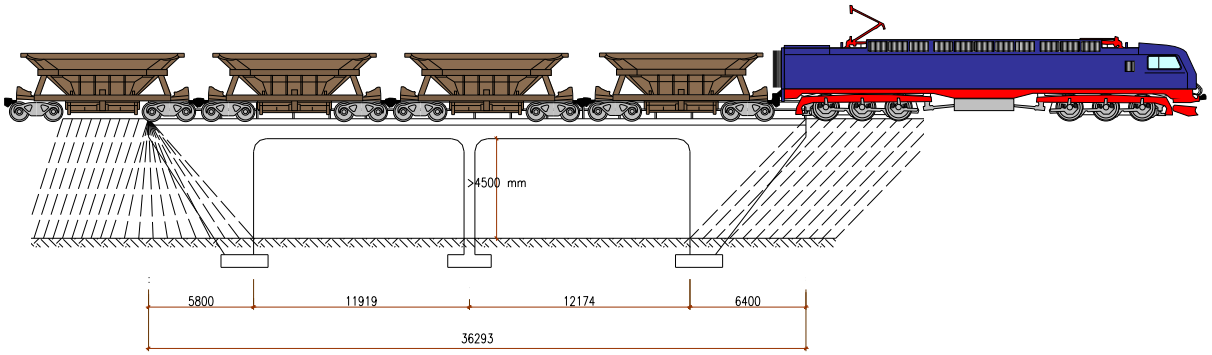
Stirrup rupture after yielding

Reserve Capacity

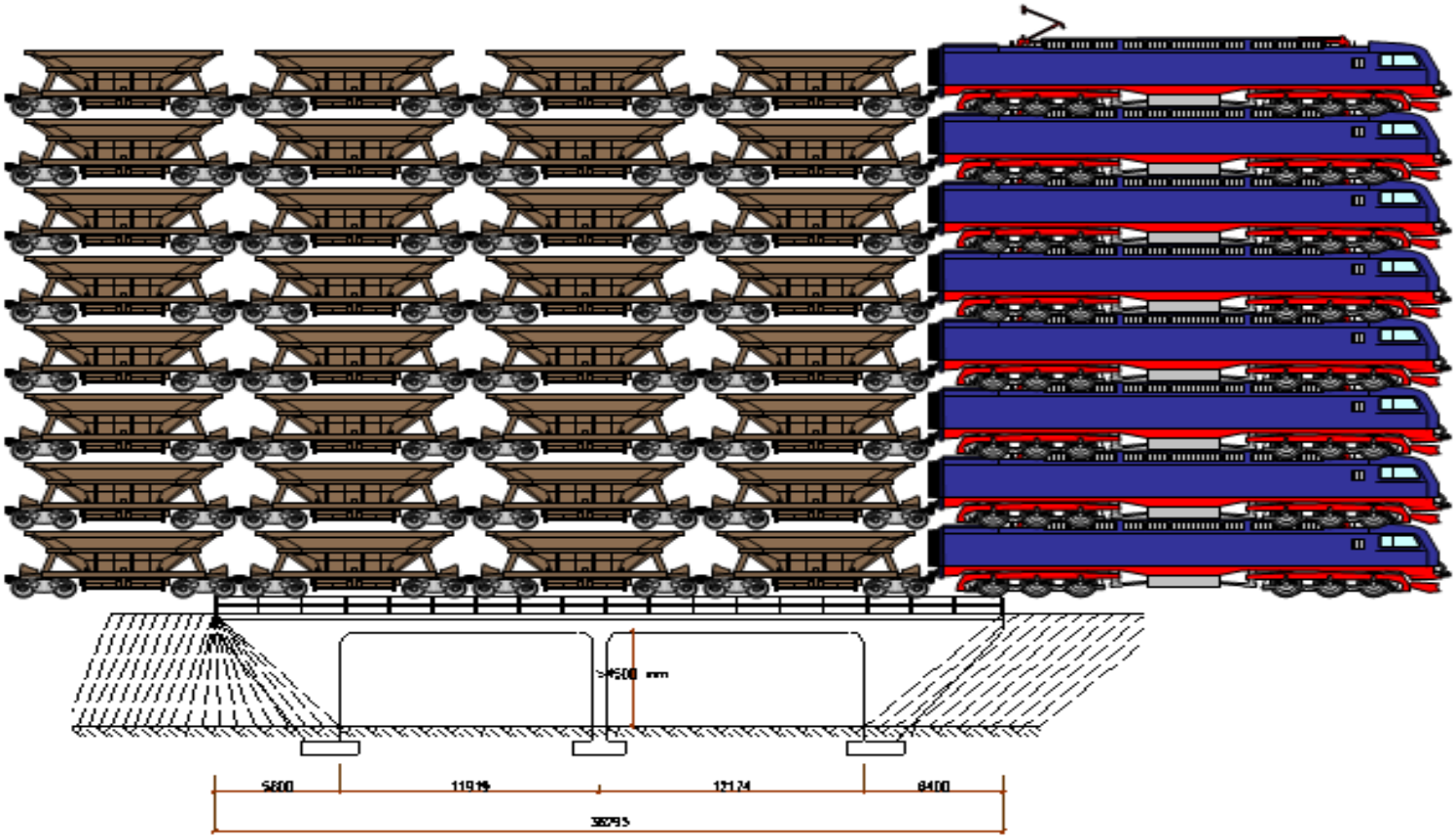
The failure load 1170 ton corresponds to
1170 ton / 25 ton ≈ 47 axles

The span of 12 m has only room for 4 axles
47 axles /4 = 11,7 carriages (on top of each other)

The strengthening gives approx. 25 % of the capacity, so without strengthening we have a capacity of approx. 34/4 = 8,5 carriages



A little more than the design case



See also Arto Puurula Ph D (2012) at
http://pure.ltu.se/portal/files/36697444/Arto_Puurula.pdf

MAIN LINE

MAINTENANCE, RENEWA**L** AND
IMPROVEMENT OF RAIL TRANSPORT
INFRASTRUCTURE TO REDUCE
ECONOMIC AND
ENVIRONMENTAL IMPACT

Björn Paulsson, UIC/TRV, Project Manager

Lennart Elfgren, LTU,
Scientific &Technical Coordinator

SEVENTH FRAMEWORK PROGRAMME

This project is co-funded by the European Commission with the FP7

Presentation of the MAINLINE Project

Background

Builds on earlier projects as Sustainable Bridges (2003-07)

Scope

- Make **rail infrastructure** more **cost effective**
- Model **degradation** due to increased traffic and time/age
- Create tools for **whole life assessment** to make it possible to balance **economic** end **environmental** costs

Presentation of the MAINLINE Project

3 years - (Oct 2011- Sept 2014)
Total budget 4.5 M€ (3 M€ from EC)

