

Waste Effectiveness of the Construction Industry: Understanding the Impediments and Requisites for Improvements.

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Abstract

Construction industry contributes a large portion of waste to landfill, which in turns results in environmental pollution and CO₂ emission. Despite the adoption of several waste management strategies, waste reduction to landfill continues seeming an insurmountable challenge. This paper explores factors impeding the effectiveness of existing waste management strategies, as well as strategies for reducing waste intensiveness of the construction industry. Drawing on series of semi structured focus group discussions with experts from the UK leading construction companies, this paper combines phenomenological approach with a critical review and analysis of extant literatures.

Five broad categories of factors and practices are responsible for ineffectiveness of construction and demolition waste management strategies, which subsequently results in waste intensiveness of the industry. These include end of pipe treatment of waste, externality and incompatibility of waste management tools with design tools, atomism of waste management strategies, perceived or unexpected high cost of waste management, and culture of waste behaviour within the industry. To reduce waste intensiveness of the construction industry, the study suggests that six factors are requisites. These are tackling of waste at design stage, whole life waste consideration, compliance of waste management solutions with BIM, cheaper cost of waste management practice, increased stringency of waste management legislation and fiscal policies, and research and enlightenment. The proposed strategies are not only important for achieving low waste construction projects, they are important for reducing waste intensiveness of the construction. Implementation of the suggested measures would drive waste management practices within the construction industry.

Keywords: Effective Waste management; Landfill; BIM; Construction waste; Reuse and recycling.

39 **1. Introduction**

40 Owing to its waste intensiveness and consumption of large resources, construction industry has
41 particularly remained a major target for environmental sustainability (Anderson et al, 2002).
42 Evidence shows that the industry consumes up to 50% of mineral resources from nature (Anink
43 *et al.*, 1996) and generates up to 35% of waste to landfill (Solís-Guzmán *et al.*, 2009). It also
44 contributes over 33% of global CO₂ (Baek *et al.*, 2013). In addition, waste reduction and
45 reduced resource excavation have significant economic benefits (Coventry and Guthrie, 1998).
46 Evidence shows that reducing construction waste by 5% could save up to £130million in the
47 UK construction industry (BRE, 2003). Although these clearly show that reducing waste
48 generated by construction activities tends to provide both economic and environmental
49 benefits, waste generated by Construction and demolition (C&D) activities remains alarming.
50 These concerns have influenced formulation of various strategic policies towards diverting
51 construction waste from landfill sites.

52
53 Several waste management techniques and strategies have been adopted over the years, with
54 ability to efficiently manage waste becoming criteria for measuring successful construction
55 operations. Governments across nations have formulated various strategies towards minimizing
56 waste to landfill, thus becoming a major driver of construction waste management in many
57 regions (Yuan, 2013). For instance, in a bid to ensure that economic growth associated with
58 increasing construction activities does not result in increasing waste and environmental
59 pollution, waste management across the entire project lifecycle remains a top priority of the
60 European Union's Environment Action Plan (EU, 2010). These set of policies often become
61 reviewed over the years to express change in government approach towards tackling impending
62 environmental problems associated with waste generation.

63
64 While government's efforts towards waste management is usually influenced by environmental
65 concerns (Defra, 2011), financial gains associated with the strategies usually influence the
66 industry professionals (Al-Hajj and Hamani, 2008; Oyedele *et al.*, 2013). As such, economic
67 benefit of implementing different waste management strategies is well investigated (Begum *et*
68 *al.*, 2006; Durana *et al.*, 2006). However, the efficacy of Construction and Demolition (C&D)
69 waste management strategies and associated Life Cycle Analysis (LCA) towards actual waste
70 minimization are usually based on general assumptions, thus remains inadequately explored.
71 Yuan and Shen (2011) reviewed trends in C&D waste management research and concluded
72 that although various strategies have been employed towards managing waste in construction
73 projects, there is no benchmark for determining effectiveness of the different approaches.

74

75 In addition, evidence shows that despite increasing waste management research and policies,
76 proportion of construction waste landfilled increases. For instance, proportion of C&D waste in
77 UK landfill sites increases from 33% in 2010 (Paine and Dhir, 2010) to 44% in 2013,
78 according to the Department for Environment, Foods and Rural Affairs. This increasing
79 proportion of C&D waste is not necessarily because of increasing construction activities.
80 Rather, while other sectors have effectively put a check on their waste going to landfill through
81 a set of proven strategies, waste landfilled by construction industry remains alarming. As such,
82 there is a decrease in rate of landfill waste from household, industrial, commercial, mining and
83 other activities (DEFRA, 2013). This suggests that existing strategies for managing
84 construction waste remain largely ineffective and poorly conceptualised.

85

86 Meanwhile, Van Manen (1990) suggests that when an important phenomenon has been poorly
87 conceptualised, a phenomenological approach is required to correct the misapprehensions.
88 Phenomenologists believe that by putting asides the general belief about a concept and
89 interacting with key players, it is possible that a new meaning and understanding could be
90 derived (Crotty, 1998). Although, continuous efforts are being made towards diverting waste
91 from landfill, opportunities offer by phenomenological understanding of waste management
92 strategies is yet to be explored. In order to understand the impediments to effective waste
93 management, this study approach the problem from phenomenological perspective. The overall
94 aim of this study is to scrutinise construction waste management techniques in a bid to identify
95 impediments and strategies for improving their effectiveness.

96

97 To achieve this goal, the study would fulfil the following objectives:

- 98 1. To identify and evaluate existing construction waste management strategies towards
99 understanding impediments to their effectiveness.
- 100 2. To suggest strategies/framework for improving waste effectiveness of the construction
101 industry.

102 Unlike other studies seeking to develop waste management strategies, the focus of this study is
103 to illuminate factors hindering effectiveness of the existing strategies as well as measures that
104 could be put in place to improve rate of diverting whole-life C&D waste from landfill. This
105 paper offers insights into factors and strategies to be considered to achieve effective waste
106 management strategy. It would assist both construction professionals and policy makers in
107 understanding impediments that hinder effectiveness of existing waste management techniques
108 as well as strategies required for their improvement.

109

110 **2. Construction Waste Management Strategies**

111 Apart from waste landfill, which has been widely discouraged as a waste management strategy,
112 several strategies are being employed towards diverting waste from landfill. Summarised in
113 Figure – II, the existing waste management strategies are briefly swotted below.

114

115 **2.1. Sorting and Recycling**

116 Waste recycling has been widely adopted in many industries, among which the construction
117 industry is not left out. This strategy has been recognised as the next line of action in a bid to
118 prevent waste landfilling, the oldest and most environmental harmful form of waste treatment
119 (Manfredi *et al.*, 2009). Recycling is one of the strategies adoptable after waste has occurred
120 and it involves sorting of the waste materials into “recyclable and non-recyclables” during the
121 construction activities or at the recycling site (Barros *et al.*, 1998). The option of site sorting
122 has been widely encouraged across the UK, as it eases recycling operations and ensures
123 accurate separation of inert and non-inert materials (Poon *et al.*, 2001). The strategy is not
124 necessarily an approach for reducing waste in construction activities, but it proves valuable due
125 to its tendency to divert waste from landfill sites. In addition, recycling as a waste management
126 strategy ensures that waste materials are reprocessed to produce derivative materials, which
127 replace the need for the use of virgin materials for materials production. It therefore saves the
128 environment from pollution due to materials excavation, transportation and processing
129 (Davidson, 2011; Treolar *et al.*, 2003).

