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Behavioral determinants towards enhancing construction waste management: A Bayesian Network analysis

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ABSTRACT

In this study, a Bayesian Network analysis is used to define causal behavioral determinants towards improving practices in construction waste management (CWM). For this purpose, a structured survey questionnaire was developed and administered to field workers at construction projects. The collected data was used to develop a probabilistic relational model with single- and multi-factor analysis to assess conditional probabilities underlying various determinants. The results indicate that behavior is highly influenced by attitude, past experience, and social pressure with 21, 20, and 10% higher chance of improvement by these factors, respectively. Behavior in CWM appears to be more sensitive to changes in personal factors such as attitude than corporate factors such as training. When simultaneously controlling all factors, the behavior is improved with personal factors by 9% more than with corporate factors. Additionally, it was found that the probability of having effective CWM practices on-site reaches 83% when workers have a positive attitude towards waste management, are well experienced in CWM practices, and are influenced by social pressure. Achieving this result also requires independency at work and availability of training sessions. The model raises the awareness of construction stakeholders about factors influencing workers' behavior towards CWM and presents quantified strategies that increase the chances of minimizing the generation of construction waste. It can serve as a motivation and a decision support tool for adopting and implementing sustainable CWM practices.

1. Introduction

The need for effective construction waste management is of ever-growing importance in this era of shrinking natural resources and scarcity, coupled with increasing challenges in siting new landfills particularly in and around land-limited and continuously developing metropolitan urban areas. The growth in quantities of construction waste in such areas has exacerbated associated adverse environmental and socio-economic impacts (Poon et al., 2003) at a considerable loss in land resources for the expansion of existing landfills or the creation of new ones (Esin and Cosgun, 2007; Lu and Yuan, 2010). As a result, the construction industry is increasingly becoming under pressure to promote sustainable CWM practices guided by the 3Rs principles of reducing,[1] reusing,[2] and recycling[3] (Calvo et al., 2014; Tam and Tam, 2006). Ideally, the 3Rs principle is supported by economic benefits including 1) cost reduction in material purchasing (Bossink and Brouwers, 1996), 2) saving in transportation cost from construction site to landfills, 3) saving in disposal cost at landfills (i.e. landfill tipping fee), and 4) revenue from selling waste materials (Yuan, 2013).

The construction industry is inherently geared and suited towards the adoption of the 3Rs principle. However, effective implementation seems to be highly influenced by the awareness, or the lack thereof, of various stakeholders (workers, contractors, and owners) of corresponding benefits albeit the false preconception that CWM contributes highly to project expenses (Johnston and Mincks, 1995) or the perception of CWM as an activity with a low priority compared to other objectives for meeting project deadline and maximizing profit (Manowong, 2012; Teo and Loosemore, 2001). On the contrary, the non-consideration of sustainable waste management practices has proved to cause budget and time overruns as well as a negative influence on the environment (Lu and

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[1] Most effective with emphasis on preventing the generation of waste at source.

[2] Entailing using construction material more than once for the same function (reusing formwork) or for a new function (reusing the remaining cut-corners of steel bars for supporting shelves) (Esin and Cosgun, 2007; Poon, 2007).

[3] Changing the waste material into a new product with different characteristics, e.g. recycling concrete waste into aggregates, (Tam, 2008b).

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Yuan, 2010). For this reason, improving stakeholders' awareness about environmental and economic considerations of CWM has emerged as a vital driver for spreading a culture within organizations and encouraging the adoption of sustainable practices (Osmani et al., 2008; Yuan, 2013). Workers' awareness in particular is reflected in their attitude and behavior towards waste management with recently reported evidence ascertaining that promoting best practices is a behavioral and social process (Begum et al., 2009; Udawatta et al., 2015), thus raising considerable attention to the role of human factors in minimizing and managing construction waste (Yuan and Shen, 2011). In short, the identification of factors that influence the behavior of construction field workers regarding waste management, as well as the quantification of relationships between respective factors, are imperative towards improving waste management practices.

While various statistical analysis techniques with different levels of complexity were recently applied to examine these factors (Table 1), they fell short of quantifying relationships between causal factors for improving behavior towards waste management. In this context, a behavioral Bayesian Network (BN) offers the advantage of allowing the quantification of relationships between related factors by building a probabilistic relational model that relies on field survey data (Korb and Nicholson, 2004). As such, in this study, a behavioral BN-based approach with qualitative and quantitative components is adopted to develop a model that identifies structural information about influencing factors in CWM. The model also identifies the causality or relationships between these factors while defining probability distributions that quantify these relationships with the aim of supporting effective implementation of CWM plans.