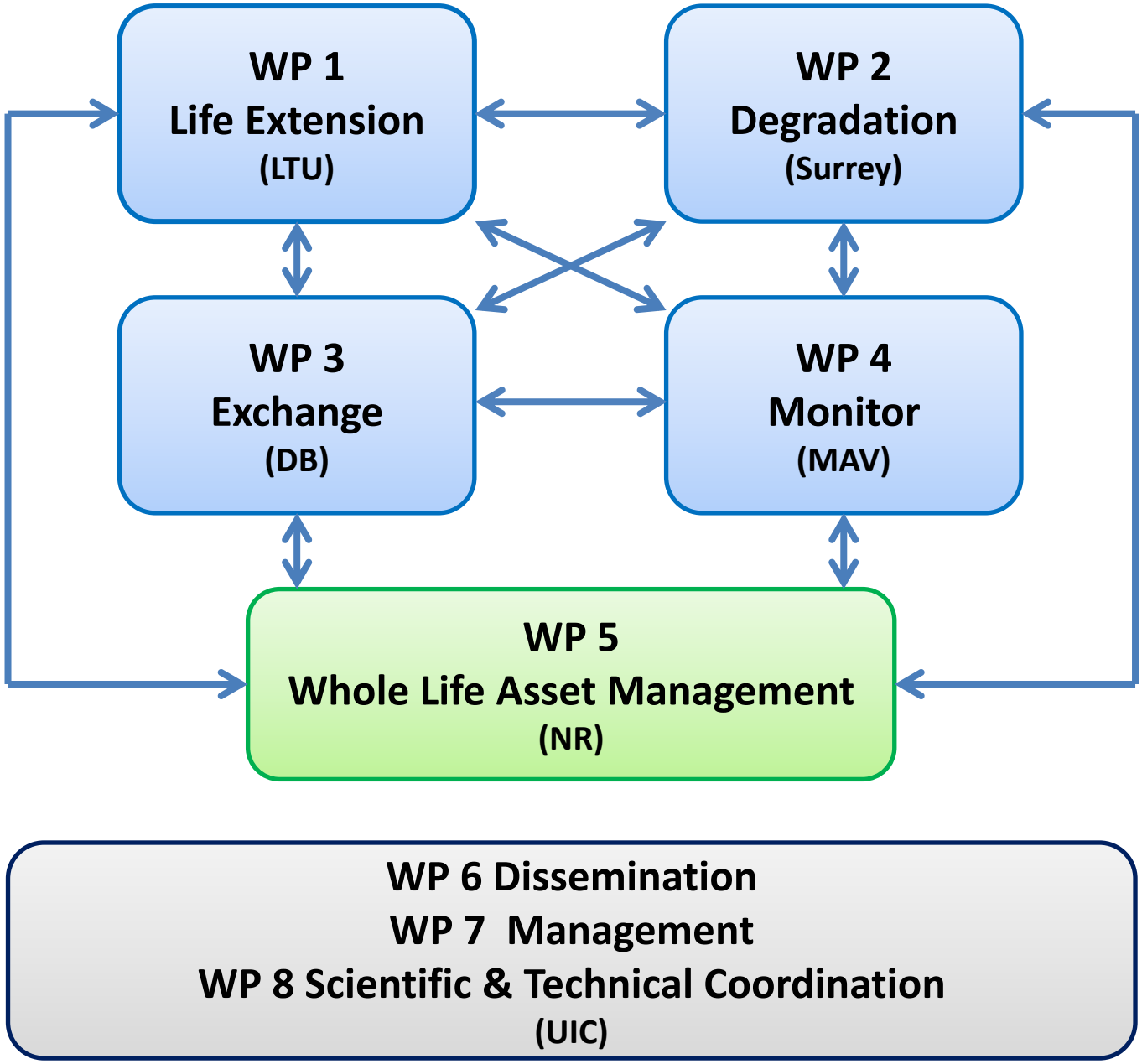
19 Participants wherof
7 Infrastructure Mgrs (NR, DB, TRV, TDD, AV,SETRA, UIC)
2 Contractors (SKANSKA, COMSA)
5 Consultants (COWI, SKM, DAMILL, TWI, ARTTIC)
5 Universities (Surrey, Bologna, Minho, Graz, LTU-SBU)
11 countries (FR, UK, DE, SE, DK, AT, ES, PT, CZ, HU, TZ)

Project Manager:
Björn Paulsson, UIC/TRV

Partners in the MAINLINE Project

N°	Org.	Short Name	Country
1	UIC	UIC	FR
2	Network Rail I	NR	UK
3	COWI	COWI	DK
4	Sinclair Knight Merz	SKM	UK
5	University of Surrey	Surrey	UK
6	TWI Ltd	TWI	UK
7	University of Minho	UMINHO	PT
8	Luleå tekniska universitet	LTU-SBU	SE
9	DB Netz AG	DB	DE
10	MÁV Magyar Államvasutak Zrt	MAV	HU

N°	Org.	Short Name	Country
11	Universitat Politècnica de Catalunya	UPC	ES
12	Graz University of Technology	TUGraz	AT
13	TCDD	TCDD	TR
14	DAMILL AB	DAMILL	SE
15	COMSA EMTE	COMSA	ES
16	TRAFIKVERKET	TRV	SE
17	SETRA	SETRA	FR
18	ARTTIC	ARTTIC	FR
19	Skanska a.s	SKANSKA	CZ


WP 1
Life Extension
(LTU)
WP 2
Degradation
(Surrey)
WP 3
Exchange
(DB)
WP 4
Monitor
(MAV)
WP 5
Whole Life Asset Management
(NR)
WP 6 Dissemination
WP 7 Management
WP 8 Scientific & Technical Coordination
(UIC)

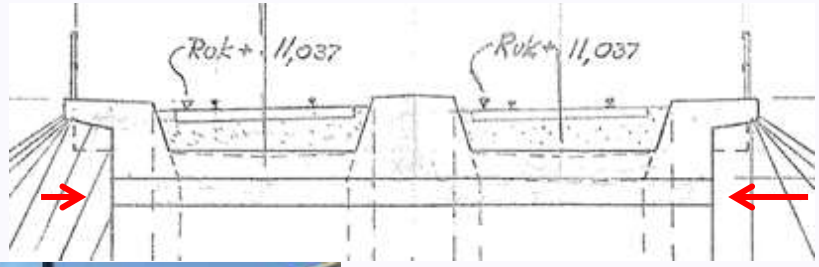
WP1 Extend Life

- Explore and evaluate **new technologies** to extend life of old infrastructure
- Develop **assessment methods** to determine if the life can be extended
- Develop **new technologies** and a **guideline** for the application
- **Transfer** knowledge to Eastern Europe and developing economies

