Consultants' Perspectives on Materials Waste Reduction in Ghana

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Abstract

The construction industry is responsible for producing a whole variety of waste, depending on factors such as the stage of construction, type of construction work and practices on site. This paper reports on a study to assess the level of contribution of some waste minimization measures to waste reduction, and the level of practice of such measures in the Ghanaian construction industry. A structured questionnaire survey was conducted to elicit views of consultants on twenty six waste minimization measures. Data obtained from the study were analyzed using descriptive analysis, where minimization measures were grouped under high, medium and low levels of contribution and practice. The results showed that out of twenty six waste minimization measures, purchasing raw materials that are just sufficient, using materials before expiry dates and using more efficient construction equipment are perceived by consultants as those with high level of contribution to waste minimization, and also those which are highly practiced. The results further showed that encouraging re-use of waste materials, use of low waste technology and recycling of waste materials on site are considered as measures with low level of contribution to waste minimization and also low level of practice. The findings from the study present the Ghanaian construction industry with measures which significantly contribute to materials waste minimization on construction sites. The adoption of these waste minimization measures could yield great cost savings to the construction industry and prevent environmental degradation.

Keywords: waste minimization, measures, construction industry, Ghana

1. Introduction

The construction industry plays a vital role in meeting the needs of society and enhancing quality of life (Shen & 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). Compared with other industries, construction generates fairly large amount of pollutants, including solid waste, noise, dust and water (Ball, 2002; Morledge & 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 & 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). Environmental protection has recently become an important issue all over the world. 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.

Construction waste has caused serious environmental problems in many large cities (Begum et al., 2006; Chen et al., 2002; Teo & Loosemore, 2001). Polat and Ballard (2004) defined waste simply as "that which can be eliminated without reducing customer value". In a study on methods for waste control in the building industry in Brazil, Formoso et al. (1999) classified waste into 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 & Ballard, 2004; Formoso et al., 1999; Womack & Jones, 1996). Waste can be categorized according to its source - the stage in which the root causes of waste occurs. Bossink and Brouwers (1996) in a study on waste rates in the Dutch construction industry 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). In a study on construction material waste source evaluation in Singapore, Ekanayake and Ofori (2000) divided construction waste 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 (Ekanayake & Ofori, 2000).

The Environmental Protection Department of Hong Kong (2000) defines materials waste as comprising of unwanted materials generated during construction, including rejected structures and materials, materials which have been over-ordered or are surplus to requirements, and materials which have been used and discarded. Furthermore, materials waste can be defined as "any material, apart from earth materials, which needs to be transported elsewhere from the construction site or used within the construction site itself for the purpose of land filling, incineration, recycling, re-using or composting, other than the intended specific purpose of the project due to materials damage, excess, non-use, or non-compliance with the specifications or being a by-product of the construction process" (Ekanayake & Ofori, 2000). In a study on dominant causes of waste generation in Egyptian construction, Garas et al. (2001) categorized material wastes by activity, to include over-ordering, overproduction, wrong handling, wrong storage, manufacturing defects and theft or vandalism.

Begum et al. (2006) conducted a study on implementation of waste management and minimization in the Malaysian construction industry and categorized waste minimization into source reduction and recycling. Source reduction is defined 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. Poon et al. (2004) also studied how to reduce building waste at construction sites in Hong Kong, and defined 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. 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". Different measures for minimizing materials waste have been reported (Begum et al., 2006; Faniran & Caban, 1998). In a study on application of Lean Construction to reduce waste in Turkish construction, 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. Coffey (1999) studied cost-effective systems for solid waste management and 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. Ayarkwa and Adinyira (n.d) report 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 in the construction industry since cost reduction arising from minimization of materials waste is of direct benefit to all stakeholders.

This paper presents the opinion of consultants on the level of contribution of some waste minimization measures to waste reduction, and the level of practice of such measures in the Ghanaian construction industry.

