UTS ePRESS

Construction Economics and Building

Vol. 21, No. 3
September 2021

Citation: Al-Hamadani, S., Egbelakin, T., Sher, W., and Von Meding, J. 2021. Drivers of Applying Ecological Modernization to Construction Waste Minimization in New South Wales Construction Industry. *Construction Economics and Building*, 21:3, 80–104. http://dx.doi.org/10.5130/AJCEB.v21i3.7655

ISSN 2204-9029 | Published by UTS ePRESS | https://epress.lib.uts.edu.au/journals/index.php/AJCEB

ARTICLE (PEER REVIEWED)

Drivers of Applying Ecological Modernization to Construction Waste Minimization in New South Wales Construction Industry

Sulala Al-Hamadani[1,*], Temitope Egbelakin[2], Willy Sher[3], Jason Von Meding[4]

[1] School of Architecture and Built Environment, University of Newcastle, New South Wales, Australia, Sulala.AlHamadani@uon.edu.au

[2] School of Architecture and Built Environment, University of Newcastle, New South Wales, Australia, willy.sher@newcastle.edu.au

[3] School of Architecture and Built Environment, University of Newcastle, New South Wales, Australia, t.egbelakin@newcastle.edu.au

[4] School of Construction Management, Florida Institute for Built Environment Resilience (FIBER), Florida, USA, jason.vonmeding@ufl.edu

Corresponding author: Sulala Al-Hamadani, School of Architecture and Built Environment, University of Newcastle, New South Wales, Australia, Sulala.AlHamadani@uon.edu.au

DOI: http://dx.doi.org/10.5130/AJCEB.v21i3.7655

Article History: Received: 29/03/2021; Revised: 20/06/2021 & 03/07/2021; Accepted: 03/07/2021; Published: 10/09/2021

Abstract

The application of ecological modernization (EM) (to delink industry growth from environmental damage) to minimize construction waste has not been explored within construction industry in general, and the New South Wales (NSW) construction industry in particular. This study seeks to identify the drivers of applying EM to construction waste minimisation (CWM) in the industry. Also, to determine the CWM measures that are critical for each of the drivers. A survey was adopted in this study to target stakeholders engaged in the delivery of construction projects in NSW from design to completion. The survey was selected to reach a large number of respondents within a manageable period. A pilot study was conducted to ensure the reliability of the research design before a full-scale data collection was launched. The data from 240 valid responses was analysed using factor analysis, relative importance index and descriptive statistics. The results revealed five important drivers for EM's application to CWM. These are agents of change, government policies, supply chain dynamics, skill building and technological innovations.

DECLARATION OF CONFLICTING INTEREST The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. **FUNDING** The author(s) received no financial support for the research, authorship, and/or publication of this article.

The CWM measure that are critical for each of these drivers were also identified. The study provides insights into the application of EM to address the construction industry problem of waste generation as by-product of its growth. It also shows the ability to protect the environment while enabling continuous economic growth. Furthermore, it demonstrates the applicability of EM to minimize the construction waste of NSW construction industry.

Keywords

NSW; Construction Waste; Ecological Modernization; Industry Growth

Introduction

The problem of continuous generation of construction and demolition (C&D) waste continues to challenge the economy and environment in Australia. It has increased from 16.9 Mt in 2007 to 20.4 Mt in 2017 (Pickin, et al., 2018). Among the Australian states and territories, the state of New South Wales (NSW) is the main contributor for this problem, mainly because of its economic and population growth (NSW Environment Protection Authority, 2015; Pickin, et al., 2018; NSW Environment Protection Authority, 2019). The amount of C&D waste has increased continuously in NSW from 4 Mt in 2004 to 12.7 Mt in 2018 (Department of Environment & Climate Channge NSW, 2007a&b; NSW Environment Protection Authority, 2019). Moreover, the quantities of C&D waste generated in NSW outweigh the other waste streams of MSW and C&I (NSW Environment Protection Authority, 2019a).

The problem of continuous increase of C&D waste in NSW explained above is related to growth of the state's construction industry. It is projected that the NSW construction industry will continue to grow throughout the next decade (Australisan Construction Industry Forum, 2017, 2019). The continuous increase in waste in NSW, reaching 21.4 million tonnes in 2017-18, has been blamed on the growth in construction activities (12.7 million tonnes out of the 21.4 was C&D waste) (NSW Environment Protection Authority, 2019a). Although NSW construction industry is one of the industries that has not been impacted by COVID-19 pandemic restrictions (Infrastructure NSW, 2020), NSW government put plans to support the industry and its growth. It extended construction work hours to include weekends and public holidays (NSW Department of Planning, Industry and Environment, 2020). In addition, the NSW government has released plans to fast-track construction projects approvals to boost the industry growth (Johnston, 2020; Sanda, 2020). Overall, it is projected that the NSW construction industry will continue to generate significant amounts of C&D waste as a by-product of its activities, with a potential growth in generation of C&D waste (Perrottet, 2018).

To reduce the amount of C&D waste generated in NSW and its associated environmental and financial problems, there is a need for a strategic approach towards construction waste minimization (CWM). This aligns with guidance provided by the waste management hierarchy and key research outcomes highlighted in existing literature (Peng, Scorpio and Kibert, 1997; Tam, 2008; Udawatta, et al., 2015b). To adopt the strategic approach of CWM, industry growth and the environment need to be reconciled.

Various theories and concepts were found to contribute to the sustainability debate in light of growth. Examples include the 'concept of de-growth or sustainable de-growth', 'sustainable consumption', 'sustainable development (SD)' and 'ecological modernization (EM)'. Among these is the theory of ecological modernization (EM), which could be applied to deal with the environmental problem of C&D waste in NSW. That is because EM not only accepts win-win relationships between the environment and economic growth, but supports environmental improvements for greater economic development (Baker and Eckerberg, 2008; Langhelle, 2000). This involves delinking the growth of the construction industry from the environmental damage its waste generates. EM encourages positive sum relationships (win-win) between industry growth and the environment (Mol, 1995; Christoff, 1996; Mol and Sonnenfeld, 2000).

EM contends that through human ingenuity, the economy can continue growing whilst simultaneously protecting the environment (Jänicke, 1985; Huber, 1991; Jänicke, Binder and Mönch, 1994; Mol and Spaargaren, 1993; Jänicke, Binder and Mönch, 1997). EM theorists state that economic growth can be delinked from environmental damage through EM core themes, representing changes in the role of technology, institutions, economic imperatives and government policies and interventions (Berger, et al., 2001; Jänicke and Jacob, 2004; Huber, 2008). This study conceptualizes that the application of EM could be applied to significantly minimise the environmental problems associated with C&D waste in NSW.

The objectives of this study thus is (i) to identify the drivers of applying EM to CWM within the context of the NSW construction industry, and (ii) to determine the CWM measures that are critical for each of the drivers. To identify these drivers and the critical measures, quantitative methods were employed on the measures that were identified from literature, and included in the survey. factor analysis was conducted to identify the drivers that are important when applying EM to CWM, whereas, descriptive statistics and relative importance index were used to identify critical measures to CWM. The next sections provide a literature review of EM and its applicability to CWM measures, and the methodological approach of the study. This is followed by the findings, which are presented and discussed before concluding the study.

Ecological Modernization Theory (EM)

Developed in the early 1980s within the geographical limits of Western Europe, EM continues to be developed to address issues related to economic growth and the environment (Jänicke, 1985; Huber, 1991). Since then, it has evolved considerably to deal with the scope of economic reforms along ecological lines (Mol, 1997; Mol, 1999). Mol (2006) reported that it was at this point (the evolution of EM as mainstream theory) that ecological rationality began to challenge the domination of economic perspectives. The applicability of EM has expanded to include a wide range of contexts and countries (Mol and Sonnenfeld, 2000; Sonnenfeld and Mol, 2002). EM originators acknowledge the severity of environmental problems and the economic costs of addressing them (Jänicke, Binder and Mönch, 1994; Mol and Spaargaren, 1993; Jänicke, Binder and Mönch, 1997). EM thus translates environmental problems into economic positive-sum games that protect the environment without compromising the economic growth. Wright and Kurian (2010, p.400) defined EM as 'a modernistic and technocratic approach to deal with environmental problems by assuming that there is a 'techno-institutional fix' for economic and environmental problems'.

EM promotes technologies that make industries sustainable by both preventing and ameliorating environmental damage (Fisher and Freudenburg, 2001; Cohen, 2006; Huber, 2008). The economic imperative of EM provides an important role for market dynamics and economic agents as facilitators of ecological reform (Mol, 2000; Seippel, 2000; Berger, et al., 2001; Huber, 2008). EM advocates a transformed role for government: decentralised, less hierarchal and consensual with a focus on well-planned intervention (Spaargaren, 2003). It sees the role of the state as central in attaining sustainability (Buttel, 2000; York and Rosa, 2003; Jänicke, 2008). EM supports open policy-related decisions by increasing participation opportunities for wider groups of interest (Berger, et al., 2001). These opportunities align with an increased role for non-governmental bodies, economic agents and transformations in the institutional structures of society (Fisher and Freudenburg, 2001). EM can be adopted to analyse the shifts necessary to reduce ecological crises (Berger, et al., 2001). As in this study, the application of EM to CWM can be interpreted as an approach to delink construction industry growth from environmental problem of waste.

The applicability of EM to the construction waste problem

The applicability of EM to the construction waste problem can be viewed via the impact of its themes on CWM. According to Mol (1997), these themes are the core changes that form the basis of EM. The main contributors to EM have agreed on core themes of change that characterise EM (Mol, 1997; Mol and

Spaargaren, 1998). These involve changes in the roles of technology to prevent environmental problems; increases in the roles of industry dynamics and economic agents in ecological restructuring/greening the industry; harmonious views of economic and environmental interests; reformist roles of environmental movements; and changes in the roles of government. Based on EM literature and its application to CWM, an EM-based theoretical framework for CWM is conceptualized in this study. This framework is illustrated in Figure 1. EM themes thus give rise to core changes applicable to the problems of construction waste through CWM measures as explained in Table 1.

