Journal of Cleaner Production 203 (2018) 696–707

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Environmental impacts of short building lifespans in China considering time value

Jingjing Wang [a], Yurong Zhang [b], Yuanfeng Wang [a, *]

[a] School of Civil Engineering, Beijing Jiaotong University, Beijing, 100044, PR China
[b] College of Civil Engineering and Architecture, Zhejiang University of Technology, Hangzhou, 310014, Zhejiang, PR China

ARTICLE INFO

Article history:
Received 7 March 2018
Received in revised form
13 July 2018
Accepted 29 August 2018
Available online 30 August 2018

Keywords:
Building
Short lifespan
Life cycle assessment (LCA)
Time value
China

ABSTRACT

China has about 60 billion m^2 of existing buildings, with approximately 2 billion m^2 newly constructed each year. This accounts for half of all new buildings globally. A large number of buildings were demolished during the urban renewal process in China, significantly reducing the average lifespan of buildings and wasting vast amounts of energy and resources. However, the corresponding environmental impacts of reduced building lifespans have not been studied. Moreover, how to accurately evaluate future environmental impacts of construction projects is still a difficult problem, since in some cases the environmental impacts may not be realized for many years. In order to investigate the relationship between building lifespans and the corresponding environmental impacts, this paper first estimated the average lifespan of buildings in China through literature review, field investigation and calculation (using survival rate and demolition rate, respectively), revealing that the average building lifespan in China is from 25 to 35 years which is far shorter than the designed lifespans of buildings in China. It is also much shorter compared to the building lifespans in ten developed countries. Six buildings in Hebei Province in China were selected as case studies to conduct life cycle environmental (LCE) impact assessment. The results of the case studies indicate that (1) extending the building's lifespan from 30 to 50 years would reduce 40% of its total LCE impacts; (2) the environmental impacts caused by buildings (per area per year) in China is 2.3 times than that in the UK; (3) when environmental impacts are considered over time, they would decrease dramatically with the increase of discount rate, indicating that the buildings in developed cities in China with higher discount rates are more sensitive to environmental degradation.

1. Introduction

China has about 60 billion m^2 of existing buildings, with approximately 2 billion m^2 newly constructed each year (CD, 2010), which accounts for half of all new buildings globally and is over six times larger than the U.S. housing market (Shan and Yai, 2011; Wang, 2014). This has led to continued increasing energy demand for buildings, which reached 864 million tce in 2015, and accounted for roughly 20% of China's total energy consumption at that time (TBER, 2017). Moreover, it is predicted by IPCC fifth report, the building related greenhouse gases (GHG) emissions will contribute 30% of world's GHG emissions in 2030 (IPCC, 2014). Some investigations show (Luo, 2011; Hu et al., 2010) that the actual lifespan of buildings in China is no more than thirty years, which is far shorter than the designed lifespans of buildings. Many buildings should, therefore, last many more years before they are pulled down, and over demolition is the most direct reason for the short lifespan phenomenon (Liu et al., 2014). It is predicted that more than half of China's existing residential structures will be dismantled to make way for new development during the next two decades (CD, 2010).

The shorted average lifespan of buildings results in the increase of floor spaces of buildings demolished, leads to the increase of floor space of buildings completed, and the increase in the annual monetary output of the building sector. According to the report, *Researches on Building Demolition Management Policy,* published by the China Academy of Building Research in July 2014, nearly 4.6 billion square meters of buildings were demolished during the Eleventh Five-Year Plan (2006–2010) of China, among which about 2 billion square meters belonged to buildings with a lifespan less than 40 years. And this figure increased to 2.3 billion square meters during the twelfth five-year period (2011–2015) (CABR, 2014).

---

* Corresponding author.
E-mail address: cyfwang@bjtu.edu.cn (Y. Wang).

https://doi.org/10.1016/j.jclepro.2018.08.314

In China, construction waste comprises 30 to 40 percent of the total volume of urban waste (Huang et al., 2013). The erection of a 10,000 square meter building typically creates 500–600 tons of waste, and the demolition of a similarly sized building creates 7000 to 12,000 tons (CD, 2010) of waste. According to Dong et al. (2005), demolition and rebuilding will increase the life cycle cost (LCC) of buildings from the perspective of overall costs, and from 2011 to 2015 more than an extra 2300 billion CNY were spent on the over demolition of buildings (CABR, 2014). Approximately 40% of building land is created by the demolition of older developments in China (CD, 2010) every year. Moreover, over demolition will produce approximately 10% extra carbon emissions (CABR, 2014).

Many scholars have pointed out that one way of extending resource and energy productivity is by prolonging the service life of products (Power, 2008). Thus, the issue of the lifespan of existing buildings has attracted widespread attention and caused intense debate in China (Wang, 2014; Liu, 2014). However, unlike some manufactured products, whose service life or lifespan can be fairly accurately estimated from experience and similar products, the lifespan of a building is not easy to estimate due to non-technical factors, such as poor urban planning, and commercial interests which often limit the actual building's residual service (Nemry et al., 2010).

