Summary of SBRI RFCS project

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Introduction

The partners that have participated in the previous RFCS project SBRI acquired a deep knowledge about what is needed to be disseminated in the frame of the new RFCS project SBRI+. The new partners of this project (FOSTA, UPT, CVUT, TECNALIA, UNINA, ATKINS, BmS, BKE, UNIZAG, DOMI) have all been chosen as experts in their countries as far as sustainability assessment of steel and composite construction is concerned.

However, their level of understanding of this topic might differ. Therefore, in order to provide high quality, professional and consistent seminars across Europe, a special training for the project's partners took place during the kick-off meeting. The different partners attended the meeting in order to become familiar with this new concept and with the different documents and software created during WP1, WP2 and WP3. This documents resumes the key points of SBRI.

Project partners

The following partners were involved in the SBRI project :

- **Universität of Stuttgart** – Institute of Structural Design (Coordinator), Germany
- **Universidade de Coimbra**, Faculdade de Ciências e Tecnologia, Portugal
- **Aktiengesellschaft der Dillinger Hüttenwerke**, Germany
- **ArcelorMittal** S.A., Luxembourg
- **Institut français des sciences et technologies des transports, de l'aménagement et des réseaux** (former: LCPC), France
- **Rambøll** Danmark A/S, Denmark
- **BRISA** Engenharia e Gestão S.A., Portugal
- **Service d´études techniques des routes et autoroutes** SETRA, France
- **Bundesanstalt für Straßenwesen** BASt, Germany

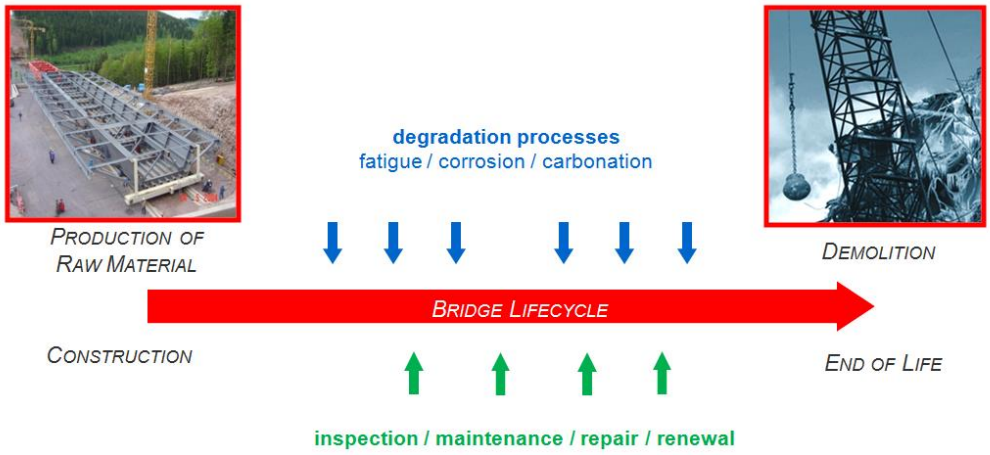
Motivation

In the current situation, the bridge market is dominated by concrete. Steel and Composite bridges represent an interesting alternative only if additional criteria (aesthetics, construction time, overall height,...) are accounted for.

However, there is a rise of traffic volume and vehicle gross weight and authorities are now looking for long living structures (whose lifecycle is > 100 years). Consequently, we chose to put forward the sustainability by lifecycle design of bridges.