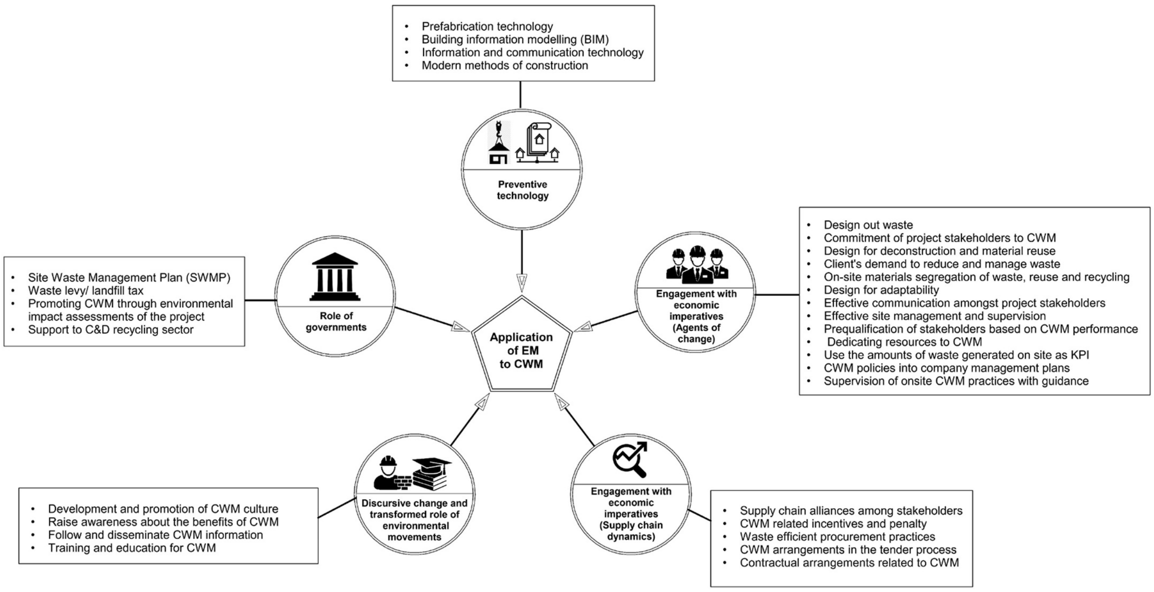

Figure 1. EM based theoretical framework for CWM

Methodology

To investigate the drivers of EM application to CWM, and the critical CWM measures to promote them, the methodological approach of this study starts by explaining the justification for the research design adopted in this study. The survey design, approach to data collection and its analysis are then illustrated and justified.

SURVEY

Stakeholders engaged in delivery of construction projects from design to completion were used as the study respondents. To reach these participants, the study employed random sampling to select respondents (Gravetter, et al., 2020). Their contact details were obtained from the Australian business register database (Australian Business Register, 2019). Survey was selected to collect data in this study based on its ability to reach a large number of respondents within a manageable period (Walliman, 2005). The literature review of the important CWM measures contributed to development of survey. The CWM measures in the survey were selected to cover different areas that matched the core themes of EM. The survey covered general demographic information of respondents and questions in relation to importance of CWM measures. Likert scale was employed as a scale of measurement, as it enabled the measurement of opinions (Bowling, 2014). In this study, a Likert scale of 1 to 5 was employed to portray the degree of importance of CWM measures. 1 was for not important and 5 for very important. A pilot study was conducted with 20 professionals from the NSW construction industry to examine the clarity and feasibility of administering the survey. Pilot

Table 1. Application of EM themes to CWM measures

EM theme	EM theme in the context of CWM	CWM Measures	References
Preventive technology: Changing role of technology from causing to preventing environmental damage	Prioritization and implementation support for waste preventive technologies that contribute to CWM	Prefabrication technology	(Tam, et al., 2007); (Jaillon, Poon and Chiang, 2009); (Udawatta, et al., 2015b); (Formoso, et al., 2002); (Saez, et al., 2013)
		Building information modelling (BIM)	Ahankoob, et al., (2012); Liu, et al., (2015); Cheng, Won and Das (2015); (Lee, Kim and Yu, 2014); (Mehran, 2016);(Udawatta, et al., 2015b); (Smith, 2014); (Wong, Wong and Nadeem, 2009); (Porwal and Hewage, 2013)
		Information and communication technology (ICT)	(Udawatta, et al., 2015b); Ilozor and Kelly, 2011; Osmani (2013); (Domingo, Osmani and Price, 2009)
		Modern methods of construction (MMC)	(Poon, Yu and Ng, 2003); (Begum, et al., 2009); (Lu and Yuan, 2010); (Osmani, 2013); (Baldwin, et al., 2007)
Engagement with economic imperatives: Increasing the role of industry dynamics and economic agents in ecological restructuring	Improved and increased role of project stakeholders and supply chain dynamics to effectively implement CWM measures	Supply chain alliances among stakeholders	(Dainty and Brooke, 2004); Udawatta, et al., 2015b); (Alwi, Hampson and Mohamed, 2002)
		Design out waste	(Greenwood, 2003); Coventry, Shorter and Kingsley (2001), Osmani, Glass and Price (2008); (Wang, Kang and Wing-Yan Tam, 2008);(Nowosielski, Kania and Spilka, 2010)
		Commitment of project stakeholders to CWM	(Johnston and Mincks, 1995); (Lu and Yuan, 2013); (Udawatta, et al., 2015b)
		Design for deconstruction and material reuse	Osmani, Glass and Price (2008),(Lu and Yuan, 2013); (Akinade, et al., 2017); (Rios, Chong and Grau, 2015); (Salama, 2017)

Table 1. continued

EM theme	EM theme in the context of CWM	CWM Measures	References
		Client's demand to reduce and manage waste	(Dainty and Brooke, 2004); (Udawatta, et al., 2015a); (Udawatta, et al., 2015b)
		On-site materials segregation of waste, reuse and recycling	(Al-Hajj and Hamani, 2011); (Marinelli, et al., 2014); (del Río Merino, Izquierdo Gracia and Weis Azevedo, 2010); (Lu and Yuan, 2010); (Marinelli, et al., 2014); (Begum, et al., 2009)
		Contractual arrangements related to CWM	(Dainty and Brooke, 2004); Osmani (2013); Ekanayake and ofori (2004); Negapan et al. (2013)
		Design for adaptability	Osmani, Glass and Price (2008); (Udawatta, et al., 2015b); (Lu and Yuan, 2013); (Morgan and Stevenson, 2005); (McKechnie and Brown, 2007)
		Effective communication amongst project stakeholders	(Teo and Loosemore, 2001); (Poon, Yu and Wong, 2004); (Wang, Kang and Wing-Yan Tam, 2008); (Gavilan and Bernold, 1994); (Manowong, 2012)
		Effective site management and supervision	(Poon et al., 2004); (Poon, Yu and Jaillon, 2004); (Peng, Scorpio and Kibert, 1997); (Wang, et al., 2010); (Saez, et al., 2013); (Kulatunga, et al., 2006)
		CWM arrangements in the tender process	(Wang, Kang and Wing-Yan Tam, 2008); (Udawatta, et al., 2015b); (Dainty and Brooke, 2004)
		Prequalification of stakeholders based on CWM performance	(Udawatta, et al., 2015b); (Yuan, 2013a)

Table 1. continued

EM theme	EM theme in the context of CWM	CWM Measures	References
		Resources dedication for CWM	(Dainty and Brooke, 2004); (Lu and Yuan, 2013); (Yuan, 2013a); (Ajayi and Oyedele, 2017)
		CWM policies into company's management plans	(Udawatta, et al., 2015b); Osmani (2012)
		Supervision of onsite CWM practices with guidance	(Cha, Kim and Han, 2009); Kulatunga, et al. (2006); (Udawatta, et al., 2015b)
		Market for reused and recycled materials/ products	(Cha, Kim and Han, 2009); (Wang, et al., 2010); (Yuan, 2013b); (Udawatta, et al., 2015b)
		Use the amounts of waste generated on site as KPI	Dainty and Brooke (2004); (Cha, Kim and Han, 2009)
		CWM-related incentives and penalties	(Adams, et al., 2011); (Al-Hajj and Hamani, 2011); (Dainty and Brooke, 2004); (Domingo, Osmani and Price, 2009);(Cooper, 1996); (Jingkuang and Yousong, 2011); (Osmani, 2013); (Wang, Li and Tam, 2014); (Cha, Kim and Han, 2009); (Chen, Li and Wong, 2002)
		Waste efficient procurement practices	(Gavilan and Bernold, 1994); (Faniran and Caban, 1998); (Greenwood, 2003); (Lu and Yuan, 2011); (Al-Hajj and Hamani, 2011); (Cha, Kim and Han, 2009); (Marinelli, et al., 2014); (Gamage, Osmani and Glass, 2009)

UTS ePRESS

Table 1. continued

EM theme	EM theme in the context of CWM	CWM Measures	References
Discursive change and transformed role of environmental movements: Harmonious views of economic and environmental interests / Reformist role of environmental movements	Promotion of equal views of environmental and economic interests of CWM, and improved role of industry trainers in relation to CWM education, training and contribution to policy.	Development and promotion of CWM culture	(Johnston and Mincks, 1995); (Yuan and Shen, 2011); Osmani, Glass and Price (2008); (Begum et al., 2009); (Zaman and Lehmann, 2011); (Wong and Yip, 2004);(Udawatta, et al., 2015b) ; (Kulatunga, et al., 2006)
		Raise awareness about the benefits of CWM	(Lu and Yuan, 2013); (Yuan, 2013a)
		Follow and disseminate CWM information	(Cha, Kim and Han, 2009); Ilozor and Kelly, 2011; Baldwin, et al., (2007); (Domingo, Osmani and Price, 2009)
		CWM training and education	(Wang, Kang and Wing-Yan Tam, 2008); (Johnston and Mincks, 1995);(Begum et al., 2009); Osmani, Glass and Price (2008); (Formoso, et al., 2002); (Nowosielski, Kania and Spilka, 2010);(Udawatta, et al., 2015b) ; (Teo and Loosemore, 2001)
Role of governments: Changing the role of government from command and control to contextual steering	Government's role to promote and enforce C&D waste preventive policies and interventions	Site Waste Management Plan (SWMP)	(Tam, 2008); (McGrath, 2001); (Mcdonald and Smithers, 1998); (Johnston and Mincks, 1995)
		Waste levy/ landfill tax	(Jaillon, Poon and Chiang, 2009); (Martin and Scott, 2003); (del Río Merino, Izquierdo Gracia and Weis Azevedo, 2010)
		Promoting CWM through environmental impact assessments of the project	(Yuan, 2013a); (Chen, Okudan and Riley, 2010); (Ajayi and Oyedele, 2017)
		Governmental support to sustainable C&D recycling sector	Oyedele et al. (2009); (Cha, Kim and Han, 2009); (Ajayi and Oyedele, 2017)

CWM: Construction Waste Minimisation; EM: Ecological modernization study is recommended to improve the data collection instrument development (Johanson and Brooks, 2010). The pilot test contributed to refine and validate the CWM measures extracted from literature and present them in clearer way (Table 1).