130

131 Peng *et al.* (1997) argues that substantial recycling operation, with respect to construction
132 waste, has helped communities in freeing up large spaces in their landfill sites as construction
133 and demolition usually generate large waste. Corsten *et al.* (2013) believe that an effective
134 recycling operation saves an additional annual emission of 2.3MtCO₂ in Netherland. A typical
135 Japanese building constructed of recycled materials would save at least 10% of energy need
136 according to Gao *et al.* (2001). Other benefits in forms of job creation and economic gains are
137 also claimed to the credit of recycling as a strategy for waste management. However, several
138 pre-requisite are important to the success of recycling operation. A substantially large area of
139 land of not less than 0.8 hectare, easily accessible site, experienced recycling specialists as well
140 proper recycling equipment (Peng *et al.*, 1997) such as screeners, crushers and wind-sifting are
141 expected of a typical recycling site. Dedicated construction professionals available to
142 adequately sort the waste materials play major part in successful recycling operations.

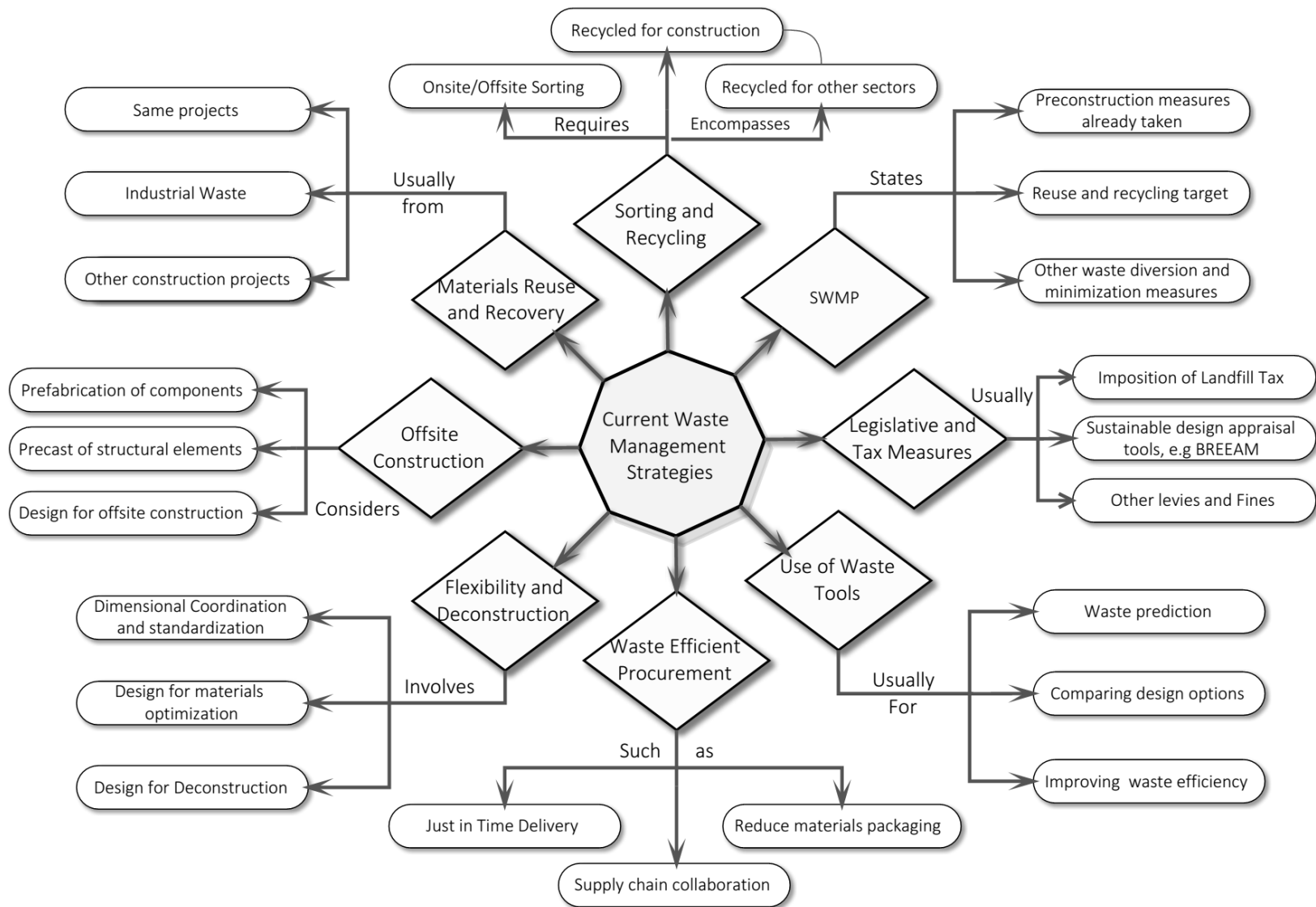


Figure I: Summary of Existing Waste Management strategies

145 **2.2. Materials Re-Use**

146 Materials reuse is an essential approach to diverting waste from landfill sites. Unlike recycling,
147 materials reuse involves the use of the materials with little or no alteration to its physical state,
148 and without any change to its chemical constituents (Guthrie and Mallet, 1995). In the
149 Construction industry, material re-use has been adopted as a means of diverting own waste as
150 well as domestic and other industrial waste from landfill. Construction demolition materials
151 have been widely reused for land reclamation, road surfacing, and as constituents of concrete
152 aggregates. Coal fly ash is also a valuable material, of industrial origin, being used to replace
153 percentages of cement in concrete mix and rendering materials (Halliday, 2008). Materials
154 leftover, off-cuts, excavated soil, etc., generated from construction sites have also found use in
155 the same or other projects.

156

157

158 **2.3. Use of Waste Prediction Tools**

159 In order to effectively manage waste in construction projects, different means of measuring and
160 predicting likely project waste have emerged in the industry. It involves the use of different
161 tools, usually at the design stage, to predict potential waste arising from construction process.
162 NetWaste is one of the most popular tools used in the UK for waste prediction. It assists
163 designers in estimating cost and quantities of waste from the project, and helps in selecting
164 suitable strategy for improving waste effectiveness of the project (WRAP, 2008). Developed
165 by the UK WRAP, NetWaste collects basic project information such as building volume and
166 materials type in order to perform its waste evaluative function. Design Out Waste Tools for
167 Building/Civil Engineers, DOWT-B/DOWT-CE are other tools developed by the same body
168 for, identifying the potentials for designing out waste, recording design solution for waste
169 mitigation, calculating the impacts of such solution, and comparing impacts of different design
170 alternatives for Building and Civil Engineering projects (WRAP, 2010).

171

172 Other tools and approaches have been used for projecting construction waste outside the UK. A
173 Spanish model for waste prediction was developed by Solís-Guzmán *et al.* (2009) based on
174 data from 100 construction projects. Components and Global Index measuring waste per
175 square metre and material types respectively were proposed by Jalali (2007). A Singaporean
176 Model for waste score determination, BWAS, was also developed by Ekanayake and Ofori
177 (2004). BWAS was developed for comparing different design scenarios for their waste

178 effectiveness so that adequate mitigation strategies could be taken. These set of tools are
179 employed during the concept and developed design stages of building delivery process.

180

181

182 **2.4. Site Waste Management Planning (SWMP)**

183 SWMP is a legislative requirement for construction activities in many nations. In the UK for
184 instance, a legislative framework, SWMP regulation (2008), requires every project above
185 £300,000 to produce SWMP before actual construction activities. Every maintenance,
186 demolition, excavation, alteration, civil engineering project and decoration above the amount
187 was required to produce SWMP before the regulation was repealed in December 2013. Until
188 date, industry professionals are still expected to voluntarily produce SWMP for effective waste
189 management or as a means of ensuring compliance with green certifications such as BREEAM
190 and Codes for Sustainable Homes. Similarly, in Hong Kong, Site Waste Plan was introduced to
191 construction industry in 2003, although it has since received negative feedback from industry
192 practitioners, as it is believed to reduce productivity (Tam, 2008). Waste Management Plan is
193 also an important requirement for planning approval of significant projects in Australia (Hardie
194 *et al.*, 2007).

