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To demolish or not to demolish: Life cycle consideration of repurposing buildings

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ABSTRACT

Reduction in energy and resource consumption, as well as other environmental impacts, can be achieved for end of life building stock by recovering building waste after demolition through material reuse and recycling; or building repurposing through selective deconstruction and building system reuse. This research investigates and compares the potential life cycle environmental impacts of building repurposing through reuse of structure and demolition scenarios followed by new construction involving an existing library tower. New building design variations, with and without a Trombe wall, are detailed for both types of scenarios. The Athena EcoCalculator for Commercial Assemblies was used in analysis of life cycle stages of resource extraction and construction; maintenance, repair, and replacement of building assemblies; and disposal. Impacts from energy consumption for building operations were not included. Repurposing scenarios showed a potential reduction, between 20 and 41%, in six of the seven environmental impact categories assessed. The highest reduction is achieved for the Eutrophication Potential followed by Smog Potential at 37% reduction. Human Health Criteria is the impact category with the least reduction at 20% followed by Acidification Potential at 29%. Global Warming Potential and Fossil Fuel Consumption which are closely correlated show an avoided impact of 33 and 34% respectively as a result of the decision to go for repurposing after selective deconstruction rather than complete demolition and new construction. The benefits of repurposing compared to new construction demolition go beyond avoided environmental impacts. Comprehensive consideration of all relevant factors pertinent to the local context is also discussed.

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1. Introduction

The built environment is a maker and breaker of sustainability efforts in many countries of the world. Infamously known as the forty-percent sector, the building sector is responsible for 40% of the global energy and resource consumption (UNEP, 2016). One-third of global greenhouse gas emissions is also attributable to the same sector. Existing building stock in Canada, is associated with 50% of natural resource extraction, 35 of greenhouse gas emissions, 33% of energy consumption, 25% of landfill waste, as well as 10% of particulate matter (ISEDC, 2015). Commercial and institutional (C&I) buildings in Canada number between 443 413 and 521 119 (NRC, 2013) and contribute to the majority of these impacts. C&I buildings therefore present an opportunity area for targeted and meaningful action to reduce overall impact of the built environment. Efforts of dealing with different scales of environmental problems will succeed if the contribution of buildings and associated infrastructure is considered in earnest.

The literature is full of recommendations for minimizing the environmental impact of the built environment. The quest for sustainability in different sectors of the economy including the built environment are better understood and researched using broader economy-wide concepts such as Circular Economy and place-based material and energy flow solutions such as Industrial Symbiosis.

The use of construction and demolition waste has been investigated as part of achieving a Circular Economy in different countries (for example, Esa, Halog, & Rigamonti, 2016 in Malaysia; Smol, Kulczycka, Henclik, Gorazda, & Wzorek, 2015 in Poland). Esa et al. (2016) presented the concept of Circular Economy as a strategy for minimizing construction and demolition wastes in Malaysia. The theoretical framework developed based on this concept is meant to enable actions at three different levels, local, mid-range and global levels paying attention to aspects of construction that span from planning to demolition. In the other study from Poland, Circular Economy as used in the European Union is presented as an econ-

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omy that ideally eliminates wastes while maintaining the added value in products in a closed loop (Smol et al., 2015). As part of a journey towards a circular economy, the authors investigated the use of sewage sludge ash in the production of different construction materials such as input in bricks and tiles; raw material in cement production; and aggregates for concrete and mortar.

In the context of built-up areas such as university campuses where a group of buildings can be gainfully connected with the objective of increasing area-wide efficiencies by harnessing existing energy and materials flows that are conventionally managed, or rather mismanaged, at individual building level. The concept of Industrial Symbiosis can be used to frame the important enablers by improving the factors that affect the flows and engaging relevant stakeholders to realize an effective utilization of resources and minimization of waste.

For public policy-makers and corporate decision-makers, understanding the relative magnitude of environmental impacts and resource consumption of processes and products helps in terms of identifying where and when to intervene and what to prioritize when devising policy instruments and embarking on new product development.

Rohn, Pastewski, Lettenmeier, Wiesen, and Bienge (2014) identified over 250 resource-efficient technologies, strategies and products using literature review and expert-based evaluation. After selecting 22 areas for further life cycle based analysis and assessment, the authors concluded that there is a significant resource efficiency potential expressed in the form of material footprint.

