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Factors driving the implementation of reverse logistics: A quantified model for the construction industry

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ABSTRACT

In the light of increased environmental concerns and the unsustainability of current construction practices, 'reverse logistics' (RL) has emerged as a remedial strategy, whereby decommissioned buildings are salvaged and returned back through the value chain for recovery, refurbishment and reuse. The drivers that impact the uptake of RL are known, but if sustainability outcomes are to be enhanced, the strength of those drivers must be quantified in order to ascertain where efforts should be focused. This study aims to quantify the effects of known drivers on RL, and in so doing identify action items with the greatest potential to positively improve RL outcomes. RL drivers are culled from extant research, and categorized as economic, environmental, or social forces. A conceptual model is developed and tested against questionnaire results drawn from 49 expert respondents active in the South Australian construction industry. The results are analyzed using structured equation modeling. Economic and environmental drivers, such as the continuing relative high cost of salvaged items, along with expediency of cost, time and quality objectives overshadowing regulatory demands for use of such salvaged items, are shown to predict 34% of the variations in implementing RL. Of particular interest is the finding contradicting previous studies, showing that social drivers, such as perceived benefits from 'going green' had no significant impact. Thus, the road-map to improving RL outcomes lies in reducing costs of salvaged materials, augmenting environmental policies that promoted their use, and to initiate a regulatory framework to generate compliance. This insight will be of interest to industry policymakers and environmental strategists alike.

1. Introduction

The construction industry worldwide has an infamous reputation for consuming large amounts of raw materials, water, energy and for generating massive flows of green-house gases and carbon dioxide into the atmosphere (Dobrovolskienė et al., 2018). The construction industry consumes around 40% of total energy, generates 30% of green-house gas emissions, utilizes 17% of fresh water resources, and exacerbates to deforestation, consuming 25% of harvested wood around the globe (Li et al., 2017). Construction materials are wasted at the rate of 20–30 per cent, by weight, of all total materials on construction sites (Banihashemi et al., 2018), generating 45–65% of disposed waste in landfills (Nikmehr et al., 2017), mostly through the construction and demolition sector (Chileshe et al., 2012). Recycling remains a widespread strategy employed to reduce waste in the construction context. Even so, recycling does not necessary lead to an effective reduction of material use; energy requirements for recycling are high, and the quality of secondary materials remains inferior, perpetuating demand for energy and virgin materials (Haas et al., 2015).

Reverse Logistics (RL) is an effective remedial solution for addressing the problem of waste across a wide range of industries (de Campos et al., 2017), especially including the construction industry (Rahimi and Ghezavati, 2018). RL refers to operations and procedures for returning post-sale and post-consumption goods back into the productive cycle, by way of reversing distribution channels (Nunes et al., 2009). Nevertheless, RL has not become commonplace in the construction sector (Rameezdeen et al., 2016; Rahimi and Ghezavati, 2018). In essence, RL is only accepted by the

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market when both its drivers and contributions are well assessed, understood and promoted (Haas et al., 2015). This makes the clearer understanding of the influence of drivers to RL implementation in the construction context both relevant and urgent (Chileshe et al., 2016). As argued by Diabat and Govindan (2011, p. 665) *"Decision makers must be aware of the relative importance of the various drivers."*

Research on the current state of drivers across the supply chain of major industries, generally, (Govindan and Hasanagic, 2018), and of construction, in particular, remains scarce. Existing studies such as that by Chileshe et al. (2016) have identified key drivers, however, the influential strength of these drivers in the construction context remains undescribed (Rahimi and Ghezavati, 2018). Thus, establishing frameworks, and identifying action items with the greatest potential to enhance RL use in the construction context remain wanting.

The value of the present study lies in addressing these overlooked areas in the literature. Specifically, while previous work on RL uses qualitative and case study approaches, this study develops a quantified model that links drivers to implementation practices through a structural equation modelling (SEM) technique. In doing so, the contributions of this study are twofold. First, opportunities for enhancing RL adoption in the construction industry are identified. Also identified are the drivers that offer the most attractive prospect to increase the level of RL acceptance in the construction industry.

