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Analysis of the construction waste management performance in Hong Kong: the public and private sectors compared using big data

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ABSTRACT

There is an ongoing debate concerning the disparity between the public and private sectors in relation to construction waste management (CWM) performance: some argue that CWM performance between the two sectors should have no difference since they are under the governance of the same set of CWM related regulations, while others argue that public sector clients should perform better as they are subject to greater social scrutiny. Previous studies comparing CWM performance have suffered from insufficient quality data, leaving the debate on the CWM performance disparity largely inconclusive. Informed by the Coase Invariant Theorem, this research empirically compares CWM performance between public and private projects. It does so by using big data in the form of 2 million waste disposal records generated from around 5700 projects undertaken in Hong Kong during 2011 and 2012. It is found that there is a notable CWM performance disparity between the public and private sectors, with contractors performing better in managing both inert and non-inert waste in public projects than they do in private projects. Furthermore, the interviews and case studies conducted as part of the research suggest that CWM transaction costs are not high enough to incentivize contractors to manage waste conscientiously and therefore other institutional arrangements, such as promoting the value of environment protection leadership, are critical for achieving superior CWM performance. The research therefore supports the corollary of Coase Invariant Theorem, which asserts that certain forms of institutions would improve CWM performance by reducing transaction cost even though both sectors are subject to the same set of CWM-related formal public policies.

1. Introduction

Either public or private clients sponsor construction work. The public sector, in the form of government departments and their subsidiaries, not only manage the economy and set and maintain standards for the construction industry, but also acts directly as a client for construction works (Hillebrandt, 1974) by developing institutional premises such as town halls, governmental offices, schools, hospitals, and public housing. Owing to the large size of its budgets and of the complexities involved, the public sector is seen as indispensable to developing infrastructure projects for transport, energy, telecommunications, and water. In contrast, the private sector is primarily involved in the development of real estate such as private offices and residential buildings. In recent years, private client organizations have been increasingly involved in construction works that were traditionally developed by their public counterparts; this is known as public–private partnership (PPP), which is defined by the U.S. National Council the National Council for PPP (2014) as "a contractual arrangement between a public sector agency and a private sector entity … in delivering a service or facility for the use of the general public".

There is an ongoing debate over whether public sector clients perform better than their private counterparts in CWM, or vice versa. One may argue that as public clients are subject to higher social and political control, they are less likely to practice illegal dumping and should therefore perform better in CWM than private clients. This presumption is partly supported by Tam et al. (2007), who discovered that private clients involved in private housing and private commercial projects tend to produce the highest wastage levels when compared with other types of projects. Hong Kong Advisory Council on the Environment's (ACE's) (2007) documents highlighted the two sectors separately in terms of CWM measures. Poon et al. (2013) explained further that public sector projects in Hong Kong have imposed more stringent contractual clauses to reduce waste generation and often provided financial incentives for

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waste reduction; while private sector projects emphasize time and cost efficiency. Under the Coase Invariant Theorem, as applied to construction management by Lai et al. (2008), there should be no difference in the performance between contractors working for different types of clients. This corollary of the Coase Invariant Theorem, which assumes zero transaction costs, speculates that even though construction clients from both sectors are regulated by the same set of CWM public policies and tend to hire contractors from the same labor pool, they would behave differently. However, the presumption of the difference in CWM performance between public and private sector client–contractor relationships has rarely been tested by empirical studies, despite its importance to not only do justices to contractors but also provide a useful reference for authorities when enacting and enforcing CWM-related public policies.

Moreover, research on CWM performance has commonly suffered from insufficient quality data to support an informed debate on CWM performance. Most of the empirical studies on CWM performance, measured by waste generation rate (WGR), have a relatively small sample or sampled relatively small sites due to the difficulties involved in conducting a survey on large-scale projects (Katz and Baum, 2011; Dahlbo et al., 2015). For example: Lu et al. (2011) measured waste generation in floor areas cordoned off by site managers in four sampled construction sites in Shenzhen, China, and revealed a WGR of 3.275–8.791 kg/m^2; Formoso et al. (2002) investigated the occurrence of material waste at 74 building sites located in different regions in Brazil with an average WGR of 27.6%; Tam et al. (2007) found a WGR of 15–27% through interviewing construction professionals at 19 sites in Hong Kong; and Yuan (2013) carried out a strength, weakness, opportunity, and threat analysis of CWM using data derived from governmental reports, waste management related regulations, literature review, and focus group meetings. Owing to the small samples, it is not surprising to see WGRs varying greatly from one study to another without any form of convergence. Results of such studies cannot therefore be utilized with a high level of confidence to substantiate the speculation that public sector clients perform better in CWM than their private sector counterparts, or the opposite.

