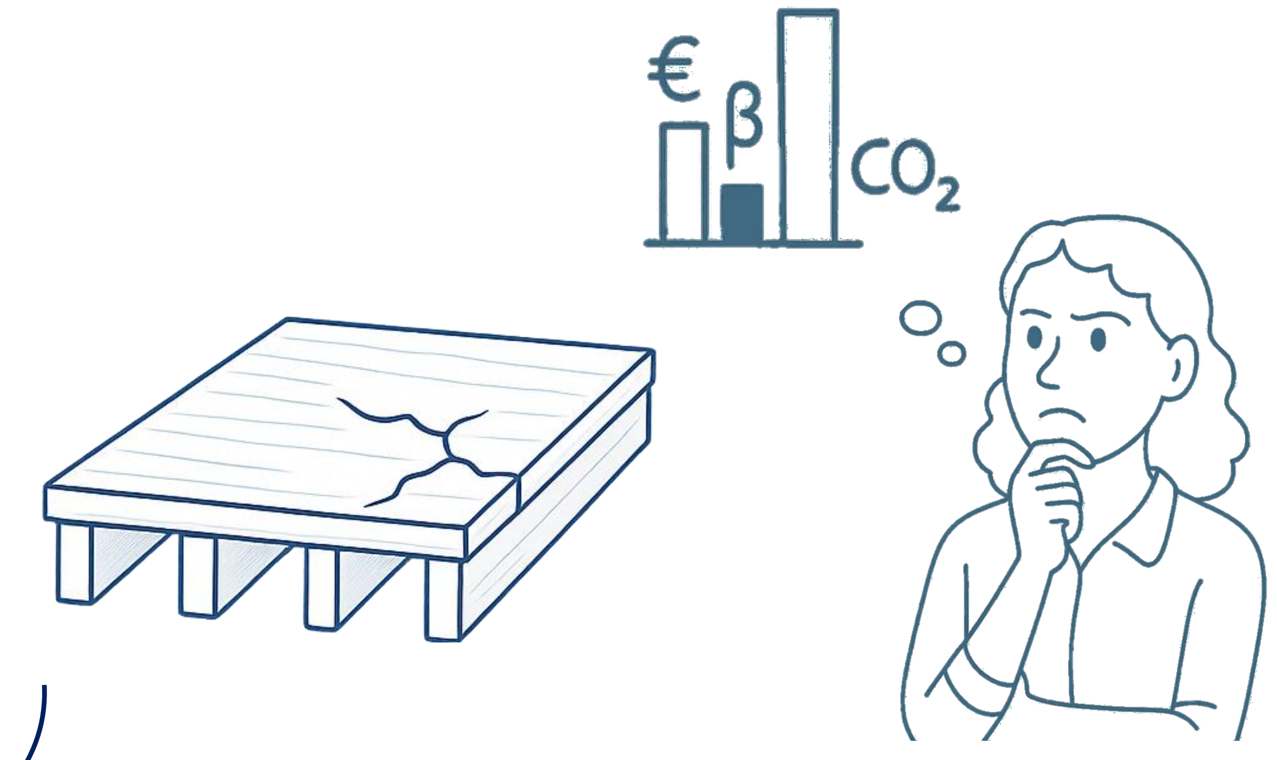
How Safe Should Existing Structures Be?

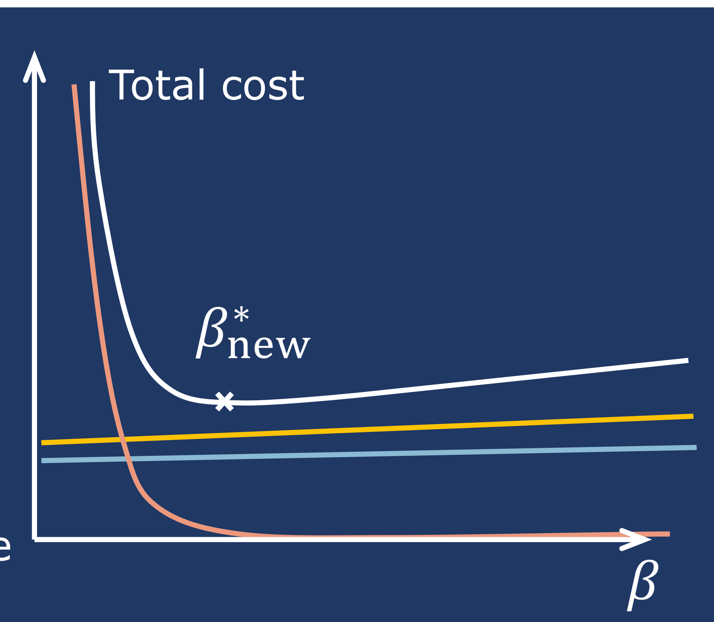
A Framework Based on Cost, Risk, and Sustainability