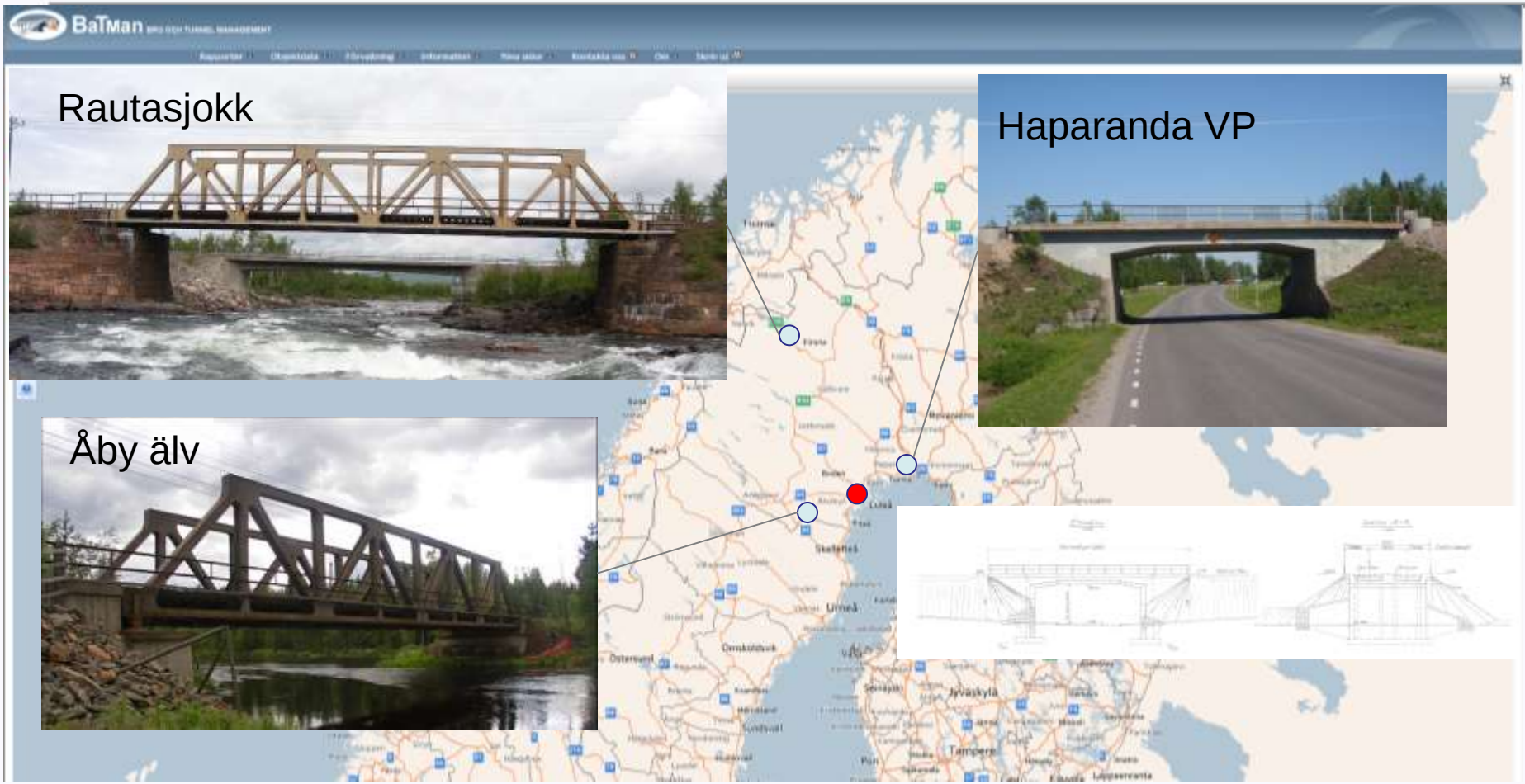
WP1 Extend Life

Tests are made on three bridges:

- Prestressing of a concrete trough bridge (Shear capacity)
- Test to failure of a steel truss bridge (Stability, Fatigue, Rivets)
- Test of strains in sister bridge
- Additional funding from Trafikverket and Hjalmar Lundbohm Research Centre



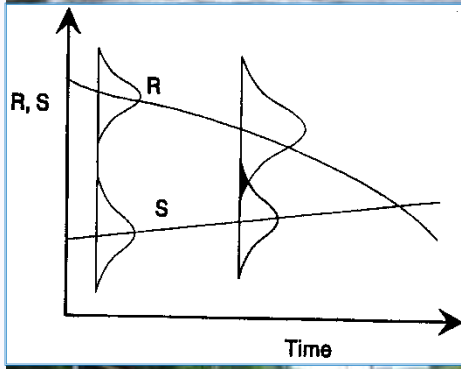
Three bridges to be tested/upgraded



WP2 Degradation & structural models

Asset types identified as focus areas:

- Cuttings
- Metallic bridges
- Tunnels with concrete/masonry linings
- Plain line and switches & crossings
- Retaining walls



Deliverables

- model of different degradation types
- effect of changes due to maintenance, repair and strengthening
- Validate models through case studies

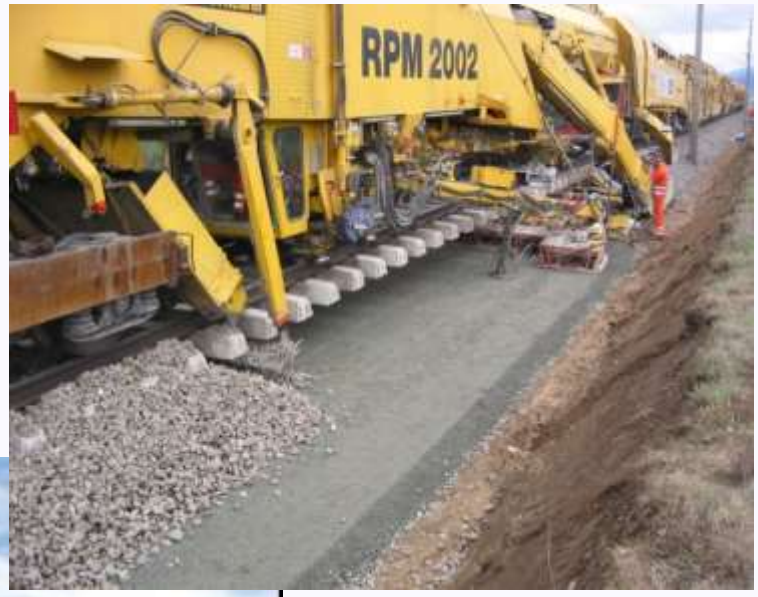
WP 3 Replacement of obsolete infrastructure

- **Benchmark of new technologies. Methods used across Europe.**
- **Development of new construction methods to replace old infrastructure**

(a) new bridge transported to site, (b) turning of bridge, (c) switching of the bridges, (d) new bridge in place and old bridge to be transported away.

WP 3 Replacement of obsolete infrastructure

- Development of new construction methods to replace old infrastructure
- And how can we enhance existing methods ?

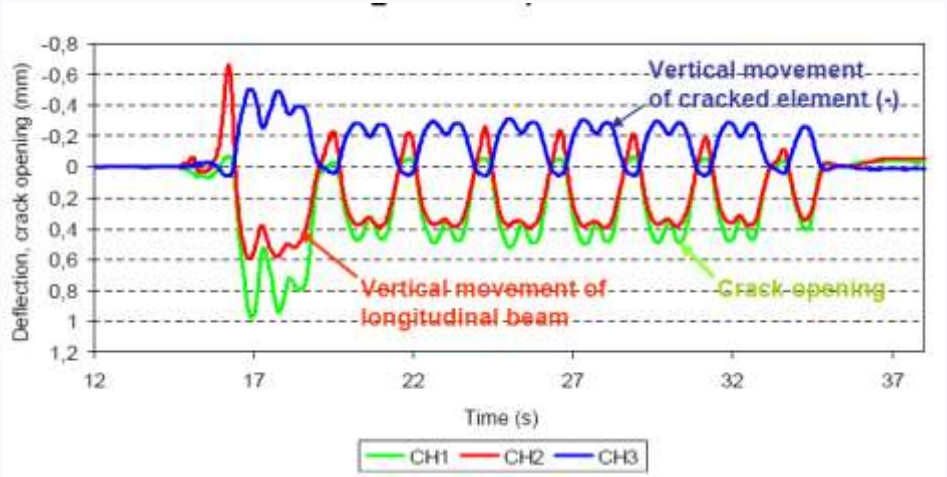


WP4 Monitoring and examination techniques

• Case study in Hungary on a steel truss bridge:
 - repair of a fatigue crack with FRP
 - monitoring and examination
 - evaluation of data

• Draft questionnaire on monitoring and examination techniques was prepared

• Revision of documents of interacting WP-s



WP5 – Whole life environmental and economic asset management

- Benchmark existing asset management tools for Life Cycle Analysis (LCA) and Life Cycle Costs (LCC)

- Develop a Life Cycle Assessment Tool (LCAT) for
  - Bridges (metallic underline)
  - Tunnels
  - Earthwork cuttings and retaining walls
  - Track (plain line, switches and crossings)