2. Research Methodology

Twenty-six (26) waste minimization measures which have been extensively studied were extracted from the literature (Osmani et al., 2007; Begum et al., 2006; Al-Moghany, 2006; Polat & Ballard, 2004; Shen et al., 2002; Shen & Tam, 2002; Poon et al., 2001; Ekanayake & Ofori, 2000; Formoso et al., 1999). Osmani et al. (2007) examined architects' approach towards construction waste minimization in the UK and found that waste could essentially arise from design decisions. The authors therefore emphasized the need for waste management in the design process. Begum et al. (2006) studied waste minimization measures in the implementation of waste management in the Malaysian construction industry and reported on highly practiced measures to reduce waste in Malaysia. Al-Moghany (2006) identified the main waste causes in Gaza Strip construction industry in order to develop methods for prevention and elimination of waste causes inherent in the construction process. The study recommended that designers should pay attention to detailing and dimensioning of materials and components

during design, and contractors should assign qualified personnel to construction projects and prepare waste management plans. Polat and Ballard (2004) studied the main waste causes in the Turkish construction industry using residential/mass housing, industrial and institutional buildings and proposed a set of recommendations for eliminating waste inherent in construction. Shen et al. (2002) collected information on material wastage on public housing, private housing, commercial projects, composite building projects, industrial projects, monastery projects and school projects in Hong Kong. The results proposed measures for waste minimization on site including good construction management practices, provision of waste reduction training to on-site staff and adoption of proper site management techniques. In a study on the implementation of environmental management in the Hong Kong construction industry, Shen and Tam (2002) recommended several waste minimization measures. Poon et al. (2001) studied on-site sorting of construction and demolition waste in Hong Kong using public housing building sites and recommended a number of measures for effective waste minimization including adoption of proper site management techniques, training of construction personnel, on-site sorting of materials, re-use and recycling. Furthermore, Ekanayake and Ofori (2000) studied the most important sources of waste in construction and possible measures to minimization waste in Singapore, and emphasized the need to avoid design changes during construction. In a study aimed at developing a method for controlling waste on building sites, Formoso et al. (1999) monitored five fairly similar sites in the city of Porto Alegre, Brazil, consisting of four residential and one commercial building, and proposed a classification for waste in the construction industry which could help construction managers minimize waste. Since the current study intended to investigate lecture theatres, offices and high rise student hostels in and around the Kwame Nkrumah University of Science and Technology, Kumasi campus, the waste minimization measures identified from the previous research were considered applicable. The 26 measures collected from literature were pre-tested in a pilot study involving ten selected experienced consultants (five Architects and five quantity surveyors) to evaluate their applicability to the current study. Most of the selected consultants in the pilot study 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. For instance “changing design of the construction process” was reworded as “minimizing design changes” and “facilitate re-using or recycling for sorting different types of waste” was reworded as “recycling of some waste materials on site”.

A structured questionnaire survey employing both closed and open-ended questions was conducted between February 2011 and December 2011. 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.

The survey targeted architects and quantity surveyors of registered firms in the Ashanti and Greater Accra regions of Ghana. 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. This is because these consultants deal directly with construction organizations, have over-site responsibility for projects, and are therefore expected to contribute to waste minimization efforts. Records of the ARCG (2010) indicated 114 fully registered architectural firms in the two regions, whilst records of the GhIS (2010) also had 60 fully registered quantity surveying firms.

All the consulting firms in the two regions were considered in the study resulting in a sample size of 174 fully registered architectural and quantity surveying firms. Out of the total sample size, 123 comprising 52 quantity surveyors and 71 architects completed and returned the questionnaires resulting in a response rate of 71%. The data collection took about 10 months to complete.

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 26 waste minimization measures were coded as WMM1 to WMM 26 respectively. The level of contribution of the 26 measures to waste reduction were evaluated based on the Likert scale of 1 to 5, where 1= ‘very low’, 2= ‘low’, 3= ‘medium’, 4= ‘high’ and 5= ‘very high’. The level of practice were also evaluated based on the Likert scale of 1 to 5 where 1= ‘Not practiced at all’, 2= ‘Not practiced’, 3= ‘Practiced’, 4= ‘Frequently practiced’ and 5= ‘Most frequently practiced’.

3 Results and Discussions

3.1 Company Profile

The average years of experience of the consultancy firms surveyed in the construction market ranged between 10 and 20 years, which indicates significant experience in the building industry. Of the respondents, architects

constituted 58% and quantity surveyors constituted 42%. Sixty-five percent of the quantity surveyors and 25% of the architects held bachelors' degree. Thirty-five percent of the quantity surveyors held Higher National Diploma (HND) certificates and 75% of the architects held postgraduate diploma. The results also showed 50% of quantity surveyors and 65% of architects had both public and private sector clients. Eight percent of quantity surveyors and 10% of architects had public sector clients and 42% of quantity surveyors and 25% of architects had private sector clients. This indicates that the sampled consultants are doing well in the construction market.