195

196 A typical SWMP involves statement of pre-construction strategies previously taken to ensure
197 waste minimization as well as detail statement of proposed strategies for waste management
198 during and after construction activities. The SWMP is typically aimed to, set waste diversion
199 target, avoid flying tipping, ensure proper waste auditing and segregation, improve efficiency
200 and profitability, and to ensure that adequate measure is taken for waste reduction, reuse and
201 recycling. Usually prepared and managed by site waste managers, the plan proposes the
202 proportion of waste to be reused and recycled, onsite area for waste storage, methods for waste
203 sorting and reduction as well as the stakeholders that would be responsible for waste removal
204 from site (Tam, 2008; McGrath, 2001; McDonald and Smithers, 1998).

205

206

207 **2.5. Design for Flexibility and Deconstruction**

208 One of the proven approaches to C&D waste management is to design the building for
209 flexibility and deconstruction. A design is flexible if it is able to adapt to both external and
210 internal change. This occurs when a design is optimized to the industry's standard so that its
211 removed materials perfectly fit into another optimized project. During design, the elements of

212 the building system are usually coordinated and standardised, preventing waste due to offcuts
213 which is one of the major causes of waste in projects (Formoso *et al.*, 2002). Industry practices
214 submit that change is less costly at pre-construction stages, thus suggesting that dimensional
215 coordination, as a design stage strategy, is an effective precautionary measure to ensure that
216 waste is prevented during construction activities. It is clear that while materials reuse and
217 recycling seek to manage waste after it occur, design coordination offers preventive measures,
218 which is both environmentally and financially preferable. As such, standardizing design for
219 waste efficiency through dimensional coordination tends to be a promising strategy for waste
220 management.

221
222 Studies on Life Cycle Analysis (LCA) of building related waste suggests that demolition stage
223 contributes a huge proportion (cf. Yeheyis *et al.*, 2013; Blengini, 2009). A holistic attempt to
224 reduce end of life waste is through the consideration of deconstruction during the design stage
225 (WRAP, 2009). Deconstruction differs from demolition in that while the former involves
226 careful dismantling of the building components in such a way that large proportion of the
227 materials and components supports reuse and recycling; the latter gives little consideration to
228 primary reuse of the building components. Adequate planning for the buildings' end of life, by
229 considering deconstruction at the design and construction stages, would ensure that a large
230 proportion of the materials and components is reused, thereby diverting substantial proportion
231 of demolition waste from landfill.

232
233

234 **2.6. Waste Efficient Procurement**

235 Procurement stage is a very vital stage for waste management planning in construction
236 projects. Several causes of construction waste such as packaging materials, double handling,
237 and improper materials storage are all associated with procurement stage. Owing to this,
238 different strategies have been used to ensure waste efficient procurement in the construction
239 industry; these among others include Just in Time delivery (JIT), reduced packaging and
240 improved collaboration between the supply chains.

241
242

243 **2.7. Offsite Construction**

244 Existing literatures identified some modern methods of construction as means of reducing
245 waste generation in the industry. These include prefabrication and off-site construction (Tam *et*

246 *al.*, 2005; Jaillon *et al.*, 2009; Lu and Yuan, 2013). Although it is noted that such technique as
247 the use of precast materials might not be purposely done for waste reduction, evidence shows
248 that they are highly effective for waste reduction. For instance, Jaillon *et al.* (2009) and Tam *et*
249 *al.* (2007) suggests that waste minimization tendency of prefabrication and modular
250 construction results in 52% and 84.7% respectively. This ensures that building elements are
251 manufactured offsite, assembled onsite, while several factors that cause waste such as materials
252 handling, poor storage as well as design changes have been entirely prevented.

253
254

255 **2.8. Legislative and Tax Measures**

256 Various legislative and tax measures have been imposed by governments towards diverting
257 waste from landfill. One of such measures is the “Pay as You Throw” ((PAYT), which is a
258 polluter pays principle through which governments have diverted substantial volume of waste
259 from landfill across many nations. PAYT is a unit based pricing through which charges is paid
260 per unit volume or weight of all waste disposed on landfill site, with ultimate aim of
261 discouraging waste landfilling and encouraging waste reduction, reuse and recycling. Before
262 the adoption of variable landfill tax, known as PAYT, other landfill penalties have been
263 imposed without success. In the US for example, a fixed billing that does not vary with
264 quantity of waste have been used; however, it did not show significant reduction in waste
265 compared to the PAYT scheme (Skumatz, 2008). Evidences from other countries such as
266 Greece, Sweden, Canada, Netherland, Switzerland, and the UK show that PAYT scheme
267 substantially reduces burden on landfill sites (Dahlén and Lagerkvist 2010; Brown and
268 Johnstone, 2014; Morris, 1998).

269
270 In the UK, cost per tonnage of waste disposed have continuously been upwardly reviewed
271 since it was imposed in 1996, up from £7 and £2 in 1996 (Read *et al.*, 1997), to £80 and £2.50
272 in 2014 per unit tonnage of active and inert waste respectively. This has made the industry to
273 have a rethink of how waste is managed, especially as financial gains determines the industry’s
274 commitment to any waste management strategy (Al-Hajj and Hamani, 2008). As such, most
275 construction firms have formed alliance with recycling and waste disposal companies who help
276 in segregating and processing the waste to divert a substantial portion from landfill sites.
277 Others have weighed the cost of landfilling against cost of other waste management strategies
278 such as materials optimization, sorting and recycling, just in time delivery, low waste
279 technologies, etc., thus selecting cheaper option for their project.

280

281 Meanwhile, apart from landfill tax, which is aimed at reducing waste to landfill, other
282 legislative toolkits have raised the construction industry's awareness about waste management.
283 These are not necessarily in forms of strategies, but they have helped in reducing C&D waste.
284 Aggregate Levy introduced in 2001 by the UK government imposes a levy of £1.60, up by £0.4
285 to £2 per tonne since 2009. It was aimed at reducing consumption of virgin aggregates thereby
286 encouraging reuse of recycled aggregates.

287

288

289 **3. Methodology**

290 Despite implementation of several waste management strategies within the construction
291 industry, waste landfilling still remains a major practice within the industry, suggesting
292 ineffectiveness of the existing waste diversion strategies. To tackle this conundrum, focus
293 group discussion was used for collecting data for both epistemological and methodological
294 reasons. Considering the epistemology, the concept of phenomenology is based on tenet that a
295 particular situation could not be truly understood until all presuppositions and preconditions
296 are suspended by a researcher (Holloway and Wheeler, 1996) in a bid to devise new meanings
297 (Crotty, 1998). It recognises the researchers as interpreters of the participants' experience and
298 actions, and it is concerned with the individual perception and account of the events under
299 investigation (Edie, 1987), devoid of objective meanings imposed by the researcher (Smith and
300 Coburn, 2007). The phenomenological approach therefore avail the researchers an opportunity
301 to understand the efficacy of the existing waste management strategy from the practitioners
302 point of view, devoid of every presuppositions. This is deemed suitable, as the approach is
303 suitable in a situation where an important phenomenon has been poorly or wrongly
304 conceptualised (Jasper, 1994; Van Manen, 1990).