Several reports are available at http://mainline-project.eu/

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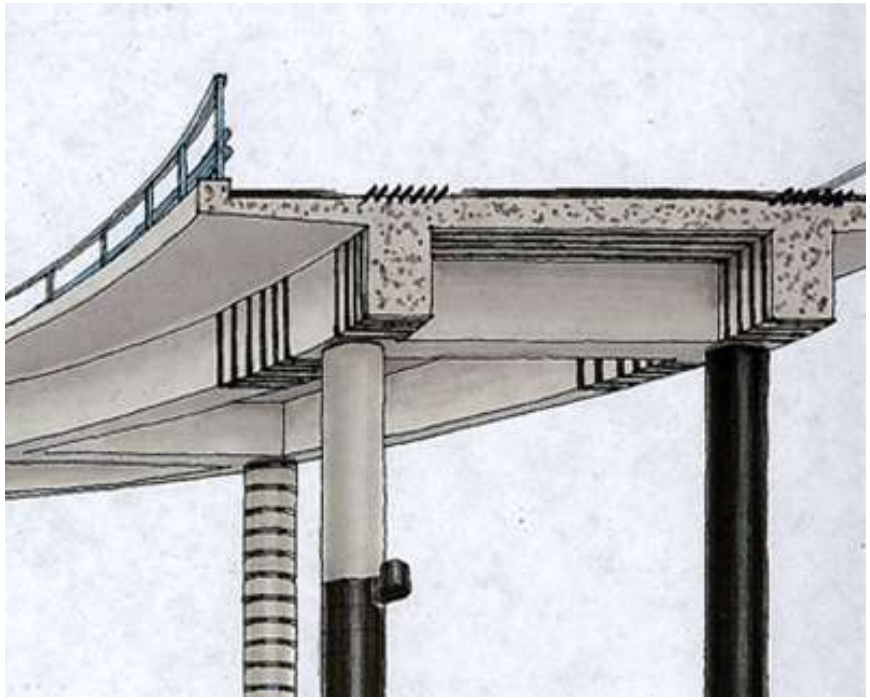
Proactive Bridge Strengthening

Background

- 300 000 railway bridges in Europe most of them older than 50 to 100 yrs
- The cost of a new bridge is circa 0,5 to 2 M€ (or in mean 1 M€)
- The cost to strengthen a bridge may be only 25 % of that
- If half the number of bridges could be strengtened, we would save $0{,}5 \cdot 300\,000 \cdot 0{,}75 = 112\,500$ M€

Carbon Fibre Reinforced Polymers - CFRP

- Strengthen the shear capacity of concrete structures
- Anchor polymer bars to concrete and steel
- Predict the Life Length of a Strengthened Bridge

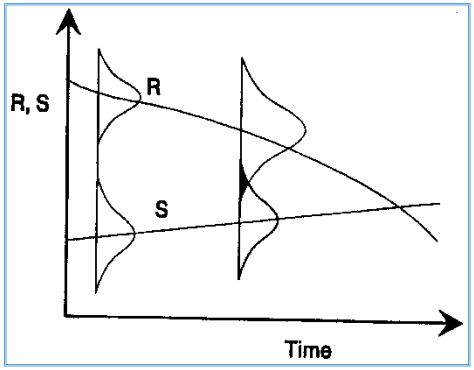


Prestressing

- Anchoring of the prestressing bars, especially if CFRP is used
- Relaxation of the prestressing force with time
- Influence of different boundary conditions

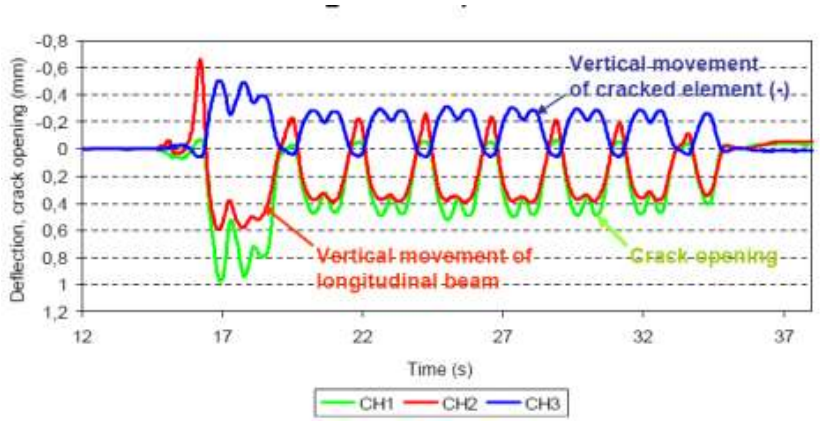
Administrative strengthening

- More **examples** of how enhanced methods may be used on existing bridges
- Evaluation of the influence of assumptions of **boundary conditions**. FE calculations are strongly dependent on boundary conditions
- **Calibration** of assessment methods by full scale testing to failure of old bridges before their destruction



Automated Monitoring

- Robust monitoring to register the actual load history needed for fatigue capacity evaluations
- Filtering data to save only essential sequences (in a similar way as our brains filters away most of the signals all the sensors in our bodies send to it).
- Guards that can be used to activate maintenance personal if anything out of order occurs on a bridge.



BIM -Building Information Modelling

3. Automate

- Configurate
- Produce
- Automatic machines

2. Integrate

- Design & Analysis
- Design & Cost estimation
- Design & Planning

1. Visualise

- VR models
- 3D
- Collision controls

1. **Visualise Kiruna City Development**

Kiruna City on top of the mine

1910
1920
1930
1940
1950
1960
1965
1970
1980
1990
Ore processing plants
Railway to Narvik
Magnetite ore body
80 m thick
4 km long
2 km deep
Hoisting and air
Sea level
Buffer
Hoisting
aulage level
Crushing
level m
0
142
230
275
320
420
540
740
775
1045
1175

Tim Johansson (2012)

1. Visualise Kiruna City development

C:\Users\tjo\Desktop\kir2.html

Kiruna

Kiruna Stadsomvandlingen

Modeller

- ☑ Viktiga hus
- ☑ Medelstora hus
- ☑ Små hus
- ☐ Vägar

Kartor

- ☐ Sprickbildning
- ☐ Järnvägsutredning
- ☐ Fördjupad översiktsplan
- ☐ Höjdkurvor
- ☐ Fastigheter

