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Reusability assessment

PROGRESS webinar 3

Life cycle assessment and reusability assessment of single-storey steel buildings
21 May 2020

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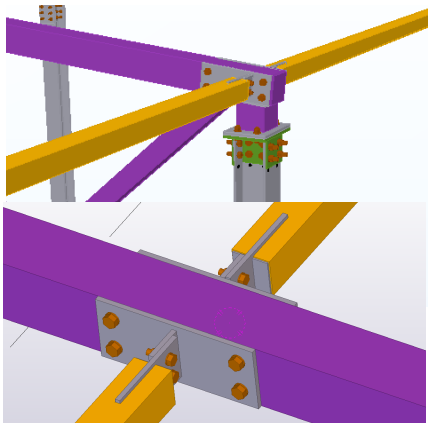
Design for deconstruction or reusability?

Design for optimum material use → Design for low embodied carbon → Design for deconstruction → Design for reuse

Example recommendations (Seppälä 2018)

- regular distance between columns,
- increasing natural loads,
- braces as buckling support, braces for stiffening,
- regular cross sections, regular load-bearing sheets,
- regular material grade,
- friction clamp connection for sandwich element detailing,
- assembling columns from standard pieces,
- base – and end plate connected with bolts to columns,
- same cross section for diagonal bars,
- “expendable” parts,
- regular distance between inside columns,
- and using screws as fasteners for load-bearing sheets.



Picture credits: Juha Seppälä

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Selected Existing methods

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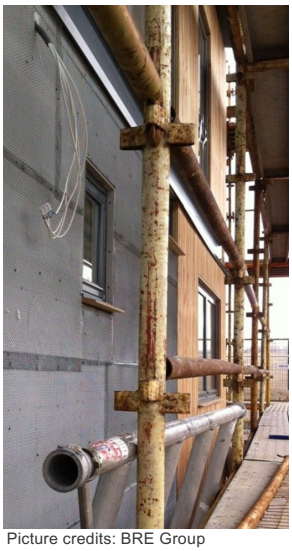
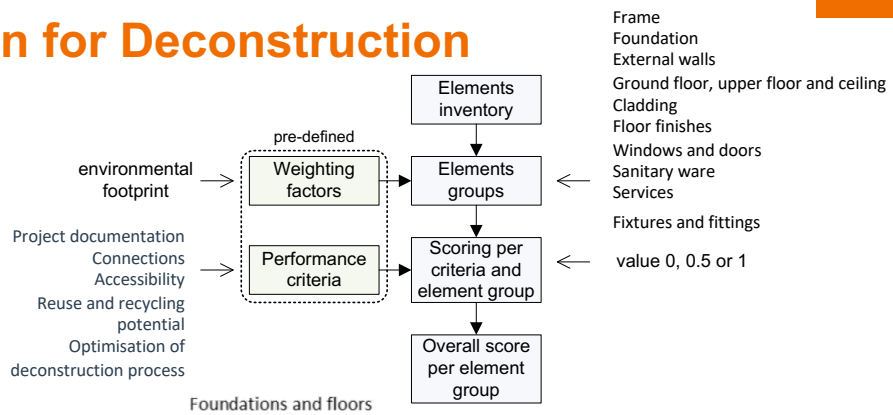
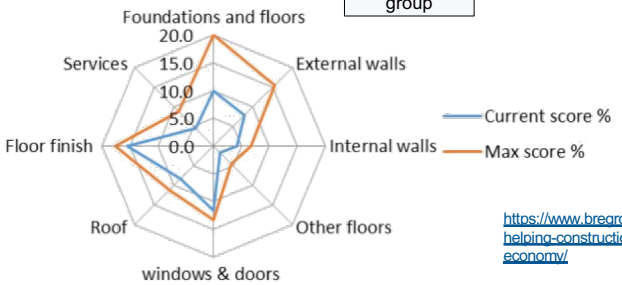
BRE Design for Deconstruction



Picture credits: BRE Group





https://www.bregroup.com/buzz/design-for-deconstruction-helping-construction-unlock-the-benefits-of-the-circular-economy/

