BEST PRACTICES FOR DIVERTING DEMOLITION WASTE FROM LANDFILL: A SYSTEMATIC LITERATURE REVIEW

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Demolition Waste (DW) tremendously contributes to the global solid waste production with a major portion destined to landfills. The DW should divert from landfill to improve the use of natural resources while reducing the adverse environmental impacts of using many land resources for waste landfilling. The development of effective processes to reuse and recycle is important to reduce landfilled waste. Thus, changing the traditional linear supply chain into a circular arrangement is a value-adding mechanism and herein, the notion of 'Reverse Logistics Supply Chain (RLSC)' has captured the attention of the construction industry. With align to this, the purpose of this paper is twofold. First, a systematic literature review (SLR) was conducted to identify the best practices for diverting DW from landfill to promote RLSC in the construction industry. Second, it outlines the next line of research which will assist future researchers to further improve the domain under study. The SLR was conducted using 81 articles available in six search systems from 2000 to 2019. The study found the best practices during pre-dismantling, dismantling and on-site operations and material recovery phases. These best practices should initiate from the design and planning phases of the project delivery process. The value of the study is to provide the industry practitioners with the best practices to reduce the amount of waste reaching the landfill. Furthermore, the study acknowledges the practitioners the corrective measures for impediments which challenge the execution of best practices in the practical context.

Keywords: demolition waste, landfill, Reverse Logistics Supply Chain

INTRODUCTION

Despite the construction industry's enormous efforts to reduce the negative environmental impacts, the construction operations are still perceived as a major source of environmental pollution. The construction industry utilises 40% of natural materials and produces 10-35% of total waste (Abarca-Guerrero *et al.,* 2017). The previous studies found that more than 44% of Construction and Demolition Waste (CDW) in the United Kingdom (UK) and 29% in the United States of America (Yu *et al.,* 2013) destined at landfills. Furthermore, 44% of CDW in Australia has been disposed of via landfill (Shen and Tam 2002), and this is 27% in Canada (Yeheyis *et*

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al., 2013). This figure is correspondingly alarming in plenty of other countries while attaining 35% of an overall global average (Solís-Guzmán *et al.,* 2009).

The CDW is generated due to activities related to construction, renovation, civil and infrastructure works and demolition. It has found that around 70% of CDW is contributed by DW (Ding *et al.,* 2016). For the past decades, landfilling was the cheapest option available for DW disposal (Oyedele *et al.,* 2013). At present, the rapid increase in construction-related activities generates an uncontrollable amount of waste at alarming rates (Ding 2018). This high rate of waste generation has congested many landfill carrying capacities while producing a plethora of adverse effects on society, both economically and environmentally (Ding 2018). Burying a large amount of DW in landfills produce volumes of CO2 and methane due to anaerobic degradation, and this will lead to extensive air, water and soil pollution (Yuan *et al.,* 2013). Landfilled DW also engenders enormous pressure on the inadequate space available in highly congested cities (Oyedele *et al.,* 2013). Thus, there is an acute need for diverting DW from landfills (Yuan *et al.,* 2013).

The notion of 'Reverse Logistics Supply Chain (RLSC)' has captured the attention of the construction industry as a viable approach to divert waste from landfills (Hosseini *et al.,* 2015). The Reverse Logistics is defined as "the process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal" (Rogers and Tibben-Lembke 1999: 2). The RLSC of DW contains a series of operational phases, namely, dismantling and on-site operations, acquisition, collection and transportation, off-site resource recovery and marketing of reprocessed products (Hosseini *et al.,* 2015). Therefore, the RLSC facilitates the maximum recovery of salvaged waste while minimising the waste destined at landfills.

