EXPLORING WASTE MINIMIZATION MEASURES IN THE GHANAIAN CONSTRUCTION INDUSTRY

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ABSTRACT

The chronic problems of construction include low productivity, low quality, poor co-ordination and high costs. High product cost is also associated with poor quality, inefficiency and high waste generation. Various studies in the construction industry have developed best practices that are not only capable of improving organization's profit but also assist in producing systematic work processes which encourage the optimal use of resources. A structured questionnaire survey was conducted to provide empirical evidence on levels of significant contribution of waste minimization measures to waste reduction, and levels of practice of same measures using weighted average and coefficient of variation criteria. Purchasing raw materials that are just sufficient, using materials before expiry dates, and using more efficient construction equipment are perceived by construction professionals as three of twenty-six measures which most significantly contribute to waste minimization, and also the three most practiced waste minimization measures in Ghana. Encouraging re-use of waste materials, use of low waste technology and recycling of waste materials on site are, however, considered as the three least significant measures contributing to waste minimization and also least practiced. Among various suggested recommendations, the construction industry is encouraged to sort and re-use waste materials, and adopt environmentally friendly and low waste technologies on site. This paper presents measures which significantly contribute to materials waste minimization on construction sites in Ghana.

Keywords: Waste, minimization, measures, construction, Ghana

1. INTRODUCTION

The construction industry plays a vital role in meeting the needs of society and enhancing quality of life (Shen and Tam, 2002; Tse, 2001). However, the responsibility of ensuring that construction activities and products are consistent with environmental policies needs to be defined, and good environmental practices improved (Environmental Protection Department, 2002; Shen et al., 2002). Environmental protection has recently become an important issue all over the world. Compared with other industries, construction generates fairly large amount of pollutants, including solid waste, noise, dust and water (Ball, 2002; Morledge and Jackson, 2001). Since construction has a major and direct influence on many other industries by means of both purchasing the inputs from other industries and providing products to almost all other industries, eliminating or reducing waste could yield great cost savings to society (Polat and Ballard, 2004). The construction industry has been encouraged to re-use built assets, minimize waste, recycle materials, minimize energy in construction and use of buildings, use environmental management systems to reduce pollution, enhance bio-diversity, conserve water, respect people and their local environment, measure performance and set targets for the environment and sustainability (Ofori et al., 2000). It is, however, regrettable that although stakeholders are now questioning the traditional routes of waste disposal in favour of sustainable waste management strategies, the majority of construction companies have placed waste reduction at the bottom of their agenda because of complexities over re-use and recycling.

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2. LITERATURE REVIEW

Construction waste has caused serious environmental problems in many large cities (Begum et al., 2006; Chen et al., 2002; Teo and Loosemore, 2001). Polat and Ballard (2004) defined waste simply as "that which can be eliminated without reducing customer value". Waste in construction is also defined as "the difference between the value of those materials delivered and accepted on site and those used properly as specified and accurately measured in the work, after deducting cost saving of substituted materials and those transferred elsewhere" (Polat and Ballard, 2004; Pheng and Tan, 1998).

According to Formoso et al. (1999), waste can be classified as unavoidable waste (or natural waste), in which the investment necessary for its reduction is higher than the economic benefit, and avoidable waste in which the cost of waste is higher than the cost to prevent it. The percentage of unavoidable waste depends on the technological development level of the company (Polat and Ballard, 2004; Formoso et al., 1999; Womack and Jones, 1996). Waste can be categorized according to its source- the stage in which the root causes of waste occurs. Bossink and Brouwers (1996) identified the main sources of waste in construction as design, procurement, material handling, operation and residual. Sources of waste are also identified from the processing preceding construction such as materials manufacturing, design, material supply, and planning, as well as from the construction stage (Formoso et al., 1999). According to Ofori and Ekanayake (2000), construction waste can be divided into three major categories: material, labour and machinery waste. The current study, however, focuses on material wastage since most of the raw materials from which construction inputs are derived come from non-renewable resources and once wasted, becomes very difficult to replace them (Ofori and Ekanayake, 2000). Garas et al. (2001) categorized material wastes by activity, to include over-ordering, overproduction, wrong handling, wrong storage, manufacturing defects and theft or vandalism.

