CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT ON THE BUILDING SITE: A LITERATURE REVIEW

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The construction industry is under increasing pressure to reduce costs and improve environment quality. The construction and demolition waste management (CDWM) is a serious contender to achieve these two goals. Countries have provided legislation and professional associations and large companies have issued rules and guidelines to efficiently dismantle and organize the evacuation of these materials, especially addressing hazardous waste. A large focus in the literature on CDWM has been on minimization of waste, but less attention has been given to practices of how to minimize waste or how to manage CDW during the construction process. In order to gain an understanding of CDW during the construction process and on the building site we have performed a systematic literature review. Our goal is to identify and document the actual topics and debates related to CDWM, avoid to repeat already existing results and uncover less researched issues or topics. To do so we built on a systematic literature review on CDWM. Our initial search had 628 articles on CDW and CDW management. Through multiple selection procedures we ended up with 100 articles published in 21 scientific journals listed on Web of Science since 2010. We focus on articles referring directly to the building site as well as the management of CDW. We systematically organize the review according to the following criteria: topic, discipline, contribution, method, theory, and audience. The preliminary results show a large production of materials analyses, LCA assessment and performance, optimization of process models and economic comparison. The actual practices on the building site and the related management issues however are largely ignored by this academic production justifying that it may be worth studying these in the future.

Keywords: construction sites, demolition waste management, literature review

INTRODUCTION

The European Union has decided that the EU member states need to increase the reuse and recycling of non-hazardous construction and demolition waste to at least 70 percent by 2020 (2008/98 / EC). In 2015, the EU came with a new proposal concerning the circular economy including a new plan for waste management. These regulations have urged EU countries to include new measures for waste prevention and recycling (de Guzmán Báez *et al*., 2012). Even though most EU-countries have started setting up regulations and guidelines for CDW, waste reduction activities are often not considered as cost-effective, efficient and compatible with core construction activities (Bølviken *et al*., 2016). In Sweden, construction waste is estimated at 8 million tons a year and half of

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it is still outside of the recycling loop. This situation is placing pressure on the construction sector which needs to drastically improve its waste management processes towards re-use and recycling. To align with the new legislation and EU policy, professional associations and large companies have delivered instructions and guidelines to efficiently dismantle and organize the reuse, recycling or deposit of these materials. The Swedish Construction Federation (2015) has issued a very detailed step by step description of the processes to improve resource management and addressing specifically the handling different types of waste. The goal of the association is to adopt a standard for the industry. Even though the introduction of the landfill tax and regulations on hazardous waste have been positive for CDW, the Swedish policies concerning CDWM tend to build on "soft" incentives rather than penalising measures which outcomes may be difficult to assess (OECD report 2015). Whereas CDWM is subject to many guidelines and recommendations in the country, the site inspections are under the responsibility of municipal environmental administrations. The scope of these inspections varies between municipalities who not always possess the necessary time and information to efficiently organise these inspections. Especially, the work undertaken by SME contractors tends to avoid inspections (Deloitte, 2016). Other EU countries such Germany, Belgium or Spain have clearer economic incentives, stronger enforcement and higher sanctions in case of non-conformity regarding the management of hazardous waste, and on site sorting[2].

However, accounts from the building sites reveal that these instructions and models to optimise waste management may be overlooked during the actual construction phase. The organization of the work on site with a long chain of multiple sub-contractors, the lack of training of the employees or long delays before the delivery of building permits, may interfere and disturb the detailed planning. Moreover, especially in the case of demolition and renovation the material to collect and recycle is often the result of an amalgam of different components altered during the years and preventing an easy and quick identification of the singular elements (Sezer, 2015). The previous description constitutes the background of the present literature review. The goal of the review is to identify and document the actual topics and debates related to the management of CDW, avoid to repeat already existing results and uncover less researched issues or topics. To do so we built on a systematic literature review on CDWM to answer to question of how is CDW managed during the construction process and at the construction site. The preliminary results of the review show a large production of materials analyses, LCA assessment and performance, optimization of process models and economic comparisons. The actual practices on the building site and the related management issues however are largely ignored by this academic production justifying that it may be worth to uncover current practices on the construction site concerning CDWM.

