Sustainability in the built environment: A typology system for supporting construction components reuse

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Construction sector consumes more than half of total global raw resources and generates the greatest and most voluminous waste stream globally. E.g. In 2010, around 29.3t of construction minerals entered the global economy accounting for 44% of total raw materials entering the economy.\(^1\)

In the UK, from the 202.8 million tonnes of total solid waste generated in 2014, around 59.4% were generated by the construction, demolition and excavation activities.\(^2\)

Up to 70% of construction and demolition waste (CDW) is recycled in lower grade applications, leading to dissipation of construction materials and components technical value, e.g. their bending moment, nominal loading capacity, expected residual capacity.\(^2\)

Promotion of sustainability through a shift from material wastage to material conservation is becoming a key driver in the construction sector.

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Rethinking construction practices

**Creation of Value**

- **Reuse**
  - The process during which discarded components are recirculated and used for the same function without destruction.
- **Design for reuse**
- **Design for manufacture and assembly**
- **Deconstruction**
  - Design for deconstruction
  - Whole life-cycle consideration at planning stage.
- **Adaptive reuse**
  - Reuse of the basic structure and/or fabric of the building.
- **Reclamation of components**
  - Reuse of components mined from existing structures in new ones.
  - Design and manufacture of construction products off-site.
- **New business models**
- **Innovation**

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but…. still not being mainstreamed due to short-term economic and organisational factors, as well as technical constraints associated with the identification, recovery and handling of construction components due to lack of information!

Need for a typology system that supports the reuse of construction components and enables lifecycle information capture.

Use of smart technologies such as radio frequency identification (RFID) integrated with building information modelling (BIM), has been advocated to be a feasible and viable route of promoting sustainability in the built environment.

The subset of ‘upstream’ and the additional ‘downstream’ properties required to promote reuse of components, remains an important knowledge gap that needs to be filled.

Reusability potential: Typology must haves

A measure of the ability of a component to retain its functionality after the end of its primary life.

May depend on:

- Essential and desirable properties and characteristics of the component;

- Nature of the original use, performance over time and exposure conditions, and the match thereto for the proposed new structural form, loading, exposure;

- Multi-dimensional value associated with the environmental and/or social “costs” of production, use and reclamation processes, its refurbishment for reuse (e.g. cleaning, painting, testing), health effects, and the associated likelihood of damage or contamination.
<table>
<thead>
<tr>
<th>Level I Classifications</th>
<th>Level II Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Action</td>
<td>The physico-mechanical role of the component in its previous deployment.</td>
</tr>
<tr>
<td>2 Material</td>
<td>The material from which the component is made and strength grade for the structural materials.</td>
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<tr>
<td>3 Deployment</td>
<td>The structural form or class in which the component was previously used</td>
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<tr>
<td>4 Exposure</td>
<td>The environmental conditions to which the component has been subjected, associated with quantifications (e.g. weather records, detail of chemical environments, Eurocode EN1992 exposure classes) where appropriate.</td>
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<tr>
<td>5 Loading</td>
<td>The loading history of the component</td>
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<tr>
<td>6 Recovery</td>
<td>The methods used to recover the component</td>
</tr>
<tr>
<td>7 Residual</td>
<td>The structural and functional properties of the component remaining.</td>
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<tr>
<td>8 Connections</td>
<td>The capacity of the component to be connected to other structural and/or functional components and artefacts</td>
</tr>
<tr>
<td>9 Availability</td>
<td>Details of when and where a component is likely to be available, and in what quantity</td>
</tr>
<tr>
<td>10 Generation</td>
<td>The number of times the component has already been reused, and whether the proposed new use would represent upcycling, recycling or down-cycling/cascading.</td>
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</tbody>
</table>

Construction workshop stakeholders results

- Proposed typology is a great starting point but needs to become more meaningful to the stakeholders involved in the construction supply chain.
- Classifications at level I should be restrained only to:
  - **Nature**;
  - **Performance**;
  - **Value-availability**.

- Development of a process map – what classifications for which products.
- Making typology operational: must be user specific!
- Vocabulary needs to be refined – common language between all stakeholders involved will improve communication and uptake.
- Training and support - governmental support required as well as acceptability of reuse by the clients.
Typology refinement - Key considerations

➢ What are the key actors in the construction supply chain?

Government and regulators – those who transpose EU Legislation and waste policy measures in assisting the construction sector to consider its impact on the environment and to improve waste management practices.

Clients – those (or someone who advises them) who seek or accept the services of another for carrying out a project for them; or carry out a project themselves.