The Environmental Protection Agency of USA (2000) defines waste minimization as "any method that reduces the volume or toxicity of a waste that requires disposal". Poon et al. (2004) also define waste minimization as "any technique, process or activity which avoids, eliminates or reduces waste at its source or allows re-use or recycling of the waste. In the opinion of Begum et al. (2006), waste minimization includes source reduction and recycling. The same authors defined source reduction as any activity that reduces or eliminates the generation of waste at source, usually within a process, and recycling as the recovery and/or re-use of what would otherwise be a waste material. Different measures for minimizing materials waste have been discussed (Begum et al., 2006; Faniran and Caban, 1998). Coffey (1999) pointed out that solid construction waste management is generally seen as a low priority when financial constraints are present and suggested that considerable waste reduction can be achieved if waste management is implemented as part of project management functions. Polat and Ballard (2004) emphasized that reduction is the best and most efficient method for minimizing the generation of waste and eliminating many of the waste disposal problems.

Ayarkwa and Adinyira (n.d.) reports of a wide variation in wastage rates of between 5% and 27% of total materials purchased for construction projects in Ghana. As construction is a locomotive sector of the national economy, waste in the construction industry affects the overall national economy. It is important therefore to explore measures contributing to construction material waste minimization and assess the level of practice of such measures by the construction industry since cost reduction arising from minimization of materials waste is of direct benefit to all stakeholders.

This paper reports on a study conducted to assess the levels of contribution of some waste minimization measures to waste reduction, and the levels of practice of such measures in the Ghanaian construction industry.

3. RESEARCH METHODOLOGY

Twenty-six (26) waste minimization measures which have been extensively studied were extracted from the literature (Begum et al., 2006; Shen et al., 2002; Shen and Tam, 2002; Poon et al., 2001; Ho, 2001; Faniran and Caban, 1998; Peng and Scorpio, 1997; Sherman, 1996). These measures were pre-tested in a multiple pilot study using interviews and questionnaire involving ten selected experienced construction practitioners to evaluate their applicability to the current study. In the view of some interviewees, waste is an inevitable by-product of construction, and waste reduction activities will not be able to eliminate the generation of waste completely. Most of them demonstrated in depth understanding and knowledge of the 26 waste minimization measures extracted from the literature for the study. They agreed with the applicability of the selected measures to the current study and suggested modification and rewording of a few of the measures.

A structured questionnaire survey employing both closed and open-ended questions was conducted. The survey targeted site managers of construction organizations, and architects and quantity surveyors of registered firms in the Ashanti and Greater Accra regions of Ghana. The questionnaire was divided into three sections. The first part sought information about the respondents' profile, the second part assessed respondents' perception on how the measures identified from literature and pre-tested in the pilot study contribute to materials waste minimization, and the final part assessed the level of practice of the measures identified.

Building construction organizations operating within Ghana register with the Ministry of Water Resource, Works and Housing (MWRWH) in four categories: class D, K, E and G, based on the nature of work the organizations engage in - building, civil engineering, electrical and plumbing works respectively. There are four financial sub-classifications within these categories - Class 1, 2, 3 and 4 - which set the limitations for companies in respect of their asset, plant and labour holdings, and the nature and size of the projects they can undertake. Class 1 has the highest resource base, decreasing through classes 2 and 3, to class 4 having the least resource base (MWRWH, 2011). Site managers of D1 and D2 building construction organizations who are registered with the MWRWH as well as senior architects of architectural firms fully registered with the Architects Registration Council of Ghana (ARCG) and senior quantity surveyors of firms fully registered with the Ghana Institution of Surveyors (GhIS) were involved in the study. D1/D2 firms were the focus of the study mainly because such firms have the capacity to employ most the waste minimization measures identified from the literature and confirmed through the interviews as applicable to the Ghanaian construction industry. According to the MWRWH (2011), there are 519 D1 and D2 building contractors in the Ashanti and Greater Accra Regions of Ghana. Records of the ARCG (2010) indicate that there are 114 fully registered architectural firms in the two regions, whilst the GhIS (2010) also had 60 fully registered quantity surveying firms.

A sample size of 226 site managers of D1 and D2 construction organizations was determined using the following formula recommended for such studies by Israel (1992):

$$n = \frac{N}{1+N(e)^2}$$

where n is the sample size, N is the population size and e is the desired level of precision (±5%). The questionnaire was administered through a face-to-face session which ensured that 188 out of the 226 site managers were completed, representing a response rate of 83%. Questionnaires were distributed to all the 174 architectural and quantity surveying firms fully registered with their respective professional bodies. Out of this, 123 were completed, resulting in a response rate of 71%.