The structure of the paper is as follows. First, we discuss how we have selected our data for the systematic literature review and how we have reviewed the articles in a method section. Second, we present the descriptive findings of the review. Third, we discuss particular themes that are neglected in the CDW literature and we finalize the paper with a conclusion

METHOD

We performed a systematic literature review through identifying, critically evaluating and integrating findings of relevant, high-quality individual studies addressing our research

[2] http://ec.europa.eu/environment/waste/studies/mixed_waste.htm

question. Systematic reviews are characterised by being objective, systematic, transparent and replicable and our review followed the following steps: scoping, planning, searching, screening, eligibility (Moher *et al*., 2009). A review can support identifying relations, contradictions, gaps, and inconsistencies in the literature, and explore reasons for these, can comment on, evaluate or develop theory and can describe future research directions.

We applied a search on Scopus and Web of Science databases for the following terms: waste management AND construction; Construction AND Demolition waste management for the years 2010-2017 (till February). From the search pattern, we initially received 628 papers in total, in different areas from business, management and accounting, computer science, engineering, environmental science and social sciences. From the initial list, we only selected *journal/review articles* and language *English*. We performed the first screening of the search based on title to see how they would be related to our research question. We checked for titles that fit our search categories and we took out all articles that focused on materials, chemistry, biology, disaster waste (e.g., earthquake debris), city waste systems, recycling factories etc. After the first screening, we had a total of 224 papers left. The second screening included reading through the abstracts in order to see if the papers would fit our search criteria of waste management and management of CDW, which diminished the list to 149 articles. We made a list of the articles and decided to only focus on articles that are published in web of science (WOS) cited journals and emerging WOS journals which leaves us with 100 articles. See list of journals below in table 1.

Table 1: List of journals included in the review.

WOS and Emerging WOS Journals included in review	No. of papers selected
Architectural Engineering and Design Management	2
Automation in construction	2
Building Research and Information	4
Civil Engineering and Environmental Systems	1
Clean Technologies and Environmental Policy	1
Construction management and economics	3
Ecological indicators	1
Environmental Engineering and Management Journal	1
Environmental Impact Assessment Review	1
Environmental technology	1
Facilities	1
International journal of life cycle assessment	2
International journal of project management	1
Journal of Cleaner Production	9
Journal of construction engineering and management	2
Journal of green building	1
Project management journal	1
Resources, Conservation and Recycling	31
Revista Tecnica de la Facultad de Ingenieria Universidad del Zulia	1
Waste management	19
Waste management and research	15
Total amount of papers	100

Descriptive Analysis

The methodological approach of most articles is a natural science approach in which different types of methods are applied. Most articles develop a mathematical model often

applied for waste generation (10 articles) or software model like BIM (4 articles) that they validate in the literature and in case studies (cf. Li and Zhang 2013). Some of these models are optimization simulation models (6 articles). The larger part of the articles adopts a more quantitative approach (23 articles) in which one set of articles applies mathematical equations, estimations of waste generation models and validations, LCA assessments and quantitative evaluations (7 articles). Other articles focus more on a quantitative survey and hypothesis testing (11) and 5 articles perform big data analysis from either governmental agencies or construction site data. Only a small number of articles applies a mixed methodology of both surveys and interviews (7 articles, cf. Al-Hajj and Hamani 2011; Lu and Yan 2012; Udawatta *et al*., 2015) or only a qualitative approach with interviews and focus groups (3 articles, cf. Ajayi *et al*., 2015; Alwan *et al*., 2017; Polesie 2012).

Many articles contextualise their findings in a particular geographical region. 45 articles have a regional focus in which Europe (18 articles) and Asia (17 articles) are strongest represented. Asia is primarily represented by China (12, cf. Ding *et al*., 2016; Wang *et al*., 2014; Yuan 2013) and Hong Kong (4, cf. Chen and Lu 2017) 38%, Europe stands for 40% of the articles of which primarily Spain (7, cf. de Guzmán Báez *et al*., 2012; Gangolells *et al*., 2014) and Portugal (3, cf. Coelho and De Brito 2011) and UK (4, cf. Alwan *et al*., 2017; Ajayi *et al*., 2015) are discussed

Table 2: Number of articles per method.

