Waste Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

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

Reducing construction waste: A study of urban infrastructure projects

Ruane Fernandes de Magalhães *, Ângela de Moura Ferreira Danilevicz, Tarcisio Abreu Saurin

UFRGS - Universidade Federal do Rio Grande do Sul, Department of Industrial and Transportation Engineering Department - DEPROT, Avenida Osvaldo Aranha, 99 - 5th Floor, Brazil

ARTICLE INFO

Article history:
Received 12 December 2016
Revised 20 April 2017
Accepted 15 May 2017
Available online xxxx

Keywords:
Construction waste (CW)
Urban infrastructure projects
Waste management
Construction waste minimization
Design stage

ABSTRACT

The construction industry is well-known for producing waste detrimental to the environment, and its impacts have increased with the development process of cities. Although there are several studies focused on the environmental impact of residential and commercial buildings, less knowledge is available regarding decreasing construction waste (CW) generation in urban infrastructure projects. This study presents best practices to reduce waste in the said projects, stressing the role of decision-making in the design stage and the effective management of construction processes in public sector. The best practices were identified from literature review, document analysis in 14 projects of urban infrastructure, and both qualitative and quantitative survey with 18 experts (architects and engineers) playing different roles on those projects. The contributions of these research are: (i) the identification of the main building techniques related to the urban design typologies analyzed; (ii) the identification of cause-effect relationships between the design choices and the CW generation diagnosis; (iii) the proposal of a checklist to support the decision-making process, that can be used as a control and evaluation instrument when developing urban infrastructure designs, focused on the construction waste minimization (CWM).

Contents

* Corresponding author.
E-mail addresses: ruane.magalhaes@gmail.com (R.F. de Magalhães), angelamfd@producao.ufrgs.br (Â.M.F. Danilevicz), saurin@ufrgs.br (T.A. Saurin).

http://dx.doi.org/10.1016/j.wasman.2017.05.025
0956-053X/

Please cite this article in press as: de Magalhães, R.F., et al. Reducing construction waste: A study of urban infrastructure projects. Waste Management (2017), http://dx.doi.org/10.1016/j.wasman.2017.05.025

1. Introduction

The construction industry is well-known as a source of negative environmental impacts, which are associated with both the production and the extraction of raw materials, and the execution of its projects. Some of the most significant impacts caused by the sector are linked to the generation of construction waste (CW), which, according to Solís-Guzmán et al. (2009), has been more and more significant due to the accelerated growth of cities (Yang et al., 2017). In Brazil, around 45 million tons of CW were produced in 2015, which is equivalent to 57% of the total solid waste produced in the country (Abrelpe, 2015).

The waste disposal in large urban areas causes problems such as the degradation of the urban landscape (Shen and Tam, 2002; Bakshan et al., 2017). Furthermore, waste disposal is associated with soil and water contamination, due to the discard of dangerous materials, such as asbestos and volatile organic compounds – VOCs (Esin and Cosgun, 2007).

In this context, urban infrastructure projects, due to their nature – such as the extensive area of intervention and excavation services – are large CW generators. Therefore, the development of construction projects with less environmental impact is a major improvement opportunity, especially regarding decision-making at the design stage, which allows the control of CW at its source (Ekanayake and Ofori, 2004; Esin and Cosgun, 2007; Esa et al., 2017; Song et al., 2017; Yang et al., 2017). However, as highlighted by Li et al. (2015), in many cases, designers lack the proper knowledge and tools for making-decisions informed by environmental criteria.

Thus, it is important to design strategies aiming at both processes and products to be streamlined, contributing to the reduction of environmental impacts on construction stage of urban infrastructure. For example, Lean Construction (LC) and green building methods may constitute appropriate approaches to developing projects with less environmental impact, especially considering the reduction of materials waste (Nahmens, 2009; Udawatta et al., 2015). Although there are several environmental certifications guiding building designs, methods for environmental assessment in projects of urban infrastructure are quite superficial or even inappropriate (Wang et al., 2015). Indeed, these methods disregard the dynamic relationships among design strategies and the determinant factors to the construction waste minimization (CWM). Besides, there is no reliable database to support a proper diagnosis of waste generation at urban construction, as well as there is not a complete understanding of the relationship between the causes of that generation.

