CascadeUp: Extending the life of reclaimed solid wood through reuse in the manufacture of mass timber products

Photo credit: Anthony Sajdler

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Background

The global construction industry creates vast quantities of wood waste; in the UK alone around four and a half million tonnes per year (*Wood Recyclers Association (WRA) | Wood Recycling*, no date). Much of this material has qualities that are lost in normal waste management. For example, recycled timber products like chipboard are short-lived and are the final material use before incineration or disposal. Reclaimed whole members tend towards shorter usable lengths and smaller cross-sections and are sold without warranties, which makes them hard to use in mainstream construction.

In a more circular future economy, this secondary timber could be reused locally in the manufacture of mass timber products. Extending the lifespan of timber keeps sequestered carbon locked up in the built environment. Structural uses, such as glued-laminated secondary timber (glulamST) and cross-laminated secondary timber (CLST) (Rose *et al.*, 2018; Dong, Rose and Stegemann, 2024), provide the longest potential for carbon storage. They also provide the largest potential upfront embodied carbon savings, if they can be adopted as a substitute for concrete and steel. There is a growing body of work on structural reuse of timber (Bergsagel and Heisel, 2023; Tamke *et al.*, 2024) and its reuse in 'mass secondary timber' (Irle *et al.*, 2019; Sandberg *et al.*, 2022; Giordano, Derikvand and Fink, 2023). However, the research to date has been largely lab-based. There is a lack of testing in real-world settings and consequently a lack of understanding of the practicality and scalability of this innovation. Our study links conceptual thinking to practical making with a tangible output, known as the CascadeUp pilot (Figure 1). This action research strategy allows us to iterate through cycles of planning, action, observation and reflection to refine our understanding of the challenges and the steps needed to overcome them. In this paper, we report observations from our practical work and reflections on the future research questions to be addressed.

Figure 1: CascadeUp pilot (photo credits: Gersende Giorgio, Digby Oldridge/UCL)

Keywords: circular economy, reuse, modularity, cross-laminated timber (CLT), glulam

Process

We gathered five batches of solid timber from demolition sites, a commercial secondary timber trading company and a social enterprise that collects and re-sells secondary timber (Figure 2, Stage 1-3). After removing foreign materials such as metal fasteners or cement residues and cropping ends, we machined the feedstock to three cross-section categories and tested samples from each batch with a non-destructive testing procedure (Stage 4). Similarly to conventional glulam and CLT, the feedstock was then finger-jointed and manufactured to mass timber products: glulamST and CLST (Stage 5). In a final step, based on a BIM model, the linear and planar components were cut to size on a CNC machine, fasteners were added and then assembled to the final structure (Stage 6-7). Its service life is now underway, having been exhibited at the UCL Festival of Engineering and the London Design Festival, and used as a stage for panel discussions and as a public engagement tool for research dissemination (Stage 8). It could be upgraded to suit different needs and contexts, but once it is no longer useful, it can be disassembled and the 'kit-of-parts' reused to maximise component lifespan (Stage 9).

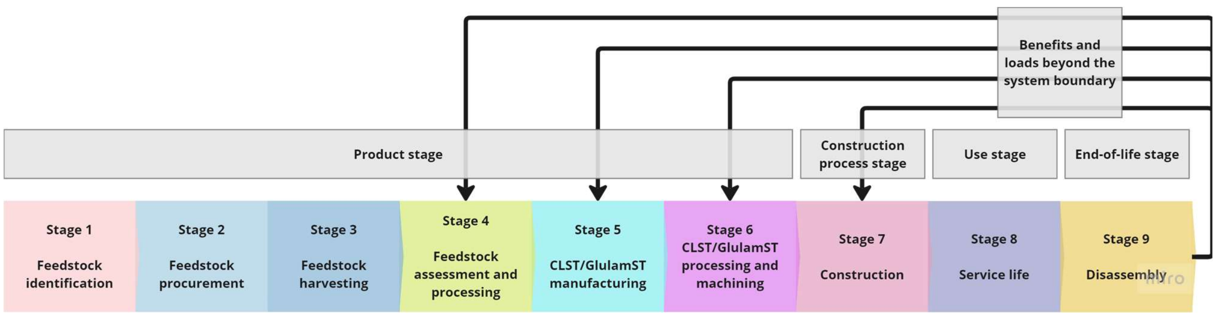

Figure 2: The nine CascadeUp pilot pre-use, use and post-use stages; disassembled parts from Stage 9 can re-enter at Stage 4-7, depending on the level of adaptation needed to facilitate reuse (Based on Technical Committee ISO/TC 207, 2006; Rose, 2019; Benedetti *et al.*, 2022).

Results and discussion

<u>Feedstock sourcing and assessment (Stages 1-4)</u>

Sourcing timber directly from demolition sites is preferable for economic reasons, and to ensure that the initiative increases the recirculation of materials and reduces the quantity being discarded. Sourcing from existing reuse enterprises is also positive in that it increases demand and can contribute to the viability of those enterprises, but the decision has already been made to recover and resell those specific materials.

Given the quantity of wood waste that is discarded, it is perhaps surprising that accessing those materials from demolition sites has been challenging. The difficulty can be explained by our need to gather materials in a short space of time, with a short lead-in. The process can be simplified by its inclusion in pre-demolition audits, by design teams specifying recovery and diversion from normal waste management, and by developing strong networks of willing developers and demolition contractors. The recipient organisation must be reliably and consistently able to receive materials as they emerge, including addressing any legal waste carrier issues around duty of care.

Recording dimensions of secondary timber manually is prone to error due to warping along the length of pieces. This complicates the approach to machining and can lead to unexpected and excessive wastage. Future research applying scanning and imaging techniques to this challenge could more efficiently establish three-dimensional geometry, characteristics such as knot positions and optimal machining, as well as capturing digital records linked to physical tagging/ID.