Despite significant efforts made to promote RLSC, the construction industry still pays less attention to the best practices which divert waste from landfills (Chileshe *et al.,* 2019). Thus, there is a need for an in-depth investigation of the diversion of DW from landfills. The current study aims to undertake a systematic literature review (SLR) to answer the review question of: 'what are the best practices which encourage the diversion of DW from landfill to promote RLSC in the construction industry?' Brondyk and Searby (2013) described the 'best practices' as robust and reputable practices which are applied and tested in the practical context while strongly rooted in the present, rigorous research. In other words, they facilitate the works to be more effective by using the latest knowledge, technology and procedures (Zemelman *et al.,* 1998). Therefore, the practices that are effective and empirically proven to divert DW from landfills are known as ‘best practices’ in the current study. The original contribution of this study is that of amalgamating existing knowledge of the best practices of diverting DW from landfills and determine the next line of research which assist future researchers in improving the domain under study.

METHODOLOGY

This study draws upon a SLR based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), which is a widely recognised standard procedure of conducting SLRs (Moher *et al.,* 2009). Two search strings with several keywords linked with Boolean connectors such as "OR" and "AND" were used to search articles as in Table 1. The keywords were searched in six electronic search systems, namely Google Scholar, Emerald Insight, Web of Science, Scopus, ScienceDirect and Taylor and Francis. Several search systems enable to extract rich repository of articles without permitting any bias in selection (Ali *et al.,* 2017). These search systems are readily available in academic institutions and hold a wide range of multi-disciplinary publications (Ali *et al.,* 2017). As per the review by Hosseini *et al.,* (2015), the first study on RLSC in construction was done in 2000. Since the research on RLSC in construction started to emerge in 2000, the time frame for the study was established from the year 2000 to 2019.

Table 1: Keywords and search strings

	Title/ Abstract/ Keywords	
Search 01	("Reverse Logistics" OR "Reverse Supply Chain")	AND "Construction Industry"
Search 02	("Deconstruction" OR "Demolition" OR "Dismantling" OR "Sort*" OR "Recycling" OR "Reusing" OR "Landfill" OR "Disposal")	AND "Construction Industry"

The initial search retrieved 351 articles for the subsequent refinement. The titles and abstracts of the 351 articles were examined to find the applicability of them for the current study. The peer-reviewed journal articles, conference papers and book chapters which published in English were included for the further refinement. The articles which were on unrelated subject areas were excluded from the repository. Subsequently, 170 articles were endured for the succeeding refinement. Next, the introduction and conclusions of each paper were examined, and 85 articles were excluded due to their inapplicability and duplications. There were six inaccessible articles, and the authors of these articles were not contacted to provide those articles since the abstracts of them affirm that they are not significantly contributing to the current review. Thus, a total of 87 articles were selected, including eight articles which were added from cross-referencing. During the full document review, the quality of papers was examined based on their rationale regarding the association of topic, methodology, findings and significance (Miles and Huberman 1994). Hence, six articles were rejected, leaving 81 articles for the current review.

The selected articles were subjected to two types of analysis. First, the bibliographic details of the selected articles were tabulated. The second involved a content analysis, which helps to make various decisions on the comprehension of the paper (Seuring and Muller 2008). Due to the space limitation, the inclusion of findings of all the reviewed articles was not permitted. Therefore, only the most relevant results of the content analysis were disclosed.

Results of the Content Analysis

This section presents the significant findings of each structural dimensions which formed from analysing, synthesising and classifying the knowledge in sorted articles.

The Best Practices to Divert DW from Landfills

The best practices related to CDW management are essentially operationalised circular economy principles within the construction and demolition sector and beyond. The following sections discuss the best practices to divert DW from the landfills.

During pre-dismantling phase

The best practices to divert the DW should initiate from the inception phase of a construction project. The designers should consider end of life (EoL) operations when they are designing a structure, and the practices like Design for Reverse Logistics (DfRL) and Design for Deconstruction (DfD) assist in diverting the DW from landfills (Chileshe *et al.,* 2018). Flexible scheduling between dismantling and salvaging stages is also significant to encourage deconstruction and on-site sorting, which are essential practices to minimise waste sent to landfills (Chileshe *et al.,* 2016b). The authors further specified that provision of adequate space for on-site sorting is essential to divert DW, which ended up at landfills.