Methods applied	No. of articles	%
Interviews, focus groups	3	5%
Mixed method (survey, interviews)	9	14%
Survey (hypothesis testing)	11	17%
Reviews	5	8%
Conceptual papers	2	3%
Secondary data	2	3%
Big/site data analysis	5	8%
Developing models and testing	10	16%
Development of software model (BIM, DSS)	4	6%
Estimations, mathematical equations, assessments, LCA	7	11%
Simulations	6	10%
Total	64	100%

Table 3: Number of articles that specifically focus on a geographical area.

Country	No. of articles	%
Australia	2	5%
Europe	18	40%
Asia	19	42%
North America	1	2%
Africa	2	4%
International (multiple countries)	3	7%
Total	45	100%

For those articles that studied the construction process, we also looked into the particular construction project phase and found that design (8 articles) and construction (16 articles) are the main areas. For articles concerning construction, production or the site, the focus is on estimation of waste and minimisation of waste (7 articles), supply network and other stakeholders (2 articles), performance and success factors (2 articles) and one article on behaviour on site (Bakshan *et al*., 2017).

Few articles discuss demolition (5 articles) and renovation/refurbishment is hardly studied (2 articles). The mixed articles discussed CDW more in general terms and mentioned multiple construction phases.

Table 4: Number of articles representing different construction project phases.

Construction Phase	No. of articles	%
Design	8	22%
Construction/production/site	16	44%
Demolition	5	14%
Renovation	2	6%
Mix (multiple phases)	5	14%
Total	36	100%

While several authors mention that the management of CDW is neglected in literature (China, 2016), we found some articles that discussed aspects like benefits (4 articles), hindrances to CDW implementation (5 articles), legal and policy issues (8 articles), economic factors and the use of IT in relation to CDW (9 articles). Articles discussing IT often focused on decision support systems (Yuan *et al*., 2012), BIM (cf. Alwan, *et al*., 2017; Akinade *et al*. 2015; Porwal and Hewage 2012) or GIS (Su *et al*., 2012). In the last couple of years, the European Union (EU) has focused on the reduction of CDW with 70% for 2020. This has led to the drawing up of many regulations on CDW during the past years, forcing EU countries to include new measures for waste prevention and recycling (de Guzmán Báez *et al*., 2012). The EU regulations are reflected in a number of European papers.

Table 5: Number of articles representing other managerial issues for CDW management.

Other managerial issues	No. of articles	%
Success factors/indicators	4	13%
Hindrances implementing CDW	5	17%
Legal issues, policy, EU	8	27%
Economic factors	4	13%
IT, BIM, decision support systems, GIS	9	30%
Total	30	100%

Thematic analysis

Even though several authors have listed indicators that influence construction and demolition waste management (Yuan 2013). There are only few studies that focus on the managerial aspects of CDW in the construction process and how these could be improved (Chinda 2016). In the thematic analysis the key managerial topics within CDW from the review are discussed to give an insight in CDW management research and argue for new future research areas.

Design for deconstruction

While most articles in the review focus on the construction or production phase, there are a number of articles that discuss the relevance of designing for waste minimization. One particular area in this field has been on the role of the architect who selects the design and material (Akinade *et al*., 2015; Li *et al*., 2015; Porwal and Hewage 2012; Wang *et al*., 2015; 2014).The consideration of CDW reduction during design as a key strategy to minimizing construction waste and an early stage is discussed by several (Wang, *et al*., 2015; 2014; Yuan 2013). Others study the influence of the attitude of designers on waste minimization (Li *et al*., 2015) or the use of technology (BIM) to design for deconstruction (Akinade *et al*., 2015). Future research could strengthen the focus of design for deconstruction with the support of new technology to minimalize waste generation and improve recycling or re-use of materials.

Strong focus on construction phase for CDW management

From the descriptive analysis CDW articles are found in all construction project phases but the primary focus for management of CDW has been the construction or production phase (see table 3). The role of the contractor in construction project success is often discussed as relevant (Alzahrani and Emsley 2013), one of the important aspects is how contractors deal with waste management and waste disposal. In project management literature, the contractor's role is perceived as important to project success. Even though most EU-countries have started setting up regulations and guidelines for CDW, waste reduction activities are often not considered as cost-effective, efficient and compatible with core construction activities. Moreover, waste management is not often valued in the industry, because of the inability to predict the production environment; unique characteristics of each project; time pressure and cost limitation (Kareem *et al*., 2015). The majority of the papers in this area focus on new-build and especially buildings (houses and offices), while only a few studies represent infrastructure or civil engineering projects in relation to CDW management (exception of e.g., de Guzmán Báez *et al*., 2012).