DATA COLLECTION AND ANALYSIS

The survey was administered online. The online mode was selected as it was convenient to administer and allowed access to a large number of potential participants (92% of Australians have internet access (Australian Communications and Media Authority (ACMA), 2015). After series of emails, 240 valid responses were used for further statistical analysis. Of the respondents, 28% were project managers, 21% architects, 16% structural engineers, 15% contractors, 14% site managers and 3% quantity surveyors. It was also noted that 86% of respondents had more than six years of professional experience in NSW construction industry. As measure of data reliability (Tavakol and Dennick, 2011; DeVellis, 2016), 'Cronbach's Alpha test' was implemented. Cronbach's alpha may be expressed from 0 to 1. An alpha value of around 0.7 indicates satisfactory internal consistency, 0.8 shows good consistency, while 0.9 indicates excellent internal consistency (Tavakol and Dennick, 2011). The Cronbach's Alpha in this study was 0.866, showing good reliability and internal consistency of survey items.

In this study, factor analysis was conducted to identify the drivers that are important when applying EM to CWM. Factor analysis is a strong statistical technique which assumes that underlying factors can be used to explain complex phenomena (Norusis, 1993). It is used to identify the pattern of correlations among a set of observed variables in fewer underlying factors (clusters) (Norusis, 1993; Doloi, 2009; Lingard, Graham and Smithers, 2000; Doloi, et al., 2012). It also remodels a large amount of data into fewer coherent factors (Shen and Liu, 2003). Prior to conducting factor analysis, Kaiser–Meyer–Olkin (KMO) index and Bartlett's test of sphericity, measures of sampling adequacy, were used to evaluate the suitability of the collected data for factor analysis (Williams, Onsman and Brown, 2010). The data had a KMO value of 0.874, exceeding the minimum acceptable value of 0.5 and within the acceptable range (Tabachnick, Fidell and Ullman, 2007; Field, 2013). Bartlett's test indicates statistical significance with a value less than the maximum of 0.05 ($\chi2 = 2926.143$, $p < 0.001$). These tests indicate the suitability of the data for factor analysis. To determine the number of important underlying factors (drivers), Principal Component analysis (PCA) was carried out on the CWM measures with 'varimax' as the factor rotation method (Corner, 2009). As an outcome of factor analysis, eigenvalues were utilized to signal the variance of each underlying factor from the total variance (Taylor, 2004). Factors with an Eigen value of 1.0 were retained (Nunnally, 1994; Brown, 2001). Variables with a factor loading below 0.4 were excluded to reduce cross-loading and to clarify the interpretation of outcomes (Lingard, Graham and Smithers, 2000; Akinade, et al., 2017; Hadi, Abdullah and Sentosa, 2016).

To identify the critical measures to CWM, relative importance index (RII) along with descriptive statistics were employed. Employing more than one method to identify the critical outcomes has been used in other studies (Poon, Ann and Ng, 2001; Chileshe, et al., 2015). The values of relative Importance Index (RII) were derived for each CWM measure based on the numerical scores from the survey responses. The values of RII were obtained based on the numerical scores from the survey responses. RII was calculated using the following equation:

$$\text{Relative importance index (RII)} = \sum w / (A^*N) \quad (1)$$

In this equation, W represents the weight for the rating scale of 1 to 5 provided by respondents, where 1 implies 'not important' and 5 implies 'very important'. 'A' represents the highest weight on the scale (5), 'N', the total number of responses in the sample, and $0 \leq \text{RII} \leq 1$. A low index value of RII can show that the CWM measure is viewed as of less importance by the survey's respondents, whereas a high index value indicates more criticality of the CWM measure (Al-Tmeemy, Abdul-Rahman and Harun, 2012; Chileshe, et al., 2015). RII was employed in different studies to identify the relative importance and criticality of those studies variables (Le and Tam, 2008; Assaf and Al-Hejji, 2006; Chileshe, et al., 2015; Al-Tmeemy, Abdul-Rahman and Harun, 2012). Descriptive statistic of mean score rating was also used. Mean score rating is commonly used to determine the relative significance of a data set (Field, 2009). It was used to identify the top ranked variables, as deemed appropriate for large samples (Norman, 2010). To further demonstrate the criticality of these 16 measures, the Top 2 Box scores (T2B) method was used. T2B is a method of reporting and summarizing positive respondent views from a Likert scale survey questions by combining the highest two responses of the scale to provide a single percentage (Sambandam and Hausser, 1998; Cui, Peng and Florès, 2015). In this study, the percentage of T2B is the calculated combination of the percentage of respondents' views that considered the CWM measures very important and important (Figure 2). All aforementioned statistical analysis were facilitated through IBM SPSS Statistics version 24 software.

Findings and Discussion

The factor analysis results revealed five important drivers for applying EM for CWM that accounted for 62.633% of the total variance (Figure 2). These drivers were labelled based on their contribution to EM and alignment with its themes. The drivers include:

- Agents of change (D1): The role of project stakeholders in applying EM via waste-efficient projects through their awareness, participation, action, and change in attitudes to CWM.
- Government policies (D2): The role of NSW state and local governments in applying EM to CMW via their CWM-related policies and regulations.
- Supply chain dynamics (D3): The role of supply chain dynamics in creating business opportunities inherent in CWM and encouraging project stakeholders to act on the ecological change.

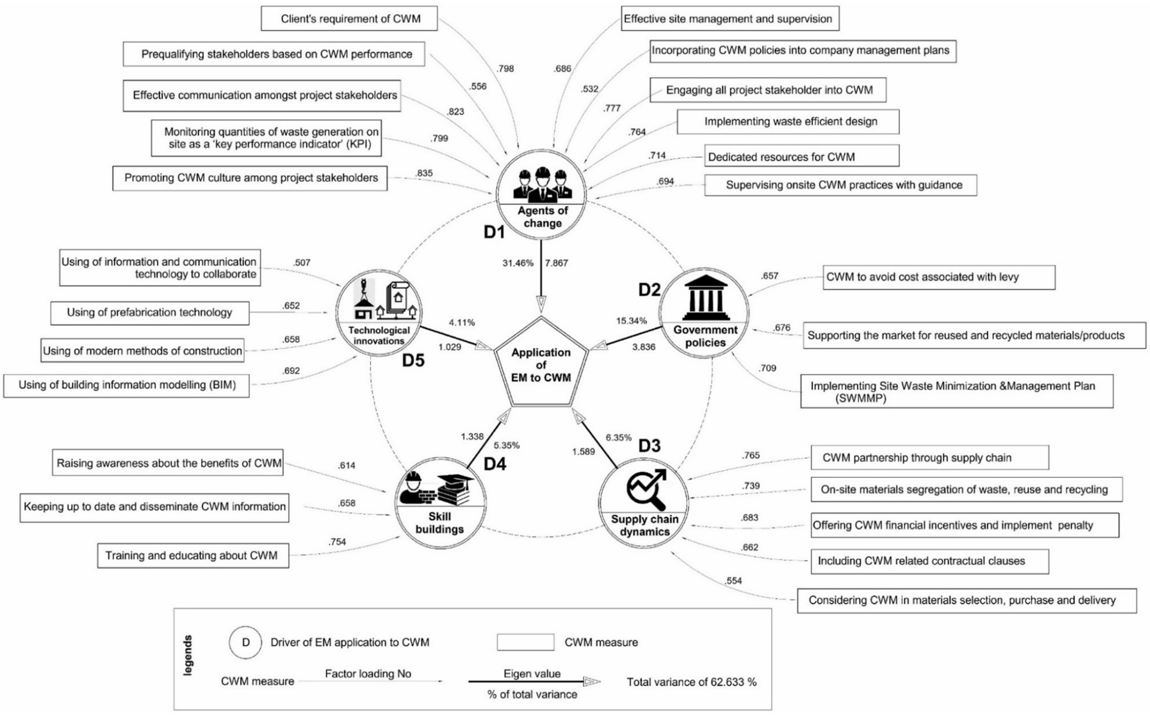

Figure 2. Drivers of EM application to CWM

Table 2. Findings of Relative importance index (RII) and descriptive statistics for the importance of CWM measures

Measure ID	Construction Waste Minimization Measures	Relative importance index (RII)	Mean Rating
M1	Promoting CWM culture amongst project stakeholders	0.878	4.39
M2	Engaging all project stakeholder with CWM	0.856	4.27
M3	Considering CWM partnerships through supply chains	0.848	4.24
M4	Training and educating about CWM	0.843	4.23
M5	Implementing waste efficient designs	0.837	4.22
M6	Using Building information modelling (BIM)	0.830	4.15
M7	On-site segregation of waste, reuse and recycling	0.825	4.13
M8	Using prefabrication technology	0.824	4.12
M9	Client's requirement of CWM	0.823	4.11
M10	Prequalifying stakeholders based on CWM performance	0.819	4.10
M11	CWM to avoid cost associated with waste levy	0.815	4.08
M12	Including CWM-related contractual clauses	0.812	4.06
M13	Considering CWM in materials selection, purchase and delivery	0.809	4.05
M14	Implementing Site Waste Minimization &Management Plan (SWMMP)	0.808	4.04
M15	Supervising onsite CWM practices with guidance	0.807	4.03
M16	Offering CWM financial incentives and implementing penalties	0.802	4.02
M17	Communicating effectively amongst project stakeholders	0.754	3.81
M18	Effective site management and supervision	0.750	3.79
M19	Supporting the market for reused and recycled materials/products	0.724	3.62
M20	Using modern methods of construction	0.715	3.58
M21	Considering deconstruction in design	0.688	3.44
M22	Using information and communication technology to collaborate	0.683	3.42
M23	Promoting CWM arrangements in tender process	0.678	3.40
M24	Raising awareness about the benefits of CWM	0.669	3.35
M25	Monitoring quantities of waste generation on site as a 'key performance indicator' (KPI)	0.667	3.33
M26	Adopting dedicated resources for CWM	0.654	3.25

Table 2. continued

Measure ID	Construction Waste Minimization Measures	Relative importance index (RII)	Mean Rating
M27	Incorporating CWM policies into company's management plans	0.647	3.23
M28	Keeping up to date and disseminating CWM information	0.639	3.20
M29	Including CWM in the Statement of Environmental Effects (SEE) of development application	0.573	2.88

- Skill building (D4): The role of stakeholders to contribute to the application of EM for reducing waste though enhanced CWM education and training.
- Technological innovations (D5): The promotion of EM for CMW via the prioritization of waste preventive technologies.

