Proceedings of International Structural Engineering and Construction, 7(2), 2020
Emerging Technologies and Sustainability Principles
Edited by Askarinejad, H., Yazdani, S., and Singh, A.

ISSN: 2644-108X
www.doi.org/10.14455/ISEC.2020.7(2).CON-11

EXTENDED TRIPLE BOTTOM LINE BASED EVALUATION OF REVERSE LOGISTICS OPTIONS FOR CONSTRUCTION WASTE MATERIAL

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The construction sector not only plays a significant role in the economic development of a country but also generates considerable construction waste. Treatment of such waste is essential to avoid loss of potentially recoverable material, minimize environmental pollution, reduce monetary losses, and other related hazards. Reverse logistics concept gains popularity due to its material recovery aspect, therefore considered a waste treatment option. However, the selection of the most appropriate treatment strategy requires a critical analysis of various factors. In the past, firstly, technical and economic factors were considered mainly before selecting a treatment method, with limited to no consideration given to environmental, social, and political factors, especially in low and middle-income countries. Secondly, the selection of such treatment methods was mostly based on qualitative assessments. To overcome these issues, at first, this study extends the concept of Triple Bottom Line (TBL) by adding two more lines of technical and political aspects and called it as extended TBL (ETBL). Secondly, a quantitative ETBL scoring method is proposed based on a probability-impact approach to help decision-makers select an appropriate reverse logistics option for construction waste material. A list of bottom-line factors was extracted from the comparison of existing practices among different countries. Lastly, suggestions to Hong Kong stakeholders were provided as per ETBL assessment, which will help future decision-making.

Keywords: Waste management, Treatment options, Environmental, Economic, Social, Political, Technical, ETBL score.

1 INTRODUCTION

The world has been facing high population growth and urbanization, especially amongst developing economies like India and China (Khaleel and Al- Zubaidy 2017). Consequently, the need for infrastructure development has increased, which leads to higher waste generation rates. Waste management is a challenging issue with associated negative impacts like environmental pollution, resource depletion, loss of recoverable values, and other related problems. In particular, low and middle-income countries have unsophisticated, non-modernized waste management systems (Asase *et al.* 2009). According to Melosi (2000), the real drive of waste management treatment strategies is to safeguard human and environmental health by decreasing the negative impacts of waste and finding beneficial reuses.

In the context of construction and demolition waste (CDW), the classification of treatment options uses hierarchical waste levels, i.e., reduce, reuse, recycle, recover, and disposal. Rogers and Tibben-Lembke (1998) contributed that the use of reverse logistics (RL) concept in managing waste can be treated as an effective waste treatment option as it helps in recapturing the value. Reverse logistics options found in waste management literature were 3R principle (reduce-reuse-recycling), incineration (energy-recovery), and landfilling (land-reuse) (Srivastava 2008, Kofoworola and Gheewala 2009).

However, Nixon *et al.* (2013) believed that the waste treatment is not an easy task due to its varying compositions. Therefore, selecting an appropriate treatment strategy is crucial, and it requires careful consideration of multi-dimensional aspects (Zhang and Li 2012). In this regard, the triple bottom line (TBL) is a useful concept for evaluating organizational performance from economic, social, and environmental aspects (Elkington 1997). Aleisa and Al-Jarallah (2017) uses the TBL concept for the evaluation of solid waste management strategies.

Mainly the focus of previous studies was based on solid waste, and also the context of reverse logistics and TBL approach was not considered before for CDW to the best of our knowledge. This study provides qualitative as well as quantitative evaluation of reverse logistics options for construction waste material using an extended TBL approach.

2 METHODOLOGY

Figure 1 outlines the overall methodological framework adopted for this study. Preliminary understanding related to TBL, RL, and CDW treatment options is developed. Bottom lines, in addition to TBL, were identified and termed as extended TBL (ETBL). This study considers two groups of countries: high-income countries (Germany, USA, UK, and Canada) and low and middle-income countries (Malaysia, India, China, Brazil, and Turkey). ETBL factors affecting the selection of a reverse logistics option were extracted from the comparison of waste management practices among both groups. Hong Kong's situation was also evaluated, and suggestions were made to the local stakeholders. In the end, a quantitative ETBL scoring method is proposed based on the probability impact approach to support decisions related to the selection of an effective waste management strategy.