2. Background

2.1. The urgent need for change

The construction industry represents around 13% of the global economy, and is a key impetus to other industries due to its close integration with major activities like infrastructural and facilities development (Ajayi and Oyedele, 2018; Banihashemi et al., 2018; Hosseini et al., 2018). Despite this significance, construction has lagged behind other industries in accommodating environmental sustainability, largely due to its consumption of major amounts of raw materials, energy, and water, while also contributing hugely to waste in landfill sites (Ajayi and Oyedele, 2018). Simply, the construction and demolition sector uses 40% of the total raw materials extracted globally and generates about 35% of the world's waste (Di Maria et al., 2018). Construction and demolition waste (C&D) is therefore a major problem facing the construction industry worldwide (Akbarnezhad et al., 2013; Ahmadian F.F. et al., 2017; Ding et al., 2018). It accounts for around 26% of total solid waste generated in the US (approximately 136 million tons annually), and 34% of all industrial waste in Europe (Jin et al., 2017; Park and Tucker, 2017).

The harmful impact of various forms of constructional waste on the environment and society is also well documented (Lu and Yuan, 2011; Banihashemi et al., 2018). One ton of waste landfilled requires around 0.6 m^3 of landfilling space, with knock-on effects in environmental degradation (Yeheyis et al., 2013; Zhou et al., 2017; Hosseini et al., 2018) and resource depletion (Gorgolewski, 2008; Shakantu et al., 2008; Tam et al., 2010). Consequently, urgent solutions are needed to tackle C&D problems (Di Maria et al., 2018, p. 3). RL is seen as the most efficient available solution to this problem (Haas et al., 2015; Govindan and Hasanagic, 2018), as discussed next.

2.2. Defining RL

The classic supply chain, or *forward supply chain*, does not take into consideration products at the end-of-life stage (Govindan and Soleimani, 2017). This dominant model based on the 'take, make, and dispose' approach has been criticized for its negative impacts on the integrity of natural resources and ecosystems (Ghisellini et al., 2016). Novel supply chain approaches are therefore required to address the drawbacks of the classic supply chain paradigm (Gálvez-Martos et al., 2018). The 'closed-loop' supply chain provides such as solution by integrating the forward supply chain with the backward looking RL, creating a closed-loop (Govindan and Soleimani, 2017; Govindan and Hasanagic, 2018). RL is defined as: *"...the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time."* (Guide and Van Wassenhove, 2009, p. 10) In the last few years, RL has received considerable attention worldwide, given its potential for optimizing and promoting sustainable production and consumption (Govindan and Hasanagic, 2018).

In the construction context, new approaches that take into account the entire value chain of the construction sector provide the best available option (Di Maria et al., 2018; Gálvez-Martos et al., 2018). This is reflected in the concept of RL—the reverse chain—that includes simultaneous processes: reuse, repair, recondition, remanufacture, and recycle (Govindan and Soleimani, 2017). With RL, products such as bricks and structural steel elements, salvaged from demolished buildings, are used again in other buildings, down-cycled for reuse for various construction purposes, or used in non-construction sectors (Nordby et al., 2009; Densley Tingley et al., 2017b; Di Maria et al., 2018). Given current technologies, traditional building demolition and material disposal, is no longer considered efficient (Smith et al., 2007; Aidonis et al., 2008; Laefer and Manke, 2008; Kibert, 2012; Hosseini et al., 2015). Material reuse, as offered through RL, is one promising strategy for improving the material efficiency of the built environment (Densley Tingley et al., 2017b; Densley Tingley et al., 2017a; Di Maria et al., 2018).

2.3. Drivers for implementing RL

The traditional supply chain model follows the procedure of take-make-use-destroy (Ghisellini et al., 2016). This model does not take into account factors such as the impact on societal and human resources, and gives no priority to the conservation of scarce resources. Contrary to this, RL aims at increasing resource efficiency, enhancing the quality of secondary materials, and optimizing the use of natural resources (Govindan and Hasanagic, 2018). That is, the RL approach is an attempt to keep the added value of products for as long as possible, working towards waste elimination (Smol et al., 2015).

RL initiatives generally address environmental concerns, durability of products, and financial savings (Pirlet, 2013; Rahimi and Ghezavati, 2018). RL similarly provides opportunities for the construction industry (Hosseini et al., 2015; Smol et al., 2015; Di Maria et al., 2018). Notwithstanding, transition to RL requires changes throughout the entire construction value chain: design, business and market models, change in models of turning waste into a resource and modes of consumer behavior (Smol et al., 2015). The implementation of substantial changes necessitates recognizing a justification of the advantages and benefits envisaged for transition to RL. These are the RL drivers (Govindan and Hasanagic, 2018). A review of relevant literature identifies ten key drivers of RL across the construction industry. See Table 1. Drawing from the typology proposed by Seuring and Müller (2008) and Denhart (2010), these are categorized into three subgroups: economic, social and environmental.

The economic drivers (EcoDri 1 and 5) are those drivers that primarily embrace the advantages associated with cost, value and financial considerations (Guide and Van Wassenhove, 2009;