Rebeauty – Artistic Strategies for Repurposing Material Components

Anne-Mette Manelius, Søren Nielsen and Jan Schipull Kauschen
Vandkunsten Architects, 14 Krudtøløbsvej, DK-14439 Copenhagen K
am@vandkunst.dk

Abstract. A cross-disciplinary method has been developed to transform discarded material components to new designs and applications. It is the thesis that discarded material resources in construction represent a triple capital related to energy, economy, and culture and is the aim of the method to support decision-makers and stakeholders with data and physical prototypes in the transition to Circular Construction. The method has been applied to produce 19 full-scale material prototypes designed for disassembly and includes six repeatable steps: Market survey of volumes and availability of components, ideation and analysis matrix, material concept development, material and process prototyping, assessment in terms of 9 criteria representing market, culture, technicality, and environment, and finally dissemination or implementation in the market. For five cases, tools, times and prototyping procedures were documented in Flow-diagrams as the foundation for the assessment of concepts in regard to economy and energy. Results support the hypothesis as LCAs show a lower potential environmental impact for concepts for brick, glass, metal, and wood but not for concrete; architectural visualizations and striking 1:1 prototypes have directly inspired the construction sector and users to further development and implementation; commissions confirm the cultural and commercial potential. The concept of Rebeauty is introduced to summarize the artistic strategies.

Keywords: Architecture, Reuse, LCA, Reversible construction, Beauty, Collaboration

1. Introduction
A cross-disciplinary and multi-criteria method has been developed to transform discarded material components to new designs and applications designed for disassembly (DfD). The method has been applied at 19 full-scale material prototypes, of which five cases has been assessed in terms of culture, potential environmental impact, and economy. The physical results are dozens of architectural visualizations, 19 full-scale prototypes made from six groups of repurposed materials and components. 5 prototypes were selected for additional assessment, concepts using brick, concrete, glass, metal, and wood, respectively. Here flow-diagrams documented the processes of handling and tools used. Flow-diagrams formed the background for 5 sets of Life Cycle Analyses (LCA) of the potential environmental impact of the material concept and prototypes were compared with 5 LCAs conducted...
with a selected conventional alternative. Finally, the potential performance of the same 5 material prototypes has been discussed by architects and the manufacturer and reused materials vendor in terms or ease of construction, sales potential, in-use potential, ease of maintenance, production costs and potential for industrialization, DfD. 1:1 work has formed the core work of the experiments in this paper and has led to data, discussions, exhibitions, lectures, and publications.

1.1. Hypothesis of energy, economy and culture as three kinds of value in renovation
It is the experience in the design and construction practice of the authors that decision-makers emphasize economy and short time economic factors. Yet, this one-sided approach to resources is not representative of the value found when material components or entire building structures have successfully been repurposed. For example, a transformed building may carry a strong identity based on previous use or the weathering of materials, and preserving the existing structure preserves resources for demolishment as well as for the production of a new structure. The same is potentially the case at other scales of reuse materials and this has formed the working hypothesis that reused materials and components represent a potential value in terms of culture, energy, and economy to be preserved and enhanced. Principles for reuse were the foundation of the cross-disciplinary challenge to find new ways to access this value and implement the Circular Economy in construction. The research and development introduced in the paper was established in the cross-disciplinary project Nordic Built Component Reuse (NBCR) [1] conducted by Vandkunsten Architects in cooperation with Nordic partners. NBCR ran for 18 months in 2014-2015 and was funded in parts by Nordic Innovation. The premise of the development work has been the vision that future construction practice will enable resource-preserving strategies, including: 1/Repurposing building waste from demolishing, dismantling, and refurbishment, and 2/Reversible construction principles known as Design for Disassembly (DfD).

1.2. Rebeauty as concept
The concept of Rebeauty was introduced in the project [1] as the artistic exploration of strategies for repurposing material components and summarized in the method introduced in this paper. Rebeauty entails notions of beauty will keep changing and that the cultural accustoming to the aesthetics of weathering and pre-use must be nurtured as part of the transition to Circular Construction. A more formal definition of the term as a general practice could be that Rebeauty is the continuous search for beauty through artistic strategies for repurposing sourced materials and components in reversible architecture.

![Figure 1](image_url)  
**Figure 1.** Sequence of development and assessment of component reuse.
2. The Rebeauty method
The transformational journey from waste material to valuable new components has been investigated through an array of methods from a reflective architectural practice [2]. Step 1-5 of the 6-step sequences illustrated in figure 1 will be introduced in the following.