The life cycle environmental (LCE) impacts caused by the short building lifespans in China is not yet well understood. Life cycle assessment (LCA), as a pre-eminent and effective tool, can be used to estimate the LCE impacts of buildings (ISO, 2006a, 2006b). However, there are some deficiencies in the traditional LCA method. For example, it is generally recognised that certain environmental decisions involve trade-offs between present and future impacts. Such trade-offs raise issues of intergenerational fairness and equity that are ethical in nature (Hellweg et al., 2003). Only a few studies have realized that whether an identical environmental impact will be worth more or less in the future is an important question that needs to be addressed. These studies indicate that figuring the environmental impacts of buildings should take the following factors into consideration: (1) LCA involves many temporal issues, especially for buildings with long lifespans. For instance, construction materials are often “stored” in buildings for many decades before they are recycled or disposed (Hellweg and Frischknecht, 2004), and it is uncertain which disposal technologies will be used for these materials in the future (Hellweg et al., 2003). (2) There is a hidden assumption in previous research that environmental impacts are constant over time. This is not an innocuous assumption. It implicitly amounts to assuming an immutability over time (Weitzman, 1994). For instance, whether an emission contributes to ozone depletion today or in 200 years is treated equally in most methods (Hellweg and Frischknecht, 2004). In order to solve the problems in (1) and (2), Levasseur et al. (2010) proposed a dynamic LCA approach to improve the accuracy of LCA by addressing the inconsistency of temporal assessment. Their approach consists of first computing a dynamic life cycle inventory (LCI), considering the temporal profile of emissions. Then, time-dependent factors are calculated to assess the dynamic LCI with real-time impact scores for any given time horizon. Jeswani et al. (2010) presented that the traditional LCA method should be deepened by improving ISO 14044 guidance related to the definition of dynamic aspects. There is also some research focusing on the cost to treat environmental pollution. Isacs et al. (2016) pointed out that there is no single correct monetary value for CO_2 because the variation in carbon value estimates depends on several uncertain aspects, including climate sensitivity, assumptions about future emissions, and decision makers' ethical standpoints. Most current research makes no explicit differentiation between treating cost at different points in time. As well, there is almost no research about the difference between such costs in different areas.

The aim of this study is to (1) investigate the factors behind the short building lifespan phenomenon in China; (2) study the actual lifespan of China's buildings; (3) analyse the relationship between building lifespans and the corresponding environmental impacts; (4) examine environmental impacts over time in relation to discounting rate.

2. Method

2.1. Building lifespan analysis

2.1.1. Reasons behind short building lifespans in China

Globally, the most common reason for demolition is redevelopment, which is completely unconnected to the physical components of buildings (TAI, 2004; O'Connor, 2004; Song, 2004). Fig. S1 (in Supporting Information) shows the top four reasons for building demolition in the world: “area redevelopment” (35%), “building's physical condition” (31%), “not suitable for anticipated use” (22%), and “fire damage” (7%) (TAI, 2004). The reasons for the demolition of existing buildings in China are complex (see Table S1 in Supporting Information). All of the influencing factors for a building's lifespan can be grouped into internal and external factors, also as shown in Fig.S1.

Internal factors mainly refer to the physical condition of a building. The poor quality of existing buildings is generally considered to be the major internal factor for the short lifespan of buildings in China (Shen et al., 2013). Poor quality includes inadequate architectural design, poor construction quality and nonconformity to building standards and regulations caused by a lack of construction supervision, and non-effective operation and maintenance plans. As well, the poor functionality of a building is a key internal factor.

Previous studies revealed that buildings were demolished not only because they were old or in bad condition. External factors that contribute to a building's lifespan include demolishing buildings to pursue commercial profits (He and Wu, 2005) due to the increasing land value (Xie, 2012; Chen, 2007), as well as poor government planning, which includes poor foreseeability, poor adaptability, and illegal construction.

2.1.2. Methodology to analyse building lifespans

Due to the potential importance of lifespans on the life cycle impacts of buildings (Lee et al., 2010; Rauf and Crawford, 2015), lifespan planning plays a vital role in achieving more sustainable buildings. However, little effort was made to investigate the determinants of building lifespans in China up until now, and the results of different research on this issue are varied. Utilizing previous studies, this paper summarizes four approaches to predict the lifespan of buildings in China: (1) literature review; (2) field investigation; (3) calculation of lifespan with survivor rate; (4) calculation of lifespan with demolition rate.

(1) Literature review is to summarize the statistical data of building lifespans from previous research.
(2) Field investigation of demolished buildings is one of the most direct and convincing methods to discover the statistical characteristic of building lifespans. The first step of this method is to investigate a lot of demolished buildings in field. The next step is to use different distribution models to simulate the data in order to obtain the statistical parameters of these demolished buildings. In general, there are several statistical and distribution models can be used to simulate the lifespan of demolished buildings, such as the Weibull, the