The Site Waste Management Plan (SWMP) of a building provide a guide to separate salvaged waste into different waste groups (Williams *et al.,* 2014). Furthermore, it broadly describes the ways of reprocessing and disposal of each waste stream collected on dismantling site (Tischer *et al.,* 2013). This helps to minimise the contamination of waste after dismantling, which is a significant cause that leads to landfilling. Therefore, some developed countries like the UK have mandated to develop SWMPs for buildings that are more than £300,000 value (Aminu and Angela 2018). The authors further suggested that all the governments should dictate to develop a SWMP for each building to minimise waste destined at landfills.

Before dismantling a building, a comprehensive on-site investigation should be conducted (Kleemann *et al.,* 2017). Herein, conducting a pre-demolition/ deconstruction audit of a building is essential to identify the potential recoverable and hazardous materials (Aminu and Angela 2018). This audit classified all the salvaged waste into reusable, recyclable, hazardous and waste for landfills (Williams *et al.,* 2014). It also reduces the uncertainty on materials which generate after dismantling (Jiménez-Rivero and García-Navarro 2016).

During dismantling and on-site operations

In many cases, the most prevalent method to dismantle is the mechanical demolition of buildings, which, as traditionally perceived, highly destructive and sophisticated technique which produces large amounts of contaminated waste to landfill (Akinade *et al.,* 2019). On the other hand, deconstruction is an alternative technique for demolition which involves methodical disassembly. A hybrid of both deconstruction and demolition has considered as a pertinent dismantling technique to maximise diversion rate from landfill (Vegas *et al.,* 2015). Thus, the decision to deconstruct/ selective deconstruct instead of demolition is a best practice to minimise waste to landfill (Chileshe *et al.,* 2018).

Effective on-site operations are important to improve the recovery rate of DW and diversion rate of waste to landfills (Yuan *et al.,* 2013). The on-site sorting helps to separate hazardous and foreign materials before they contaminate with other waste (Williams *et al.,* 2014). The construction waste management regulations of some countries like Hong Kong mandated the on-site waste sorting after dismantling. To facilitate on-site sorting, Tischer *et al.,* (2013) suggested keeping moveable containers at different locations in the demolition site from the beginning of dismantling. The waste collected and sorted at the upper floors of the building could be transported to the ground floor through vertical ducts without permitting the manual handling, which encourages the contamination (Tischer *et al.,* 2013).

According to Jiménez-Rivero and García-Navarro (2016), storing properly sorted waste on-site is a crucial practice to avoid contamination. Poon *et al.,* (2004) expressed the importance of storing the extracted salvaged waste at designated locations and labelling each category to avoid contamination. It is essential to store waste in an appropriate arrangement to prevent exposure to the moisture and unfavourable weather conditions. The guidelines which specify the precise way of handling and storing salvage waste on-site is important to ensure a maximum recovery rate from the on-site operations (Poon *et al.,* 2004).

During material recovery
The workers at the material recovery facility (MRF) should monitor the condition of salvaged waste provided by different suppliers (Huang *et al.,* 2018). This is because malpractices like random collection and subsequent sorting by unprofessional waste pickers expedite the waste to landfill. Mercante *et al.,* (2012) stressed that a detailed preliminary inspection is needed to ensure that the waste is not contaminated. The MRFs are having their waste acceptance criteria (WAC) guideline, which acknowledges the requirements to determine the acceptance or rejection of the waste load (Jiménez-Rivero and García-Navarro 2016).

Before reprocessing, the salvaged waste is introducing to the mechanical sorting plant. During the sorting phase, chemical tests are conducting to ensure that the salvaged waste is not mixed with hazardous materials like asbestos (Chileshe *et al.,* 2016a). As specified by Huang *et al.,* (2002), the impurities such as small wood chips and the old mortar mixes should be removed from the samples before introducing them to testing. The authors further explained that the material streams which sorted from mechanical sorting process are introduced to a series of material tests such as sieve analysis, Los Angeles (LA) abrasion test, friability test and the fineness test. Complying with specifications and standards during the reprocessing stage is important to divert DW from landfills (Martín-Morales *et al.,* 2011).