The waste minimization measures identified from the literature and confirmed by pre-testing were considered to have different levels of contribution to waste minimization. The study therefore used the following weighted average model (Begum et al., 2006) to examine the relative levels of significant contribution of the waste minimization measures as perceived by the construction professionals:

$$\mathrm{ASS_i} = \frac{\sum_{i=1}^{5} \mathrm{X_j N_{ij}}}{\mathrm{N}}$$

where ASS_i is the average significant score of the waste minimization measure *i*, X_j the waste minimization score assigned (on a Likert scale of 1 to 5). N_{ij} = the number of respondents who assigned the score X_j for the measure *i* and N is the total number of respondents. For each waste minimization measure, the respondents were asked to score the level of contribution to waste minimization on the Likert scale of 1 to 5 where 1= 'very low', 2= 'low', 3= 'Medium', 4= 'High' and 5= 'Very high'. The respondents were further asked to score each measures according to the level of practice in their organization on a scale of 1 to 5 where 1= 'Not practiced at all', 2= 'Not practiced', 3= 'Practiced', 4= 'Frequently practiced' and 5= 'Most frequently practiced'. The weighted average model (used to calculate ASS above) was used to calculate the average practiced score (APS) of the waste minimization measure *i*. To rank the levels of significant contribution of the minimization measures, the study employed the combined value of the weighted average and coefficient of variation. The coefficient of variation, measured as minimization index value (MIV), was calculated using the following model (Begum et al., 2006):

$$MIV_i = \frac{ASS_i + ASS_i}{\delta i}$$

where MIV_i is the coefficient of variation of the waste minimization measure *i*, ASS_i is the average significant score of the waste minimization measure *i* and δi is the standard deviation of the average significance score for the measure *i*. The same model was used to calculate the practiced index value (PIV) for the ranking of the level of practice of the minimization measures. According to Begum et al. (2006), although the ASS and APS are weighted average measures and could be used to rank all the waste minimization measures, they do not consider the degree of variation between individual responses. Since a smaller variation between individual responses give better quality to the weighted average value, when two factors carry the same or very close weighted values, the factor carrying the smaller variation is given a higher ranking. Thus, the effective assessment of ranking attributes should consider both the weighted average and the coefficient of variation measured by the minimization and practice index values.

4. RESULTS AND DISCUSSIONS

- ***Company profile***

The average years of experience of the firms surveyed in the construction market are between 10 and 20 years. This implies that all the firms have significant experience in the building industry. With regards to the average number of permanent and temporary employees, none of the firms contacted was willing to disclose. The main reason given was that it is confidential. The respondents, however, indicated that they had enough employees and could recruit additional employees when necessary.

Architects constituted 58% and quantity surveyors constituted 42% of the consultant. For the contractors, project managers constituted 68% and site engineers constituted 32%. Forty percent of the contractor-respondents and 50% of the consultant-respondents had bachelors' degree, and 36% of the contractors and 34% of consultants had Higher National Diploma (HND) certificates. The study further showed that 15% of consultants and 8% of the contractors had Master's degree. Nine percent of the contractors and 1% of the consultants had doctorate degree. The results also showed that majority of the firms (58% of contractors and 60% of consultants) had both public and private sector clients. Seven percent of contractors and 15% of consultants had public sector clients and 35% of contractors and 25% of consultants had private sector clients.

- ***Empirical evidence of the levels of contribution of the waste minimization measures***

Table 1 shows a summary of average significant scores (ASS), minimization index values (MIVs) and rankings of the levels of significance contribution of the minimization measures on the basis of MIV.

The waste minimization measure 24 (WMM 24) is ranked the first measure that most significantly contributes to waste minimization, indicating that 'purchasing raw materials that are just sufficient for a project' very highly contributes to waste minimization. WMM 1 is ranked the 26th, indicating that 'recycling of some waste materials on site' has the least significant contribution to waste minimization. The other measures evaluated have ASS ranging between 4.88 and 3.73. Thus, apart from 'recycling of some waste materials on site' (WMM 1), 'using of low waste technology' (WMM 12) and 'encouraging re-use of waste materials in projects' (WMM 16), all the other measures evaluated by the construction professionals have medium to high contribution to waste minimization in Ghana.

The ranking profile (Fig. 1) shows empirical evidence of the levels of significant contribution of the various measures to waste minimization in the implementation of waste management.

- ***Empirical evidence of the levels of practice of the waste minimization measures***

Table 2 gives a summary of average practiced scores (APS), practiced index values (PIVs) and rankings of the level of practice of the various measures on the basis of PIVs. WMM-25 is ranked the first measure highly practiced by the respondents to minimize waste indicating that 'using materials before expiry dates' is most frequently practiced to minimize waste in Ghana. WMM-1 is ranked the 26th, indicating that 'recycling of some waste materials on site' is the least practiced measure to minimize waste in Ghana. The other measures evaluated have APS ranging between 4.10 and 3.64.