305

306 From methodological point of view, the use of focus group discussion allows critical
307 examinations of intersubjective opinions among the participants, throughout the course of
308 encounter (Kvale, 1996). The approach helps in gaining in-depth understanding of the
309 phenomenon (Wimpenny and Gass, 2000) by obtaining rich data from the different groups of
310 construction and waste management professionals. The study involved four focus group
311 discussions, carried out on different occasions with design and construction professionals
312 grouped into four key teams, which were sustainability team, construction lean practitioners,
313 designers/design managers and site waste managers. Sustainability team consists of
314 construction professionals whose job roles is to advice, guide and ensure overall sustainability

315 of build processes in their respective organisation. Lean practitioners are those seeking to
 316 employ lean thinking in design and construction activities while site waste managers are those
 317 professional whose consultancy service is to prepare and manage site waste management plans
 318 for construction companies.

319
 320 All participants are from various design and construction firms ranging from small and
 321 medium to large organisation. All the participants are actively involved in project coordination
 322 and management of design and/or construction processes. None of the participants has less
 323 than seven years of experience in the industry, and their average years of experience is 12
 324 years. Apart from two moderators for each of the focus group discussions, Table –I shows
 325 number of participants in each of the discussions.

326

327 *Table – I: Overview of the focus group discussions and the participants*

<i>FG</i>	<i>Categories of the Participants</i>	<i>Main Focus of the discussions</i>	<i>No of experts</i>	<i>Years of experience</i>
1	Designers and Design managers	<ul style="list-style-type: none"> • Designers approaches for designing out waste • Design management approach to prevent waste 	8	12 – 27
2	Lean practitioners	<ul style="list-style-type: none"> • Lean thinking as a means of waste management • Strategies for preventing defects and reworks 	4	7 – 16
3	Project/Site Waste Managers	<ul style="list-style-type: none"> • Factors contributing to low waste projects • Methods for reducing C&D waste 	7	10 – 12
4	Sustainability Team members	<ul style="list-style-type: none"> • General discussions on waste preventive strategies • Project lifecycle waste reduction 	6	8 – 15
Total			25	

328

329 The four key teams were selected based on critical sampling because they are all responsible
 330 for day-to-day prevention and management of waste within the construction industry. This
 331 sampling technique was used based on assertion of Creswell (1998) that it allows logical
 332 generalisation of study and applicability of its findings to other cases (Creswell, 1998).
 333 However, participants were selected through a convenient sampling where researchers used
 334 their established network of contacts within the industry. This sampling technique gives the
 335 researchers an opportunity of purposefully selecting people that are considered information-
 336 rich for the study (Merriam, 1998). Within the field of construction management, other

337 researchers that have employed the sampling technique include Oyedele (2013), Akintoye et al.
338 (1998), Hodgson et al. (2011) and Spillane et al. (2012) among others.

339
340 The participants were informed of the need for understanding factors limiting effectiveness of
341 the existing waste management strategies as well as the strategies required for improving waste
342 management practices. The discussions were in two phases, each spanning between 40 and 45
343 minutes. Each of the first phase identified impediments existing waste management, while the
344 second stage assisted in elucidating strategies for improving waste management practices. The
345 discussions were recorded, transcribed and read several times to identify core themes in the
346 different discussions, using thematic analysis (Morse, 1994). In order to uncover complex
347 phenomenon and common themes that may be hidden in the large unstructured data, Atlas-ti
348 qualitative data analysis tool was used.

349
350

351 **4. Analysis and Grouping**

352 This section presents findings on how participants reflect on the existing waste management
353 strategies to identify their weaknesses as well as the strategies required for their improvement.
354 To enhance further grouping and discussion of the findings, a Delphi technique was used. The
355 technique is a widely used and accepted method of enquiry that is used to achieve convergence
356 of opinion from people within a domain of expertise (Hsu, 2007). The benefits that accrue to a
357 study employing Delphi technique include controlled feedback to participants, opportunity for
358 reassessment of earlier judgement, anonymity of individual participants, and establishment of
359 group consensus (Dalkey and Helmer, 1963). To build the group consensus, established
360 impediments and strategies were sent to participants of the focus group discussions. After two
361 iterative processes, limitation to existing waste management strategies were refined and further
362 grouped into five major categories based on group consensus.

363
364 The five major categories of the impediments to existing waste management strategies are:

365 *A. End of Pipe Treatment;*

366 *B. Externality and Incompatibility of waste management Tools with Design Tools;*

367 *C. Failure of Waste Management Strategies to Offer Holistic Solutions*

368 *D. Perceived or Unexpected Expensiveness of Waste Management*

369 *E. Culture of Waste Behaviour within the ACE Industry.*

370

371 Similarly, suggested strategies for improving waste effectiveness of the construction industry
372 were consensually grouped under six categories, which are:

373 *1. Design Stage Implementation*

374 *2. Whole life consideration*

375 *3. BIM compliant solutions*

376 *4. Economic Viability of Waste Management Strategies*

377 *5. Improved Legislative Provisions*

378 *6. Applied Research and education.*

379

380 Tables II and III presents findings of the focus group discussions as well as the categorisation
381 of the impediments from Delphi interview techniques. A – E in Table –II represents the above
382 categorization of the impediments

Table II: Existing Waste Management Strategies and Impediments to their Effectiveness

	Waste Management Strategies	Limitations	Focus Groups				Category
			1	2	3	4	A – E*
1	Sorting and Recycling	• Extra labour/man-hours is needed for successful sorting exercise	✓		✓		D
		• Substantial site space is required, and it cannot be done in confined sites			✓		C
		• Recycling consumes substantial energy for transportation and recycling				✓	D
		• It is an end of pipe treatment rather than waste preventive measure	✓	✓	✓	✓	A
		• It costs time, money and interfere with other site operations			✓	✓	D
		• It cannot even tackle all waste categories as some are not recyclable	✓	✓		✓	C
2	Materials Reuse	• It is not adaptable for all waste streams		✓			C
		• It is an end of pipe treatment	✓	✓	✓	✓	A
		• Uncertainty about lifecycle quality of reused materials prevents its use	✓			✓	E
3	Use of Waste Prediction tools	• Most prediction tools lack provision for actual waste reduction/minimization	✓				C
		• Building information are input manually, and this discourages its use	✓			✓	B
		• Incompatibility with drawing tools discourages their wider acceptability	✓		✓		B
		• Extra man-hours/efforts are required as they are external to drawing tools	✓	✓		✓	D
		• Not realistic in complex design with irregular shapes	✓				C
4	Site Waste management Plan (SWMP)	• Only being used as a means of fulfilling legal requirements or BREEAM points			✓	✓	E
		• No standard benchmark as it is done based on individuals' instinct	✓			✓	C
		• It requires additional man-hours/specialist			✓		D
		• No solid follow up on original plan				✓	E
5	Design for Flexibility and Deconstruction	• It requires added expertise as well as dedicated planning which are unpaid for	✓	✓	✓		D
		• Deconstruction is more expensive than demolition			✓	✓	D
		• It does not offer immediate benefits to project teams	✓	✓			E
6	Waste Efficient Procurement, e.g. JIT	• Measures such as JIT increases transportation cost			✓	✓	D
		• It sometimes delay projects			✓		D
7	Offsite Construction and Other MMC	• More expensive than in-situ mode of construction			✓	✓	D
		• It requires more careful planning which counts on project cost	✓		✓		D
8	Legislation and Tax Measures	• It gives little attention to design stages which is key to waste reduction	✓			✓	C

*A = End of Pipe Treatment; B = Externality/Incompatibility of waste management Tools with Design Tools; C = Failure of Waste Management Strategies to Offer Holistic Solutions; D = Perceived or Unexpected High Cost of Waste Management; E. Waste Behavioural Culture