The Impediments to Best Practices and the Corresponding Corrective Measures

The construction practitioners, such as designers and contractors, do not consider the post-EoL building operations during the designing and planning phases (Chileshe *et al.,* 2016a). These practitioners are not aware of the best practices such as deconstruction, DfD, DfRL and preparation of SWMP. As a result, they are reluctant to consider them during the designing and planning phases of the buildings. Therefore, it is required to educate contractors and designers on the benefits of deconstruction, DfD, DfRL and SWMP (Chileshe *et al.,* 2016a). The standards should be available regarding design tools comply with DfD and DfRL to encourage designers to follow these concepts. Densley Tingley *et al.,* (2017) suggested that local governments should amend local planning regulations in such a way to incorporate DfD and DfRL objectives in upcoming projects.

Rameezdeen *et al.,* (2015) highlighted that most of the dismantling sub-contractors are not aware of the positive outcomes of deconstruction, and even the builders only concern the budget and time of dismantling. As revealed by Jiménez-Rivero and García-Navarro (2016), the demolishers do not have adequate knowledge and skills required for efficient source separation and subsequent storage. Training and educating labourers on deconstruction and various sorting techniques improve the waste diversion from landfill (Chinda and Ammarapala 2016). Furthermore, all the demolition workers and labourers assigned for on-site sorting should have a license from the corresponding authorities (Nikmehr *et al.,* 2017). As suggested by Jiménez-Rivero and García-Navarro (2016), a separate person should be assigned at demolition sites to check and monitor the on-site sorting operations periodically.

Governments and regulatory bodies in some countries do not persuade best practices such as deconstruction and on-site sorting. For instance, Chileshe *et al.,* (2016b) revealed that the South Australian government as a client wants the buildings to be dismantled quickly due to the time and space restrictions. Therefore, the demolition sub-contractors in South Australia tempt to demolish the public buildings instead of deconstruction. Chileshe *et al.,* (2016a; 2016b) revealed that the storing extracted salvaged waste for on-site sorting is not permitted by the Environmental Protection Authority (EPA) in South Australia. Herein, EPA considers any material without immediate use as waste and ask to remove them from the site immediately. Rameezdeen *et al.,* (2015) declared that on-site sorting is not feasible because of strict environmental, health and safety regulations. Therefore, the government and regulatory bodies have a critical role to play in promoting best practices such as deconstruction and on-site sorting to minimise waste destined at the landfill. Herein, they should establish standards, specifications, guidelines, regulations and norms for the production and application of reprocessed products (Huang *et al.,* 2018). The government and regulatory bodies should promote quality assurance in RLSC by providing incentives and industry-wide training (Jin *et al.,* 2017). Besides, Ling and Nguyen (2013) specified that universities also have a responsible role in doing research and developments.

The Conceptual Framework

The summary of literature findings related to the best practices of DW diversion from landfills is depicted in Figure 1, as the status quo of the research. The study found the best practices of pre-dismantling, dismantling and on-site operations and material recovery phases in RLSC. There are impediments which challenge the execution of these best practices in real life. The SLR revealed that people in RLSC are not familiar with the best practices due to lack of knowledge, awareness and training. The lack of standards, regulations and incentives by government and regulatory bodies also affect the DW diversion from landfill. Therefore, government, regulatory bodies, industry and universities should play a critical role in promoting best practices in RLSC to divert DW from landfill.

The study helps the practitioners in RLSC to get an understanding of the best practices that need to be employed for diverting the DW from landfill. Being aware of and following these practices could be considered as the first step in the successful management of diverting DW from landfills in the construction industry. This is further confirmation to the practitioners that testing and complying with standards, regulations and specifications during RLSC would not be the adequate option to divert DW from landfill. Instead, it highlights the prerequisite of diverting bulks of DW from landfill should be considered and initiated from the early design stage of a building.