Tidplaner

- ☐ Exploateringsplaner

Vyer

- ☐ Kyrkan
Stadshuset
- ☐ Ulvspiran

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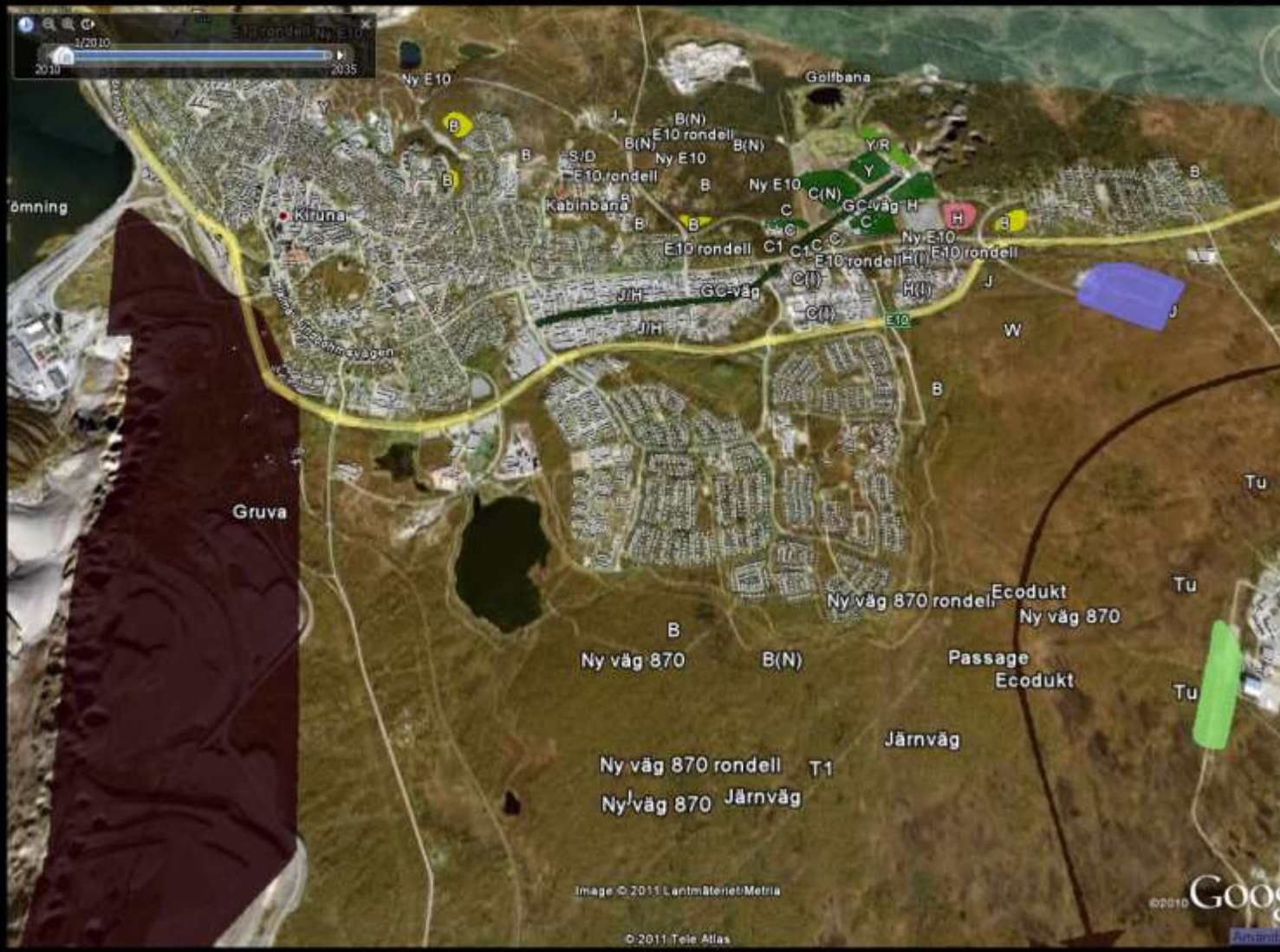

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Kiruna

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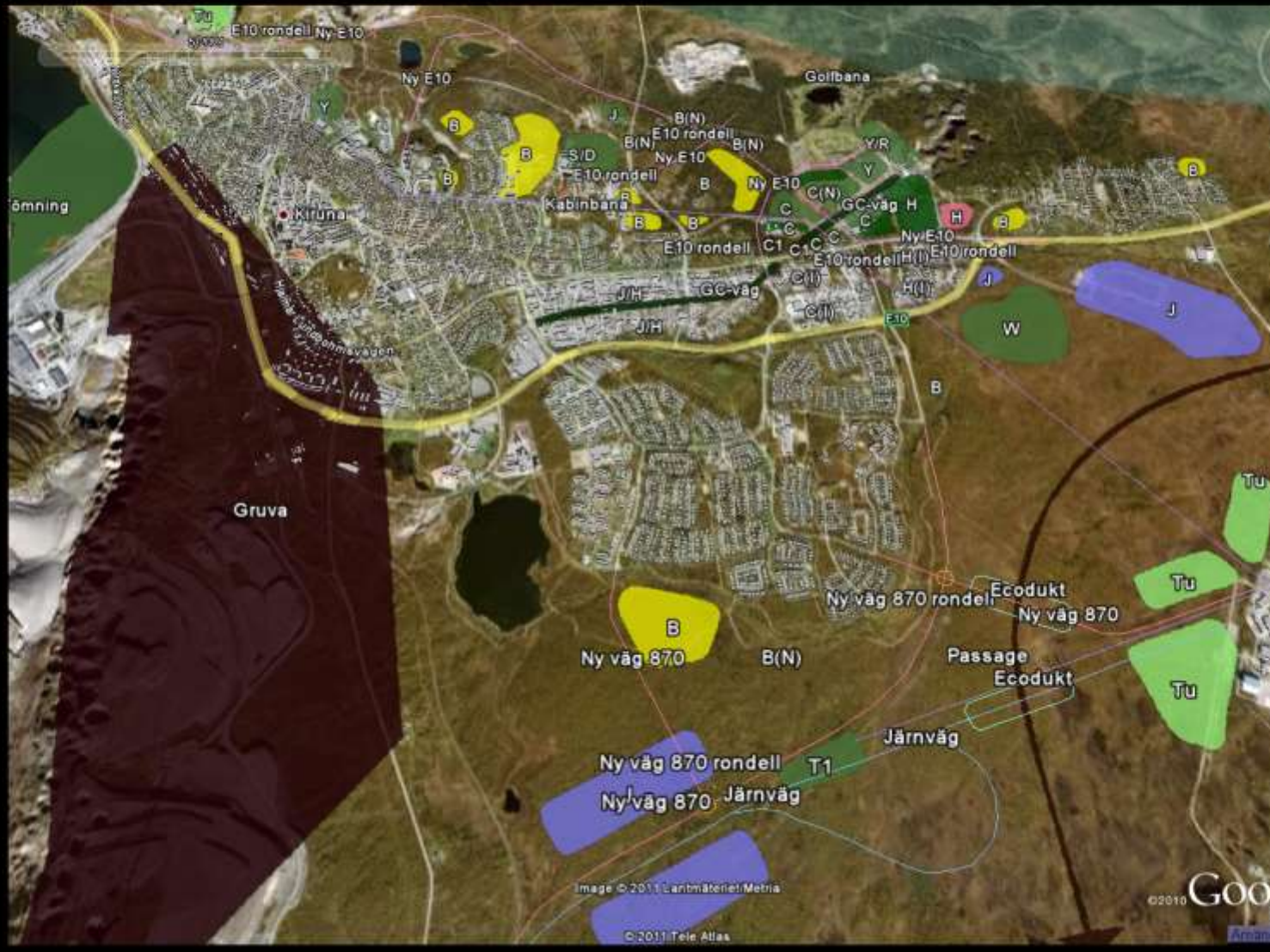

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Kiruna

Kiruna Stadsomvandlingen

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- ☑ Små hus
- ☐ Vägar

Kartor

- ☐ Sprickbildning
- ☐ Järnvägsutredning
- ☐ Fördjupad översiktsplan
- ☐ Höjdkurvor
- ☐ Fastigheter