Thus, apart from 'recycling of some waste materials on site' (WMM 1), 'using of low waste technology'(WMM 12) and 'encouraging re-use of waste materials in projects' (WMM 16), all the other measures evaluated by the construction professionals are either practiced or frequently practiced to minimize waste in Ghana. The ranking profile (Fig. 2) shows empirical evidence of the levels of practice of the various measures to minimize waste in construction projects.

Table 1: Summary of Average Significant Scores, Minimization Index Values and their Rankings

Waste minimization measures (WMM)	**Average significant score (ASS)**	**Standard deviation (δ)**	**Minimization index value (MIV)**	**Rank of minimization index value (RMIV)**
Purchasing raw materials that are just sufficient (WMM 24)	4.96	0.286	34.685	1
Using materials before expiry dates (WMM 25)	4.88	0.461	21.171	2
Use of more efficient construction equipment (WMM 5)	4.42	0.605	14.612	3
Good coordination between store and construction personnel to avoid over ordering (WMM 4)	4.46	0.689	12.946	4
Adoption of proper site management techniques (WMM 21)	4.37	0.727	12.022	5
Training of construction personnel (WMM3)	4.36	0.797	10.941	6
Accurate and good specifications of materials to avoid wrong ordering (WMM 26)	4.17	0.765	10.910	7
Proper storage of materials on site (WMM 7)	4.35	0.82	10.610	8
Checking materials supplied for right quantities and volumes (WMM 13	4.32	0.817	10.575	9
Employment of skilled workmen (WMM 14)	4.22	0.813	10.380	10
Minimizing design changes (WMM 23)	4.15	0.876	9.475	11
Change of attitude of workers towards the handling of materials (WMM 11)	4.12	0.893	9.227	12
Accurate measurement of materials during batching (WMM 15)	4.16	0.942	8.832	13
Mixing, transporting and placing concrete at the appropriate time (WMM 19)	4.21	0.978	8.609	14
Access to latest information about types of materials on the market (WMM 22)	4.07	0.948	8.586	15
Vigilance of supervisors (WMM 6)	4.13	0.982	8.411	16
Weekly programming of works (WMM 18)	4.10	0.896	8.384	17
Careful handling of tools and equipment on site (WMM 17)	4.07	1.032	7.888	18
Good construction management practices (WMM 2)	4.24	1.098	7.723	19
Adherence to standardized dimensions (WMM 10)	4.18	1.103	7.579	20
Waste management officer or personnel employed to handle waste issues (WMM20)	4.01	1.068	7.509	21
Just in time operations (WMM 8)	3.99	1.187	6.723	22
Early and prompt scheduling of deliveries (WMM 9)	4.01	1.203	6.667	23
Encourage re-use of waste materials in projects (16)	3.76	1.197	6.282	24
Use of low waste technology (WMM 12)	3.73	1.339	5.571	25
Recycling of some waste materials on site (WMM 1)	2.65	1.524	3.478	26

Table 2: Level of practice of waste minimization measures among professionals

Waste minimization measures (WMM)	**Average Practiced score (APS)**	**Standard deviation (δ)**	**Practiced index value (PIV)**	**Rank of Practiced index value (PIV)**
Using materials before expiry dates (WMM 25)	4.83	0.575	16.800	1
Use of more efficient construction equipment (WMM 5)	4.18	0.693	12.063	2
Purchasing raw materials that are just sufficient (WMM 24)	4.68	0.821	11.400	3
Adoption of proper site management techniques (WMM 21)	3.92	0.848	9.245	4
Good coordination between store and construction personnel to avoid over ordering (WMM 4)	4.09	0.834	9.808	5
Minimizing design changes (WMM 23)	4.10	0.896	9.152	6
Training of construction personnel (WMM 3)	4.07	0.913	8.916	7
Proper storage of materials on site (WMM 7)	4.02	0.905	8.884	8
Employment of skilled workmen (WMM 14)	3.99	0.900	8.867	9
Accurate and good specifications of materials to avoid wrong ordering (WMM 26)	3.71	0.905	8.200	10
Checking materials supplied for right quantities and volumes (WMM 13)	3.95	0.989	7.988	11
Change of attitudes of workers towards the handling of materials (WMM 11)	3.83	0.978	7.832	12
Vigilance of supervisors (WMM 6)	3.95	1.030	7.670	13
Access to latest information about types of materials on the market (WMM 22)	3.83	1.025	7.473	14
Accurate measurement of materials during batching (WMM 15)	3.88	1.071	7.246	15
Weekly programming of works (WMM 18)	3.64	1.017	7.158	16
Good construction management practices (WMM 2)	3.96	1.113	7.116	17
Mixing, transporting and placing concrete at the appropriate time (WMM 19)	3.88	1.092	7.106	18
Adherence to standardized dimensions (WMM 10)	3.97	1.131	7.020	19
Waste management officer or personnel employed to handle waste issues (WMM 20)	3.73	1.134	6.578	20
Early and prompt scheduling of deliveries (WMM9)	3.76	1.169	6.433	21
Just in time operations (WMM 8)	3.67	*1.143*	6.422	22
Careful handling of tools and equipment on site (WMM 17)	3.69	1.154	6.395	23
Encourage re-use of waste materials in projects (WMM16)	3.42	1.203	5.686	24
Use of low waste technology (WMM 12)	3.53	1.312	5.381	25
Recycling of some waste materials on site (WMM 1)	2.55	1.422	3.586	26