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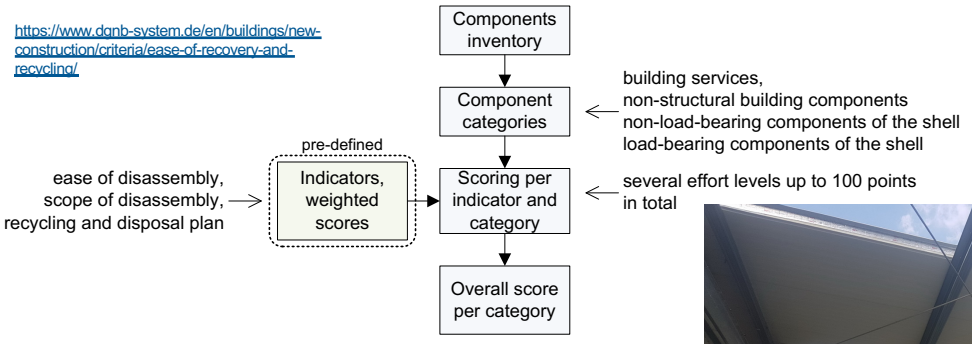
DGNB Deconstruction and Disassembly

https://www.dgnb-system.de/en/buildings/new-construction/criteria/ease-of-recovery-and-recycling/



Contribution to the sustainability goals

Picture credits: Paul Kamrath

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Reusability indicator

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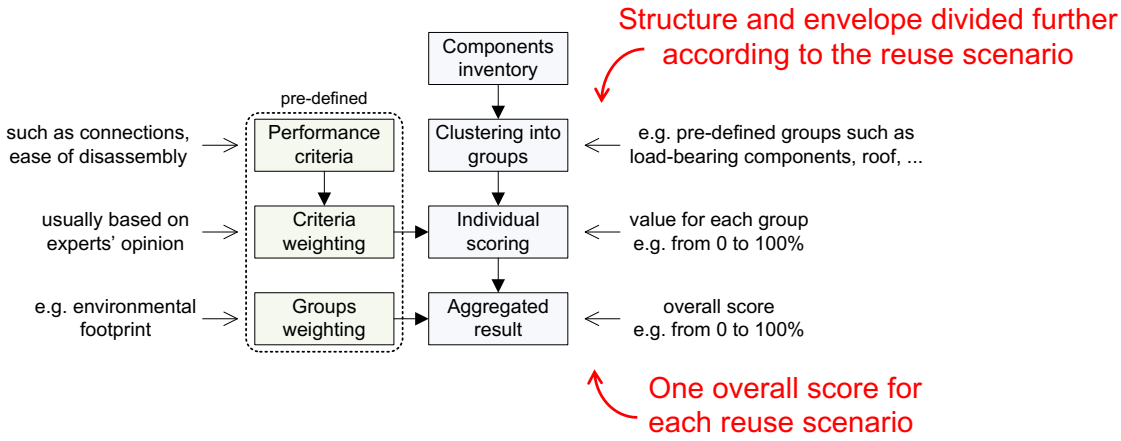
Adapting common approach for DfD assessment



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Technical reusability index

Reusability indicator of the component

$$r = \sum \rho_i w_i$$

Performance assessment result (%)

Weighting factor for each performance category (%)

Reusability indicator of the building

$$R = \frac{\sum m_i r_i}{\sum m_i}$$

Component mass (t)

Performance categories

Deconstruction, handling, separation and cleaning, reuse of design, repurposing, alteration, quality control, geometry check

Performance assessment

very easy	ρ_i = 100%
easy	ρ_i = 80%
moderate	ρ_i = 60%
difficult	ρ_i = 40%
very difficult	ρ_i = 20%
impossible	ρ_i = 0%

Hradil, P., Talja, A., Ungureanu, V., Koukkari, H., Fülöp, L., Reusability indicator for steel-framed buildings and application for an industrial hall. ce/papers, Ernst & Sohn, Vol. 1, Issue 2-3, p. 4512-4521, 2018.