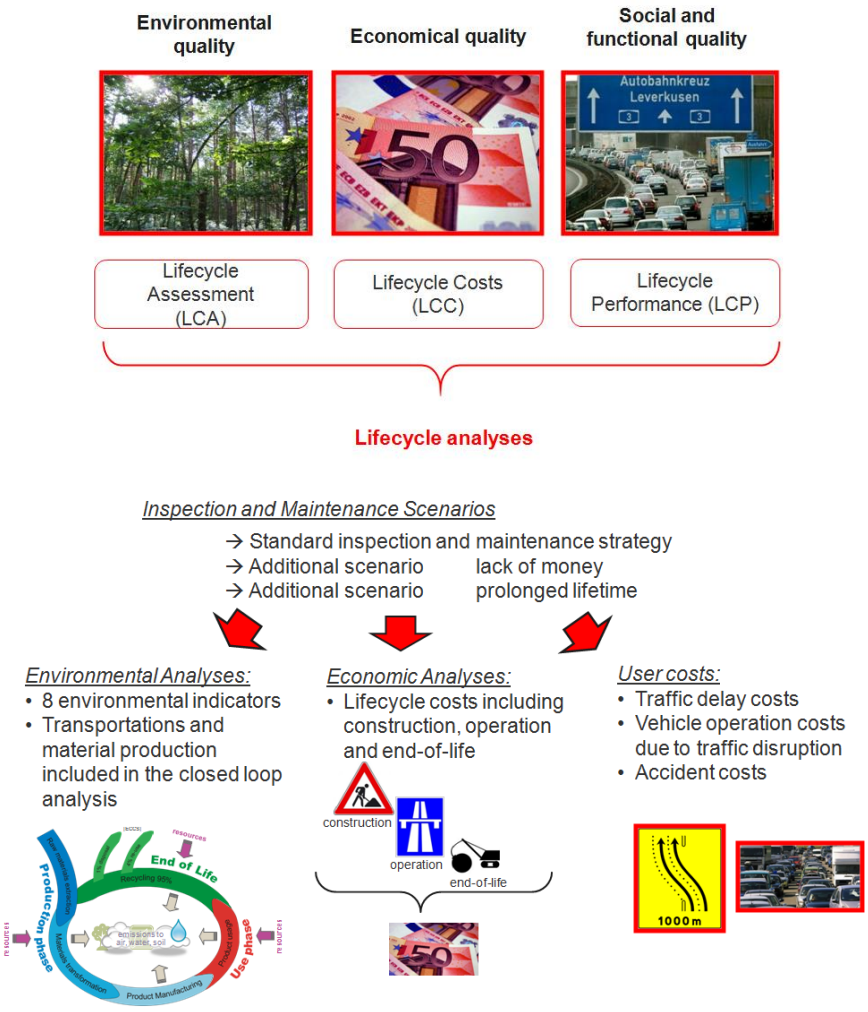
Lifecycle design of bridges

During the lifecycle of a bridge, many stages like inspection/maintenance/repair/renewal are occuring before the end of life. This leads to the need of an optimization of the lifecycle performance by a holistic approach.