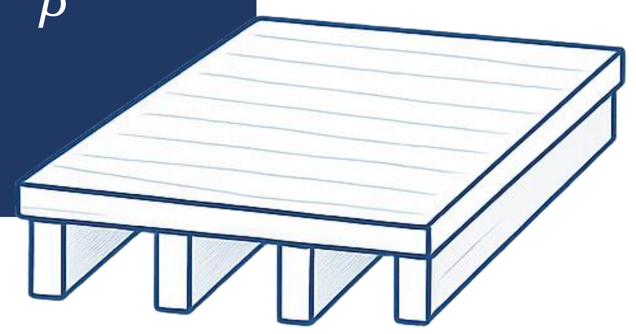


New Structures

As climate change concerns grow, **reducing carbon emissions** becomes increasingly urgent. A key strategy for mitigation is extending the lifespan of existing buildings, whether through **no intervention** or **upgrading**, rather than building new structures. This requires reassessing structural safety.

Safety is evaluated using **target reliability indices** β^*_{new} for new structures, which relate to the probability of failure. These targets can be defined through **monetary optimisation**, which balances **safety** and **cost**. This is done by implementing **construction cost**, **failure cost** and **obsolescence cost**.

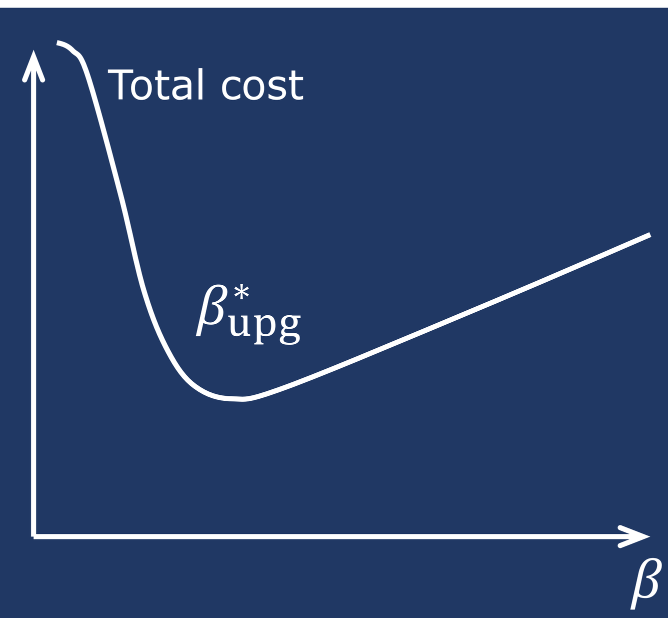




Upgraded Existing Structures

A simple and transparent equation is developed to **minimize the cost** as a function of the reliability index β for **upgrading existing structures**. The model accounts explicitly for:

- Increased cost of upgrading in order to achieve the same safety as for new structures.
- Remaining service life shorter than the standard design life.
- Available information on actual structural conditions from inspections, tests, and measurements.