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Performance checklist

Structure

Performance criteria	very difficult $\rho_i = 0.2$	difficult $\rho_i = 0.4$	moderate $\rho_i = 0.6$	easy $\rho_i = 0.8$	very easy $\rho_i = 1.0$
Deconstruction Disassembly $w_i = 30\%$	Welded connections, high risk of damage during deconstruction	Welded connections between components with difficult access	Mostly welded connections between components	Bolted connections between components with difficult access	Easily accessible bolted connections between components
Separation Cleaning $w_i = 10\%$	Machine cleaning/cutting needed to separate other materials	Hand tools for cleaning/cutting can be used to separate other materials	Bolted connections with difficult access for separation	Bolted connections need to be removed for separation	Free-standing components requiring no cleaning
Handling Manipulation $w_i = 15\%$	Exceeding standard transport dimensions, prone to damage, requires special protection	Standard transport, prone to damage, requires special protection	Manipulation by crane, not damage sensitive	Small lifting devices	Manipulation by hand
Quality control $w_i = 15\%$	No documentation, demanding environment, loading history is difficult to estimate, laboratory tests are needed	Laboratory tests are needed to check material properties	Documentation available, loading history known, on-site test needed to check material properties	Material documentation available incl. loading and maintenance history	Material documentation available Exploited in less demanding environment
Geometry checking $w_i = 5\%$	Components would not pass geometry requirements without modification	Complex geometry 3D scanning required	Need to confirm positions of bolt-holes, etc.	Straightness and distortion check needed (lasers)	Straightness enough to confirm usability (wire, visual, etc.)
Redesigning	No documentation,	No		Detailed	Designed to be reused,

Envelope

Performance criteria	very difficult $\rho_i = 0.2$	difficult $\rho_i = 0.4$	moderate $\rho_i = 0.6$	easy $\rho_i = 0.8$	very easy $\rho_i = 1.0$
Deconstruction Disassembly $w_i = 20\%$	Adhesive connections, high risk of damage during deconstruction	Rivet connections between components with difficult access	Rivet connections between components	Drilling screw connections between components with difficult access	Easily accessible drilling screw connections between components
Handling Manipulation $w_i = 5\%$	Exceeding standard transport dimensions, prone to damage, requires special protection	Standard transport, prone to damage, requires special protection	Manipulation by crane, not damage sensitive	Small lifting devices	Manipulation by hand
Separation Cleaning $w_i = 15\%$	Adhesive connections need to be removed for separation	Removal of joint sealing elements	Hand tools for cleaning/cutting can be used to separate other materials	Rivet connections need to be removed for separation	Separated Profiles requiring no cleaning
Redesigning $w_i = 15\%$	Components would not fulfil the standard design requirements without modification	New design is required, similar environmental conditions	Similar design required with different environmental conditions	Loading and maintenance history, same design required and similar environmental conditions	Designed to be reused, documentation and maintenance records in digital format
Repurposing $w_i = 5\%$	Elements with adhesive connections	Profiles with unique sizes and shapes, need to be cold formed	Profiles with limited possibility to use for another purpose	Possible to use for another purpose even outside the construction sector	There is a larger demand for another application than the original purpose
Alteration Modification $w_i = 20\%$	Sizes are unique, reuse would require complete remanufacturing, Components are damaged (delamination or buckling of a layer	Requires removal of adhesive parts, difficult adjustment of rivet-holes	Requires addition and easy adjustment of screw-holes	Requires only addition of new components	Requires no modification

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Economic prospect

Reusability indicator of the component

$$e = P(c_1 \cap c_2 \cap \cdots)n$$

Criteria (e.g. span, height, floor area)

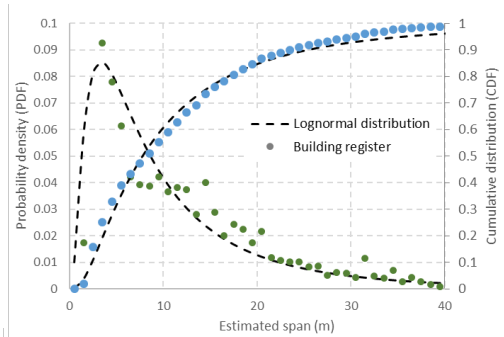
Number of new buildings in the selected area and time span

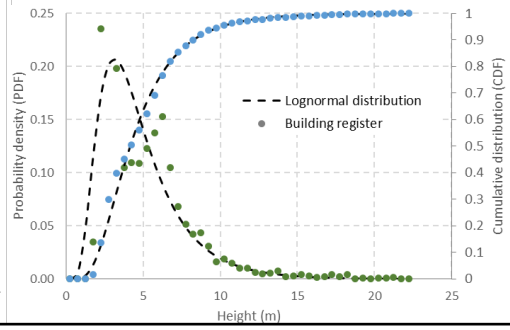
Reusability indicator of the building

$$E = \frac{\sum m_i e_i}{\sum m_i}$$

Component mass (t)

Hradil, P., Fülöp, L., Ungureanu, V., Reusability of components from single-storey steel-framed buildings, Steel Construction. Design and Research, 12 (2), 2019.