3.2 Level of Contribution of Waste Minimization Measures to Waste Reduction

The responses of the architects and the quantity surveyors on the level of contribution of the waste minimization measures to waste reduction were compared. The results showed no significant difference at 5% significance level. Educational level also did not affect the responses within each group of respondents. The responses of both groups of respondents were therefore combined for the descriptive analysis. Percentage of respondents who scored the level of contribution of the various measures from "high" to "very high" are shown in Table 1 and Figure 1.

Table 1. Percentage of respondents on contribution of waste minimization measures

Rank	Waste minimization measures	Percentage of respondents
High	Purchasing raw materials that are just sufficient (WMM 24)	99
	Using materials before expiry dates (WMM 25)	97
	Use of more efficient construction equipment (WMM 5)	95
	Good coordination between store and construction personnel to avoid over ordering (WMM 4)	94
	Adoption of proper site management techniques (WMM 21)	92
	Training of construction personnel (WMM3)	91
	Accurate and good specifications of materials to avoid wrong ordering (WMM 26)	90
Medium	Proper storage of materials on site (WMM 7)	88
	Checking materials supplied for right quantities and volumes (WMM 13)	86
	Employment of skilled workmen (WMM 14)	85
	Minimizing design changes (WMM 23)	84
	Change of attitude of workers towards the handling of materials (WMM 11)	83
	Accurate measurement of materials during batching (WMM 15)	82
	Mixing, transporting and placing concrete at the appropriate time (WMM 19)	81
	Access to latest information about types of materials on the market (WMM 22)	80
	Vigilance of supervisors (WMM 6)	80
Low	Weekly programming of works (WMM 18)	75
	Careful handling of tools and equipment on site (WMM 17)	73
	Good construction management practices (WMM 2)	68
	Adherence to standardized dimensions (WMM 10)	63
	Waste management officer or personnel employed to handle waste issues (WMM20)	62
	Just in time operations (WMM 8)	60
	Early and prompt scheduling of deliveries (WMM 9)	58
	Encourage re-use of waste materials in projects (16)	55
	Use of low waste technology (WMM 12)	53
	Recycling of some waste materials on site (WMM 1)	50