Table III: *Requisite for Reducing Waste Intensiveness of Construction Industry*

	Major categories of the Strategies	Identified Measures for Improving Effectiveness of Waste Management Strategies	Focus Groups			
			1	2	3	4
1	Design Stage Implementation	• Increasing implementation of waste management solutions right from design stage			✓	✓
		• Optimization/standardization of designs to achieve waste effective solutions	✓	✓		
		• Early collaborative waste management arrangement among project teams			✓	✓
		• Design changes should be limited to the design stages		✓		✓
		• Waste management software solutions should be implementable within design platform	✓			✓
2	Whole Life Consideration	• Waste management solutions should cover all stages of project lifecycle than construction stage		✓		
		• Waste prevention should be given adequate consideration as much as end of pipe treatment options	✓		✓	✓
		• Flexibility should be considered while planning/specifying design and construction techniques		✓		✓
		• Deconstruction should be planned at design/construction stage to reduce end of life waste		✓	✓	✓
3	Building Information Modelling (BIM) Compliance	• Improve use of BIM and Integrated Project Delivery (IPD) will enhance project's waste effectiveness	✓			
		• As the industry shifts towards BIM, waste management tools should be made BIM compatible	✓			✓
		• Capability of Waste prediction/management tools to automatically capture building information	✓			
4	Economic Viability	• Waste preventive/management measures should be made cheaper than allowing waste to occur		✓	✓	
		• Economic benefits of adopting waste management strategies should be more pronounced			✓	
		• Increasing cost of waste landfilling could make waste prevention more economical and accepted	✓			✓
		• Easily implementable strategies devoid of causing project delay should be encouraged			✓	✓
5	Legislation Drives	• Increased stringency of waste management regulations		✓		✓
		• Consideration of design stage in future waste management regulations	✓		✓	✓
		• Inclusion of waste management in project sustainability appraisal tools and building control process	✓			✓
		• Award of more points to waste effectiveness of construction projects	✓		✓	✓
6	Research and Enlightenment	• More research into impacts of different design and construction practices on waste output		✓		
		• Cost benefits analysis of various low waste building techniques should be illuminated			✓	✓
		• Increased education of design and construction professionals about waste preventive measures	✓	✓	✓	✓

386 **5. Impediments to Existing Waste Management Strategies**

387 As presented in Table – II, effectiveness of existing waste management strategies is limited by
388 different factors. These sets of impeding factors are discussed under five major categories.

389

390 *5.1 End of Pipe Treatment*

391 Current approaches to tackling waste are usually categorised into four, which are reduce, reuse,
392 recycling and disposal in order of environmental and economic preferences (Faniran and
393 Caban, 1998). However, most waste management techniques are down the hierarchy and lacks
394 platform for preventing waste occurrence (Osmani, 2012). Focus group discussants opined
395 that:

396

397 *“While many waste management strategies already exist, we are also improvising for*
398 *some others. Government is also forcing us to adopt some of them... However, it seems*
399 *that most of these strategies are only meant to address waste after it has occurred”.*

400

401 A major impediment to waste efficiency of the construction industry is that widely used waste
402 management strategies fall into categories of end of pipe treatment which are, by definition, not
403 waste preventive measures, but ways of managing waste after it occurred. Across all the focus
404 group discussions, the participants put similar argument against materials reuse and recycling
405 which are the most common approaches to waste management.

406

407 *“How would you think that reuse and recycling solve waste and environmental*
408 *problems when they proffer solution to waste after it occurs? Recycling needs waste*
409 *transportation, which in itself a means of pollution.....if you have been to recycling*
410 *site, you would realise that it is a polluting activities.*

411

412 *“The success of all these end of pipe treatments depends on whether or not the*
413 *secondary materials make their way back to construction sites”.*

414

415 *“It is unfortunate that most of the approaches are offering solutions after waste has*
416 *occurred.... In my own view, waste is only well managed if it is not generated in the*
417 *first place”.*

418

419 Apart from the argument that waste recycling is only a means of treating waste after it occurs
420 rather than preventing or minimizing it, successful recycling operation requires dedicated

421 sorting arrangement which requires cost, time, site space, labour and dedication among the
422 professionals (Teo and Loosemore, 2001; Poon *et al.*, 2001). The consensus that waste is best
423 tackled at design stage where cost of change is minimal (Faniran and Caban, 1998; Ekanayake
424 and Ofori, 2004; Osmani, 2012) suggests that the end of pipe treatments have limited
425 tendencies of reducing construction waste. In addition, Oyedele *et al.* (2014) claim that, there is
426 low acceptance of recycled products as designers rarely consider them during specifications.
427 This further suggests that reuse, recycling and other end of pipe waste management measures
428 have little tendency of reducing waste generated by construction activities. Although, the end
429 of pipe treatments are believed to be contributing towards waste diversion from landfill sites
430 (Sassi and Thompson, 2008), a holistic approach to reducing C&D waste is expected to
431 consider minimization techniques (Wang *et al.*, 2014).

432

433 5.2 *Externality/Incompatibility of Waste Management Tools with Design Tools*

434 The use of waste prediction tool is perceived as an innovative approach to tackling construction
435 waste from holistic perspective (Solís-Guzmán *et al.*, 2009). It involves the use of different
436 tools, usually at the design stage, to project likely quantity of waste, and sometimes their
437 causes, so that the industry practitioners would act towards minimizing the waste by using
438 alternative design, plan for waste reuse and recycling, among others. However, apart from
439 being that some of the tools in use only predict waste without information about their likely
440 causes and predictive measures, the tools work based on manual input of project information
441 (Jalali, 2007). Its effectiveness therefore relies on the extent of accuracy of the input data.
442 Despite its perceived benefits as a means of predicting and preventing construction waste, it is
443 limited by externality and lack of compatibility with design tools and manual input of building
444 information. Designers argue that:

445

446 *“Waste prediction tools offer excellent approach to waste management. However,*
447 *their main problem is that they are not compatible with design tools. You waste a*
448 *lot of time on waste, while manually entering the information”*

449 This was further buttressed by another participant who opined that:

450

451 *“You know, most of our activities are time bound, nobody is interested in doing*
452 *something that would waste time...assuming we can do it within the design*
453 *platform, it would be awesome to predict likely waste before actual construction”*

454 This suggests that as this strategy proves requisite to effective waste minimization at source,
455 more efforts is needed to improve mode of capturing building information. Further waste
456 management solution is not only expected to be compatible with design tool, its ability to
457 automatically capture building information would enhance its effectiveness and acceptability.

458

459 5.3 *Failure of Waste Management Strategies to Offer Holistic Solutions*

460 As echoed by the focus group discussants, a major problem leading to waste intensiveness of
461 the construction is the failure of the waste management strategies to tackle waste at holistic
462 level. By the nature of existing waste management strategies and studies, they usually address
463 stages of project delivery processes as a static stage rather than developing one stop approach
464 capable of assisting throughout the project lifecycle stages. The discussants argued that:

465

466 *Apart from doing some of these things to gain BREEAM point, the industry is more*
467 *interested in things that could help in both design and construction. How well have*
468 *we benefited if we can only manage waste after it occurred? We definitely need*
469 *something that could help us reduce waste and therefore increase profit”*

470 *“Even, waste management tools are not useful beyond the design stage. Most of the*
471 *strategies are only meant to address little portion of the problem. In my own view,*
472 *they are not holistic enough”*

473 It was established by the focus group discussants that most of the existing waste management
474 strategies are not applicable on every types of projects, sites and materials. For instance, while
475 recycling as a strategy becomes irrelevant with certain types of materials, site based sorting of
476 waste is not feasible in the case of confined sites. Despite the perceived relevance of waste
477 prediction tools, the discussant argue that it offer little or no solution to waste reduction. Again,
478 waste management legislation, which is known to be driving waste reduction in industry
479 (Yuan, 2013), also has limited provision for reducing waste through design (Osmani *et al.*,
480 2008). All these suggest that most of the existing waste management strategies lack holistic
481 framework for effective diversion of waste from landfill.