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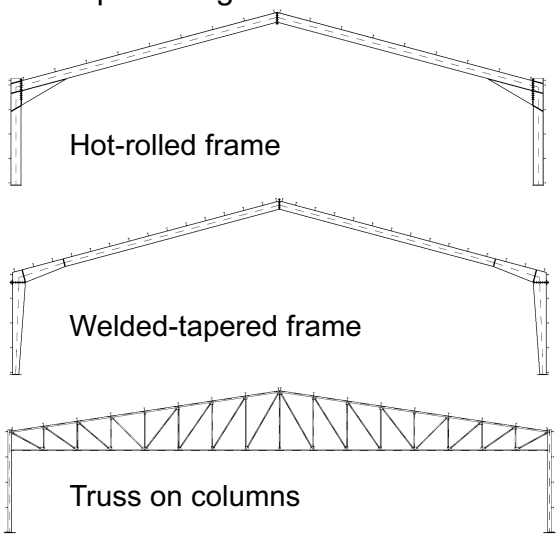
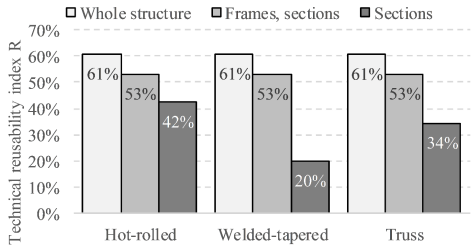
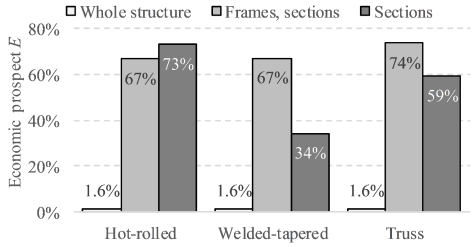
Case study

3 pre-designed structures from PRECASTEEL project and 3 scenarios







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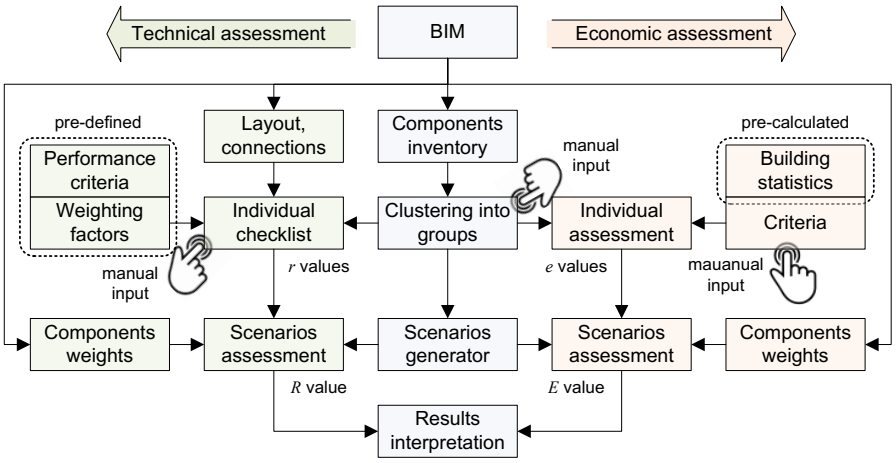
Future development: Automated evaluation of BIM model



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Summary

- Reusability assessment method can be used for new and existing buildings to compare different designs or different end-of-life scenarios
- The method can support pre-deconstruction audits, material testing plan or lifecycle assessment
- It is possible to analyse BIM models with the reusability assessment methods

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Acknowledgements

Project PROGRESS has received funding from the Research Fund for Coal and Steel under grant agreement No 747847, Ruukki Construction, Ramboll Finland, Peikko Group and Jernkontoret.

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