Removing metal fixings remains labour-intensive. Technology is emerging to automate the process (Urban Machine, 2024), but this is currently prohibitively expensive for small-scale operations. Future research could explore alternative approaches, including human-robot collaboration.

Our previous research into secondary timber assessment adopted non-destructive acoustic testing in combination with destructive bending tests (Dong, Rose and Stegemann, 2024). The study found a strong correlation between non-destructive and destructive methods in predicting stiffness. But there is a need for systematic, coordinated gathering of secondary timber properties by a community of researchers to build larger datasets and more evidence to support reuse.

<u>Yield during processing and manufacturing (Stages 4-6)</u>

Figures 3 and 4 illustrate volumetric and linear yield rate. The volumetric yield rate of 31% was below expectations based on past experience, whereas the linear yield rate of 75% was above expectations. This was partly due to an increase in linear meterage during raw machining, where the largest sections were split lengthwise to create multiple reusable boards.

Conventional building design is 'goal-oriented' – led by a design vision – whereas at a material level, CascadeUp attempted to follow a 'means-oriented' approach (Pereira, Datta and Mancini, 2016), in which the available materials govern design decisions. For example, the number and thickness of lamellae and the final beam dimensions were defined by maximising yield from a batch of roof truss elements. Once the feedstock dimensions are fully digitised, yield could be improved further by working with a greater number of different board thicknesses and widths. Yield improvements would be weighed against the management of different dimensional categories to optimise cost and material efficiency.

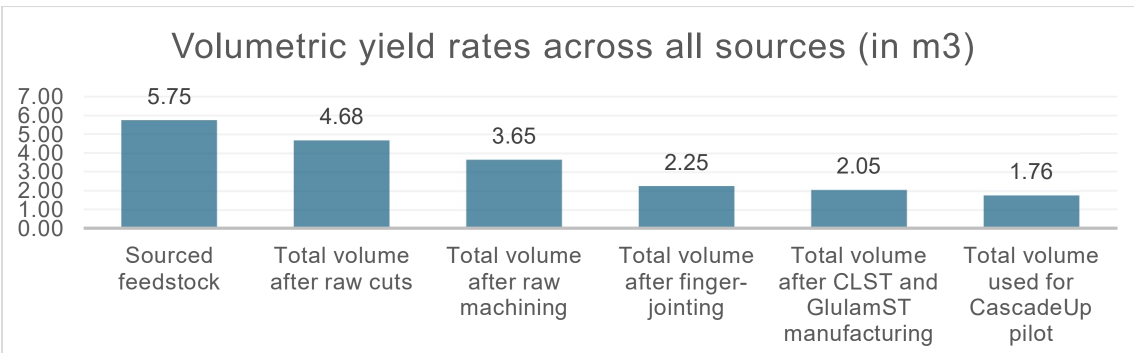

Figure 3: Volumetric yield rates across all sources

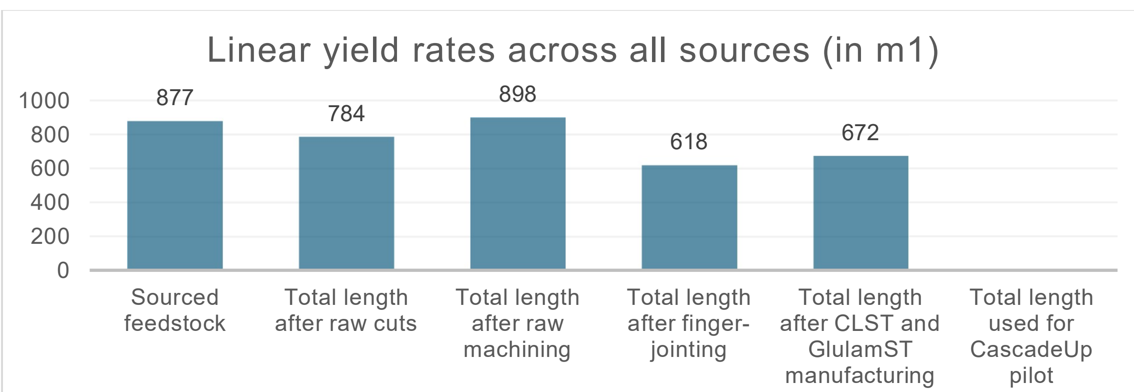

Figure 4: Linear yield rates across all sources

<u>Modular design and disassembly (Stage 9)</u>

CascadeUp explores a more modular approach to mass timber components than is normal in current practice. This aims to make the components easier to deconstruct, handle and reuse – and therefore their value to be retained through their full lifecycle. It also suits early-stage, smaller-scale production and the potential for decentralised manufacturing close to locations where waste wood is generated.

Disassembling the CascadeUp pilot is readily possible, but is not simple enough to encourage us to go back to 'flat pack' while not in use, for instance. There is more work to be done on the kit-of-parts design to facilitate disassembly and reassembly. Beyond reassembling in the same format, it would be interesting to test what other forms of structure could be constructed using the same components. This would provide a measure of the kit-of-parts' adaptability and signal ways in which end profiles and connection details could be standardised to improve the chances of enduring multiple structural lifecycles.

Conclusion

CLST and glulamST are model circular and zero primary resource consumption materials that enable long-term structural reuse of materials. They can increase the built environment's capacity as a long-term carbon sink. A production process that is currently labour-intensive provokes questions around the future of manual work and human-robot collaboration. The innovation challenges us to ask when and how local employment in a more circular future economy can be a viable alternative to global supply chains. Future research will focus on normalising material recovery within a supply network, digitising and assessing feedstock, improving yield and scaling production.

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