2.1. Market survey, step 1
The current market status was investigated along with availability of resources for mining. The market survey was done through interviews with national industry experts.

| Sourced Materials and Components | Future Use |
|----------------------------------|------------|
| 1. Ground Sub Structure          | 1. Ground sub structure |
| 2. Primary Structure             | Concrete foundation blocks |
| 3. Completion/Secondary Structure | 2. Primary structure |
| 4. Finishes                       | Wood Building Blocks |
| 5. Services, Plumbing             | Window Wall Facade |
| 6. Services, Electric and Mechanic| Glass Building Blocks |
| 7. Fittings and Furniture         | Spiro Duct Facade |

| Sourced Materials and Components | Future Use |
|----------------------------------|------------|
| 3. Completion/Secondary Structure| Interior Window Wall |
|                                  | Doors, Windows direct reuse |
| 4. Finishes                      | Wood Shutters |
|                                  | Vinyl Solar Screens |
| 5. Services                      | Wood Panelled walls |
| 6. Services                      | Concrete Pavement |
| 7. Fittings and Furniture        | |

*Figure 2. Ideation and analysis matrix based on the SfB building component classification.*

Available components for sourcing are mapped and classified (Left) followed by ideation and development of new applications in Future Use (Right).

2.2. Ideation and analysis matrix, step 2
For step 2, an approach was developed, a matrix illustrated in figure 2 for analysis of discarded material components and for the architectural ideation of their possible future use. The matrix combines SfB, an operational classification system, with principles from Design for Disassembly (DfD). SfB is named after the Samarbetsskonsten för Byggnadsfrågor, the Swedish national committee, which developed the building classification and coding system in 1950 that was later implemented in Danish construction. The codes consist of numbers and letters in a three phased code that refer to building parts, structural principles, and material resource. It is simple to analyse existing building parts according to the system as well as to code the redesigned component. Furthermore, the matrix has been used to assist the ideation of unconventional concepts when the team of architects went through the list of building parts for potential output including loadbearing structure, facades, interiors, windows, furniture as shown on the right in figure 1. The simplified matrix only features building parts and not the specific sub-parts.
The established SfB-system corresponds roughly to Shearing Layers, a basic technical presumption of DfD. Following Shearing Layers, a building should be constructed so that an exchange or alteration of a building part can be performed without interfering with layers with longer lifetime to avoid waste of resources (materials, time, and investments).

Table 1. 21 material concepts representing six material categories were developed and assessed using architectural methods. 14 concepts listed in bold were full-scale prototyped, in total 19 prototypes. LCAs were conducted for 5 selected cases.

| Brick                          | Concrete       | Glass                        | Metal                        | Soft Flooring   | Wood               |
|-------------------------------|----------------|------------------------------|------------------------------|-----------------|--------------------|
| B1.1 Pantile Façade, Front Out and Vertical LCA | C1.1 Cut Element Façade Brick LCA | G1 Laminated Glass Brick | M1 Ventilation Duct Façade LCA | S1 Woven Screen (2 prototypes) | W1 Interior Wall System (3 prototypes) LCA |
| B1.2 Pantile Façade Front Out Horizontal | C1.2 Cut Element Pavement | G2 Window Shingle Screen | M2 Braided Drywall Stud Screen | S1.1 Woven Screen Wicker Style | W2 Shutter Screen |
| B2.1 Pantile Façade Back Out Vertical | C1.3 Cut Element Infill | G3 Window Screen Wall (3 prototypes) LCA | M3.1 Sheet Origami Shingle Façade (2 prototypes) | S2 Vinyl Pillow shingle façade |
| B2.2 Pantile Façade Back Out Horizontal | C2.1 Rubble Sack brick | M3.2 Metal Sheet Shingle | M4 Cable tray Acoustic Wall Panels |

2.3. Material groups selected for concept development, step 3
Materials were selected to investigate based on one or more rough criteria such as resource Frequency, Volume, Accessibility, Potential, and Chance, and from materials groups of brick, concrete, glass, soft flooring, metal, and wood. The concepts listed in table 1 were tested through architectural means, such as the visualizations in figures 3 and 4, in order to challenge and answer the initial question – could these concepts become architecturally striking? Selection criteria included: material categories; feasibility, material amounts, and design aesthetics. The 14 concepts listed in bold table 1 were selected as promising concepts and were prototyped in full-scale.

Figure 3. Visualization of concept W1
Figure 4. Visualization of concept M1
2.4. Full-scale prototyping as physical results, step 4

The physical results of the project are 19 full-scale prototypes made from six groups of repurposed materials and components. All were designed and built for disassembly. Figures 7-11 have formed key cases: Figure 7 shows concept B1.1 Pantile Façade; Figure 8 shows the mock-up of concept C1.1 Cut Concrete Element Façade; Figure 9 shows the metal concept M1 Ventilation Duct Façade; Figure 10 shows the concept G3 for a Window Screen Wall; and Figure 11 shows the wood concept W1 Interior Wall System.

3. Assessments, step 5

For the full-scale prototyping of the five concepts, B1.1, C1.1, G3, M1, and W1, all procedures were timed and documented in flow diagrams to prepare for LCA-analyses. Along with the physical objects, this has allowed the team to assess concepts in terms of economy, energy, and culture, in the nine parameters illustrated in figure 17. A second series of illustrations depict scenarios and visions of transferred technologies and novel sourcing methods and machines that would enable increased reuse.