2. Methodology

Following a comprehensive literature review to define behavioral factors regarding CWM, the adopted methodology comprised a field survey of construction workers to measure each factor, and the development and testing of the behavioral BN model.

Factors that reportedly influence the behavior towards waste minimization and/or recycling fall under two main categories, personal (*attitude towards CWM*, *awareness towards consequences*, *work experience*, *past experience in CWM,* and *social pressure)* and corporate (*training*, *supervision* and *financial incentives)* factors with their main attributes summarized in Table 2. Personal factors, referred to as individual factors, represent the psychological and cognitive factors that are involved in shaping the individual's decision-making. On the other hand, corporate or organizational factors, refer to factors that act as part of the organizational context, which may either facilitate or constrain the success of individuals' initiatives to any behavioral change (Young et al., 2013). In order to capture the latter, a structured questionnaire survey was designed in a way that ensures simplicity and anonymity (Table 3) all while targeting the personal and corporate factors defined above as well as *behavior towards CWM* through a set of closed-ended questions of categorical data type. While *financial incentives* are recognized to affect worker's behavior towards waste management, it was excluded because site visits revealed that rewarding schemes were not implemented for motivating construction workers. Site managers attributed the absence of such incentives to a slow economy and the lack of discretionary funds through which such incentives could be provided. Instead, the questionnaire was tailored towards the magnitude of financial rewards that can motivate workers towards effective implementation of a CWM plan. Finally, the *behavior towards CWM* refers to the actual ongoing behavior related to CWM.

While various studies have targeted site workers to examine the influencing factors that shape their behavior towards CWM at the operative level (e.g. Chen et al., 2002; Teo and Loosemore, 2001), Lingard et al. (2000) explored the understanding of site workers as well as managers of waste minimization practices. The behavioral BN model, proposed in this study, is tested on a sample of field workers, as they are at the front line of construction operations. The intention is to assess and quantify the influence of personal factors, which relate to the psychological and cognitive factors that shape the worker's behavior regardless of the corporate policies enforced by the upper management. Such policies, instead, are captured through the corporate factors (e.g. supervision), as illustrated in Table 2.

During the data collection process, 123 construction sites were contacted. This number is almost equal to the total number of ongoing construction projects in the study area at the time when the survey was conducted (OEA-Beirut, 2013). Lebanon, the source of the field survey data presented in this study, is struggling from haphazard dumping of CW due to shortages in designated landfills as well as the absence of regulations on proper disposal of CW (Srour et al., 2013). The vast majority of generated waste – 0.5 million tons from buildings under construction and over 1 million tons from demolition activities – is disposed of in valleys and abandoned quarries (Bakshan et al., 2015).

As a first step, site managers were contacted to discuss the study objectives and to seek permissions for workers' participation in the survey. Out of 123 buildings, 65 expressed willingness to participate or a positive response rate of 53%, which was considered representative. Note that the survey procedure consisted of semi-structured interviews, where a structured questionnaire was used to interview the field workers. The questionnaire was field-tested and explained thoroughly prior to administering it to workers in order to reduce measurement errors or chances of misunderstanding. During the interviews, the responses were noted by the interviewers based on detailed discussions with the workers. The field workers who participated in the survey are those who were onsite and available to be interviewed during site visits, leading to a total of 69 participants whose responses were then used to establish the behavioral BN model.

The survey questions aimed at measuring personal, corporate and behavior factors with corresponding states to be incorporated in the behavioral BN model. For example, two questions that correspond to awareness towards environmental and economic benefits of CWM are used as indicators for the *awareness towards consequences* factor. On the other hand, three states are considered for the *awareness towards consequences* node (i.e. "Not Aware", "Aware" and "Fully Aware"), and the state of the factor is identified based on the respondents' answers to these two questions. If the answers for both questions are "No", then the state of *awareness towards consequences* is "Not Aware". If both answers are "Yes", then the state is "Fully Aware". The state "Aware" is considered when one of the answers is "No" and the other one is "Yes". Similarly, the state of *past experience in CWM* factor is picked from the three states (i.e. "No Exp", "Little Exp", and "Advanced Exp") based on the answers of the two questions that correspond to past experience in waste reduction and reuse.

Regarding the *attitude towards CWM* factor, three states are considered, including "Negative", "Neutral" and "Positive". The state is decided based on the answers to the three questions related to this factor. The question related to the respondent's perception towards the importance of CWM has four options that are also mapped to "Negative", "Neutral" and "Positive" states. The state "Not important at all" is considered as "Negative", the state "Slightly important" is integrated as "Neutral", and the states "Important" and "Very important" are considered as "Positive". Similarly, the states "Strongly disagree" and "Disagree" of the question related to the perception towards charging financial penalties are combined into one state "Negative". The states "Agree" and "Strongly agree"