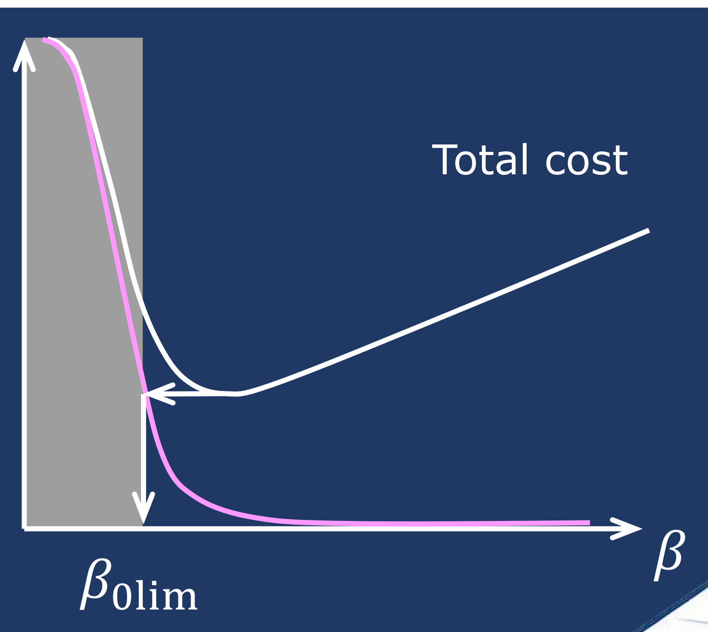


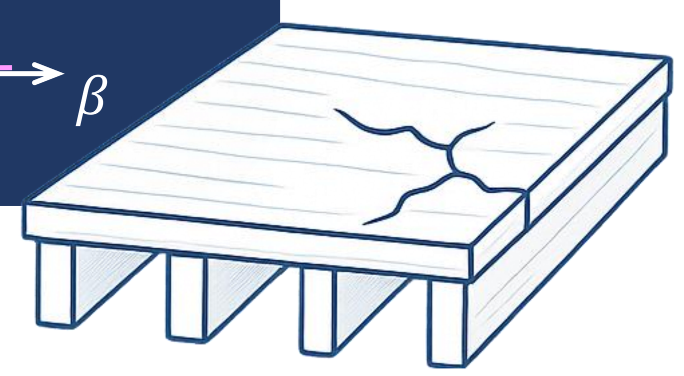
Including CO_2

Emissions are **monetised** and integrated into the optimisation through the **cost of carbon**. Currently, however, typical carbon cost values are **too low to give the emissions a significant impact** on the target of the cost-based optimisation.

No Intervention

A **limiting reliability index** $\beta_{0\text{lim}}$ is derived by equating the expected cost of upgrading to that of taking **no intervention**. Above this threshold ($\beta > \beta_{0\text{lim}}$), performing no intervention is more **cost-effective** than **upgrading the structure** and therefore $\beta_{0\text{lim}}$ can be used as a **target reliability index** when no intervention is taken in an **existing structure**.





Human Safety Criteria

Target reliability indices must meet human safety criteria. One such criterion is **Individual Risk (IR)**, which ensures that people are not exposed to **risks exceeding those of everyday life**. IR sets the absolute minimum for reliability. Another criterion is the **Life Quality Index (LQI)** criterion. Which states that if society is willing to invest more into safety than it costs to achieve a small risk reduction, then the risk reduction should be performed.

The **current LQI acceptance criterion** is based solely on cost optimisation for new structures, but the **difference between new and existing** structures should be accounted for, and therefore, an LQI acceptance criterion only for existing structures is developed.

Results

Based on two case studies, a **timber joist system** and a **concrete beam**, it was found that applying target reliabilities specified for **new structures** β^*_{new} to **upgraded existing structures** (as in **DS 11990**) resulted in a maximum cost increase of only approximately 4.5% compared to β^*_{upg}. Consequently, adopting reliability targets designed for new structures in code calibration contexts appears **justified**. Nonetheless, the proposed method remains valuable for evaluating structures within a reliability-based design framework.

When **no structural intervention** is performed, but a **reassessment** of the structural system is required, **DS 11990** allows the use of a reduced reliability index. This project propose to adopt the **limiting reliability index** from the **no-intervention case** as the target reliability index. The results show that this limiting value is governed by the **IR criterion**. While this criterion cannot be used for calibrating partial safety factors, since it represents an **absolute minimum**, it remains **applicable** within a **reliability-based design framework**.

Frederik Dam Sørensen, Katja Elisabeth Nørgaard & Victor Skov