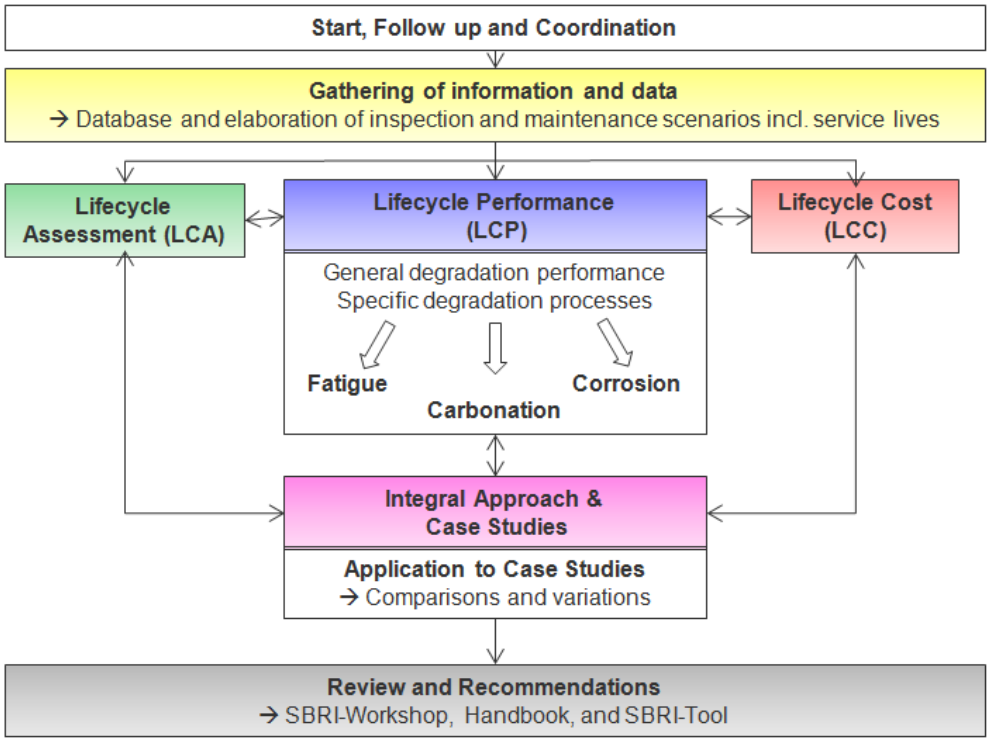


Methodology – Holistic Approach

Three kinds of Lifecycle analyses are performed in the project : Lifecycle Assesment, Lifecycle Costs and Lifecycle Performance.



Project Aims and Technical Approach



Inspection and Maintenance Scenarios

The standard inspection strategy for bridges across Europe consisted of :

- Gathering information about inspection scenarios (types, frequencies, aims and costs)
- Finding an inspection scenario common to most countries (Europe)
- Defining a standard inspection strategy

Type of Inspection	Frequency [years]
Routine	annually
Main, principal or periodic special	6
Special or exceptional	twice during lifecycle

There might be some additional scenarios. For example :

A lack of money leads to :

- less frequent inspections in early stage and more frequent towards the end
- a delay of repair actions.

A prolonged lifetime leads to additional inspections and maintenance actions towards the end.

Element	Average service life (years)
Superstructure concrete	100
Concrete edge beam	40
Safety barrier	40
Superstructure steel	100
Steel corrosion protection	35
Expansion joints	40
Road surface	20
Water Proofing Layer	40
Metal cornice gutter	25
Elastomeric bearing	35
Railing	40

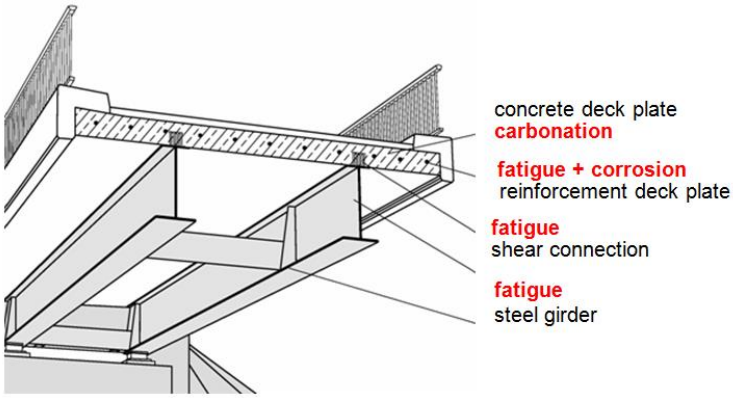
Element	Maintenance action	Standard maintenance frequency (years)
Superstructure concrete	Small area repairs	25
Concrete edge beam	Minor repairs	25
Safety barrier	Partial replacement	25
Steel corro-sion protec-tion	Repainting of corrosion pro-tection	25
Expansion joints	Partial replacement	10
Road surface	Minor repairs	10
Water Proof-ing Layer	No maintenance actions *	0
Metal cornice gutter	No maintenance actions *	0
Elastomeric bearing	Clean, painting, lubricating	20
Railing	Painting	20

(*) – Elements with no maintenance actions. Total replacement takes place when the service life is reached.

Lifecycle Performance – Degradation processes

The LCP countains the long term behavior for each bridge component due to degradation:

- description of lifecycle performance for fatigue, corrosion and carbonation
- definition of degradation processes as functions of time, e.g. fatigue strength dependent on N cycles (S-N curve): Dsc = f(N).

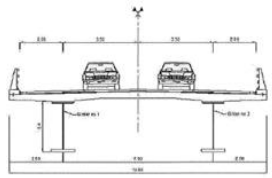


Case Studies – Bridge types

The different bridge types are depicted below. Each bridge type includes variants for comparisons and optimization.

