Doreen Steven Mlote

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Title: Built to Last or Built to Reuse – Creating a Sustainable Legacy Through the Necessary Transition from Designing for Building's Durability to Designing for Disassembly and Adaptability

Essay:

Materials and the processes involved in the construction of buildings globally contribute up to 50% of total greenhouse gas emissions (GHG), affecting climate change in the bigger picture (Ding, 2014). The building designs, materials used, maintenance, renovation, and other emissions throughout a building's life cycle all directly influence a building's impact on the environment. The primary issue at hand is the massive construction waste produced at the end of buildings' lives or when the buildings no longer meet the required needs for space use and must be demolished to pave the way for new ones. Current engineers and designers have inherited from our ancestors the concept of designing and constructing for durability and resilience, creating long-lasting fixed structures. This legacy has been passed over for many generations, with some of the structures built long before the 7th century seen to be standing until today (Machak & Pet'ko, 2021). However, as time goes on, the demand changes with changing needs for occupancy and the use of spaces. Structures must be designed differently to adapt to these changes. There is a significant need to replace the focus on designing for durable structures with designing for adaptable and flexible structures for better longevity of use and lower environmental impact. Otherwise, we expect continuous production of construction waste from demolished buildings and thus an increase in GHG emissions contribution from construction processes.

The need for durable buildings has been vivid since the emergence of the use of cementing materials from 12,000 BC to the recent emergence of modern reinforcing materials like epoxy and fibres (Kirca, 2018). From the Great Wall of China to the long-standing Egyptian Pyramids, about 3000 years of massive building activity have left countless monuments in various states of preservation (Arnold, 1991; Romer, 2007). The Egyptian pyramids, for instance, have proven the idea of durability and resilience as long-standing structures for decades now. Our ancestors used the limited materials and the scarce knowledge and experience they had and yet could design and construct structures that still withstand the tests of climate changes and time.

However, due to constant changes in the need for space use, various structures have been torn down purposely to pave the way for newer structures to accommodate new purposes, even though they are still capable and durable for longer use. Some examples of demolished buildings include; (i) The then-called 'Singer Tower' – Singer Manufacturing Company's 47-story building in New York whose construction was finished in 1908, it was, by then, the tallest structure in the world. However, the structure then held a different record: it was the highest building ever purposefully destroyed. In 1967, this building was demolished and eventually rebuilt into a building with more office space, presently known as 'One Liberty Plaza' (Newcomb, 2003; Waldek, 2020). (ii) The Chicago Federal Building – The responsibility of creating the new federal building in Chicago, which would take the place of the smaller one that the city had fast outgrown, fell to Architect Henry Ives Cobb in the late 19th century. He built a massive, gilded dome-topped 'Beaux Arts' building that debuted in 1905. However, the structure was demolished and replaced with a more contemporary one only about 60 years later (Waldek, 2020). (iii) Old Main Library, Cincinnati – Although it appeared simple from the outside, Cincinnati's Old Main Library was home to a magnificent main atrium with resilient and durable cast-iron spiral staircases leading to endless rows of bookcases. However, to house the books better, a modern structure was built just down the street in 1955, and this library was demolished (Rohlf, 1984; Waldek, 2020). In all these cases, although the structures had not reached their end-of-life in terms of durability, they had to be demolished as their structures and layouts no longer met the purposes and requirements of the users.

This problem has escalated from building level to cities level, a term currently referred to as 'resource sinks'. Due to the need for urban renewal, rapid urban development, and population densification, material flows have no positive value for future generations – more buildings are created with no concrete plan for waste management or circularity. Recently, as research fields have grown, the emergence of new methods, new composite materials and new hybrid materials have also widened the knowledge and experience for designing durable, sustainable and resilient buildings and cities (Laboy, 2022). However, for generations now, researchers have been focusing on improving the processes and material properties in an attempt to enhance buildings' durability for "long-term use" – a mentality that has fixed many engineers' and designers' mindsets on only innovations that could be done for the building structure to remain standing for as long as possible without considering the possibility in change of occupancy needs. In some parts of the world, such as Africa, some engineers and designers have further decided to maintain obsolete construction methods since they believe that what works, structure-wise, does not need to be fixed (Bouhmoud & Loudyi, 2021).

For the building sector to contribute to the environment, we need to target design methods that encourage, and support the goal of net-zero waste at the final stage of a building's life cycle. To attain net-zero waste, we need to change our focus from designing for durability to designing for flexibility so that buildings can adapt to changes in the need for use by future generations. Firstly, this can be done by implementing Design for Disassembly and Adaptability (DfD/A) methods in buildings construction. DfD/A offers a way where building components can be dismantled, disassembled, and reassembled as per need. This allows the building layout and components to be able to accommodate future changes that may occur without the need for demolishing the structure. With DfD/A methods, a building can be broken down into multiple layers (such as the core load-bearing structure, the room separators, the façade, and the service structures) which can have different life expectancies. Each layer can be refurbished separately as needed in the future. This is, in fact, way more in line with the longevity of the building than durability by itself could ever attain.