3.1. Environmental assessment (LCA)

Theoretical results were made through double sets of comparable LCAs and extensive workflow charts conducted for wood, metal, brick, concrete, and glass prototypes. The vinyl prototypes proved too toxic to become marketable and no LCA was conducted for soft flooring. Compared with their conventional, new alternative based on virgin materials, the LCAs for all but the concrete concepts showed that less energy was used in the mining and repurposing of materials to prototypes [1].

![Figure 17](image-url)

**Figure 17.** Assessed performance from 0-10 of six cases based on discussions of nine criteria. 10 is best and the dotted line at level 5 indicates the performance of the conventional alternative. 5+ is thus considered an improvement of the conventional alternative.
3.2. Discussed assessments
The team members (the architect and the reuse materials vendor) discussed an assessment of the cultural and commercial value of the prototypes. The discussed values are summarized in Figure 17. In the commercial assessment of concepts Ease of construction was compared with the discussed cultural value for the customers of Danish material reuse vendor Genbyg.

The discussion to assess the practical value has been summarized to nine parameters and a scale from 0–10 where 0 indicates the poorest assessment and 10 the highest. 5 indicates the standard performance of a conventional, new alternative. The availability of the materials for the component systems varies. For wood and concrete, the availability is very high, for metal and glass the availability is considered medium, and for brick and soft-flooring the availability of resources is considered low. With assessments of 4 and 5 in the categories Industrialisation preparedness, Costs performance, and (on-site) Construction performance, at least half of the prototypes perform at a comparable level or a little lower than conventional alternatives.

The In-Use performance – (User performance in the figure 13) includes maintenance and risks. Wood, Brick, and Glass concepts are assessed high, metal and concrete are assessed at 4, a little lower than conventional alternatives, but the soft flooring concept is presumed to work poorly due to odour issues. The concepts rate high in Cultural potential, DfD performance and Environment. Concrete has a poor environmental assessment at 2.

4. Conclusions
In the project the team has looked for new ways to access material resource value in terms of energy, economy, and culture to support decision makers with the implementation of Circular Economy in construction. It can be concluded from the presented method, resulting in 19 full-scale prototypes and the 9 criteria-assessment of 5 cases, that the 6-step Rebeauty method can be operational to develop and qualify new reuse concepts. The 9 assessment criteria discussed are nuances of energy, economy, and culture and the results support the hypothesis of the triple potential value of reusable resources. The results support the use of the various existing methods in new ways: The physical results show the cultural relevance and architectural value, the Matrix is operational because it uses a well-known classification system in a new way and literally displays if new components are at a higher structural or lower than before. New commissions for products and methods have confirmed this potential.

4.1. LCAs show low potential climate impact – except for concrete
It has been the intention to improve methods and quality of environmental evaluations of reused materials through the use of flow charts and expanded LCA work. LCAs alone confirm the hypothesis of lower potential environmental impact of reuse. For the assessed designs and prototypes for brick, glass, metal, and wood, the potential environmental impact is lower than for conventional products.

While all cases have high architectural and cultural qualities, it can be concluded that in terms of energy, the assessed concrete concept was technically challenging. It was expensive and shows a higher potential environmental impact when reused. It is thus still a challenge to reuse concrete at a high level.

5. Perspectives
The introduced method is complex and will likely prove difficult to repeat in detail but should be possible in principle since the experience, skill, and the architectural stance of another cross-disciplinary team will be different than the present. While the discussion of architectural value will differ based on architectural taste, the capability and experience of the manufacturer, and scale or functions of application, using the cross-disciplinary method will assist the decision-making process and responses to tenders. If followed, the method can provide data as well as a number of media to develop, visualize, assess and document the potential to reuse material components in a building or a district to be demolished or transformed. Yet, the numerous criteria that the cases were assessed at do not represent methods and mediums that all need consideration when developing or testing new component systems.
While the production of Flow-Diagrams was time consuming, they have led to very precise LCAs as well as very precise analysis of the work flow of reuse which can assist improvements in procedures.

The results of the experimental work introduced in this paper establish the data and the experience that clients and other stakeholders in Danish construction ask for before trying anything new. The assessed performance of the prototypes is expected to improve if concepts are scaled up. Furthermore, prices for virgin materials can be expected to rise due to its scarcity, which is expected to strengthen the competitive level of handling mining and repurposing procedures. When the cultural value is added to pre-used materials that tell a story of a place or a time, it will be more likely that the cost of producing material components from reused materials is possible to calculate more accurately and will become affordable in commercial projects.

6. References

[1] Manelius AM (ed) and Nielsen S 2017 Rebeauty – Nordic Built Component Reuse (Copenhagen: Vandkunsten Architects) pp 1-92

[2] Schön D 1983 The Reflective Practitioner: How Professionals Think In Action (New York: Basic Books)

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