It is important to identify the CWM critical measures in the context of the NSW construction industry. Such findings could contribute to the application of EM drivers identified. They could also contribute to efforts to improve their implementation within NSW by relevant construction stakeholders. Out of 29 measures, the top 16 CWM measures had high RII and average mean values of 4 and above. These measures were considered critical for CWM for NSW construction projects.

To further demonstrate the criticality of these 16 measures, the Top 2 Box scores (T2B) method was used. T2B explains the combination of the percentage of respondents' views that considered the CWM measures very important and important (Figure 3). The rationale for focusing only on the critical CWM was to enable a more detailed discussion of these critical measures in light of EM. Such a rationale has

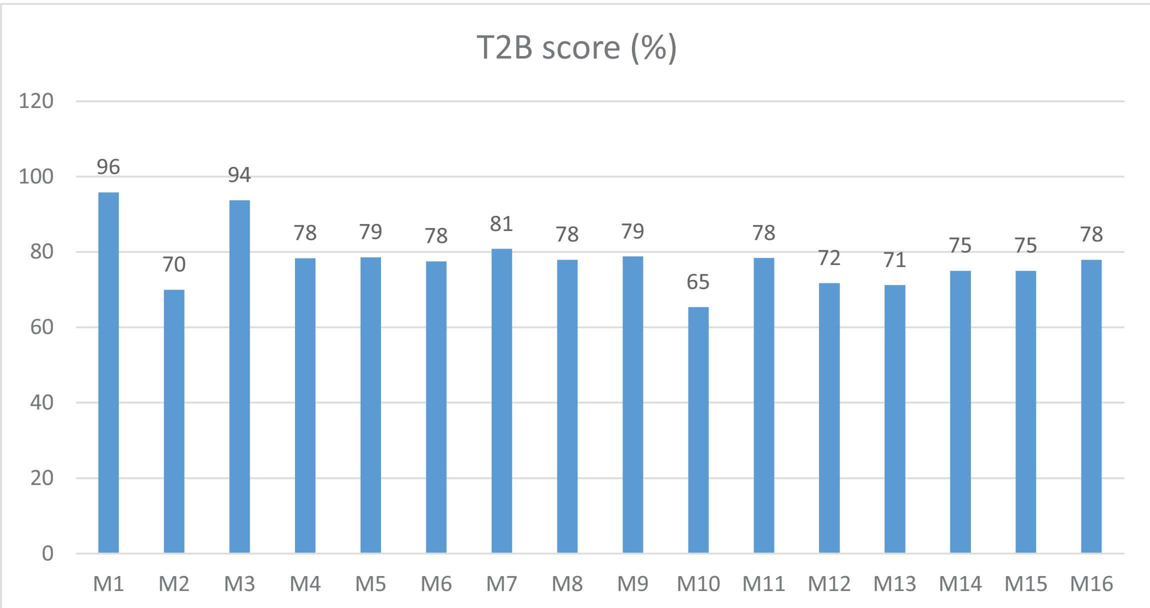

Figure 3. T2B scores for CWM critical measures

been adopted by several studies related to the issues of the construction industry and its waste (Chileshe, et al., 2015; Akinade, et al., 2017; Ajayi, et al., 2017b; Wang, Li and Tam, 2014; Yuan, 2013a). The following sections discuss the drivers of EM application to CWM and the critical measures within them.

AGENTS OF CHANGE

The economic imperative of EM attaches an important role to economic agents (such as designers, clients, suppliers, contractors, and sub-contractors in this study) as facilitators of ecological reform (Mol, 2000; Mol and Sonnenfeld, 2000; Mol and Spaargaren, 2000; Seippel, 2000; Berger, et al., 2001; Huber, 2008). Supporters of EM theory believe that a protected environment is important for economic benefits, and that the role of economic agents is vital to stimulate ecological development (Fisher and Freudenburg, 2001). Based on the outcomes of the factor analysis, the role of project stakeholders emerged as a driver of EM for CWM with an eigenvalue of 7.867 that accounted for 31.46% of the total variance (Figure 2). Project stakeholders thus are agents of change for applying EM for CWM, and their role is critical in the pursuit of an ecologically modernized NSW construction industry. This could be achieved through their roles in the engagement of all project stakeholders into CWM (M2); implementation of waste efficient designs (M5); promotion of CWM culture among project stakeholders (M1); supervision of onsite CWM practices with guidance (M15); pre-qualification of stakeholders based on CWM performance (M10); and demand for CWM as project clients (M9).

Engaging all stakeholders in CWM (M2) is an important aspect for waste-efficient projects. To encourage this, promoting a CWM culture among project stakeholders (M1) is needed. This shift in attitudes and behaviours to CWM on Australian construction projects was echoed by Udawatta, et al. (2015a) and Udawatta, et al. (2015b). Such changes require actions to be taken by contractors on project sites. In this study, survey respondents outlined 'supervise onsite CWM practices with guidance (M15)' as a critical measure. The importance of these onsite CWM related actions was mirrored by Ajayi, et al. (2017b). CWM can be through 'pre-qualifying stakeholders based on CWM performance'. Respondents indicated the importance of the CWM prequalification process. There is general agreement that designers can play a major role in relation to CWM by 'implementing waste efficient design' (Greenwood, 2003; Osmani, Glass and Price, 2008; Baldwin, et al., 2009). This study found 'waste efficient design (M5)' an important CWM measure. Clients can be considered as one of most important stakeholders for promoting CWM (Udawatta, et al., 2015a). This is because the costs of wasted materials as well as of waste disposal are borne by them (Ekanayake and Ofori, 2004; Domingo, 2011). This study found that the role of clients in CWM (M9) is critical. Shen et al. (2004) stressed the role of clients in influencing other stakeholders to adopt CWM approaches. Dainty and Brooke (2004) highlighted the importance of developing a CWM culture among clients reflected through CWM requirements from other project stakeholders.

GOVERNMENT POLICIES

EM sees the role of the government as central in attaining sustainability (Christoff, 1996; Buttel, 2000; York and Rosa, 2003; Jänicke, 2008). EM promotes a government's adoption of contextual steering policies, with a focus on changing curative and reactive policies to preventative ones (Berger, et al., 2001). In the context of this study, this theme suggests that governments should focus on waste prevention policies and interventions. As shown in Figure 2, the role of the government via its CWM-related policies is vital for applying EM to CMW, having an eigenvalue 3.836 that explained 15.34% of the total variance. The role of the government (D2) in applying EM to CMW can take place via increased influence and implementation of waste levies (M11) and site waste minimization and management plans (SWMMP) (M14).

Since its introduction in 1971, the NSW government has gradually raised the waste levy to $138.20/tonne in 2017-18 for metropolitan areas, and from $10/tonne in 2009-10 to $76.70/tonne in 2017-18 for regional regulated areas (POEO, 2015; NSW Environment Protection Authority, 2020). The NSW construction industry spent about $133.4 million on waste levies in the 2018-19 fiscal year, and is expected to spend a $726.7 million up until 2022 (Perrottet, 2018). The levy is the government's key economic instrument to encourage CWM and resource recovery and, as a result, less waste sent to landfills (NSW Office of Environment and Heritage, 2011; NSW Environment Protection Authority, 2020). Osmani (2012) and Martin and Scott (2003) stressed the role of landfill tax as a legislative measure to promote CWM. Participants in this study viewed the waste levy (M11) as critical measure for CWM.

SWMMP is a tool to manage and minimize waste on construction sites (NSW City of Newcastle, 2019; NSW City of sydeny, 2019). In NSW a SWMMP is one of the requirements of development applications (DA) (NSW City of Newcastle, 2019; NSW City of sydeny, 2019). The DA stresses that the plan should consider waste avoidance and minimization, reuse, recycling and the means of waste disposal. In line with this study finding of SWWMP as critical measure to more waste-efficient projects, Udawatta, et al. (2015b) stressed its importance as a critical solution for waste management on construction projects in Australia.

SUPPLY CHAIN DYNAMICS

As a core theme of EM, the economic imperative suggests an increase in the role of industry dynamics in ecological restructuring (Mol, 1999; Welford and Hills, 2003; Huber, 2008). Supply chain dynamics are important to drive the application of EM for CMW; this was shown from the results of factor analysis, with 1.589 of eigenvalue that explained 6.35% of the total variance (Figure 2). The findings indicated that all the measures contributing to CWM through supply chain dynamics were critical to CWM. The application of EM to CWM through supply chain dynamics could be through: CWM partnership through supply chain (M3); On-site materials segregation of waste, reuse and recycling (M7); CWM-related contractual clauses (M12); CWM financial incentives and penalties (M16); and consideration of CWM in materials selection, purchase and delivery (M13). The respondents' opinions thus support their increase uptake as a contributor to CWM.