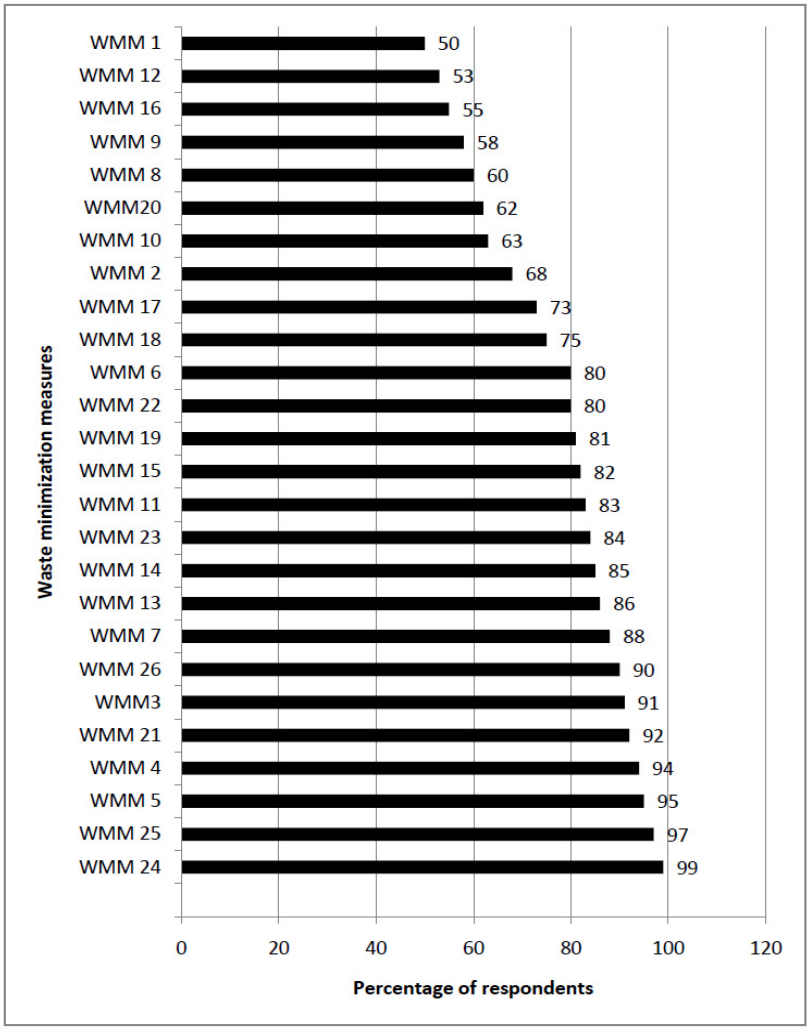

Figure 1. Contribution of waste minimization measures to waste reduction

From the results, 99% of the respondents considered "purchasing raw materials that are just sufficient for the work" to contribute to waste reduction on construction sites in Ghana. Ninety seven percent (97%) and 95% considered "using materials before expiry dates" and "using more efficient construction equipment" to contribute to waste reduction on construction sites respectively. For the rest of the waste minimization measures studied, percentages of respondents who considered the measures to contribute to waste reduction ranged between 58% and 94%, except "recycling of some waste materials on site", "use of low waste technology" and "encouraging re-use of waste materials in projects" which accounted for only 50%, 53% and 54% of the respondents respectively.

The 26 waste minimization measures were further categorized into three levels of contribution to waste reduction: high, medium and low (Table 1 and Figures 3, 4 and 5 respectively). High level of contribution comprised those measures rated by more than 90% of the respondents. Medium level of contribution comprised measures rated between 80% and 90% of the respondents and low level comprised those rated below 80% of the respondents. Six measures including "purchasing raw materials that are just sufficient" (WMM 24), "using materials before expiry dates" (WMM 25) and "using more efficient construction equipment" (WMM 5) were categorized as high level contributors to waste reduction, with ratings of more than 90% of respondents (Figure 3). Among the measures in this category include those that directly result in cost savings to the construction organization. Thus, consultants considered waste minimization measures which result in cost saving to the organization as high contributors to waste reduction on construction sites in Ghana. Waste begins at the time of purchasing materials

for a project, and the purchasing activity determines the materials that are to be supplied to the site. Excess materials brought to the site can result in materials wastage. Residual materials if not used on time may expire and become waste material. Longdon (2007) stated that because materials are considered inexpensive compared to labour, a waste allowance is generally included within the order to account for design and construction process waste. This can lead to ordering of surplus materials (usually entering the waste stream) resulting in financial loss to the organization. The use of more efficient construction equipment can also save the organization frequent repair costs and excessive use of fuel and lubricants.

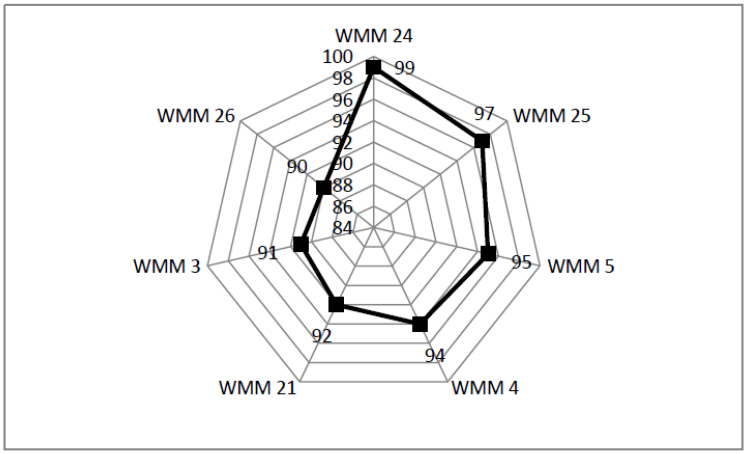

Figure 3. Measures contributing to high reduction of materials waste (Note 1)

Nine measures including "proper storage of materials on site" (WMM 7), "checking materials supplied for right quantities and volumes" (WMM 13) and "employment of skilled workmen" (WMM 14) were categorized as medium level contributors to waste reduction, with ratings between 80% and 90% of respondents (Figure 4). Measures in this category, if not implemented, can result in financial loss to the organization. Thus, in the opinion of the consultants, waste minimization measures which can result in financial loss to the organization are medium contributors to waste reduction on construction sites in Ghana. The result points to the need for proper materials control and the adoption of good practices on site. Wrong ordering of materials can result in project delays, material wastage on the construction site and financial loss to the organization. Better attention to materials control may have significant influence on the pursuit of increased profit. Over-ordering or shortage in materials supplied to the site and improper storage and handling of materials on building project sites can all result in materials waste, time and cost overruns and financial loss to the organization. Harris and MacCaffer (2001) assert that construction companies pay more attention and spend more time with control of labor and plant than they do with control of materials. However, there is evidence that losses due to materials are often higher than those due to other causes.

