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The nexus among employment opportunities, life-cycle costs, and carbon emissions: a case study of sustainable building maintenance in Hong Kong

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ABSTRACT

Hong Kong's construction industry is currently facing problems involving a rapidly aging workforce and labor shortage. With Hong Kong as the case study, this paper illustrates how existing residential buildings can be repaired and maintained using alternative materials, in order to minimize life-cycle labor inputs, costs, or carbon emissions. With different combinations of repair and maintenance materials, two of the three objectives can be achieved at any one time, when labor inputs, costs, and carbon emissions are set as separate constraints. With our methodology, we are able to identify materials that would cost the least, emit minimum carbon levels, and require the right levels of labor resources in relation to residential building maintenance. These can support the adoption of green technologies that suit the socio-economic and physical environment of Hong Kong.

1. Introduction

Since its peak in 1997, the annual gross value of the construction market in Hong Kong had shrunk for nine consecutive years. By 2006, it was reduced to 69% of its peak value in 1997. In the last quarter of 2008, the construction industry had the highest unemployment rate of all industry groups, with 6.1% unemployment against an average of 3.8%. Nevertheless, the value of repair and maintenance increased by 59% although the value of new building and civil engineering works decreased by 53% and 70%, respectively (C&SD, 2008). The construction industry was officially revived after the launch of the ten mega construction projects initiated by the HKSAR (Hong Kong Special Administrative Region) Government in 2007. However, one problem arising from this construction market revival is the shortage and aging of construction labor. During recession, many construction workers take involuntary early retirement or leave the industry altogether to retrain and work in the services industry. Thus, there is now a high demand for manpower from the worker level up to technologists. The previous over-capacity problem has thus turned into a problem of under-capacity.

Increasing repair and maintenance works have many considerable social benefits, such as generating construction employment during recession. In relation to this, labor-saving maintenance technologies and materials can also help save labor resources, which are in short supply during a construction boom. However, these problems present challenges for industry experts to redesign buildings so that they can be more affordable and environment-friendly. This is because buildings account for 89% of electricity use and more than 53% of total greenhouse gas (GHG) emissions in Hong Kong (EMSD, 2007). Repair and maintenance works offer an opportunity to retrofit existing buildings and make them more environmentally friendly by reducing their carbon footprints during the operational stage (Nelson, 2008; Pearce, 2003, 2006). However, materials used in repair and maintenance still incur sizeable carbon emissions because of their embodied carbon (EC). Hence, the problem is achieving balance between better living conditions that result from further repair and maintenance works, and the sizeable construction costs and carbon emissions involved. This is further complicated by the exacerbated pressure on labor sources that are already in short supply. What is the best trade-off between the benefits and the costs?

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In this paper, we intend to demonstrate that, with different combinations of repair and maintenance materials, we can minimize any two of the following at the constraint of the others: labor requirement (social aspect), life-cycle cost (LCC, economic aspect), and carbon emissions (environmental aspect). For example, using non-parametric methods, we can calculate how we can minimize LCC and carbon emissions while keeping labor requirements at acceptable levels. However, previous studies have indicated that it is impossible to achieve maximum social, economic, and environmental benefits simultaneously (Kemfert and Welsch, 2000; Gallagher et al., 2006; Koetse et al., 2008; Cox et al., 2013).

In practical terms, we have to work with a constraint while optimizing two other variables, i.e., there has to be a compromise among the three factors. In addition, in the context of Hong Kong, the problem of over-capacity has generally changed to a problem of under-capacity in particular work trades over the last few years. Due to such changes, we treat labor as a constraint imposed by market supply, rather than a variable to optimize. Similarly, due to the current objectives of the Government to reduce GHG emissions, we set carbon as a constraint in another scenario analysis to be presented later. Finally, in many cases, there is a set budget for maintenance and repair works. In addition, the choice of materials can be made to optimize the carbon and labor variables as long as the budget is not exceeded. Therefore, in this research, we aim to provide solutions to two of the three objectives at any one time, which have more practical significance in the industry.

In times when there is a shortage of labor supply, as in the case of Hong Kong today, there is a need to minimize labor requirement rather than vice versa. Hence, for the sake of simplicity, we present the case of minimizing employment only. Nevertheless, the case of minimizing labor requirements can be readily changed to a setup for maximizing labor requirements (and hence employment opportunities), as in the case of Hong Kong then, when it was undergoing recession a few years ago. The remainder of this paper is organized into sections. Section 2 describes the concept of sustainable building maintenance and the relevant issues of employment, LCC, and carbon emissions in the building sector. Section 3 presents the research hypotheses, and Section 4 presents the research methodology. Section 5 provides a preliminary case study, and finally, Section 6 presents the conclusion.