482

483 This corroborated earlier submission by Yuan *et al.* (2012) and Hao *et al.* (2007) who suggest
484 that waste minimization strategies are usually implemented on static perspective while there is
485 need for dynamic and interdependent approach to determining effective waste management
486 strategies. Notwithstanding the interrelationship and interdependency of every stages of
487 building delivery stages (Sterman, 1992), existing practice in C&D waste management

488 research often results in scattered findings, as researchers usually concentrate on each stage of
489 project delivery processes. This results in stage based solutions to C&D waste management.
490 Thus, there is need for more holistic approach that considers all materials types as well as
491 every stage of project delivery process.

492

493

494 *5.4 Perceived or Unexpected High Cost of Waste Management*

495 Rather than landfilling, construction professionals are more likely to adopt waste management
496 strategies in as much as it presents economic cases (Al-Hajj and Hamani, 2011; Oyedele *et al.*,
497 2013). However, this study suggests that a major barrier to implementing waste management
498 strategies is due to its perceived cost and time impacts on project costs. Although, penalty is
499 being paid for waste landfilling, focus group discussants illuminates that they sometimes
500 compare cost impacts of waste landfilling to potential impacts of waste management on project
501 duration and cost. They suggest that while some increases design and construction cost as they
502 require extra man-hours, others interfere with site activities and could potentially result in
503 project delay, which in turns increases project cost (Enshassi *et al.*, 2009). The discussants
504 stated that:

505

506 *In a situation whereby the cost of appointing waste management experts is more*
507 *than the cost of landfilling, what do you do? I bet you will definitely prefer to*
508 *landfill your waste.*

509 *We mix up our waste on most sites because you need dedicated people and ample*
510 *site space to sort waste into recyclable and non-recyclable. However, we have*
511 *waste management company that take everything away from the site..., I think they*
512 *separate them and sell back some of the waste to us.*

513 *Although Just in Time delivery could reduce waste generation, but it is cheaper to*
514 *deliver your materials in bulk. If you use JIT, you will pay multiple transportation*
515 *fees and sometimes, your materials would be delayed.*

516 The experts opined that C&D waste has not been properly addresses because nobody is
517 interested in paying for it.

518 *You know we get contract through competitive bidding. If you say because you want*
519 *to design for deconstruction or reduce waste through some techniques, and then*
520 *raise your price, you might end up not getting any contract.*

521 *Offsite construction reduces waste significantly because of its involvement of design freeze,*
522 *which prevents reworks. But you cannot use offsite construction only because you want to*
523 *reduce waste because you have to pay premium for it*
524

525 All these statements suggest a strong belief that waste management is more expensive
526 than waste landfilling. In line with the experts' opinion, previous studies also suggested
527 that some waste preventives measures tend to be more expensive. For instance, Dantata *et*
528 *al.* (2005) posit that deconstruction is about 17-25% more expensive than deconstruction.
529 Durmus and Gur (2011) also argue that while planning for deconstruction, which is waste
530 effective than demolition, careful planning and additional time would be spent by the
531 designers. Although waste minimization tendency of prefabrication and modular
532 construction could be up to 84.7% (Tam *et al.*, 2007), financial premium is expected to be
533 paid as it is more expensive than in-situ construction.

534

535 5.5 *Waste Behavioural Culture within the ACE Industry*

536 Teo and Loosemore's theory of waste behaviour posit that there is a prevailing culture of waste
537 behaviour within the construction industry (Teo and Loosemore, 2002). The theory suggests
538 that while top managers usually perceive waste as trivial issues, the operatives always opine
539 that waste is an inevitable problem of the managers. Although this was not directly raised by
540 the discussants, some of their response suggests the belief. For instance, a discussant claims
541 that:

542 *"I think a lot has to be done by Government if SWMP is to achieve its desired goal. Since it*
543 *has no standard benchmark, we produce it for every site as required by law. Ask me about*
544 *its implementation and effectiveness; it is absolutely used for ticking boxes... We however*
545 *take its implementation serious only when we want to use it for achieving BREEAM points"*
546

547 *"It is the government that is more sincere and committed to environmental management,*
548 *the main motivation for waste management and other policies within the industry is the*
549 *financial gains, and sometimes, to gain desired BREEAM or other assessment points"*
550

551 This opinion was also echoed by Ikau *et al.* (2013) and Osmani *et al.* (2008) who reiterated that
552 a major reason for waste intensiveness of the construction industry is that workers believe that
553 waste is inevitable, thereby giving less attention to its management. This means that without

554 legislation as a driver of waste management behaviour, culture of waste behaviour within the
555 industry means that construction industry is likely to remain waste intensive.

556

557 **6. Requisites for Improving Waste Diversion Rate**

558 Reducing waste in landfill sites remains a pressing challenge facing the construction industry.
559 Evidence shows that more than a third of waste in global landfill might be of construction
560 origin (Solís-Guzmán *et al.*, 2009). By devising appropriate requisites capable of improving
561 effectiveness of waste management strategies, it is certain that environmental problems
562 associated with increasing waste generation would be prevented. In addition, substantial
563 financial savings could be made from effective waste management.

564

565 By corroborating findings in Table – III with extant literatures, measures capable of
566 improving C&D waste management are discussed under six headings, which are design stage
567 implementation, whole-life consideration, BIM compliance, economic viability, legislative
568 drivers, and research and enlightenment. The six broad factors describe basic requisite
569 measures needed to be considered in order to reduce waste intensiveness of the construction
570 industry. Figure II summarizes and depicts the requisites for improving waste intensiveness of
571 the construction industry.