Respondents highlighted the importance of supply chain partnership (M3) in relation to CWM. Dainty and Brooke (2004) found that effective measures associated with CWM were those that supported 'waste minimization partnerships' throughout supply chains. Mendis (2011) stressed the positive relationship between contractual obligations and CWM. It is argued that CWM partnerships among stakeholders can be strengthened via contractual arrangements and incentives, where these measures were identified as important to CWM. Udawatta, et al. (2015b) found financial rewards to be one of the most important solutions to promote CWM. CWM may also be considered through materials procurement processes (Nagapan, et al., 2012; Ajayi, et al., 2017a). This was mirrored by the respondents of this study. As much as CWM supply chain partnerships with materials suppliers are important, they are also required with waste contractors (Dainty and Brooke, 2004; Ajayi, 2017). Authors have stressed the importance of on-site materials sorting (Domingo, 2011; Ajayi, 2017; Dainty and Brooke, 2004). Respondents agreed that on-site materials sorting is important for CWM within NSW construction industry.

SKILL-BUILDING

Skill building in relation to CWM can significantly contribute to the application of EM to reduce waste. As demonstrated in figure 2, the outcomes of the factor analysis showed that there is significant role for the industry trainers to drive change to EM via CWM training and education. This driver has an eigenvalue of 1.338 that comprised 5.35% of the total variance. Training and education about CWM can be conducted by several organizations and bodies, including the construction companies themselves. In NSW, the education and training associated with the construction industry is provided by universities, technical and further education institutions (TAFE), and relevant trade/industry associations (industry trainers), along with construction companies themselves. Training and education about CWM (M4) was found to be critical to CWM. Education and training are essential components contributing to CWM (Osmani, Glass and Price, 2008; Begum, et al., 2009; Lu and Yuan, 2010; Udawatta, et al., 2015b). Therefore, this study suggests that industry trainers can potentially contribute to CWM through their knowledge providing capabilities, direct or embedded awareness programmes, and education and training of industry stakeholders. Meanwhile, some of them as 'industry associations' can serve as dissemination platforms for CWM related information alongside training. In alignment with this, Udawatta, et al. (2015b) highlighted the significance of education and training for all project stakeholders to enhance CWM practices on Australian construction projects. For industry associations, some authors outlined their role in relation to environmental improvements, heightened awareness, motivation for improvement of environmental behaviours, and effective means of communicating environmental messages to companies (Smith A, 1998; Hunt, 2000; Revell and Rutherfoord, 2003). This mainly due to their close links to industry and ability to provide sector specific information.

TECHNOLOGICAL INNOVATIONS

Technological innovation is a core theme at the heart of EM. In this study, the role of technology in waste minimization is conceptualised as the need for waste preventative technology to minimize construction waste. Technological innovations play a significant role in the shift to EM (Howes, et al., 2010). EM supports the preventive roles of technological innovations to environmental damages (Revell, 2007; Howes, et al., 2010). The results of the factor analysis showed that technological innovation emerged as a key driver to be applied to EM, having an eigenvalue of 1.029 that accounted for 4.11% of the total variance (Figure 2). The results of the study showed that prefabrication technology (M8) and building information modelling (BIM) (M6) are critical measures of technological innovation to CWM.

Prefabrication technology such as prefabricated wall and floor panels, columns, stairs, and facade panels has been increasingly adopted in different construction industries around the world, and CWM is one of the advantages that encourages its use (Jaillon, Poon and Chiang, 2009; Lu and Yuan, 2013). In this study, prefabrication technology (M8) has been found to be a critical measure to CWM in the NSW construction industry. To enhance the efficiency of the Australian construction industry, prefabrication was promoted in the 'Australian Construction Vision 2020' as one of eight key visions (Hampson and Brandon, 2004; Steinhardt, Manley and Miller, 2014). This indicates recognition of the benefits of prefabrication as an approach to improve the efficiency of construction industry. In alignment with this study findings, Udawatta, et al. (2015b) emphasized the importance of prefabrication to make the Australian construction projects more waste efficient. In relation to BIM, variant studies identify BIM as enabler for project stakeholders to effectively minimize waste on their construction projects (Ahankoob, et al., 2012; Liu, et al., 2015; Cheng, Won and Das, 2015). In this study, the use of BIM (M6)' has been identified as critical, and its use can make significant contributions to CWM. BIM thus should be considered as a compelling business case for companies within NSW.

Conclusions

This study investigated the application of EM to reduce the continuous growth of C&D waste currently plaguing the construction industry of NSW. Five important drivers for EM's application to CWM were identified. These drivers conform to the conceptualization of EM's application to CWM via its themes, as represented in the EM-based CWM framework (Figure 1). These drivers were: 'agents of change (D1)', 'government policies (D2)', 'supply chain dynamics (D3)', 'skill building (D4)', and 'technological innovations (D5)'. The role of project stakeholders as agents of change (D1) was found to be important in driving the application of EM to CMW. As agents of change, project stakeholders, such as designers, contactors, sub-contractors, suppliers, and clients can have an important role as conductors of ecological restructuring via the implementation of CWM. Such a role is critical in the pursuit of an ecologically modernized NSW construction industry. The role of the NSW state and local governments (D2) via their CWM-related policies was identified as vital for applying EM to CMW. Supply chain dynamics (D3) to create business opportunities inherent in CWM were also identified as a driver for the application of EM for CMW. It was found that skill building in relation to CWM (D4) can significantly contribute to the application of EM. Technological innovation (D5) emerged as a key driver for applying EM to CWM as well. The critical measures for each of the drivers for applying EM to CWM within the context of the NSW construction industry were also identified.

The outcomes of this study provide a guide for applying EM to CWM for the NSW construction industry. That is, to delink construction industry growth from construction waste generation, and, as a result, enable NSW construction industry growth to occur without compromising and damaging the environment. They can also contribute to reduced C&D waste recycling and gradual diversion of waste sent to the state's C&D landfill sites. Furthermore, the outcomes presented in the study can be used as a yardstick to inform CWM-related policymaking and future CWM-related studies. Data gathering from NSW in Australia and the unexplored potential of EM application to CWM were limitations related to this study. Future studies can investigate the application of EM for other types of waste on construction projects, such as workers, costs, construction machinery, time and materials. They can also examine the application of EM to delink the growth of the construction industry from other aspects of enviornmental harm, such as energy consumption or greenhouse gas emissions.

References

Adams, K., Johnson, P., Thornback, J. and Law, C., 2011. An Action Plan for halving construction, demolition and excavation waste to landfill. prepared on behalf of the Strategic Forum for Construction Report, 2011 (Vol. 10).

Ahankoob, A., Khoshnava, S.M., Rostami, R. and Preece, C., 2012. BIM perspectives on construction waste reduction. Management in Construction Research Association (MiCRA) Postgraduate Conference, pp. 195-199.

Ajayi, S., 2017. *Design, procurement and construction strategies for minimizing waste in construction projects* (Doctoral dissertation, University of the West of England).

Ajayi, S.O. and Oyedele, L.O., 2017. Policy imperatives for diverting construction waste from landfill: Experts' recommendations for UK policy expansion. *Journal of cleaner production,* 147, pp.57-65. https://doi.org/10.1016/j.jclepro.2017.01.075

Ajayi, S.O., Oyedele, L.O., Akinade, O.O., Bilal, M., Alaka, H.A. and Owolabi, H.A., 2017a. Optimising material procurement for construction waste minimization: An exploration of success factors. *Sustainable materials and technologies,* 11, pp.38-46. https://doi.org/10.1016/j.susmat.2017.01.001

Ajayi, S.O., Oyedele, L.O., Bilal, M., Akinade, O.O., Alaka, H.A. and Owolabi, H.A., 2017b. Critical management practices influencing on-site waste minimization in construction projects. *Waste management,* 59, pp.330-339. https://doi.org/10.1016/j.wasman.2016.10.040

Akinade, O.O., Oyedele, L.O., Ajayi, S.O., Bilal, M., Alaka, H.A., Owolabi, H.A., Bello, S.A., Jaiyeoba, B.E. and Kadiri, K.O., 2017. Design for Deconstruction (DfD): Critical success factors for diverting end-of-life waste from landfills. *Waste management,* 60, pp. 3-13. https://doi.org/10.1016/j.wasman.2016.08.017

Australian Communications and Media Authority (ACMA), 2015. *Communications report 2013–14 series Report 1—Australians' digital lives* [Online]. Available: https://www.acma.gov.au/sites/default/files/2019-08/research-digital-lives-Mar-2015.pdf [Accessed 19 jan 2019].

Al-Hajj, A. and Hamani, K., 2011. Material waste in the UAE construction industry: main causes and minimization practices. *Architectural engineering and design management,* 7(4), pp.221-235. https://doi.org/10.1080/17452007.2011.594576

Al-Tmeemy, S.M.H., Abdul-Rahman, H. and Harun, Z., 2012. Contractors' perception of the use of costs of quality system in Malaysian building construction projects. *International Journal of Project Management,* 30(7), pp.827-838. https://doi.org/10.1016/j.ijproman.2011.12.001

Alwi, S., Mohamed, S. and Hampson, K., 2002. Waste in the Indonesian construction projects. In Proceedings of the 1st CIB-W107 International Conference-Creating a Sustainable Construction Industry in Developing Countries (pp. 305-315). CSIR.

Assaf, S.A. and Al-Hejji, S., 2006. Causes of delay in large construction projects. *International journal of project management,* 24(4), pp.349-357. https://doi.org/10.1016/j.ijproman.2005.11.010

Australian Business Register, 2019. *active ABNs and names lookup* [Online]. Available: https://abr.business.gov.au/Search/Advanced [Accessed 01 Jan 2019].

Australisan Construction Industry Forum (ACIF), 2017. Australian Construction Market Report 2017 [Online]. Available: https://www.acif.com.au/subscribe/type/acif-forecasts-may-2017 [Accessed 29 July 2021].

Australisan Construction Industry Forum (ACIF), 2019. Australian Construction Market Report MAY 2019 [Online]. Available: https://www.acif.com.au/documents/item/869 [Accessed 29 July 2021].

Baker, S. and Eckerberg, K., 2008. Introduction: In pursuit of sustainable development at the sub-national level: The 'new'governance agenda. *In Pursuit of Sustainable Development.* Routledge. https://doi.org/10.4324/9780203928165

Baldwin, A., Poon, C.-S., Shen, L.-Y., Austin, S. and Wong, I., 2007. Reducing construction waste by decisions within the design process. CIB World Building Congress, 2007. pp.2568-2583.