A well-executed literature review that constitutes an extensive research agenda makes a robust contribution to the domain of the study (Snyder 2019). Congruently, as shown in Figure 1, and in line with the status of quo of contemporary research, several future research directions were proposed through the analysis of what has been done and what needs to be done related to the field of study. Accordingly, there is a need to investigate how early phases in a building life-cycle contribute to diverting waste at the EoL of the building. The current study is focused only on the presentation of best practices during pre-dismantling, dismantling and on-site operations and resource recovery phases. However, since the acquisition, collection and transportation and marketing are also considered as important phases in RLSC; more empirical research is needed to identify best practices within these phases. The study found that the best practices of DW diversion from landfills are impeded by the causes which rooted from the elements such as people, process, policy and technology in RLSC. Therefore, future research could be done to investigate the impact of these four elements in RLSC on DW diversion from landfills. The current study underlined that most of the practitioners engaged in the forward supply chain and RLSC in construction are lacking the knowledge on best practices of DW diversion from landfills. Manowong (2012) found that even if some practitioners in the forward supply chain are knowledgeable on these best practices, they are not encouraged by the clients who have the attitude that implementing these practices are a financial burden for the project. Correspondingly, the attitudes of the practitioners are discouraging them from following these best practices. Therefore, how to change the attitudes of practitioners in forward supply chain and RLSC to increase DW diversion from landfill in an interesting future research direction.

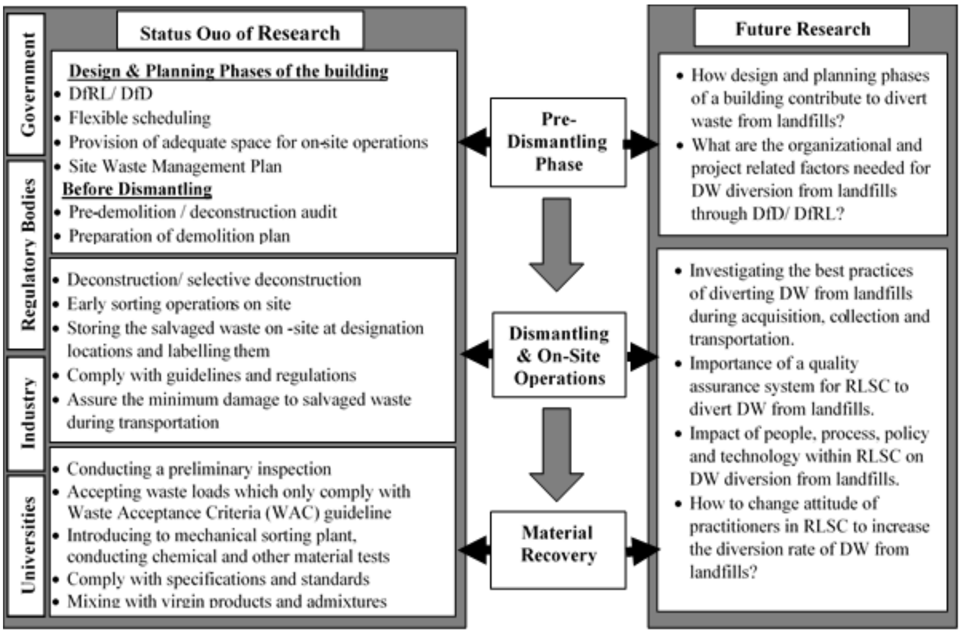

Figure 1: Future research directions of DW diversion from landfills

CONCLUSION

Diverting DW to landfills is a highly notorious activity which has led to a plethora of adverse effects on environmental and social wellbeing. This study aims to identify the best practices which divert the DW from landfills to promote RLSC in construction and determine future research in the domain of the study. The SLR was done using the PRISMA guideline, including 81 articles from 6 search systems during the period from 2000 to 2019. The study found the best practices during pre-dismantling, dismantling and on-site operations and material recovery phases. These practices should initiate from the designing and planning phases of a building. However, there are constraints for the successful execution of best practices. The study found that the lack of knowledge on these practices impedes the execution of these practices. Besides, the absence of incentives and support from government and regulatory bodies also affect the implementation of these best practices. Thus, the study established that the government, regulatory bodies, industry and universities need to play a proactive role in promoting the best practices to divert DW from landfill.

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