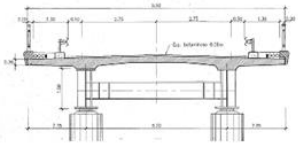
Case A – small motorway bridge:

- 3 spans: 50 - 60 – 50 m
- Width: 2 x 11m
- 2 or 3 lanes alternatively



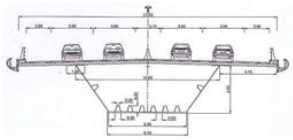
Case B – crossing of a motorway:

- 2 spans or 1 span or 3 spans
- Width: 12.50 m
- 2 lanes
- Concrete alternatives for comparison



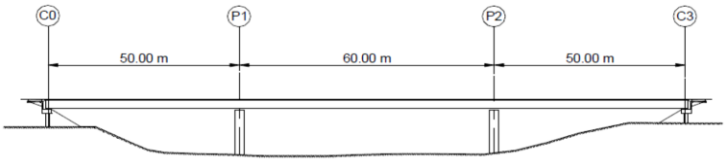
Case C – big motorway bridge:

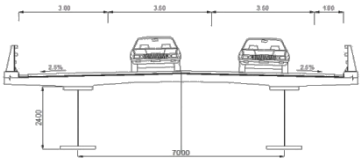
- 5 spans: 90 - 3 x120 - 90 m
- Width: 20 m, 2 x 2 lanes
- composite box girder section
- one or two superstructures



Case study A

The case A consists of a small motorway bridge (continuous twin girder bridge).





The design variants are :

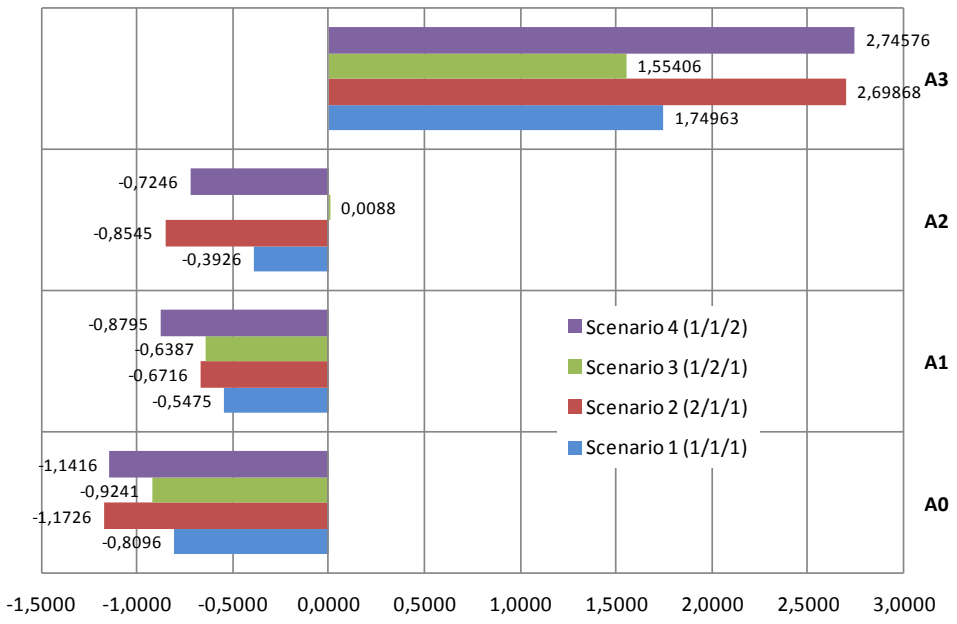
- A0: Standard
- A1: High-strength steel S355 / S460
- A2: Use of self-weathering steel
- A3: Allowing the increase of traffic by providing three lanes
- A4: Three lanes and improved fatigue by post-weld treatment

The conclusion is :

- Regarding LCA: improved for A1, worsened for A2
- Regarding LCC: A2 best solution for life cycle costs, A1 for construction costs
- RegardingUser Costs: A3 and A4 profit.

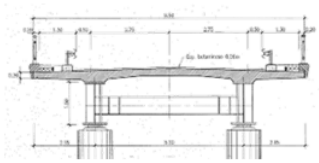
By applying the multi-criteria approach, the weighting considers the following order : *environmental impact : economical impact : user costs,* with the higher ranking (higher performance) for the higher values. These scenarios have been considered :

- Scenario 4: 1:1:2
- Scenario 3: 1:2:1
- Scenario 2: 2:1:1
- Scenario 1: 1:1:1



The conclusions for Case A are that a 3rd lane (A3) gives the best performance for all scenarios. Work activity causes major environmental impacts due to traffic congestion and increased user costs.