Baldwin, A., Poon, C.-S., Shen, L.-Y., Austin, S. and Wong, I., 2009. Designing out waste in high-rise residential buildings: Analysis of precasting methods and traditional construction. *Renewable energy,* 34(9), pp.2067-2073. https://doi.org/10.1016/j.renene.2009.02.008

Begum, R.A., Siwar, C., Pereira, J.J. and Jaafar, A.H., 2009. Attitude and behavioral factors in waste management in the construction industry of Malaysia. *Resources, Conservation and Recycling,* 53 (6), pp.321-328. https://doi.org/10.1016/j.resconrec.2009.01.005

Berger, G., Flynn, A., Hines, F. and Johns, R., 2001. Ecological modernization as a basis for environmental policy: Current environmental discourse and policy and the implications on environmental supply chain management. *Innovation: The European Journal of Social Science Research,* 14 (1), pp.55-72. https://doi.org/10.1080/13511610125074

Bowling, A., 2014. *Research methods in health: investigating health and health services*, McGraw-hill education (UK).

Brown, J., 2001. What is an eigenvalue? *JALT Testing & Evaluation SIG Newsletter,* 5.

Buttel, F.H., 2000. Ecological modernization as social theory. *Geoforum,* 31(1), pp.57-65. https://doi.org/10.1016/S0016-7185(99)00044-5

Cha, H.S., Kim, J. and Han, J.-Y., 2009. Identifying and assessing influence factors on improving waste management performance for building construction projects. *Journal of construction engineering and management,* 135(7), pp.647-656. https://doi.org/10.1061/(ASCE)0733-9364(2009)135:7(647)

Chen, Y., Okudan, G.E. and Riley, D.R., 2010. Sustainable performance criteria for construction method selection in concrete buildings. *Automation in construction,* 19(2), pp.235-244. https://doi.org/10.1016/j.autcon.2009.10.004

Chen, Z., Li, H. and Wong, C.T., 2002. An application of bar-code system for reducing construction wastes. *Automation in Construction,* 11(5), pp.521-533. https://doi.org/10.1016/S0926-5805(01)00063-2

Cheng, J.C., Won, J. and Das, M., 2015. Construction and demolition waste management using BIM technology. 23rd Ann. Conf. of the International Group for Lean Construction, Perth, Australia, 2015. pp.381-390.

Chileshe, N., Rameezdeen, R., Hosseini, M.R. and Lehmann, S., 2015. Barriers to implementing reverse logistics in South Australian construction organisations. *Supply Chain Management: An International Journal*, 20(2), pp.179-204 https://doi.org/10.1108/SCM-10-2014-0325

Christoff, P., 1996. Ecological modernisation, ecological modernities. *Environmental politics,* 5(3), pp.476-500. https://doi.org/10.1080/09644019608414283

Cohen, M.J., 2006. Ecological modernization and its discontents: The American environmental movement's resistance to an innovation-driven future. *Futures,* 38(5), pp.528-547. https://doi.org/10.1016/j.futures.2005.09.002

Cooper, J., 1996. Controls and incentives: A framework for the utilisation of bulk wastes. *Waste Management,* 16(3), pp.209-213. https://doi.org/10.1016/S0956-053X(96)00043-8

Corner, S., 2009. Choosing the right type of rotation in PCA and EFA. *JALT testing & evaluation SIG newsletter,* 13(3), pp.20-25.

Coventry, S., Shorter, B. and Kingsly, M., 2001. Demonstrating waste minimization benefits. *CIRIA report*, *536*.

Cui, G., Peng, L. and Florès, L.P., 2015. Selecting ideas for new product development: Comparison of monadic test and adaptive concept screening under the G theory framework. *European Journal of Innovation Management*, 18(3), pp.380-396 https://doi.org/10.1108/EJIM-04-2014-0046

Dainty, A.R. and Brooke, R.J., 2004. Towards improved construction waste minimisation: a need for improved supply chain integration? *Structural Survey,* 22(1), pp.20-29. https://doi.org/10.1108/02630800410533285

Del Río Merino, M., Izquierdo Gracia, P. and Weis Azevedo, I.S., 2010. Sustainable construction: construction and demolition waste reconsidered. *Waste management & research,* 28(2), pp.118-129. https://doi.org/10.1177/0734242X09103841

Devellis, R.F., 2016. *Scale development: Theory and applications (Vol.26)*. Sage publications.

Doloi, H., 2009. Analysis of pre-qualification criteria in contractor selection and their impacts on project success. *Construction Management and Economics,* 27(12), pp.1245-1263. https://doi.org/10.1080/01446190903394541

Doloi, H., Sawhney, A., Iyer, K. and Rentala, S., 2012. Analysing factors affecting delays in Indian construction projects. *International journal of project management,* 30(4), pp.479-489. https://doi.org/10.1016/j.ijproman.2011.10.004

Domingo, N., 2011. *Reducing construction waste in healthcare projects: a project lifecycle approach* (Doctoral dissertation, Loughborough University).

Domingo, N., Osmani, M. and Price, A., 2009. Construction waste minimisation in the UK healthcare industry. IN: Dainty, RJ. Proceedings of the 25th Annual ARCOM Conference, 2009. ARCOM (cc ARCOM and the authors), 7-9 September 2009, Albert Hall, Nottingham. Association of Researchers in Construction Management, 2, pp.1021-30.

Ekanayake, L.L. and Ofori, G., 2004. Building waste assessment score: design-based tool. *Building and Environment,* 39(7), pp.851-861. https://doi.org/10.1016/j.buildenv.2004.01.007

Faniran, O. and Caban, G., 1998. Minimizing waste on construction project sites. *Engineering, construction and architectural management,* 5(2), pp.182-188. https://doi.org/10.1108/eb021073

Field, A., 2009. Correcting problems in the data. Discovering statistics using SPSS. London: SAGE Publications Ltd.

Field, A., 2013. *Discovering statistics using IBM SPSS statistics*, sage.

Fisher, D.R. and Freudenburg, W.R., 2001. Ecological modernization and its critics: Assessing the past and looking toward the future. *Society & natural resources,* 14(8), pp.701-709. https://doi.org/10.1080/08941920119315

Formoso, C.T., Soibelman, L., De Cesare, C. and Isatto, E.L., 2002. Material waste in building industry: main causes and prevention. *Journal of construction engineering and management,* 128(4), pp.316-325. https://doi.org/10.1061/(ASCE)0733-9364(2002)128:4(316)

Gamage, I., Osmani, M. and Glass, J., 2009. An investigation into the impact of procurement systems on waste generation: the contractors' perspective. *Proceedings of the Association of Researchers in Construction Management (ARCOM), Nottingham, UK*, pp.103-104.

Gravetter, F.J., Wallnau, L.B., Forzano, L.A.B. and Witnauer, J.E., 2020. Essentials of statistics for the behavioral sciences. Cengage Learning.

Gavilan, R.M. and Bernold, L.E., 1994. Source evaluation of solid waste in building construction. *Journal of construction engineering and management,* 120(3), pp.536-552. https://doi.org/10.1061/(ASCE)0733-9364(1994)120:3(536)

Greenwood, R., 2003. *Construction waste minimisation: good practice guide*, Cardiff University, Centre for Research in the Built Environment.

Hadi, N.U., Abdullah, N. and Sentosa, I., 2016. An easy approach to exploratory factor analysis: Marketing perspective. *Journal of Educational and Social Research,* 6(1), pp.215.

Hampson, K.D. and Brandon, P., 2004. *Construction 2020-A vision for Australia's property and construction industry*, CRC Construction Innovation.

NSW Office of Environment and Heritage, 2011. *Impact of the waste levy on commercial and industrial recycling.* Centre for International Economics Canberra & Sydney [Online]. Available: https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/wasteregulation/cie-waste-levy-comm-recycling.pdf?la=en&hash=59AD443C341CA2E9D5FF32E61C68789A8B26D71B [Accessed 02 June 2019].

Howes, M., Mckenzie, M., Gleeson, B., Gray, R., Byrne, J. and Daniels, P., 2010. Adapting ecological modernisation to the Australian context. *Journal of integrative environmental sciences,* 7(1), pp.5-21. https://doi.org/10.1080/19438150903478597

Huber, J., 1991. Ecological modernization. Away from scarcity, soberness and bureaucracy. *by A. Mol, G. Spaargaren, A. Kalpxijk. Den Haag: SDU.*

Huber, J., 2008. Pioneer countries and the global diffusion of environmental innovations: Theses from the viewpoint of ecological modernisation theory. *Global Environmental Change,* 18(3), pp.360-367. https://doi.org/10.1016/j.gloenvcha.2008.03.004

Hunt, J., 2000. Environment, information and networks: how does information reach small and medium-sized enterprises. *Small and medium-sized enterprises and the environment*, pp.194-202. https://doi.org/10.9774/GLEAF.978-1-909493-11-7_17

Infrastructure NSW, 2020. RESPONSE TO COVID-19. [Online]. Available: https://www.infrastructure.nsw.gov.au/industry/response-to-covid-19/ [Accessed 28 July 2021].

Jaillon, L., Poon, C.-S. and Chiang, Y., 2009. Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. *Waste management,* 29(1), pp.309-320. https://doi.org/10.1016/j.wasman.2008.02.015

Jänicke, M., 1985. *Preventive environmental policy as ecological modernisation and structural policy*, IIUG Berlin.

Jänicke, M., 2008. Ecological modernisation: new perspectives. *Journal of cleaner production,* 16(5), pp.557-565. https://doi.org/10.1016/j.jclepro.2007.02.011

Jänicke, M., Binder, M. and Mönch, H., 1994. *Green Industrial Policy and the Future of" dirty Industries"*, Forschungsstelle für Umweltpolitik, FU Berlin, Fachbereich Politische Wiss.