Furthermore, the review shows a clear gap in studies concerning renovation/refurbishment (exception Li and Yang 2015) which is stated to have a different process for CDW than for new-build, primarily because renovation waste contains mixed material and becomes more difficult to sort and recycle or re-use. This particular area would need to be strengthened especially since renovation is a large and relevant area for CDW in which there has been a lack of focus.

Management practice and behaviour for CDW on site

A majority of the articles (16) have a focus on minimizing waste during construction. With a focus of CDW on the construction site, studies focus on investing in CDW management and education, as well as having site space for CDW and sorting waste on site (Wang, *et al*., 2010). Research has also looked into changing the waste management culture within an organization. For example, Udawatta *et al*., (2015) studied approaches to changing the attitudes and industry behaviour towards waste minimization; engage all stakeholders in construction waste management, have adequate supervision of waste management activities, good company policies, training and education for all stakeholders as well as financial rewards and incentives (Udawatta *et al*., 2015). Other authors discuss behavioural aspects as relevant for improving practices in CDW management (Bakshan *et al*., 2017; Teo and Loosemore, 2001) as well as improving stakeholder's awareness about environmental and economic considerations of CDW is vital for changing a culture and encourage adoption of sustainable practices (Bakshan *et al*., 2017; Osmani *et al*., 2008; Yuan 2013). These studies raise considerable attention to the role of human factors in minimizing and managing construction waste (Yuan and Shen 2011). While human factors and behavioural factors are discussed as relevant, few articles study behaviour and practices in-depth or for a longer period of time, which makes it difficult to gain a good insight in current practice or developments towards new practices on site. Future research could focus on the current practices and behaviour on site from contractors as well as multiple subcontractors in relation to CDW.

Focus On Technology Use for CDW

A number of articles discuss the use of technology to support CDW management, minimize waste generation as well as giving possibilities to design for deconstruction. Especially, Building Information Modeling is discussed as a possible technology that can be used to design for deconstruction (Akinade *et al*., 2015) or support strategic sustainable development using BIM (Alwan *et al*., 2017). While the review primarily focused on management of CDW, new technologies were mentioned to support this, however, a more detailed analysis of research on the use of BIM for CDW would be needed to see the benefits of BIM in empirical settings.

Urbanization and CDW

Literature on CDW is strong in Asia and Europe, but there are different perspectives and contexts in these areas. Whereas the focus of Asian studies is related to pollution, but also to urbanization and how to deal with CDW in small spaces, highly urbanized areas and off-site CDW (cf. Li and Yuan, 2012), this has less been discussed in European studies. Especially, with an increasing urbanization in many countries, and a major focus on renovation of existing buildings in urban areas, it becomes relevant to study how the AEC industry can alter and align their CDW practices towards a more sustainable process in urban areas (Buser and Bosch- Sijtsema, 2017).

CONCLUSIONS

This paper intended to gather the different studies and perspectives mobilised to discuss the management of CDW of the construction process and in particular the building site. Focusing on the topics and methods, we have carried out a systematic review of international publications in this area relevant for the Swedish context. The review found that, though there are a large amount of publications on the subject of waste on the building site, only a few are addressing management issues. Besides these studies often present a list of factors or hindrances influencing CDWM based on survey or other literature review. Only three are drawing on qualitative material to document the current situation although none of them is building of a specific theory to do so.

Equally, the topic of renovation and reuse of material is fairly overlooked by the literature. The main management topics relevant from the review for future studies are: design for deconstruction, a focus on infrastructure as well as renovation of the construction phase, a qualitative long-term focus on practice and behaviour on site, influence of BIM and new technology in CDWM, and urbanization in relation to CDW. Whereas the introduction of stricter legislation in Europe has not yet created noticeable academic interest for studying the practices of the industries, some of the contractors in Sweden have added recycling competences to their portfolio and innovation practices concerning CDWM would become relevant to study. So, it is maybe time to look beyond the quantitative models for estimating waste and observe and analyse what the actual practices on site are, and how to possibly improve their performance.

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