Case study B



Case B – motorway crossings:

Design of variants

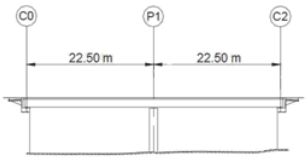
Span distribution B0: 2 spans: 22.5 – 22.5 m

B0.1: Standard

B0.2: Cast-in-place reinforced concrete, B0.3: Precast reinforced concrete

B0.4: Multiple rolled composite girders, prefabricated slab, S355

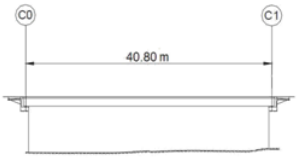
B0.5: Multiple rolled composite girders, prefabricated slab, HSS



Span distribution B1: 1 span: 40.8 m, integral abutments

B1.1: Twin plated composite girders, prefabricated slab

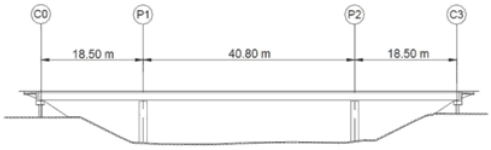
B1.2: Multiple rolled composite girders, prefabricated slab



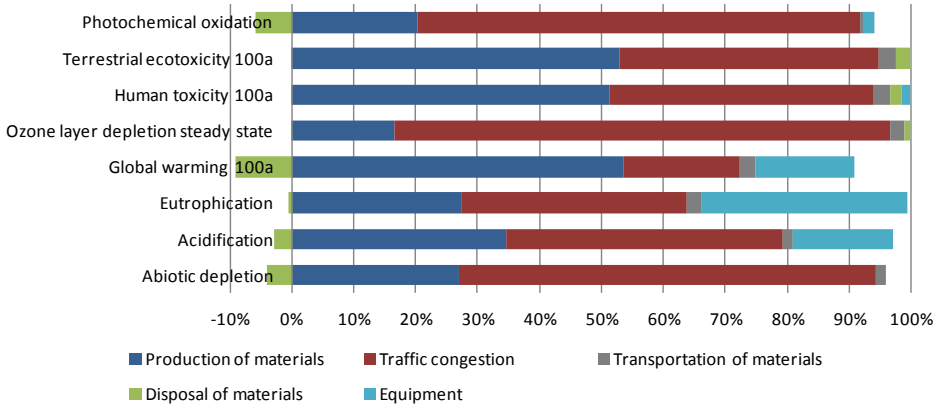
Span distribution B2: 3 spans: 18.5 – 40.8 – 18.5 m

B2.1: Twin plated composite girders, prefabricated slab

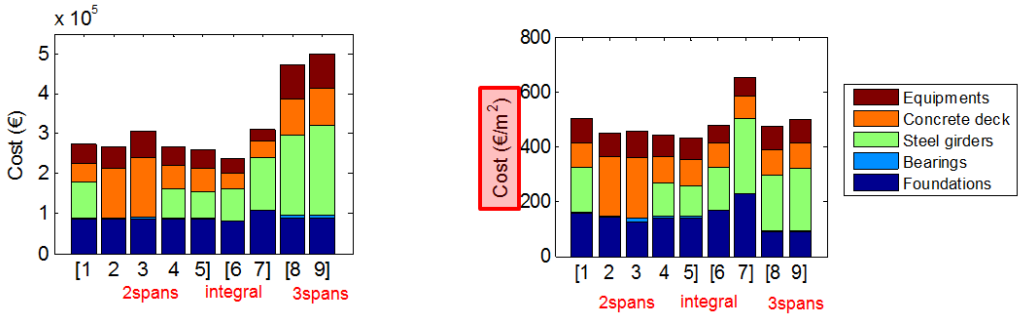
B2.2: Twin plated composite girders, prefab. slab, weathering steel