572

573

574

575

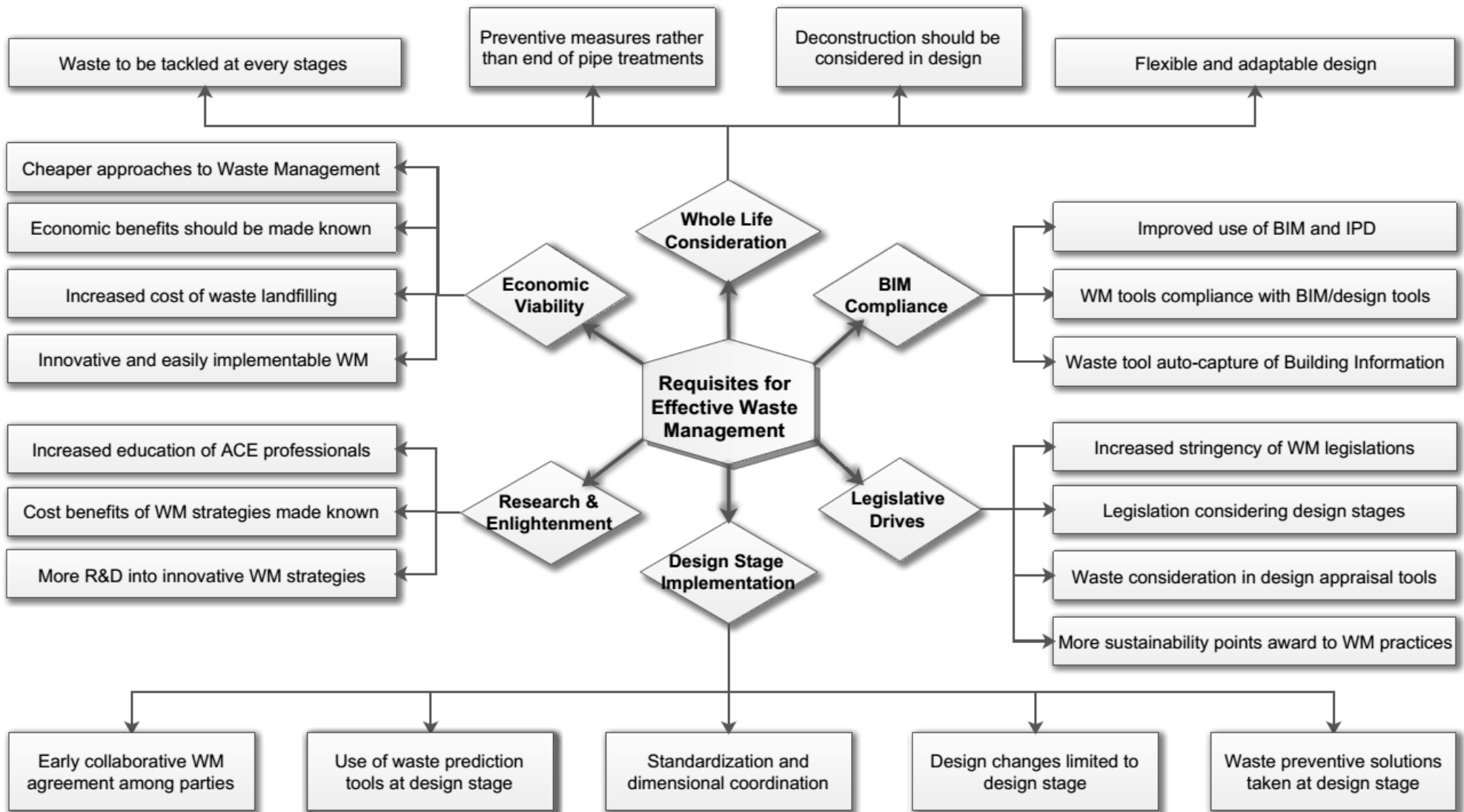
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582

Figure II: Requisites for reducing waste intensiveness of the construction industry

583 6.1 Design Stage Implementation

584 Design stage is a very crucial point for waste preventive measures in construction activities. It
585 is no news that change is cheaper at design stage when there would be no need for any reworks
586 that could otherwise lead to materials and time wastage. Osmani (2012) noted that according to
587 Innes (2004), about 33% of construction waste occurs because of design related factors. This
588 implies that attempts to tackle waste at design stage would result in substantial reduction in
589 waste. UK government funded WRAP also claim that waste could be designed out in
590 construction projects using some set of tactics known as waste spectrums. These according to
591 WRAP involve design for reuse and recovery, design for offsite construction, design for
592 deconstruction and flexibility, design for materials optimisation, and waste efficient
593 procurement (WRAP, 2009).

594
595 To reduce waste intensiveness of the construction industry, the industry's experts strongly
596 believe that design stage is a decisive point. The discussants equally opined that:

597 *"A good area which we should be looking into if we are really sincere about waste*
598 *management is in the aspect of design"*

599
600 *"If we want to reduce waste, we need to ensure that our design dimensions are coordinated*
601 *and the overall design is optimized for waste efficiency"*

602
603 *"By limiting design changes to the design stage, we would be able to prevent waste*
604 *generation to a great extent"*

605 Waste management strategy is expected to be implementable at early design stage where
606 designers would have the best opportunity to optimize their design and compare different
607 design alternatives for waste efficiency. Other discussants suggest that:

608
609 *Existing waste minimization strategies at design stage only allows waste prediction on a*
610 *platform external to design tools. Many of the tools even lack functionality for supporting*
611 *waste minimization techniques. It will be excellent if we can implement the waste*
612 *management simulation within the design platform. We need something like what Revit*
613 *calls energy simulation, which could be done along with design*

614
615 These assertions suggest that a platform that allows waste prediction and benchmarking, design
616 optimization, and tendency for setting waste target in user interactive and decision support
617 manner would adequately assist in reducing. In addition, design stage should be more

618 recognised in waste management practices rather than current practices that usually adopt end
619 of pipe measures in tackling waste.

620

621 *6.2 Whole-life Consideration*

622 Causes of waste have been linked to all stages of project delivery process, ranging from design
623 to completion. Although the actual waste occur onsite during construction activities, various
624 pre-construction operations such as design errors, scheduling mistakes, lack of dimensional
625 coordination, etc. have been pointed out as major causes of waste (Faniran and Caban, 1998;
626 Ekanayake and Ofori, 2003; Coventry et al, 2001). However, existing practices show that
627 different strategies are adopted at various stages of building delivery activities. For instance,
628 waste management tools such as WRAP NetWaste are used for waste predictive measures at
629 design stage without capability to assist onsite during construction activities. Existing Site
630 Waste management tools such as the US Waste Spec and the UK SmartWaste only consider
631 onsite waste, suggesting inadequacy of current solutions in tackling preconstruction causes of
632 waste. The respondents suggest that:

633

634 *Large volume of waste comes from deconstruction and refurbishment; we seriously need to*
635 *plan for demolition if we are targeting sustainability in our waste management.*

636

637 *A large portion of C&D waste comes from building renovations, repartitioning and so on.*
638 *There is need to adapt our designs to future change in building use so that little waste will*
639 *be generated from them.*

640

641 *When we are planning to reduce waste, every stage of building delivery processes and even*
642 *end of life should be considered all together*

643

644 The above assertions suggest that the industry practice is expected to shift from addressing
645 waste management from one aspect of project lifecycle. It means that there is need to adopt
646 measures capable of mitigating all waste causative factors at design, procurement and
647 construction stages. By so doing, it would mean that waste causative factors have been
648 prevented during preconstruction activities while framework for managing construction and
649 post construction waste is also set. As such future waste management solutions is not only
650 expected to consider all stages, its capability to predict, monitor and prevent waste is expected
651 to be a build on most present-day waste management strategies which proffer solutions after

652 waste has occurred. This becomes needed, as the best strategy for waste management is to
653 prevent its occurrence (Faniran and Caban, 1998).

654

655

656 *6.3 Building Information Modelling Compliance*

657 The adoption of BIM is becoming commonplace within the construction industry. This is not
658 only because of its collaborative facilities, but also because of the industry's shifts towards its
659 adoption, as influenced by governments' leads. BIM is a technologically enhanced approach
660 that enhances digital representation, storage, management and sharing of building information
661 in a way that allows access to the projects database throughout its lifecycle. The process
662 aspects of BIM gives it more popularity than its software technology (Eadie *et al.*, 2013), and
663 its ingenuity is based on its ability to generate adequately coordinated project information that
664 augments information management and collaboration (Race, 2012; Eastman *et al.*, 2011).

665

666 According to the focus group discussants, the main challenge of existing waste management
667 tools, such as NetWaste in the UK, is manual input of project geometry and lack of
668 compatibility with basic design tools. These results in extra efforts to predict and prevent
669 design related causes of waste.