Tidplaner

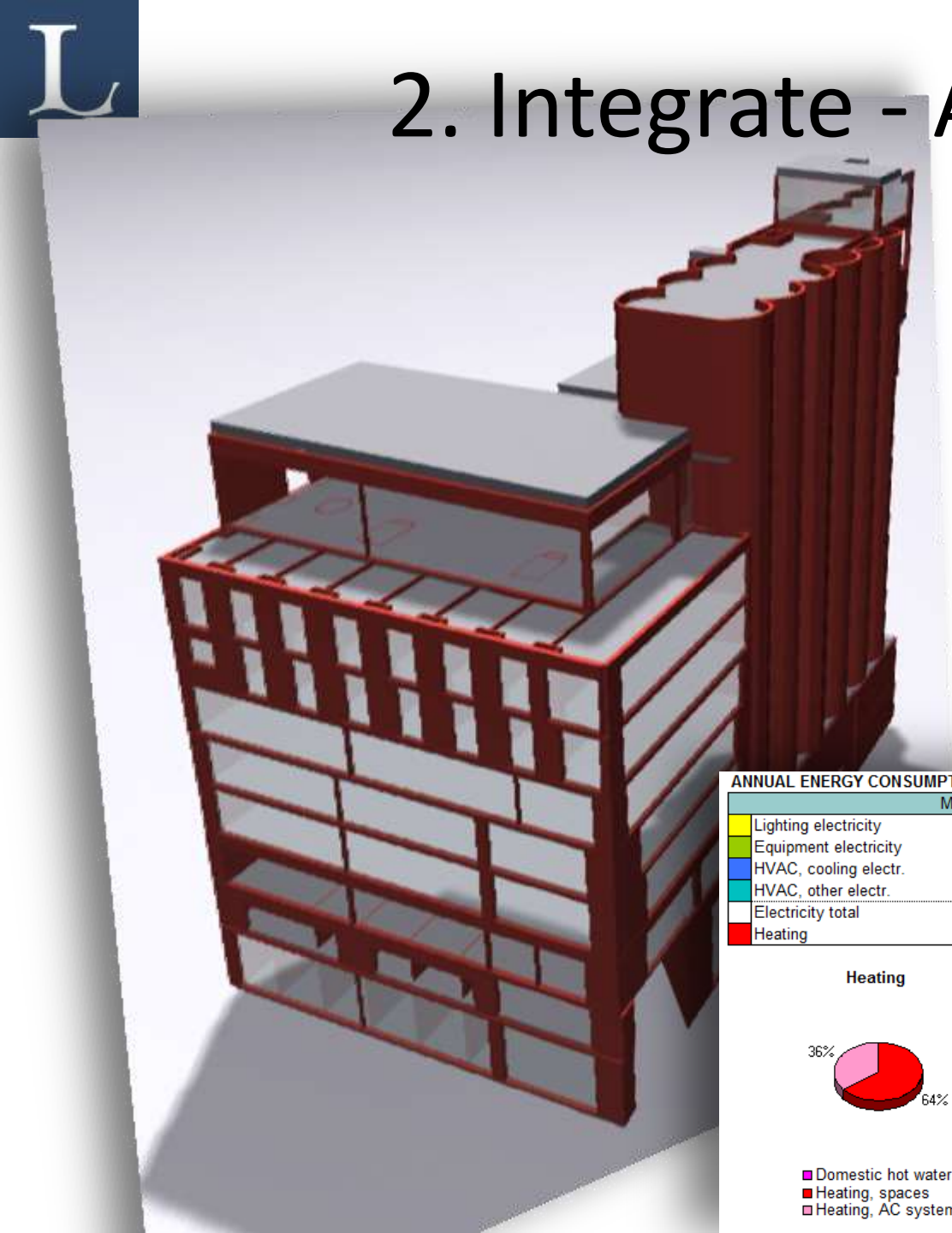
- ☑ Exploateringsplaner

Vyer

- ☐ Kyrkan
Stadshuset
- ☐ Ulvspiran

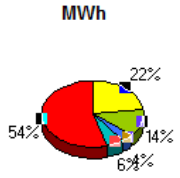
2. Integrate - Analysis

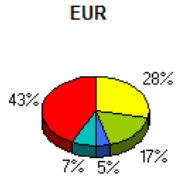
Jutta Schade (2009)
Tamas Racz (2011)

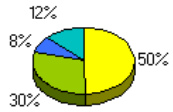


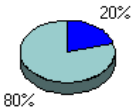
ANNUAL ENERGY CONSUMPTION

	MWh	EUR	kWh/m²	kWh/m³
Lighting electricity	346	15708	33.7	12
Equipment electricity	210	9535	20.5	7.3
HVAC, cooling electr.	55	2519	5.4	1.9
HVAC, other electr.	87	3959	8.5	3
Electricity total	699	31721	68	24.2
Heating	841	23788	81.9	29.2









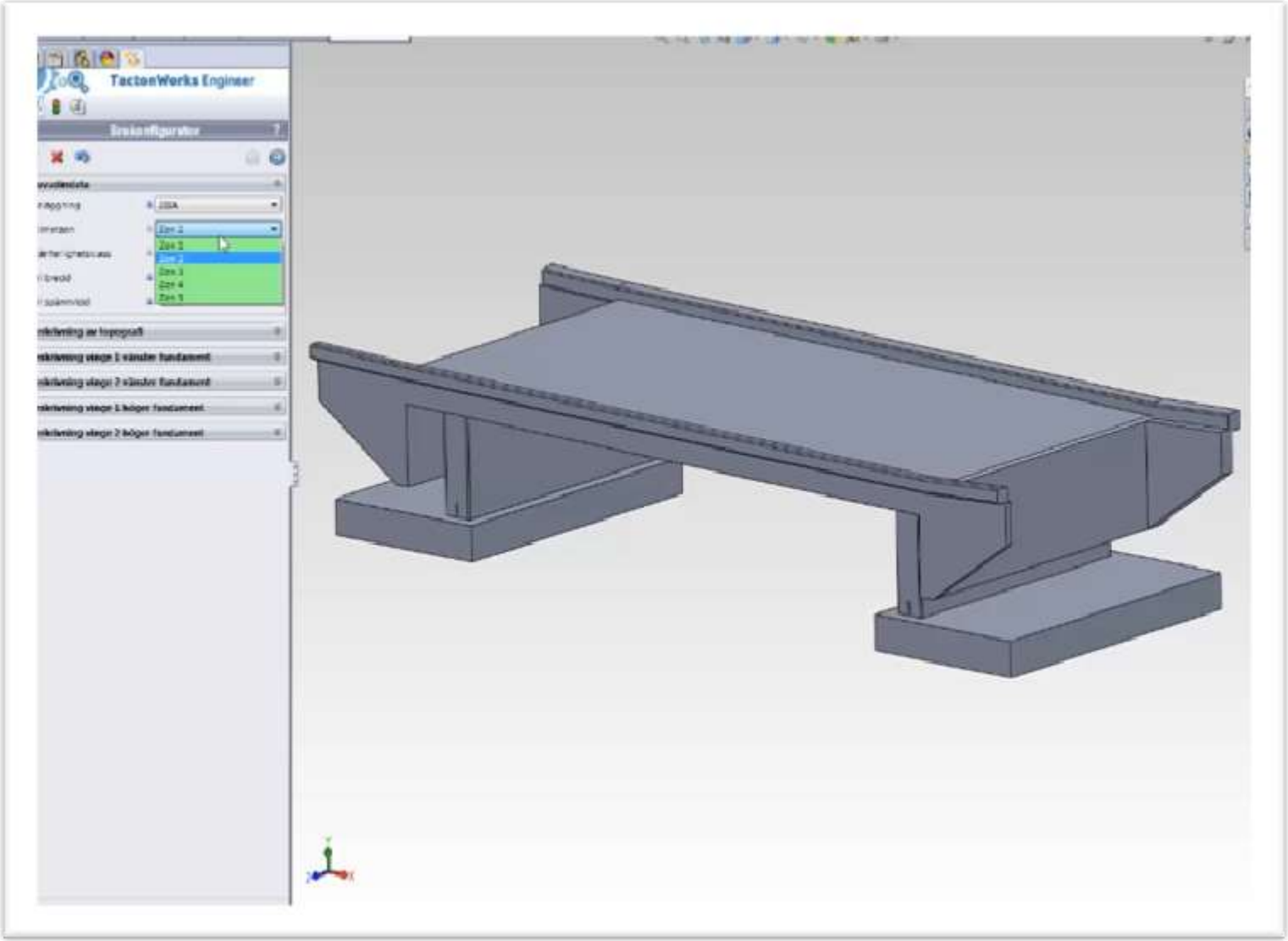
Domestic hot water
Heating, spaces
Heating, AC system

Lighting electricity
Equipment electricity
HVAC, cooling electr.
HVAC, other electr.