Designers and Engineers – those who either prepare or modify a design and are responsible for optimising the reuse of materials and/or reduce waste from construction projects.

Construction Product Manufacturers – any person who makes a construction product through a process involving raw materials, components or assembly.

Suppliers (distribution/retail) – those who supply construction materials/components to a construction project.

Contractors (main and specialist) – those who carry out or manage construction work.

Demolition (Deconstruction) – those who deliberately pull down, destroy or take apart a structure, or a substantial part of a structure, including dismantling for re-use.

Waste management industry (resource management industry) – those who offer a service to transport, treat and dispose of waste, including reuse, recycling, energy recovery and landfill.

➢ Are the attributes specific and comprehensible enough to allow each actor to assess reusability?

➢ Do the elements at each level of the typology include all the attributes needed to adequately describe all characteristics that one would need to know/use to assess reusability potential?

➢ Decomposition of attributes to too many layers must be avoided so that typology does not become less reliable and comprehensible.
Stakeholders in CSC

Key enablers: KE

Government and Regulators

KE/KF
Designers and engineers

KE
Product manufacturers

KE/KF
Suppliers (Distribution and retail)

KE/KF
Waste managers (Resource Managers)

KF
Contractors (Main and specialist)

KF
Demolition (Deconstruction)

Client

Key facilitators: KF
Typology refinement - Key considerations

- What are the key actors in the construction supply chain?

**Depends on each actor** – if the person making the assessment is a technical expert, then some attributes can be esoteric, i.e. in Level III (and perhaps IV).

- Are the attributes specific and comprehensible enough to allow each actor to assess reusability?

- Do the elements at each level of the typology need to be adequately described in a technical/nature-based way?

- Decomposition of attributes to too many levels does not become less reliable.
Tree of hierarchy of typology attributes

**KE**
- Nature of component
- Performance
- Availability - Value

**KE/KF**
- Action
- Material
- Deployment
- Exposure
- Loading history
- Recovery
- Residual properties
- Generation
- Connections and finishes
- Availability

**KF**
- Structural
- Semi-structural
- Modular
- Steel, Timber, Concrete
- Domestic housing
- Industrial
- Infrastructure
- Marine
- Indoor
- Fatigue loading
- Impact/transient loading
- General demolition
- DfD/DfR/DfMA/etc.
- Dimensions
- Structural capacity
- Standard connections
- Lime or cement binder
- Amount arising
- Embodied carbon
- Marketability
- Component-specific recovery
What are the key actors in the construction supply chain?

Is the decomposition of attributes to too many layers a useful feature of the typology?

Are the attributes specific and comprehensible enough to allow each actor to assess reusability?

Do the elements at each level of the typology include all the attributes needed to adequately describe all characteristics that one would need to know/use to assess reusability?

Hierarchy of classifications is needed to make it a useful tool to all stakeholders involved in construction supply chain, from starting from simple classifications to very specialised technical dimensions, but this should be done in such a way so that typology does not become less reliable and comprehensible.
To sum up…

Typology for reuse is considered by stakeholders to be useful in promoting sustainability.

Simplicity combined with completeness is key: Ensure that all attributes required for assessing reusability and sustainability of reuse are accounted.

Once this typology means something to all stakeholders this can then become a useful tool:

- aiding communication between the stakeholders, and
- enabling a vigorous transformation of the currently unsustainable practices into more effective and resourceful ones;
- drive innovation.
Funded by

infrastructure BUusiness models, valuation and Innovation for Local Delivery

https://research.ncl.ac.uk/ibuild

CVORR Complex Value Optimisation for Resource Recovery

To find out more visit us at: https://leedsplus.wpengine.com/cvorr/

Image by: JMacPherson, licensed under CC-BY 1.0
Thank you for listening!

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A component’s life story evolves from design, to use and reuse.

Transformation of its characteristics and functionality.

- **Nominal information (static, essential):** characterises the component in its **as-installed state**, the **action** of the component (i.e. its structural and/or functional role as installed), the **material** from which it is made and **grade** thereof, the **installation method** and **connection type**, the **type of structure** in which it was deployed, **environmental impact** (e.g. embodied carbon, energy or water), inferred **residual capacity information** (i.e. how the component was expected to degrade with time in service) and information on the previous **reuse history** (if any).

- **Service history information (dynamic, desirable):** evolves in response to the **physical** (stresses, strains, accidental damage), and **environmental** (temperature, humidity, chemical exposure etc.) **loads** the component endures during its service lifetime, and other **residual properties** (e.g. evidence of corrosion, records from monitoring programs such as acoustic emissions).
What are the key actors in the construction supply chain?

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