670

671 *With the current yearning for BIM and IPD, increasing project collaboration will reduce*
672 *waste generation significantly*

673

674 *If the waste management tools are BIM compatible and are able to capture building*
675 *information automatically, then there is nothing stopping their use.*

676

677 The participants imply that future waste management tools are expected to be BIM compliant
678 as the industry practice shifts towards whole BIM adoption. Such tools are expected to provide
679 framework of operation within BIM design platform, and compatibility with several other BIM
680 tools for other design related functions. This would ensure that waste output is easily simulated
681 as an integral part of building design, with intent of comparing different options. Equally, to
682 ensure efficient waste prediction and prevention, as well as its wide adoption within the
683 industry, such tool would automatically map its material database with existing BIM database.

684

685

686

687 6.4 Economic Viability

688 A major driver for adopting waste management strategy is the economic cases it presents. Al-
689 Hajj and Hamani (2011) and Oyedele *et al.* (2013) suggest that contractors are more likely to
690 adopt waste minimization strategy if its implementation results in more financial gains than
691 leaving waste to occur. Tam (2008) claims that waste management planning is less adopted in
692 Hong Kong construction industry as it is believed to reduce productivity rather than increasing
693 profit. Industry practice suggests that contractors compare cost of waste minimization to cost
694 of waste landfilling, thereby adopting cheaper option for each project. It was argued that:

695
696 *With almost yearly increases in landfill tax, more people are finding alternative solutions.*
697 *If the trend continues, waste landfilling could become something of the past, especially as*
698 *money almost matters.*

699
700 *Most people are just aware of environmental benefits of landfilling; there is more need for*
701 *emphasis on its economic benefits. A lot of cost goes into material waste. This include its*
702 *original cost, transport cost, labour spent on it, and the landfill tax. People need to know*
703 *that cost of waste is more than landfill tax*

704
705 Apart from making waste management appealing by raising penalties for waste
706 landfilling, the above assertion advocates effective demonstration of economic benefits of
707 existing waste management strategies. It also reinforces the general belief that waste is
708 not being management due to its perceived high cost. As such, for any waste management
709 strategy to be adequately adopted and effectively used, such strategy would not only be
710 easily implementable, it must have cheaper cost of implementation, which presents more
711 financial gains than cost of waste disposal.

712 713 6.5 Legislative Drives

714 One of the major factors that shape the construction industry is the national and regional
715 legislation. As planning approval is required before any physical construction activities, it
716 means that the project has to fall within the framework provided by the legislation. In the UK
717 construction industry for example, compliance with the provision of Code for Sustainable
718 Homes has become a requirement for all residential building construction. This has continued
719 to drive sustainable building practices as the code becomes more stringent. Before the
720 compulsory SWMP was repealed (in December 2013), it has been the industry's standard to
721 prepare and monitor detailed SWMP for all projects over £300,000. These practices suggest

722 relevant impacts of legislation in driving sustainable practices within the construction industry.
723 Participants in the focus group discussions suggest a number of measures through which
724 legislation could further assist waste management practices.

725
726 *By including waste management capacity in sustainability assessment tools such as*
727 *BREEAM and Code for Sustainable Homes, people will take it more serious*

728
729 *If we are to overcome the problem of waste in construction, more stringent legislation and*
730 *penalties for improper waste management practices are expected from the government*

731
732 *To the best of my knowledge, waste management legislations addresses mainly the*
733 *construction stage, other stages need to be considered as well*

734
735 Buttrressing the above assertion, Osmani (2012) argues that waste management legislation has
736 been practically non-existing with respect to design stage, despite being that major causes of
737 waste are design related (Faniran and Caban, 1998). As the legislation is expected to
738 continuously drive future waste management strategy, more stringent legislation and fines are
739 not only expected, waste preventive standard is also expected to be set for design stage.

740

741 *6.6 Research and Enlightenment*

742 Inadequate knowledge of effective waste management practices as well as poor
743 understanding of the cost benefits of waste preventive measures was stressed by many
744 respondents during the focus group discussions. The participants illuminate this is some
745 of their assertions quoted below:

746
747 *There is need for more research and education on innovative waste management*
748 *techniques as well as waste management tools capable of assisting in both design and*
749 *construction*

750 *Unlike sustainable technologies such as PVC and others, lifecycle cost benefit of using low*
751 *waste construction techniques such as prefabrication is not known. We need more*
752 *education and more awareness about this as well, and I think it would assist decision-*
753 *making*

754

755 The need for research into impacts of different design options and techniques on waste
756 management was illustrated in the above quotation of discussants' expressions. In
757 addition, it was clearly stressed that by enlightening design and construction professionals

758 on different waste management and preventive measures, substantial waste could be
759 diverted from landfill sites. This position is also corroborated by a number of existing
760 studies. While suggesting management measures capable of enhancing waste
761 management practices, Yuan (2013) similarly identified research and development, major
762 stakeholders' awareness and improvement of operatives. Osmani *et al.* (2012) equally
763 identified education programmes as a potential way of improving waste management
764 practices. Thus, increasing awareness and education are indispensable to improving waste
765 effectiveness of the construction industry.

766
767

768 **7. Conclusion**

769 Owing to its contribution of substantial portions of global waste to landfill, effective
770 management of construction related waste is an important requisite for the global sustainability
771 agenda. In a bid to prevent pollutions and enhance financial gains, several waste management
772 strategies and policies have been developed. However, construction industry remains waste
773 intensive. This study identifies impediments to existing waste management strategies as well as
774 requisites for reducing waste intensiveness of the construction industry. Using series of focus
775 group discussions, this study shows that the reason for ineffectiveness of the existing waste
776 management strategy is due to its treatment of waste after it has occurred rather than proffering
777 waste preventive solutions. In addition, existing waste preventive solutions put unpaid burdens
778 on design professionals, as the tools are external to design tools and require extra efforts, which
779 discourages their use. It is noted that apart from a culture of waste behaviour that is prevalent
780 within the construction industry, most of the existing waste management strategies are either
781 expensive or incapable of providing holistic solution to tackling C&D waste. All these point to
782 the reasons for ineffectiveness of existing waste management strategies and subsequent waste
783 intensiveness of the construction industry.

784

785 To reduce waste intensiveness of the construction industry, this study suggests that a number of
786 measures are requisites. This includes increasing implementation of waste preventive measures
787 at design stage, consideration and planning for whole life waste including waste from
788 renovation and end of life, improved compliance of waste management tools with design tools
789 as well as their BIM compliance, cheaper approach to waste management, increasing
790 stringency of waste management legislation and fiscal policy, and research and enlightenment.

791
792

793 The study has implications for practices for both construction professionals and policy makers.
794 At the industry level, waste preventive strategies are expected to be collaboratively adopted at
795 the preconstruction stage, especially as the design stage is very decisive in determining waste
796 effectiveness of a construction project. Rather than the prevailing practices that are
797 concentrated on construction stage, whole project lifecycle as well as buildings' end of life are
798 to be considered. Similarly, as the industry shifts towards full BIM adoption, waste
799 management solutions are expected to be BIM compliant in such a way that waste preventive
800 measures becomes integral part of project delivery process. To cap it all, improving waste
801 management skills and awareness of the design and construction professionals is indispensable
802 to achieving waste effective projects. At policymaking level, legislative approach to waste
803 management should not only consider construction stage, it is expected to set minimum waste
804 preventive standard for design. This is due to the strong emergence that legislation drivers and
805 economic viability of any strategy enhance its adoption in construction industry. As such, for
806 waste management strategy to be well adopted, it would either be legislation driven or more
807 financially viable than landfill tax and other associated cost of waste disposal.

808
809 As this study is limited to qualitative data as well as UK context, other studies employing
810 quantitative data could determine generalizability of its findings. Its transferability to other
811 nations could also be determined. As a number of measures has been explored by this study, it
812 is expected that future studies quantitative identify the actual measures that are critical to
813 reducing waste intensiveness of the construction industry.

814

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