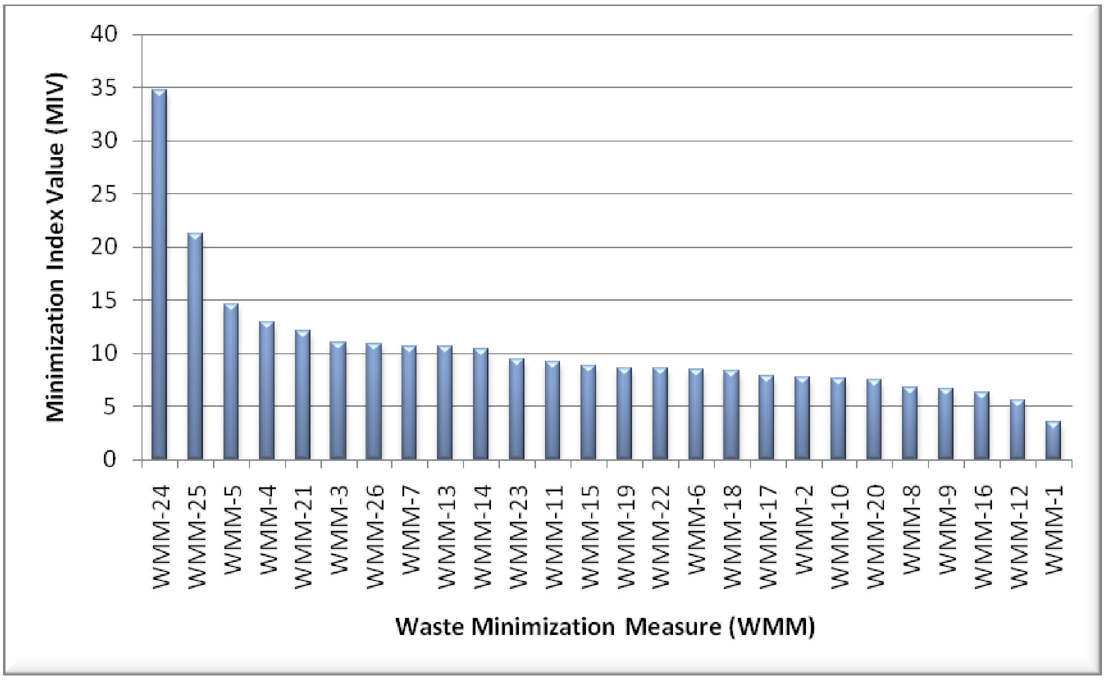

Figure 1: Ranking profile of the levels of significant contribution of waste minimization measures

