Materials passports facilitate circularity in the construction industry

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The construction industry consumes over 40% of Earth's raw material resources. It's time to rethink not just what we build, but how we value what's already built. Digital materials passports can help us reuse and repurpose materials in the built environment, driving a shift towards a circular construction industry.

The last century brought ground-breaking advances in new materials that transformed nearly every aspect of human life. This progress has come at a cost: the extraction, processing, and use of materials—now deeply intertwined in our globally interconnected world—have dramatically altered Earth's ecosystems. Some scientists have proposed that the Anthropocene Epoch[1] began around 1950, marking the point when human actions became the main driver of global environmental change. Today, six of the nine planetary boundaries that define a safe operating space for humanity have been overstepped[2]. Despite international efforts to curb greenhouse gas emissions, the world is not on track to meet the climate change goals outlined in the Paris Agreement.

A major contributor to this crisis is the construction industry. Over 40% of all raw materials extracted from Earth are used in the built environment—our buildings, roads, and infrastructure. As demand for construction grows, so too does the strain on these finite natural resources. The construction sector is therefore one of the most resource-intensive industries, responsible for one third of the world's overall waste and nearly 40% of global energy-related CO_2 emissions.

Before Earth becomes uninhabitable, we all need to radically rethink how we value its limited raw materials. Demolishing and building from scratch is often cheaper and easier than retrofitting or deconstructing buildings into reusable parts, but this linear approach squanders resources. Instead, we must make the most of the materials already in use in the built environment and prevent them from becoming waste. Urban mining, the recovery of valuable materials like concrete and metals from existing buildings and construction and demolition debris, is gaining traction. However, to meaningfully advance sustainability, we need to go a step further and recognise the value of any material. All existing materials can be seen as treasures to be protected, preserved and reintegrated into a circular economy chain, not only the most valuable ones. A material might have just one life but multiple cycles, and recovering and finding new uses for existing materials is the treasure hunting game that everyone should be playing. Imagine that we ban skips or dumpsters and, through a radical creativity approach, we find alternative

uses for all materials to be reused, adapted, repurposed or recycled. This approach transforms material use into a collective endeavour where there are no single winners, but every material is valued and everyone wins.

I call for an ethical materials stewardship that encompasses responsible sourcing, use and management of materials throughout their multiple cycles. Such stewardship considers the social, environmental, and economic impacts of materials from cradle-to-cradle[3]. Materials passports are key to enabling this materials stewardship and creating a circular economy.

What are materials passports?

Material passports give every material an identity. Each passport is a digital record that consolidates essential information about the material in a centralised, accessible location. By tracking a material's chain of custody, materials passports reduce waste, support better design, and improve reuse and recyclability. They also promote data transparency and traceability, document circularity metrics, measure carbon expenditure, and inform decision-making processes[4].

For example, a wooden frame window without material passports is just a window that can go to waste once a building is deconstructed. The same window with materials passports can be classified by a complete **system passport**, with data organized into [hierarchical] passport categories depending on the level of complexity: 1) a **material passport** describing the wooden frame, such as dimensions, type of timber used, source, and how it was harvested; 2) a **product passport** describing the window handle, including its different components, maintenance and assembly guides; 3) a **product passport** describing the glass panel such as percentage of sand and calcium carbonate used, manufacturing process, and type of energy used; 4) a **product passport** for the rubber sealing linked to all the materials (passports) used to produce it. The window system passport aggregates all the product and material passports and centralises all the information about all the materials used to manufacture the window, including how they can be reused, repaired, and/or recycled.

From concept to implementation

Ideally, the materials passports databases would be open source, adopted worldwide by all stakeholders along the materials supply chain. The main barriers to the widespread adoption of materials passports are the lack of governance, and challenges with data standardization, privacy and collection. Currently, materials passports are implemented in multiple data storage formats, mostly developed by commercial solutions, including Building Information Modelling, blockchain, web-based platforms, and QR codes or RFID tags[5]. Although several studies have outlined data requirements for materials passports[6,7], there is

no agreed-upon standard for what a passport should include, and data collection across a material's lifecycles remains resource-intensive and inconsistent.

Our 2024 policy paper[8] provides clear guidance for every stakeholder across the construction industry to implement materials passports. As architects, we advocate for passports to be considered live documents that travel with materials through their life cycles and can be created or updated at any stage, even for materials already used in buildings.

One practical recommendation is to start small, creating passports for a few existing building materials that have high circularity potential and collecting only the most essential information to support their reuse. The United Kingdom Green Building Council recently published a reference guide[9] outlining the key data that a material passport should hold and proposing a materials passport template with the following fields: basic information, circular economy information, sustainability information and product information. Overall, the data gathered and recorded for each material should reflect its economic, environmental and social value.

To standardize data collection and ensure interoperability between passport databases, we propose aligning passport data with the widely used Uniclass classification system (material, product, system, element and building passports). This standardization would allow stakeholders across the materials supply chain (manufacturers, designers, contractors, clients) to adopt a common framework and naming system. Each material could be assigned a unique Uniclass-based identifier and linked to a QR code, enabling easy access and data updates.

For materials passports to truly reach their potential, however, we must systemically change how we value materials. Anyone involved in any stage of the materials lifecycle should become a materials steward. Future multidisciplinary research that brings material science, material culture and design together should measure the unintended consequences of innovation and seek a balance between technological advancement and safeguarding the human-nature ecosystem[10]. We must focus on designing for disassembly, prioritize cradle-to-cradle approaches, facilitate reuse, and drastically reduce the extraction of raw materials. As Michael Braungart states, "A misuse of material resources is not just suicidal for future human generations but catastrophic for the future of life"[3]. Thus, above all, we must treat every material, at every stage of its life, as a treasure to be protected and preserved.

Figure 1: The image illustrates the conventional cradle-to-grave approach compared to the cradle-to-cradle approach where materials are extracted, manufactured, used, salvaged and treated as treasures that have multiple lives. Illustrated by Ana Rute Costa.

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