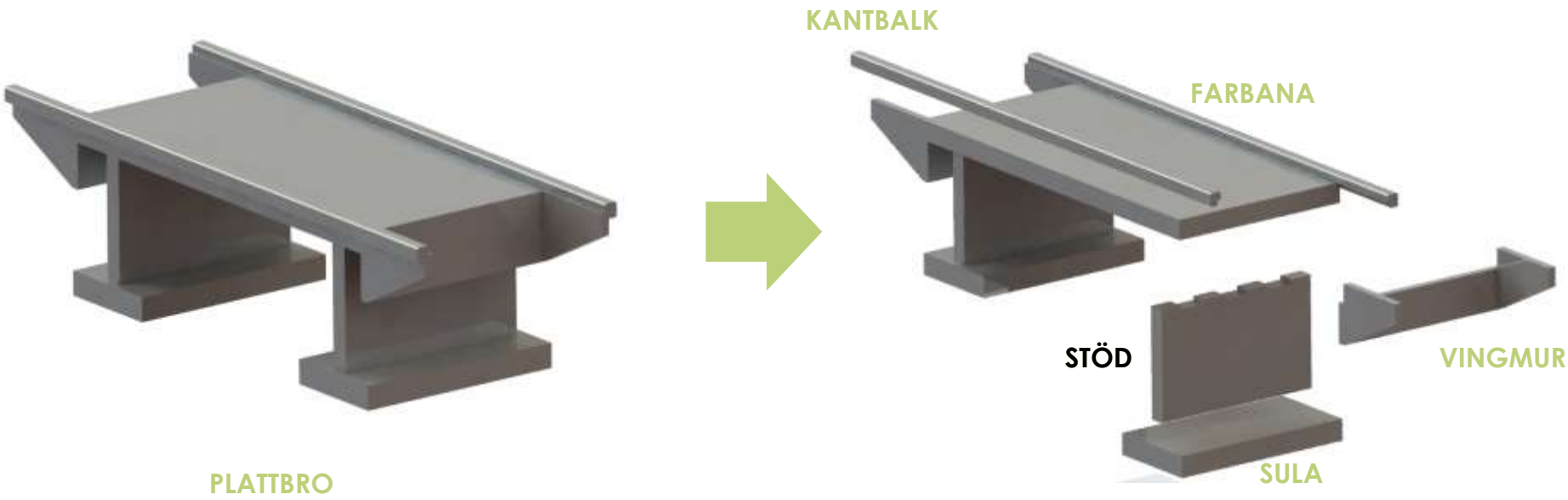
Facility electricity
User electricity

Patrik jensen (2012)