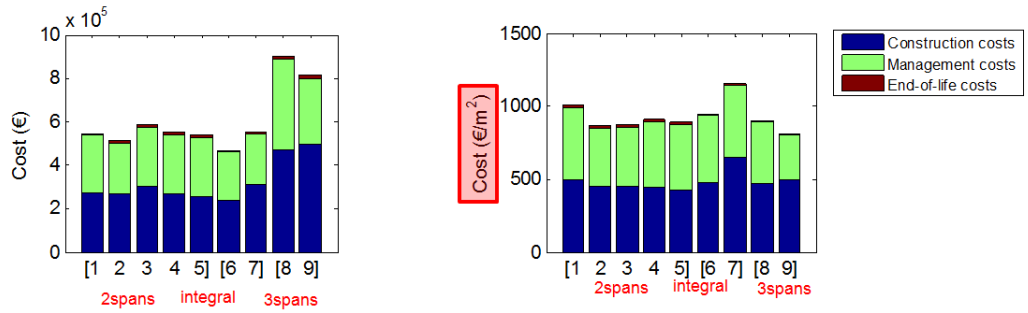
Regarding the LCA, the material production and operation stage dominate all impact categories. The traffic congestion is crucial while the transportation of material is negligible. It has to be noted that delf-weathering steel in Case B2.2 reduces the impacts in all categories due to reduced traffic congestion as no maintenance is needed. The table below represents Case B2.1 with 3 spans.



Regarding the LCC, the importance of the different elements from construction costs are depicted in the graphs below. It can be concluded that 3-span bridges are more expensive, neutral when looking at [€/m²] due to different lengths.



The importance of the different elements from lifecycle costs are depicted in the graphs below. It can be concluded that integral bridges require less maintenance and cause reduced management costs and that looking at [€/m²] the 3-span bridges appear preferable.