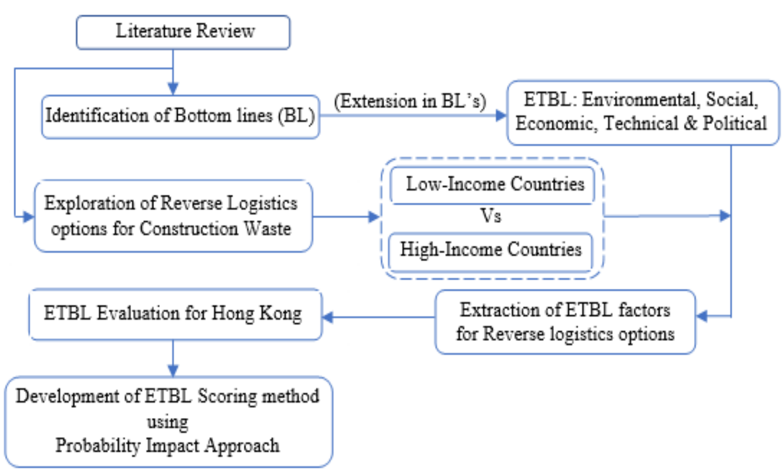

Figure 1. Overall methodology framework.

3 ETBL BASED COMPARISON OF REVERSE LOGISTICS OPTIONS

CDW has two main types, i.e., inert waste (chemically non-reactive) and non-inert waste (chemically reactive). Both inert and non-inert parts of CDW can be recycled, e.g., recycled aggregates or reuse of packaging material. Usually, the non-inert part of CDW is considered for incineration due to its composition. Landfilling is the least preferred option due to issues like land scarcity, environmental pollution, resource depletion, etc., but the most used option in low and middle-income countries even today. Metal extraction, landfill mining, harvesting of methane gas, installation of solar plants are the few examples of landfill reuse (Linnaeus University 2018, Green 2017). Table 1 presents the five bottom lines, i.e., environmental, social, economic, technical, and political, that were used to compare high-income countries and low and middle-income countries from the perspective of reverse logistics options.

Table 1. ETBL based comparison among two group of countries. (Abbas *et al.* 2006, Arslan *et al*. 2012, Zhang and Li 2012, Abdelhamid 2014, Mmereki *et al.* 2016, Gupta 2018, Massara 2018).

High-Income Countries Scenario	Low and Middle-Income Countries Scenario
Environmental scenario	
• Promoting green and environmentally friendly solutions for waste management. • Effective measures for controlling hazardous emissions from dumpsites. • Reuse of landfills for value recovery purpose. • Material recovery is high due to efficient use of reverse logistics practices.	• Green solutions are not very much implemented but efforts are in right direction. • Uncontrolled hazardous gases emit from the dumpsites which are toxic to human life. • Land degradation due to continuous dumping of waste. • Resource depletion is high due to poor reverse logistics practices.
Economic scenario	
• Lower recycling cost. • Disposal charges varies with compositions. • Incineration is not the preferred method. • Availability of funds for innovative ideas.	• Governments promoting 3R. • Less attention given to waste segregation at landfills. • Higher development cost for green facilities & techniques. • Less financial supports to risky but innovative ideas.
Social scenario	
• People awareness level related to waste management practices is high. • Access to education related to sustainable waste-management techniques. • Society led pro-environmental activities such as recycling initiatives.	• Society prefers 3R methods, but lack motivation for implementation. • Not everyone is supposed to handle and deal with waste as it considered as a carrier path for a poorer group of society. • Lower workforce availability for managing waste related operations.
Technical scenario	
• High technical expertise. • Advanced use of technologies. • Promoting recycling technologies • Standardize maintenance of related facilities.	• Lack of technical expertise. • Low to non-existent use of advanced methods. • Disposal at landfills and incineration are common methods. • Difficulties in the maintenance of related facilities.
Political scenario	
• Overall better policy guidelines. • Follows waste management hierarchy for enforcement. • Political stakeholders participate in improving waste management related activities	• Policies are restricted to papers, poor implementation. • Lack of enforcement in effective implementation of 3R principle. • None to very less interests shown by political stakeholders in improving waste management related activities

Based on the comparison among different countries for ETBL based evaluation of reverse logistics options, Table 2 presents a list of bottom-line factors. Here the list of factors is restricted to the review carried out for this study, which may be extended further for future studies.

Table 2. Bottom lines (BL) factors.

Aspects	BL Factors
Environmental	Emission content (v_1), Global warming potential (v_2), Resource degradation (v_3), Space requirement (v_4), Energy consumption (v_5), Eco-Toxicity (v_6).
Economic	High initial investment (w_1), Financial subsidies (w_2), Startup funds availability (w_3), Exportable income from treated waste (w_4), Cost-Benefit analysis (w_5), Profit margins for operators (w_6).
Social	Public response against WM charges (x_1), Impact on human health (x_2), Society awareness level (x_3), Access to basic education (x_4), Society led initiatives (x_5), Workforce engagement requirement (x_6).
Technical	Skills and expertise (y_1), impact towards volume reduction (y_2), Use of advance technologies (y_3), Worker-Training complexity level (y_4), Infrastructure requirement (y_5), Facility maintenance requirement (y_6).
Political	Political commitment (z_1), Policy guidelines (z_2), Method implementation strategies (z_3), Gap between policies and practice (z_4), Trans-boundary arrangements (z_5), Delays due to political unrest causes waste stockpile (z_6).