3. Automate - configurate



A structure is broken down into elements

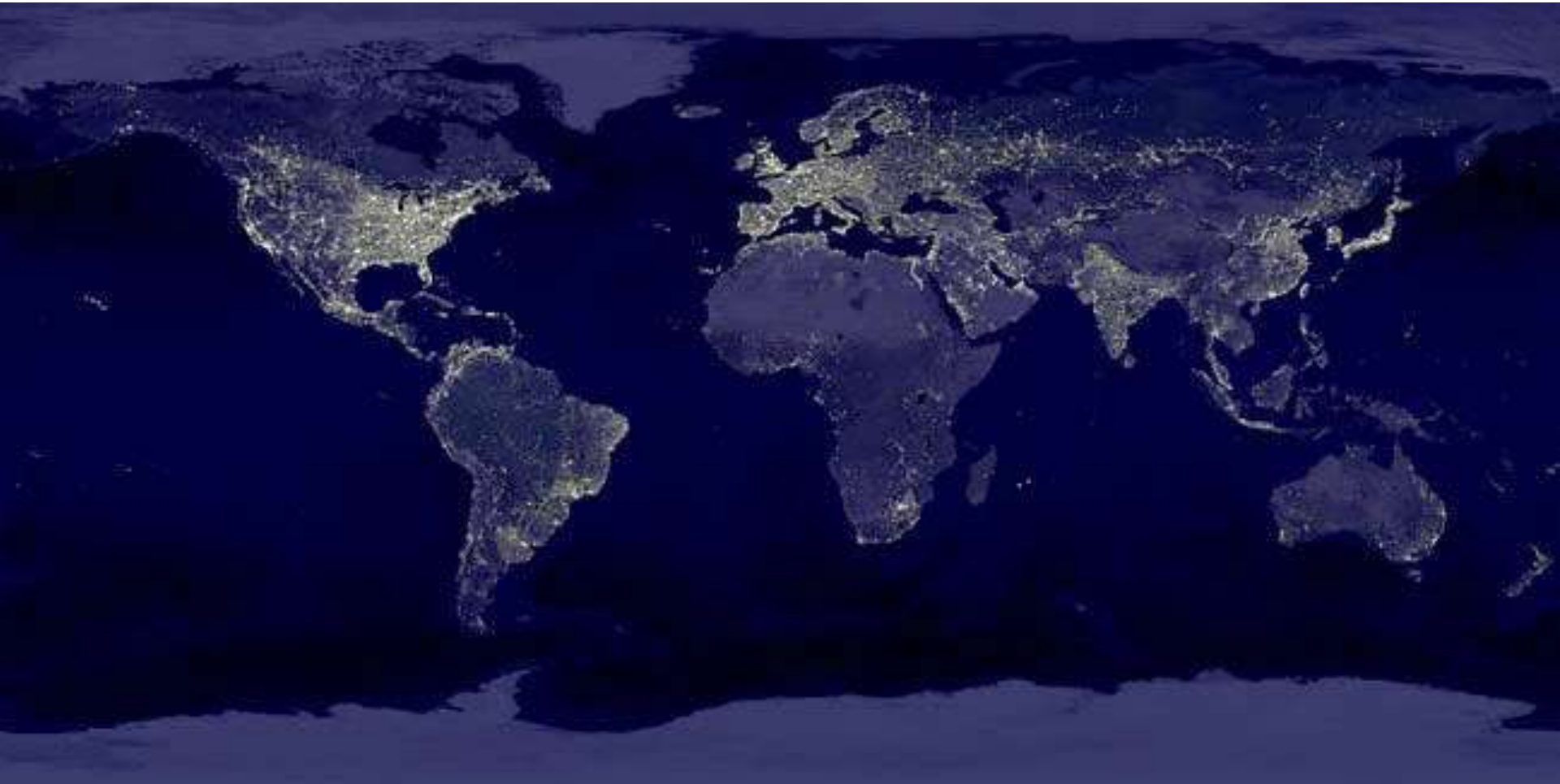


Outline – My journey

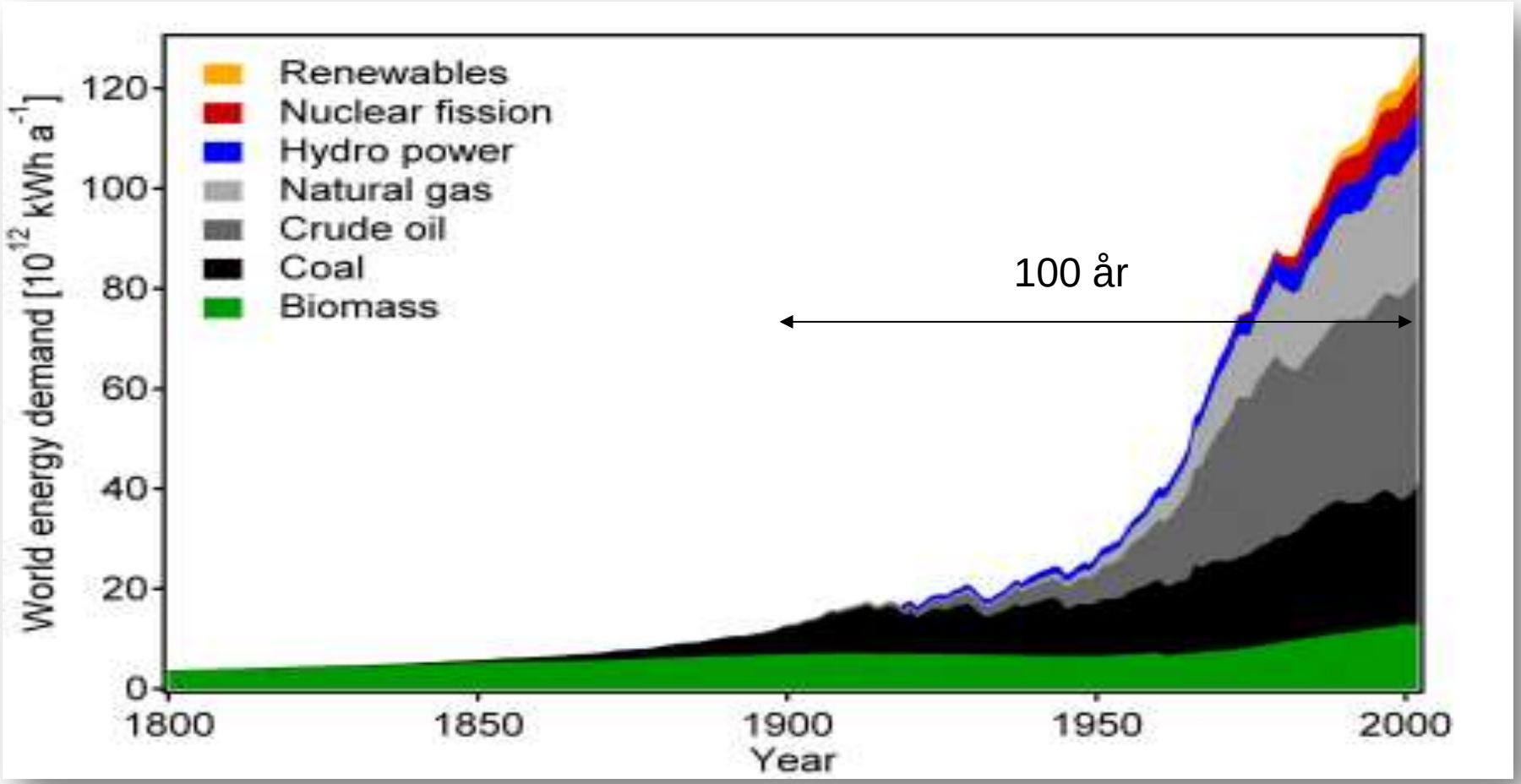
- Background
- Swedish Universities of the Built Environment
- EU Projects – Sustainable Bridges & Mainline
- Possible Future Projects
  - Proactive Bridge Strengthening
  - BIM – Building Information Modelling
  - **Climate Change, Energy, Ethics & Moral**

Tomorrow

Energy is running the world



Energy consumption



The energy will be more expensive

Climate Change

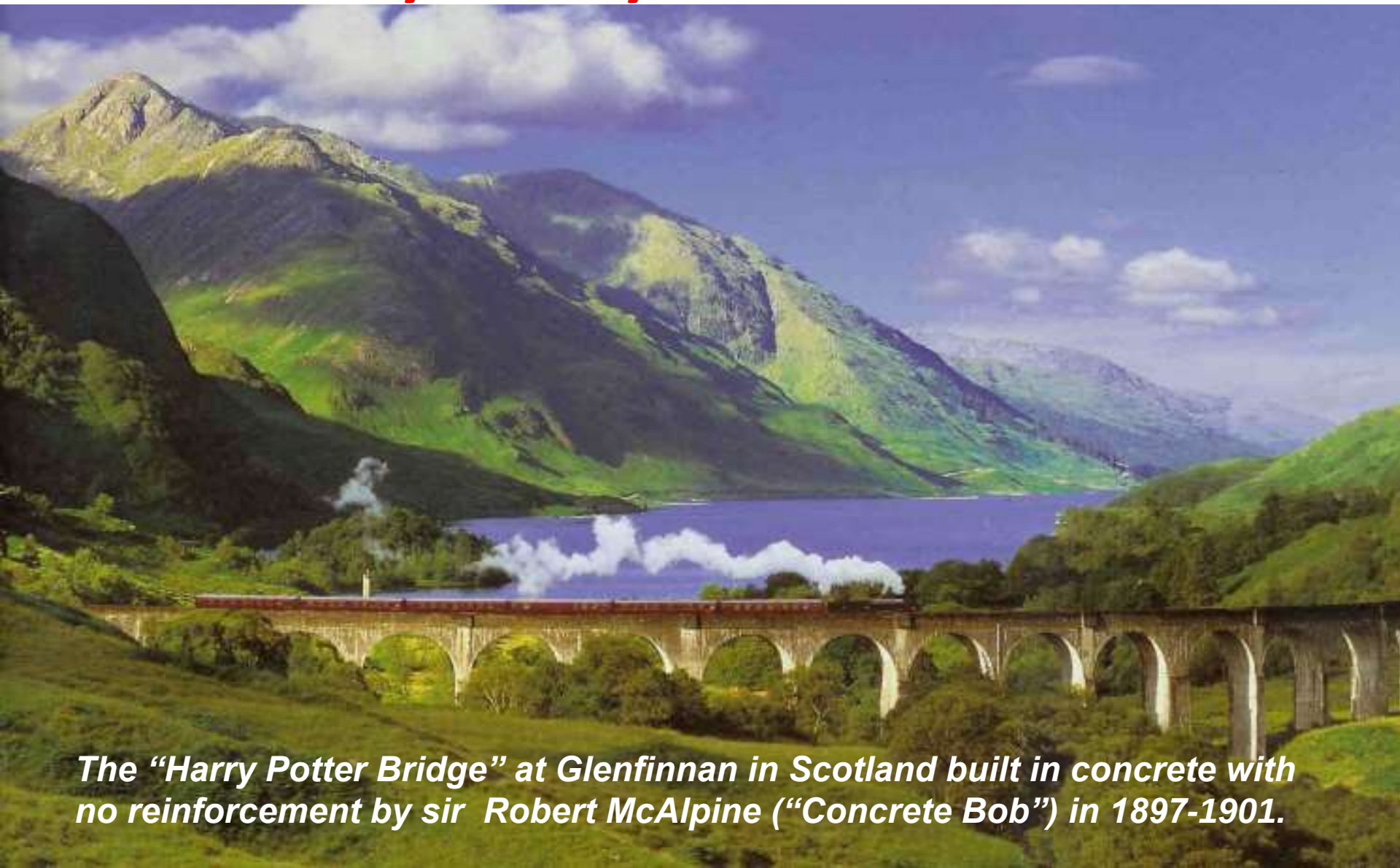
The Future

- It is human to carry on as usual
  - as if nothing special is going to happen
  - but it is not wise.
- We must form our own opinion:
  - Figure out what is going to happen
  - What do we think is right?
- No one can do everything but everyone can do something. There will be a need of Civil Engineers

Need of Research

- Sustainable, robust and resilient structures made of refined materials. Life cycle costs, maintenance, strengthening, risk analysis
- Calibrate calculation models to tests of real structures (when they are to be demolished)
- More cooperation – National, European and International projects

Thank you for your kind attention



The "Harry Potter Bridge" at Glenfinnan in Scotland built in concrete with no reinforcement by sir Robert McAlpine ("Concrete Bob") in 1897-1901.