There are also studies that focus on broad aspects of sustainable construction (Sfakianaki, 2015), others on use of life cycle studies (Chau, Leung, & Ng, 2015; Dadhich, Genovese, Kumar, & Acquaye, 2014). Based on a literature review on the area of construction, Sfakianaki (2015) has emphasised the role of coordinated supply chain action in the construction sector and the need for construction companies to train and invest in resource- efficient building methods and practices. The author remarked the need for commitment of all stakeholders and new ways in managing and implementing sustainability. Dadhich et al. (2014) examined the issue of developing sustainable supply chains in the UK taking the case of plaster board supply chain using life cycle assessment to identify hotspots. With a focus on types of life cycle studies used in evaluating the environmental impacts of building construction, Chau et al. (2015) compared Life Cycle Assessment (LCA), Life Cycle Energy Assessment (LCEA) and Life Cycle Carbon Emissions Assessment (LCCO2A) based on their objectives, methodologies, and findings.

One area of focus in addressing the environmental impacts of buildings that is widely published is proper management of building waste. Significant resource and energy can be conserved, and other environmental impacts avoided, when building waste is recovered or recycled (Dodoo, Gustavsson, & Sathre, 2009; Roussat, Mehu, & Dujet, 2009; Scheuer, Keoleian, & Reppe, 2003; Thormark, 2001, 2006). This, however, is limited to the construction and demolition phases of buildings (Yeheyis, Hewage, Alam, Eskicioglu, & Sadiq, 2013). Another line of endeavor is the field of modular offsite construction which, when compared to conventional onsite construction, has shown reduced in construction waste, energy consumption, and transportation emissions (Al-Hussein, Manrique, & Mah, 2009; Jaillon, Poon, & Chiang, 2009).Whole building modular prefabrication works well within the residential building sector and is a good way of reducing the environmental impact of buildings where offsite construction is a viable alternative to new onsite construction. There are practical hindrances for whole building modular offsite construction for high-rise commercial and institutional buildings. Besides, most of the buildings needed for decades to come in many developed countries are already built. In these countries, the turnover of the building stock is slow and the magnitude of new construction compared to existing building stock is less than 2% (e.g. AutoDesk, 2015; Gursel 2010). According to Natural Resources Canada (NRC, 2013) 27% of commercial and institutional buildings in the country were 50 years old. Thus, reducing the environmental footprint of these old buildings and in general the whole built environment calls for a scaled-up focus on improving the performance of existing building stock.

Prolonging the useful lifetime of an existing building by adapting it to new requirements of a different use can potentially save material, embodied energy, and transport related impacts when compared to new construction. Research in this area has mainly focused on either retrofitting within the lifetime of a building (Mata, Kalagasidis, & Johnsson., 2010) or reuse of disassembled materials in a second life (Gao, Ariyama, Ojima, & Meier, 2001). A preliminary study carried by Wondimagegnehu and Urness (2012) cited around 12–15% potential reduction in energy consumption based on studies residential buildings by Gao et al. (2001) and asserted that this can be further increased if remaining construction materials include recycled products.

An additional benefit associated with repurposing buildings with some level of renovation and adaptation is the avoidance of the development of new land for new construction. This merit is particularly important in institutions such as universities with limited access to land in the same location where they currently operate. Interest on research around the implications of repurposing old buildings has increased over the past two decades. The literature uses the concept of adaptive reuse which is synonymous with the repurposing concept referred to in this paper. Repurposing and adaptive reuse imply retaining the major part of the original building such as the structure while upgrading other parts to suit new standards and changing user requirements (Bullen, 2007). During the course of the upgrading activity, old materials and building components are changed and higher energy efficiency is sought.

As more repurposing projects are realized, there is an increasing need to understand more about the life cycle performance of the material dimension and implication of the process of repurposing buildings. This life cycle focus on materials becomes more relevant specifically as we move toward energy efficient buildings as the material component in the form of embodied impact becomes increasingly important. Understanding repurposing projects as giving new life to buildings, where embodied impacts can remain locked, will lead to innovative approaches from the design boards to the facility management boards. There is, however, a recognition that not every building will be good enough for repurposing. Bullen (2007) has a list of factors that are considered to pose challenges in furthering adaptive reuse (see also Bullen & Love, 2010; Yung & Chan, 2012).

Making the case for adaptive reuse of buildings as a way of contributing to the sustainability of the built environment is not rare (e.g. Conejos, Langston, & Smith, 2015; Langston, Wong, Hui, & Shen, 2008). Examining the merits and demerits of repurposing versus complete replacement by new construction in terms of reduction in material and embodied energy and other impacts will help in making informed decision as to what is best in a specific circumstance. The fact that buildings are designed and constructed to respond to a local climatic condition alludes to the vitality of appreciating the geographic differences before one is tempted to transpose results from research done in one place to another.

Many of the available studies are on the repurposing of heritage or historical buildings (Yung & Chan, 2012; Wang & Zeng, 2010). Very few have been done on commercial buildings (Jagarajan et al., 2015). There is thus a need for adding to the existing body of knowledge surrounding the environmental implications of repurposing projects compared to new constructions for the C&I building sector. Moreover, studies of cold region locations, such as the province of Alberta in Western Canada, are nonexistent.

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