Jänicke, M., Binder, M. and Mönch, H., 1997. 'Dirty industries': Patterns of change in industrial countries. *Environmental and resource economics,* 9(4), pp.467-491. https://doi.org/10.1007/BF02441762

Jänicke, M. and Jacob, K., 2004. Lead markets for environmental innovations: a new role for the nation state. *Global environmental politics,* 4(1), pp.29-46. https://doi.org/10.1162/152638004773730202

Jingkuang, L. and Yousong, W., 2011. Establishment and application of performance assessment model of waste management in architectural engineering projects in China. *Systems Engineering Procedia,* 1, pp.147-155. https://doi.org/10.1016/j.sepro.2011.08.025

Johanson, G.A. and Brooks, G.P., 2010. Initial scale development: sample size for pilot studies. *Educational and psychological measurement,* 70(3), pp.394-400. https://doi.org/10.1177/0013164409355692

Johnston, D., 2020. *NSW Government vows to fast-track major construction projects during coronavirus crisis* [Online]. Available: https://www.bordermail.com.au/story/6716362/construction-wheels-must-keep-turning-in-covid-19/ [Accessed 10 April 2020].

Johnston, H. and Mincks, W.R., 1995. Cost-effective waste minimization for construction managers. *Cost Engineering,* 37(1), p.31.

Kulatunga, U., Amaratunga, D., Haigh, R. and Rameezdeen, R., 2006. Attitudes and perceptions of construction workforce on construction waste in Sri Lanka. *Management of Environmental Quality: An International Journal,* 17(1), pp.57-72. https://doi.org/10.1108/14777830610639440

Langhelle, O., 2000. Why ecological modernization and sustainable development should not be conflated. *Journal of environmental policy and planning,* 2(4), pp.303-322. https://doi.org/10.1080/714038563

Le, K.N. and Tam, V.W., 2008. On generic skill development: An engineering perspective. *Digital Signal Processing,* 18(3), pp.355-363. https://doi.org/10.1016/j.dsp.2007.04.015

Lee, S.-K., Kim, K.-R. and Yu, J.-H., 2014. BIM and ontology-based approach for building cost estimation. *Automation in construction,* 41, pp.96-105. https://doi.org/10.1016/j.autcon.2013.10.020

Lingard, H., Graham, P. and Smithers, G., 2000. Employee perceptions of the solid waste management system operating in a large Australian contracting organization: implications for company policy implementation. *Construction Management & Economics,* 18(4), pp.383-393. https://doi.org/10.1080/014461900050024806

Liu, Z., Osmani, M., Demian, P. and Baldwin, A., 2015. A BIM-aided construction waste minimisation framework. *Automation in construction,* 59, pp.1-23. https://doi.org/10.1016/j.autcon.2015.07.020

Lu, W. and Yuan, H., 2010. Exploring critical success factors for waste management in construction projects of China. *Resources, conservation and recycling,* 55(2), pp.201-208. https://doi.org/10.1016/j.resconrec.2010.09.010

Lu, W. and Yuan, H., 2011. A framework for understanding waste management studies in construction. *Waste management,* 31(6), pp. 1252-1260. https://doi.org/10.1016/j.wasman.2011.01.018

Lu, W. and Yuan, H., 2013. Investigating waste reduction potential in the upstream processes of offshore prefabrication construction. *Renewable and Sustainable Energy Reviews,* 28, pp.804-811. https://doi.org/10.1016/j.rser.2013.08.048

Manowong, E., 2012. Investigating factors influencing construction waste management efforts in developing countries: an experience from Thailand. *Waste Management & Research,* 30(1), pp.56-71. https://doi.org/10.1177/0734242X10387012

Marinelli, M., Dolan, M., Spillane, J.P. and Konanahalli, A., 2014. Material waste in the Northern Ireland construction industry: On-site management causes and methods of prevention. In: Raiden, A B and Aboagye-Nimo, E (Eds) *Procs 30th Annual ARCOM Conference*, 1-3 September 2014, Portsmouth, UK, Association of Researchers in Construction Management, pp. 113-122

Martin, A. and Scott, I., 2003. The effectiveness of the UK landfill tax. *Journal of environmental planning and management,* 46(5), pp.673-689. https://doi.org/10.1080/0964056032000138436

Mcdonald, B. and Smithers, M., 1998. Implementing a waste management plan during the construction phase of a project: a case study. *Construction Management & Economics,* 16(1), pp.71-78. https://doi.org/10.1080/014461998372600

Mcgrath, C., 2001. Waste minimisation in practice. *Resources, conservation and recycling,* 32(4), pp.227-238. https://doi.org/10.1016/S0921-3449(01)00063-5

Mckechnie, E. and Brown, E., 2007. Achieving effective waste minimisation through design: guidance for construction clients, design teams and contractors. *Oxon,: Ed. Waste & Resources Action Programme*.

Mehran, D., 2016. Exploring the Adoption of BIM in the UAE Construction Industry for AEC Firms. *Procedia Engineering,* 145, pp.1110-1118. https://doi.org/10.1016/j.proeng.2016.04.144

Mendis, D.P., 2011. Contractual obligations analysis for construction waste management (Doctoral dissertation, University of British Columbia).

Mol, A., 1995. The Refinement of Production: Ecological Modernization Theory and the Chemical Industry (The Hague: cip-data Koninklijke Bibliotheek).

Mol, A. and Spaargaren, G., 1998. Ecological modernization in debate: a review. 14th World Congress of the International Sociological Association, Montreal, 1998.

Mol, A.P., 1997. Ecological modernization: industrial transformations and environmental reform. *The international handbook of environmental sociology*, pp.138-149.

Mol, A.P., 1999. Ecological modernization and the environmental transition of Europe: between national variations and common denominators. *Journal of Environmental Policy & Planning,* 1(2), pp.167-181. https://doi.org/10.1080/714038532

Mol, A.P., 2000. The environmental movement in an era of ecological modernisation. *Geoforum,* 31(1), pp.45-56. https://doi.org/10.1016/S0016-7185(99)00043-3

Mol, A.P., 2006. Environment and modernity in transitional China: frontiers of ecological modernization. *Development and Change,* 37(1), pp.29-56. https://doi.org/10.1111/j.0012-155X.2006.00468.x

Mol, A.P. and Sonnenfeld, D.A., 2000. Ecological modernisation around the world: An introduction , 9(1), pp.1-14. https://doi.org/10.1080/09644010008414510

Mol, A.P. and Spaargaren, G., 1993. Environment, modernity and the risk-society: the apocalyptic horizon of environmental reform. *International sociology,* 8(4), pp.431-459. https://doi.org/10.1177/026858093008004003

Mol, A.P. and Spaargaren, G., 2000. Ecological modernisation theory in debate: a review. *Environmental politics,* 9(1), pp.17-49. https://doi.org/10.1080/09644010008414511

Morgan, C. and Stevenson, F., 2005. Design and Detailing for Deconstruction-SEDA Design Guide for Scotland-No. 1, Scottish Ecological Design Association (SEDA), Northumberland, UK.

Nagapan, S., Rahman, I.A., Asmi, A., Memon, A.H. and Zin, R.M., 2012. Identifying causes of construction waste–case of Central Region of Peninsula Malaysia. *International Journal of Integrated Engineering*, *4*(2). Retrieved from https://publisher.uthm.edu.my/ojs/index.php/ijie/article/view/190

Norman, G., 2010. Likert scales, levels of measurement and the "laws" of statistics. *Advances in health sciences education,* 15(5), pp.625-632. https://doi.org/10.1007/s10459-010-9222-y

Norusis, M.J., 1993. SPSS Inc. 1993 SPSS for windows: professional statistics, release 6. *Chicago: SPSS Inc*.

Nowosielski, R., Kania, A. and Spilka, M., 2010. Recycling as an important element of engineering design. *Journal of Achievements in Materials and Manufacturing Engineering,* 42(1-2), pp.188-195.

Department of Environment & Climate Channge NSW (DECC), 2007a. *NSW Waste Avoidance and Resource Recovery Strategy 2007* [Online]. Available: https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/wastestrategy/070242-warr-overview07.pdf?la=en&hash=ACC172D0CECC5AE215741570B722E87D8E7D497B [Accessed 29 July 2021].

Department of Environment & Climate Channge NSW (DECC), 2007b. *Report into the Construction and Demolition Waste Stream Audit 2000-2005* [Online]. Available: https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/warrlocal/070320-constr-demol-waste1.pdf [Accessed 29 July 2021].

NSW City of Newcastle, 2019. *Prepare a Site Waste Minimisation and Management Plan* [Online]. Available: https://newcastle.nsw.gov.au/Newcastle/media/Documents/Council/Forms%20and%20Permits/RPA/Prepare-a-Site-Waste-Minimisation-and-Management-Plan.pdf?ext=.pdf [Accessed 15 jan 2021].

NSW City of Sydeny, 2019. *Guidelines for Waste Management in New Developments* [Online]. Available: https://www.cityofsydney.nsw.gov.au/development-guidelines-policies/guidelines-waste-management-new-developments [Accessed 01 jan 2021].

NSW Department of Planning, Industry and Environment (NSW DPIE), 2020. *Construction hours extended to support industry during COVID-19* [Online]. Available: https://www.planning.nsw.gov.au/News/2020/Construction-hours-extended-to-support-industry-during-covid-19 [Accessed 05 April 2020].

NSW Environment Protection Authority, 2015. Waste and recycling | State of the Environment 2015. NSW: New South Wales State of the Environment.

NSW Environment Protection Authority, 2019. *Waste Avoidance and Resource Recovery Strategy Progress Report 2017-18* [Online]. Available: https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/recycling/19p1690-warr-strategy-progress-report-2017-18.pdf?la=en&hash=89CD40E994CC383F6A1E23512714FD3FF5C69C6C [Accessed 15 Feb 2020].

NSW Environment Protection Authority, 2020. *Waste levy* [Online]. Available: https://www.epa.nsw.gov.au/your-environment/waste/waste-levy [Accessed 25 July 2020].

Nunnally, J.C., 1994. *Psychometric theory 3E*, Tata McGraw-Hill Education.