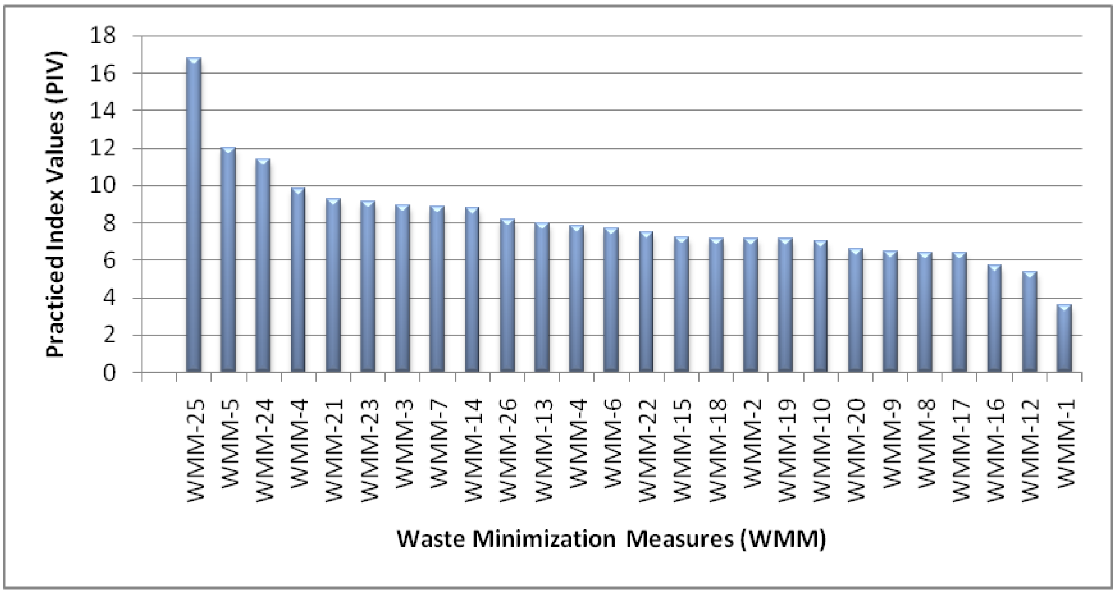

Figure 2: Ranking profile of the levels of practice of waste minimization measures

The empirical evidence presented in Tables 1 and 2 and Figures 1 and 2 shows that the ranking of the various waste minimization measures by the weighted average criteria (i.e. the ASS and the APS) give the same results as that by the coefficient of variation criteria (i.e. the MIV and the PIV). Thus, both criteria are effective for assessing the relative levels of significance contribution and relative levels of practice of the various measures in the implementing of construction waste management. The study has shown that the measures that are highly practiced by construction organizations (i.e. 'purchasing raw materials that are just sufficient' (WMM 25), 'using materials before expiry dates' (WMM 24) and 'use of more efficient construction equipment' (WMM 5), are those that directly result in cost savings to the organization, and the least practiced measures (i.e. 'encouraging re-use of waste materials in projects' (WMM 16), 'using of low waste technology' (WMM 12) and 'recycling of some waste materials on sites' (WMM 1) are those that require investment or further processing of materials to obtain value. Thus, the results show little awareness among construction professionals on the importance of waste minimization. This corroborates with the findings of Teo and Loosemore (2001) and Lingard et al. (2000) on waste minimization in Australia. In Australia, waste management was reported as a low project priority amongst construction workers. Waste sorting and recycling although widely publicized by government bodies in Australia, were still not used on most sites at the time. Applying environmentally friendly technology on site and using low waste technology are considered less attractive environmental management measure to construction organizations in Ghana, confirming findings of Begum et al. (2006) and Shen and Tam (2002). Such measures were seen as adding to their production cost hence defeating their perceived views of waste minimization as a cost saving technique.

5. CONCLUSION AND RECOMMENDATIONS

The study has provided empirical evidence on the levels of contribution and the levels of practice of waste minimization measures in the Ghanaian construction industry. It has shown that purchasing raw materials that are just sufficient, using materials before expiry dates and use of more efficient construction equipment are perceived as the three measures that most significantly contribute to waste minimization and also the most practiced waste minimization measures. Encouraging re-use of waste materials in projects, using low waste technology and recycling of some waste materials on sites are, however, perceived as the least significant factors that contribute to waste minimization and the least practiced measures simply because such measures are seen as adding to their production cost instead of reducing cost. These findings will assist in the formulation of appropriate policy interventions to address the construction waste management problem in the Ghanaian construction industry. The findings will also help firms to improve the quality of construction in Ghana.

In order to assist the construction industry to minimize materials wastage, the authors recommend that government should enact laws and establish policies that engender positive attitudes towards waste minimization at all levels in a construction project. Also the construction industry in Ghana should collaborate with relevant government agencies to develop appropriate guidelines for preparing waste management plans for the construction industry. The construction industry should also adopt low waste and environmentally friendly technologies on site, and government should provide incentives to the construction industry to encourage the reduction, recycling and re-use of construction waste. Construction organizations should also provide waste reduction training to site staff to raise their environmental awareness and improve working procedures to reduce waste generation in construction projects.

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