Thereby, this article aims to identify the best practices to reduce the construction waste in the design stage of public urban infrastructure projects. As a result, the following items are discussed: (i) the main building techniques related to urban design typologies analyzed; (ii) the cause-effect relationship between the design choices factors and the characterization of CW generated; and (iii) the checklist to support the decision-making process, that can be used as a control and evaluation instrument at development of urban infrastructure projects, focused on the CWM.

This paper is divided into five sections. Section 1 contextualizes the research problem and the paper goals. Section 2 deals with the literature review, addressing causes of CW generation and mechanisms for its minimization. Section 3 presents the method, while Section 4 brings the results and its deployments. Finally, Section 5 presents the conclusions and some research opportunities.

2. Materials waste

The generation of CW may be linked to many causes like design decisions, construction planning, execution problems, among others. In design stage, unforeseen changes in design, insufficient detailing and flaws in product specification, besides the poor communication between the team of the project, are considered significant causes of materials waste (Osmani et al., 2008; Al-Hajj and Hamani, 2011; Liu et al., 2015).

During the construction stage, the materials wastes are related to factors such as transportation damages, improper handling, excess offcuts caused by unskilled labor, unplanned storage, and weather (Lingard et al., 2000). Formoso et al. (2002) performed a mapping of both direct and indirect material waste causes of different types of common building materials in Brazilian constructions, pointing out recurrent problems related to the lack of design standardization (Li et al., 2015; Esa et al., 2017); lack of modular coordination (Udawatta et al., 2015); poor integration between subsystems; insufficient planning site layout (Nagalli, 2014); and lack of resources optimization.

In addition, some materials are the highest waste generators than other by their own nature (Nagalli, 2014; Hassan et al., 2015; Song et al., 2017), especially in its volume CW generation per square meter built (m^3 of waste/m^2 built), such as concrete, mortar, bricks, steel and ceramics/tiles. In some studies, it was also highlighted the earthmoving work, the excavations and the initial cleaning of land as waste sources (Jaillon et al., 2009; Solís-Guzmán et al., 2009; Katz and Baum, 2011; Marrero et al., 2017). Jaillon et al. (2009) emphasizes the expressive wood waste amount in its use on timber formworks, resulting in around 70% in increase of CW production.

The actions taken to reduce damages are the key to minimizing the waste generation; both in design and construction stage. This issue can be solved by different perspectives. Regarding the material waste minimization in design stage, Saez et al. (2013) identified the best practices to be adopted by the design team such as the massive adoption of prefabricated systems; the use of recycled materials at the construction site; and the construction site planning, observing the availability of adequate area to waste management.

Another current approach is the adoption of Lean Construction principles and practices in both project management and construction, since the LC is based on the notion of processes continuous improvement, focusing on waste reduction (Marhani et al., 2013). The LC can also help to minimize rework in managing the design stages, through the implementation of Building Information Modeling tool – BIM (Cheng and Ma, 2013; Li and Yang, 2014; Alwan et al., 2017; Ajayi et al., 2016; Won et al., 2016); schedule monitoring methods and pull planning (Ghosh et al., 2014). According to Ghosh et al., 2014, by means of the adoption of LC, the design team can detail more precisely many components, reducing approximately 6% in the waste generation at source.

Given those impacts, both economic and environmental, this article intends to show some studies developed to support the reduction on CW generation in urban infrastructure projects.

3. Method

This study is structured into four steps, as shown in Fig. 1, and detailed next.

3.1. Main building techniques of urban infrastructure designs

The first step was the identification of the main building techniques associated with the studied design typologies. For that purpose, we analyzed budgetary compositions and technical specifications pricing systems officially released by the Brazilian Federal Government namely: State Department of Budget and Constructions (ORSE), Table of Price and Compositions for