Osmani, M., 2012. Construction waste minimization in the UK: current pressures for change and approaches. *Procedia-Social and Behavioral Sciences,* 40**,** pp. 37-40. https://doi.org/10.1016/j.sbspro.2012.03.158

Osmani, M., 2013, August. Design waste mapping: a project life cycle approach. In *Proceedings of the Institution of Civil Engineers-Waste and Resource Management*, 166(3), pp.114-127, ICE Publishing. https://doi.org/10.1680/warm.13.00013

Osmani, M., Glass, J. and Price, A.D., 2008. Architects' perspectives on construction waste reduction by design. *Waste management,* 28(7)**,** pp.1147-1158. https://doi.org/10.1016/j.wasman.2007.05.011

Peng, C.-L., Scorpio, D.E. and Kibert, C.J., 1997. Strategies for successful construction and demolition waste recycling operations. *Construction Management & Economics,* 15(1)**,** pp.49-58. https://doi.org/10.1080/014461997373105

Perrottet, H.D., 2018. *NSW Budget 2018-19 Half-Yearly Review* [Online]. NSW. Available: https://www.budget.nsw.gov.au/sites/default/files/budget-2018-12/2018-19%20Half-Yearly%20Review.pdf [Accessed 05 july 2020].

Pickin J, Paul Randell, Jenny Trinh, and Bill Grant., 2018. National Waste Report 2018. Department of the Environment and Energy.

POEO, 2015. *Waste Levy Guidelines - Office of Environment and Heritage* [Online]. Available: https://www.environment.nsw.gov.au/resources/wasteregulation/150489-waste-levy-guidelines.pdf [Accessed 20 June 2020].

Poon, C.-S., Yu, A.T. and Jaillon, L., 2004. Reducing building waste at construction sites in Hong Kong. *Construction Management and Economics,* 22(5), pp.461-470. https://doi.org/10.1080/0144619042000202816

Poon, C., Ann, T. and Ng, L., 2001. On-site sorting of construction and demolition waste in Hong Kong. *Resources, conservation and recycling,* 32(2), pp.157-172. https://doi.org/10.1016/S0921-3449(01)00052-0

Poon, C.S., Yu, A.T. and Ng, L., 2003. Comparison of low-waste building technologies adopted in public and private housing projects in Hong Kong. *Engineering, Construction and Architectural Management,* 10(2), pp.88-98. https://doi.org/10.1108/09699980310466578

Poon, C.S., Yu, A.T.W., Wong, S.W. and Cheung, E., 2004. Management of construction waste in public housing projects in Hong Kong. *Construction Management & Economics,* 22(7), pp. 675-689. https://doi.org/10.1080/0144619042000213292

Porwal, A. and Hewage, K.N., 2013. Building Information Modeling (BIM) partnering framework for public construction projects. *Automation in construction,* 31, pp. 204-214. https://doi.org/10.1016/j.autcon.2012.12.004

Revell, A., 2007. The ecological modernisation of SMEs in the UK's construction industry. *Geoforum,* 38(1), pp. 114-126. https://doi.org/10.1016/j.geoforum.2006.07.006

Revell, A. and Rutherfoord, R., 2003. UK environmental policy and the small firm: broadening the focus. *Business Strategy and the Environment,* 12(1), pp. 26-35. https://doi.org/10.1002/bse.347

Rios, F.C., Chong, W.K. and Grau, D., 2015. Design for disassembly and deconstruction-challenges and opportunities. *Procedia engineering,* 118, pp.1296-1304. https://doi.org/10.1016/j.proeng.2015.08.485

Saez, P.V., Del Río Merino, M., González, A.S.-A. and Porras-Amores, C., 2013. Best practice measures assessment for construction and demolition waste management in building constructions. *Resources, Conservation and Recycling,* 75, pp.52-62. https://doi.org/10.1016/j.resconrec.2013.03.009

Salama, W., 2017. Design of concrete buildings for disassembly: An explorative review. *International Journal of Sustainable Built Environment,* 6(2), pp.617-635. https://doi.org/10.1016/j.ijsbe.2017.03.005

Sambandam, R. and Hausser, G., 1998. An Alternative methods of reporting customer satisfaction scores. *Quirk's Marketing Research Review. Retrieved July,* 19, 2019.

Sanda, D., 2020. *NSW fast-tracks projects to boost economy* [Online]. Available: https://www.canberratimes.com.au/story/6737557/nsw-fast-tracks-projects-to-boost-economy/?cs=14231 [Accessed 29 April 2020].

Seippel, Ø., 2000. Ecological modernization as a theoretical device: strengths and weaknesses. *Journal of Environmental Policy and Planning,* 2(4), pp.287-302. https://doi.org/10.1002/1522-7200(200010/12)2:4<287::AID-JEPP59>3.0.CO;2-V

Smith A, K.R., 1998. Small Firms and the Environment. *In:* Trust:, A. G. R. G.andBirmingham. (eds.).

Smith, P., 2014. BIM implementation–global strategies. *Procedia Engineering,* 85, pp.482-492. https://doi.org/10.1016/j.proeng.2014.10.575

Sonnenfeld, D.A. and Mol, A.P., 2002. Ecological modernization, governance, and globalization: Epilogue. *American behavioral scientist,* 45(9), pp.1456-1461. https://doi.org/10.1177/0002764202045009009

Spaargaren, G., 2003. Sustainable consumption: a theoretical and environmental policy perspective. *Society &Natural Resources,* 16(8), pp.687-701. https://doi.org/10.1080/08941920309192

Steinhardt, D.A., Manley, K. and Miller, W., 2014. What's driving the uptake of prefabricated housing in Australia? (Unpublished). Available: https://eprints.qut.edu.au/81178/ [Accessed 14 August 2021].

Tabachnick, B.G., Fidell, L.S. and Ullman, J.B., 2007. *Using multivariate statistics*, Pearson Boston, MA.

Tam, V.W., 2008. On the effectiveness in implementing a waste-management-plan method in construction. *Waste management,* 28(6), pp.1072-1080. https://doi.org/10.1016/j.wasman.2007.04.007

Tam, V.W., Tam, C.M., Zeng, S. and Ng, W.C., 2007. Towards adoption of prefabrication in construction. *Building and environment,* 42(10), pp.3642-3654. https://doi.org/10.1016/j.buildenv.2006.10.003

Tavakol, M. and Dennick, R., 2011. Making sense of Cronbach's alpha. *International journal of medical education,* 2, p.53. https://doi.org/10.5116/ijme.4dfb.8dfd

Teo, M. and Loosemore, M., 2001. A theory of waste behaviour in the construction industry. *Construction Management and Economics,* 19(7), pp.741-751. https://doi.org/10.1080/01446190110067037

Udawatta, N., Zuo, J., Chiveralls, K. and Zillante, G., 2015a. Attitudinal and behavioural approaches to improving waste management on construction projects in Australia: benefits and limitations. *International journal of construction management,* 15(2), pp.137-147. https://doi.org/10.1080/15623599.2015.1033815

Udawatta, N., Zuo, J., Chiveralls, K. and Zillante, G., 2015b. Improving waste management in construction projects: an Australian study. *Resources, Conservation and Recycling,* 101, pp.73-83. https://doi.org/10.1016/j.resconrec.2015.05.003

Walliman, N., 2005. *Your research project: a step-by-step guide for the first-time researcher*, Sage.

Wang, J.-Y., Kang, X.-P. and Wing-Yan Tam, V., 2008. An investigation of construction wastes: an empirical study in Shenzhen. *Journal of Engineering, Design and Technology,* 6(3), pp.227-236. https://doi.org/10.1108/17260530810918252

Wang, J., Li, Z. and Tam, V.W., 2014. Critical factors in effective construction waste minimization at the design stage: a Shenzhen case study, China. *Resources, Conservation and Recycling,* 82, pp.1-7. https://doi.org/10.1016/j.resconrec.2013.11.003

Wang, J., Yuan, H., Kang, X. and Lu, W., 2010. Critical success factors for on-site sorting of construction waste: a China study. *Resources, conservation and recycling,* 54(11), pp.931-936. https://doi.org/10.1016/j.resconrec.2010.01.012

Welford, R. and Hills, P., 2003. Ecological modernisation, environmental policy and innovation: priorities for the Asia-Pacific region. *International journal of environment and sustainable development,* 2(3), pp.324-340. https://doi.org/10.1504/IJESD.2003.003847

Williams, B., Onsman, A. and Brown, T., 2010. Exploratory factor analysis: A five-step guide for novices. *Australasian journal of paramedicine,* 8 (3), pp.1-13 https://doi.org/10.33151/ajp.8.3.93

Wong, A., Wong, F.K. and Nadeem, A., 2009. Comparative roles of major stakeholders for the implementation of BIM in various countries. Proceedings of the International Conference on Changing Roles: New Roles, New Challenges, Noordwijk Aan Zee, The Netherlands, 2009.

Wong, E.O. and Yip, R.C., 2004. Promoting sustainable construction waste management in Hong Kong. *Construction Management and Economics*, *22*(6), pp.563-566. https://doi.org/10.1080/0144619042000226270

Wright, J. and Kurian, P., 2010. Ecological modernization versus sustainable development: The case of genetic modification regulation in New Zealand. *Sustainable Development,* 18(6), pp.398-412. https://doi.org/10.1002/sd.430

York, R. and Rosa, E.A., 2003. Key challenges to ecological modernization theory: Institutional efficacy, case study evidence, units of analysis, and the pace of eco-efficiency. *Organization & Environment,* 16(3), pp.273-288. https://doi.org/10.1177/1086026603256299

Yuan, H., 2013a. Critical management measures contributing to construction waste management: Evidence from construction projects in China. *Project Management Journal,* 44(4), pp.101-112. https://doi.org/10.1002/pmj.21349

Yuan, H., 2013b. A SWOT analysis of successful construction waste management. *Journal of Cleaner Production,* 39, pp.1-8. https://doi.org/10.1016/j.jclepro.2012.08.016

Yuan, H. and Shen, L., 2011. Trend of the research on construction and demolition waste management. *Waste management,* 31(4), pp.670-679. https://doi.org/10.1016/j.wasman.2010.10.030

Zaman, A.U. and Lehmann, S., 2011. Urban growth and waste management optimization towards 'zero waste city'. *City, Culture and Society,* 2(4), pp.177-187. https://doi.org/10.1016/j.ccs.2011.11.007