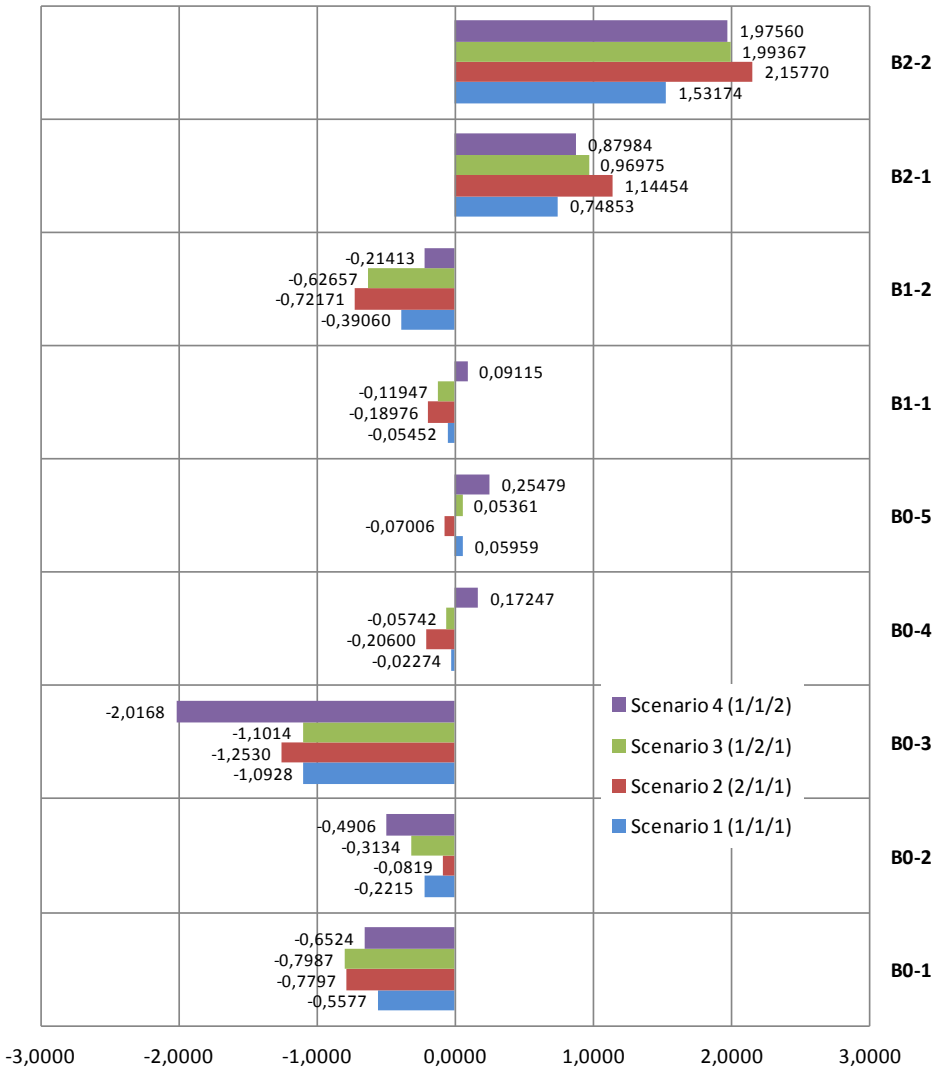


Regarding the multi-criteria approach, the weighting considers the following order :
environmental impact : economical impact : user costs, with the higher ranking (higher performance) for the higher values. These scenarios have been considered :

- Scenario 4: 1:1:2
- Scenario 3: 1:2:1
- Scenario 2: 2:1:1
- Scenario 1: 1:1:1

The conclusions for case B are :

- 3-span bridges (B2): for all scenarios best performance.
- Reinforced concrete bridge cast-in-place (B0-2) would have been chosen according to construction costs (taking user costs into account the integral steel-composite bridge (B1) is preferred).
- Position in the transport network is important for user costs.



Conclusions

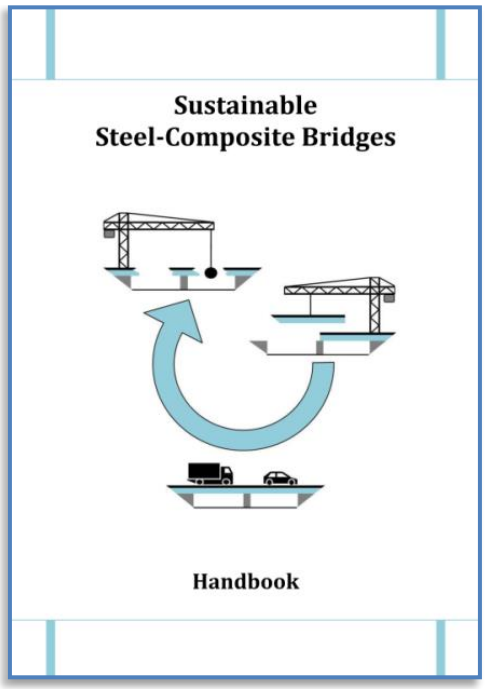
A – small motorway bridges:
Best overall performance when providing a third lane.

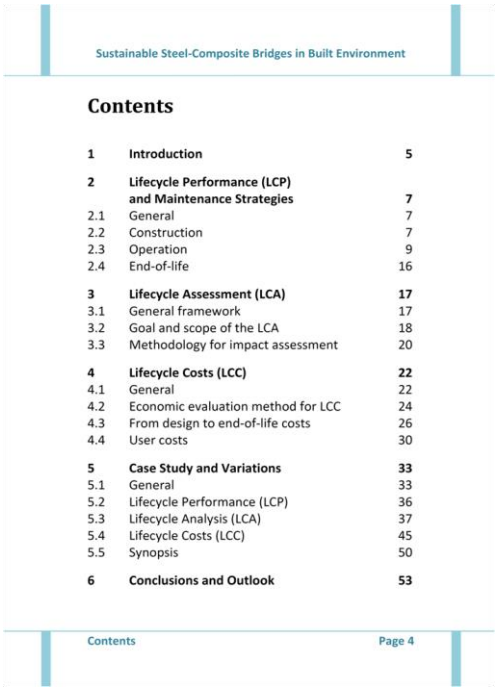
B – crossings of motorways:
For short spans, integral abutments are to be preferred.
Importance of the user costs gives favorable position to steel-concrete composite bridges.

C – big motorway bridges:
Two-deck solution reduces user costs during maintenance actions and may be preferred despite the most expensive construction costs.

SBRI-Handbook

The handbook contains the description of the lifecycle analysis in a concise way as well as its pplication to a case study and some comparisons.





SBRI-Tool

The SBRI-Too allows the calculation of LCA and LCC and the comparisons of alternative solutions by multi-criteria approach. Databases are integrated. It is available for free using the following links :

ECCS: www.steelconstruct.com

ArcelorMittal: http://www.arcelormittal.com/sections/en/library/steel-research-reports/bridges.html.