2. Sustainable building maintenance

Sustainability is defined as “providing for the needs of the present without detracting from the ability to fulfill the needs of the future” (ASHRAE, 2006). In relation to “sustainable building,” there is a distinction between the sustainability of the construction activity and the sustainability of works constructed (Mora, 2007). For the former, which refers to the production and construction phases, the adverse effects on the environment include fossil fuel consumption, water contamination, noise pollution, waste generation, dust and gas emission, and land misuse (Chen et al., 2000; Tam et al., 2002). For the latter, which covers the entire building life cycle from raw materials extraction to design, construction, operation and demolition, the environmental effects are more complicated (Zimmermann et al., 2005; Ding, 2008). In relation to these, the promotion of green strategy in a building's life cycle plays a significant role in achieving sustainability (Zhang et al., 2011).

There is a growing body of literature about sustainable buildings in Hong Kong. According to Chen et al. (2000), energy embodied in steel and aluminum ranks as the first and second largest, respectively, in terms of energy demand in the building sector. On average, they are also responsible for over 75% of the total embodied energy use in a residential building. In commercial buildings, Chau et al. (2007) identified concrete, reinforcement bars, copper power cables, and copper busbars as the four components that produce the greatest amount of life-cycle carbon emissions.

Previous studies have provided guidelines and criteria to evaluate the electricity consumption and carbon emissions of residential buildings in Hong Kong (e.g., Li et al., 2014). The current paper investigates the electricity consumption and carbon emissions arising particularly from repair and maintenance works. Poor living environments are often associated with older buildings that exist without proper management and maintenance. Typical actions on ageing buildings include refurbishment, upgrading, or redevelopment (Baldwin et al., 2006). However, redevelopment implies the generation of higher levels of carbon emissions given that there is a large amount of carbon embodied in building materials, while housing retrofits can engender substantial environmental improvements compared with redevelopment (Sunikka and Boon, 2003). However, simple refurbishments are only possible if the existing dwelling has sufficient quality that meets current needs (Itard and Klunder, 2007). Otherwise, a program comprising of comprehensive maintenance and retrofitting works should be implemented.

In developed economies, repair and maintenance works improve a building's element conditions as well as its durability and value, thus leading to greater energy savings (Martinaitis et al., 2004). In the UK, retrofitted thermal insulation, double glazing, ventilation control, and sunspaces for high-rise buildings contribute to energy saving in the heating loads between 25% and 60% (Gorgolewski et al., 1996). In Italy, the maintenance of low energy houses contributes to a savings of 26%–35% in residential buildings' energy consumptions (Blengini and Di Carlo, 2010). In Denmark, it is estimated that the energy saving potential for space heating would reach 80% within the current residential building stock until 2050 if the energy performances are upgraded during building renovations (Tommerup and Svendsen, 2006).

In Hong Kong, the proportion of older dwellings to the total number of buildings is increasing, and the rate of replacement has been low (Langston et al., 2008). The total number of buildings in Hong Kong is about 44,000 (Yip and Ho, 2013), and the number of new flats built between 2004 and 2008 is just 1%–2.5% of the total (REDA, 2009). Hence, the Hong Kong Buildings Department published the “*Building Maintenance Guidebook*” to provide guidance for those dealing with the problems associated with ageing buildings (HKBD, 2002). In the guidebook, timely precautionary measures are required to prevent the deterioration of some 9300 private domestic buildings in Hong Kong, which are at least 30 years old. In addition, legislations on mandatory building and window inspection schemes have been enacted, requiring private building owners to regularly inspect their buildings and windows, respectively, and immediately fix all defects that might be discovered.

For building maintenance, Baldwin et al. (2006) and Carbon Trust (2008) examined the maintenance sector in Hong Kong, UK, and other developed countries, respectively. Sunikka and Boon (2003) studied environmental policies and measures in renovating existing social housing, while both Martinaitis et al. (2004) and Chau et al. (2005) discussed the benefits of refurbishment of real properties. In the field of energy saving technologies, Gorgolewski et al. (1996), Majumdar (2001), and West (2001) examined energy efficient technologies in the UK, India and Australia, respectively. Blengini and Di Carlo (2010) carried out a detailed Life Cycle Assessment (LCA) on a low-energy family house in Italy. In Hong Kong, the Hong Kong Housing Authority (HKHA) (2012) identified energy saving technologies.

In the field of sustainable building materials, the HKHA (2005) developed technical guidelines for major building materials, procurement strategies, and specifications for environmentally friendly materials. Chau et al. (2007) also assessed the effects on the life cycle environment of the different types of building materials