4 ETBL BASED EVALUATION FOR HONG KONG

Hong Kong, like many other regions of the world, producing a large amount of CDW. 30% of the total waste belongs to CDW only, i.e., 4,207 tonnes per day out of the mammoth 15,516 tonnes per day (EPDHK 2017). Existing infrastructure, e.g., landfills, are approaching their maximum capacities due to the massive amount of waste going to landfills without exploiting the potential reverse logistics options. Therefore, to have a better environment, optimum utilization of resources should be practiced by better implementation of waste management strategies. Table 3 identifies the current scenario of construction waste-related problems in Hong Kong from ETBL aspects. With the help of explored solutions from different countries, possible improvement measures to Hong Kong were suggested aligning (CIC 2017) perspective.

Table 3. ETBL based evaluation and suggestions for Hong Kong.

ETBL	Problems	Suggestions
Environmental	High construction waste generation rate	• Prevent overproduction during construction operations. • Waste reduction through designing out waste.
Economic	Lack circular economy concepts	• Promote the use of reverse logistics practices. • Cost-Benefit analysis for the available treatment options.
Social	Lack of public participation	• Arrange frequent public awareness seminars. • Engaging the public in social activities and gave bonuses.
Technical	High-tech installations with limited land availability	• Promote small scale innovative solutions. • Explore and promote opportunities for landfill reuse.
Political	Lack effective implementation of regulations	• Ensure effective implementation of “Polluter pays principle”. • Ensure submission of a construction waste management plan at the bidding stage.

5 ETBL BASED QUANTITATIVE SCORING METHOD

In this section, ETBL based quantitative scoring method is proposed using the probability-impact approach to provide a quantitative basis for selecting an appropriate reverse logistics option. The proposed method is discussed here using general notations for method explanation purpose only. For occurrence, 'O' the possible response is binary, i.e., either '1' or '0' and for impact 'I' the Likert scale has been considered here, i.e., 1 to 5, 1 being very low impact and 5 being very high impact. Higher scores of any reverse logistics option 'RLO' indicate that the decision made was strongly impacted by all the existing ETBL aspects and vice-versa. The scores for respective BL state the impact of individual BL towards the option selection. Eq. (1) show the ETBL score for a typical reverse logistics option. Eq. (2) to Eq. (6) represents the BL score for each BL in ETBL. As an example, for a typical reverse logistics option, the maximum ETBL score would be 150. If all the six BL factors for each five BL's were found to be existing, i.e., (1) in a particular region and the impact of all were very high, i.e., '5' towards selecting that option. The minimum score would be zero if these factors were non-existent.

$$ETBL_{RLO} = BL_{RLO.ENV} + BL_{RLO.ECO} + BL_{RLO.SOC} + BL_{RLO.TEC} + BL_{RLO.POL} \tag{1}$$

$$BL_{RLO.ENV} = \sum_{v=1}^{V} (O_v \times I_v) \tag{2}$$

$$BL_{RLO.ECO} = \sum_{w=1}^{W} (O_w \times I_w) \tag{3}$$

$$BL_{RLO.SOC} = \sum_{x=1}^{X} (O_x \times I_x) \tag{4}$$

$$BL_{RLO.TEC} = \sum_{y=1}^{Y} (O_y \times I_y) \tag{5}$$

$$BL_{RLO.POL} = \sum_{z=1}^{Z} (O_z \times I_z) \tag{6}$$

Where, 'v', 'w', 'x', 'y' and 'z' represents the number of factors considered for five different ETBL's as presented in Table 2. However, more BL's and their factors may be added for future considerations by conducting a country-specific case study.

6 CONCLUSIONS AND RECOMMENDATIONS

Countries all around the world are striving for sustainable waste management systems. The selection of a suitable treatment strategy is vital for having a sound waste management system. Countries lack quantitative tools to support such decision making. It is observed that low and middle-income countries face more problems due to lack of awareness, weak infrastructure support, poor policy implementation, and a massive amount of waste dumped into landfills. While, the high-income countries have better systems, adequate policy guidelines, supporting infrastructure systems to dispose of a reduced amount of waste to landfills. The reverse logistics concept is considerably more visible in high-income countries when compared to low and middle-income countries. A quantitative ETBL scoring method proposed in this study would be useful in evaluating a particular reverse logistics option from multiple bottom-line aspects and could significantly assist the decision-making process in the future. Additionally, suggestions are provided to the stakeholders of Hong Kong after evaluating the situation from ETBL aspects.

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