With DfD/A, buildings act as material banks – storing the used materials for future reuse. DfD/A enables many components to fit into a closed-loop material flow, where they may be reassembled, reused, and recycled to create new buildings of equal or even better quality – leading to a circular economy. DfD/A methods should be implemented in early design stages of a project. Connections points of different parts must be easily accessible, and instructions and guidelines as well as inventories of reusable components and connections must be preserved to make disassembly and reassembly simpler when needed in future. It is also crucial to make sure that the materials' quality can sustain repeated use and are not degraded within a short time.

The significance of DfD/A stems from the growing demand for flexible, scalable, multifunctional, and customizable buildings. As the world's population grows, the need for housing and office space also grows meanwhile, the land space for construction becomes lesser. Buildings that were used before for different purposes may need to be converted to allow different usage and if they are unable to accommodate the changed needs, demolition is opted for. Nevertheless, demolition of such buildings that are rather still durable has proven that the design for fixed durability is ineffective and costly for both the economy and the environment. DfD/A methods are not only significant but also the only probable solution to designing structures for today's needs whilst thinking about tomorrow's generation's.

To lessen the environmental impact from the built environment, using recycled, upcycled and sustainable building materials has been the approach of most researchers, so far, to reach the goal of sustainable construction (Laboy, 2022; Morris, Allen, & Hawkins, 2021; Robertson, Lam, & Cole, 2012). Only a few have tried to use and implement DfD/A methods an example being the 'Circle House' project in Denmark. The Circle House project was designed to be scalable in the future but also with the objective of 90% of materials used, to be recycled and used again without significantly losing their value (Jensen & Sommer, 2018). The design of the Circle House broke down the building into layers with different life expectancies; the core structure (50-100 years), the outer skin (25-50 years), the services such as stairs (15-25 years), space layout (5-15 years) and finally furnishings (0-5 years) (Jensen & Sommer, 2018; Merrild, Jensen, & Sommer, 2016). Since each layer can be easily disassembled and reassembled, each layer will be maintained separately whenever required. This design, among others, presents evidence that DfD/A are feasible and highly potential for the future.

The transition from design for fixed durability to design for disassembly and adaptability will not be easy but will be a worthwhile investment for future generations. To begin with, current buildings should be assessed on their degrees of adaptability and resilience – that is how much adaptable they are currently and how much load their structures can withstand without failure. Collection of this information will help engineers and designers to determine how best to optimise their usage for different needs, for as long as possible, but also to understand how new building layouts should be predicted and constructed in a flexible way. With DfD/A, each layer of the building gets separate assessment, for example, the load-bearing core structure can be designed for durability and resilience since it can remain fixed while the building layouts and separations change to match the occupancy needs and requirements as they change in the future.

In addition to that, Life Cycle Assessment (LCA) tools are effective for predicting the environmental impacts of buildings throughout their life. However, the available LCA tools are obsolete and should be modified to match the design spectrum and boundaries associated with DfD/A methods. This will help to obtain accurate results on not only the environmental impact that we expect future generations to face but also how much savings we are targeting by using the DfD/A methods. This is an area that has not yet been covered by researchers in the field but evidently displays potential in environmental protection in the long term through DfD/A methods.

Moreover, LCA should go hand in hand with carbon accounting of all processes as well as encouraging certification of materials through the use of ‘Material Passports’. Although there is unquestionably a rising need for carbon accounting of buildings, there is currently a very small sample of buildings available for comparison. Carbon accounting is the process of completely auditable calculation, analysis, measurement, and reporting of a company's GHG emissions, whereas materials passports’ main objective is to record the materials used in a building in order to maximize its potential for reuse. Companies should be cooperative in storing and sharing necessary data so that we can account for all the GHG emissions and estimate the savings we are earning as we transit towards DfD/A methods.

The way forward is to not only create awareness of the significance and the potential of DfD/A methods but also to create policies and guidelines that assist engineers and designers to study current designs and account for future designs. Who is responsible to push this forward? Architects, designers, engineers, researchers, policymakers, building owners, developers, and all within the influence, are to do their part in ensuring that proper actions are taken to shift towards designing for disassembly and adaptability.

Ultimately, the built environment can drive sustainable innovation and growth and is essential to the global economy. However, in order for all generations to benefit from it, we cannot ignore the negative impact it has on environment. The contribution of construction processes to GHG emissions is significant, with its percentage increasing each year. Through the implementation and enforcement of the DfD/A and LCA methods, everyone has a role to play in creating our generation’s legacy of protecting the environment for future generations. Buildings that can be disassembled will make better use of their materials, will be more adaptable, and will last longer. A closed and circular material flow is created by such a design strategy which promotes a continuous use of materials over various building life cycles. If we are to achieve net zero waste and protect the environment, we are to start designing buildings that are adaptable to the needs of the future generations. Let us ask ourselves: What are we passing over to the next generations, durable but inflexible structures for them to break or adaptable parts to rebuild and reuse?

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