This paper reports on the findings of an empirical study that seeks to test the hypothesis of the disparity of CWM performance between the public and private sectors. The research is contextualized in Hong Kong where a large set of data that has become available recently. This 'big data' covered around 5764 sites, large and small, scattered over Hong Kong, which produced 2,212,026 waste generation/disposal records in the two consecutive years of 2011 and 2012. According to the Law of Large Numbers, the average of the results obtained from a large number of trials should converge to a certain value as more trials are performed (Sen and Singer, 1993). It is conjectured that the CWM performance of the public and private sectors could converge with big data and that it could provide a fuller picture of CWM in various projects, based on which more reliable conclusions can be drawn. The result shows there being a considerable disparity of CWM performance between the public and private sectors. It is further discovered that CWM transaction costs are not high enough to force contractors to undertake CWM conscientiously and therefore other institutional arrangements are critical for achieving superior CWM performance. This research provides empirical evidence to support the corollary of Coase Invariant Theorem.

The remainder of this paper is structured into five sections. Pursuant to this introductory section is an elaboration of the main concepts, including construction waste, waste management performance, and waste generation rate. Section 4 elaborates the theoretical lens for the paper, which is the Coase Invariant Theorem as applied to construction management by Lai et al. (2008). Section 5 describes a detailed description of the methodology. Big data is utilized to elucidate the CWM performance between the two sectors by examining different types of projects. Interviews and site visits were conducted to help understand the reasons behind the performance disparity. The sixth section presents the results, discussion, and findings. Conclusions and implications for further research are given in Section 7.

2. Construction and demolition waste

Construction and demolition (C&D) waste, sometimes simply called construction waste, is defined as the waste that arises from construction, renovation, and demolition activities (Kofoworola and Gheewala, 2009). It may include surplus and damaged products and materials arising in the course of construction work or used temporarily during the process of on-site activities (Roche and Hegarty, 2006). In Hong Kong, both terms are used to represent the surplus materials generated by site clearance, excavation, construction, refurbishment, renovation, demolition, and road works (Lu and Yuan, 2011). In this paper, the terms 'construction waste' and 'C&D waste' are used interchangeably to represent inclusively material waste from all construction activities without confining to a certain stage of construction, renovation, or demolition. Although C&D waste is often included as one of the forms of municipal solid waste (MSW), C&D waste is considered heterogeneous when compared to general MSW (e.g. household waste) or other industrial solid waste (ISW) (e.g. hospital waste or electronic equipment) (Lu et al., 2011). Construction is an environmentally unfriendly activity. Its waste often constitutes a prodigious portion of the total MSW that contributes to degradation of the environment (Lu and Tam, 2013; Boiral and Henri, 2012; Coelho and de Brito, 2012).

Construction waste can also be classified according to its composition. The European Waste Catalog (EWC) classifies construction waste into eight categories such as concrete, bricks, tiles and ceramics; wood, glass and plastic; bituminous mixtures, coal tar and tarred products; metals, soil, stones and dredging spoil; insulation materials and asbestos-containing construction materials; etc. In Hong Kong, the composition of construction waste is divided into the two major categories: inert construction waste (ICW) and non-inert construction waste (non-ICW) (EPD, 2005). Lu (2013a) views the inert and non-inert dichotomy as a philosophy underlying the CWM system in Hong Kong, including its policies, regulations, and practices. The ICW comprises soft inert materials such as soil, earth, silt, slurry as well as hard inert materials such as rocks and broken concrete, while the non-inert materials include metals, timber, plastics and packaging waste (EPD, 2005). Owing to its inertia, non-combustibility, and less odorous nature, ICW can be used for land reclamation and site formation, and thus its negative impact on the natural environment is theoretically negligible (Lu, 2013a). The non-ICW is disposed of in landfills, which take the valuable land space in Hong Kong. Anaerobic degradation of this waste creates water, air and soil pollution by the production of CO_2 and methane. Citizens normally adopt a Not-In-My-Back-Yard (NIMBY) stance in siting these CWM facilities. It is therefore of paramount importance to manage construction waste properly and its performance should be unambiguously measured and closely monitored.

3. Waste generation rate (WGR) as a performance indicator

Waste generation rate (WGR) is widely used as an indicator to measure construction waste management (CWM) performance. WGR can be calculated by dividing the waste in volume (m^3) or quantity (tons) by either the amount of virgin materials purchased, or the amount required by the design, or per m^2 of gross floor area