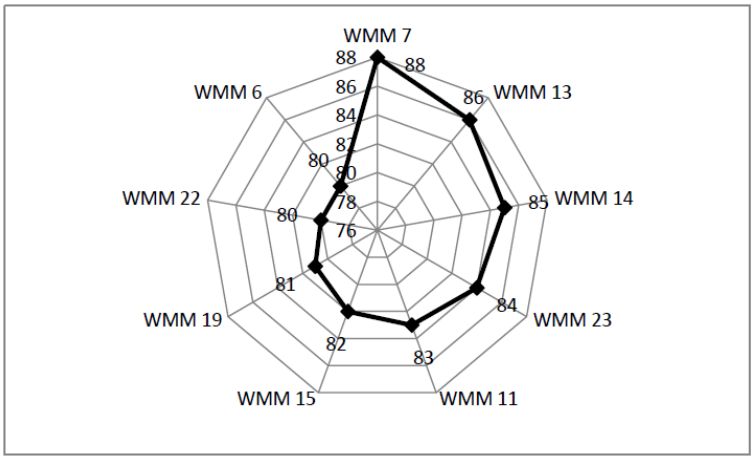

Figure 4. Measures contributing to medium reduction of materials waste (Note 2)

Ten measures including "encouraging re-use of waste materials in projects" (WMM 16), "use of low waste technology" (WMM 12) and "recycling of some waste materials on site" (WMM 1) were categorized as low contributors to waste reduction, with ratings of below 80% of respondents. The measures in this category require financial resources to achieve, especially re-use and recycling of waste materials. In the opinion of the consultants these are not major contributors to waste minimization in Ghana. These measures are seen as adding to the organization's production cost instead of cost savings. The result corroborates the findings of Begum et al. (2006), Shen and Tam (2002) and Horvath (1999) who noted that like other materials in the economy, re-use and recycling of construction materials are driven by economic benefits.

3.3 Level of Practice of Waste Minimization Measures

The responses of the architects and the quantity surveyors on the level of practice of the waste minimization measures to waste reduction were compared, and the results showed no significant difference at 5% significance level. Educational level also did not affect the responses within each group of respondents. The responses of both groups were therefore combined. The percentage of respondents who evaluated the level of practice of the various measures from "frequently practiced" to "most frequently practiced" are shown in Table 2 and Figure 2 .

Table 2. Percentage of respondents on practice of waste minimization measures

Rank	Waste minimization measures	Percentage of respondents
High	Using materials before expiry dates (WMM 25)	100
	Use of more efficient construction equipment (WMM 5)	100
	Purchasing raw materials that are just sufficient (WMM 24)	100
	Adoption of proper site management techniques (WMM 21)	98
	Good coordination between store and construction personnel to avoid over ordering (WMM 4)	97
	Minimizing design changes (WMM 23)	96
	Training of construction personnel (WMM3)	95
	Proper storage of materials on site (WMM 7)	93
	Employment of skilled workmen (WMM 14)	90
Medium	Accurate and good specifications of materials to avoid wrong ordering (WMM 26)	88
	Checking materials supplied for right quantities and volumes (WMM 13)	86
	Change of attitude of workers towards the handling of materials (WMM 11)	85
	Vigilance of supervisors (WMM 6)	83
	Access to latest information about types of materials on the market (WMM 22)	81
	Accurate measurement of materials during batching (WMM 15)	81
	Weekly programming of works (WMM 18)	80
	Good construction management practices (WMM 2)	80
Low	Mixing, transporting and placing concrete at the appropriate time (WMM 19)	79
	Adherence to standardized dimensions (WMM 10)	78
	Waste management officer or personnel employed to handle waste issues (WMM20)	75
	Early and prompt scheduling of deliveries (WMM 9)	73
	Just in time operations (WMM 8)	70
	Careful handling of tools and equipment on site (WMM 17)	65
	Encourage re-use of waste materials in projects (16)	63
	Use of low waste technology (WMM 12)	62
	Recycling of some waste materials on site (WMM 1)	55

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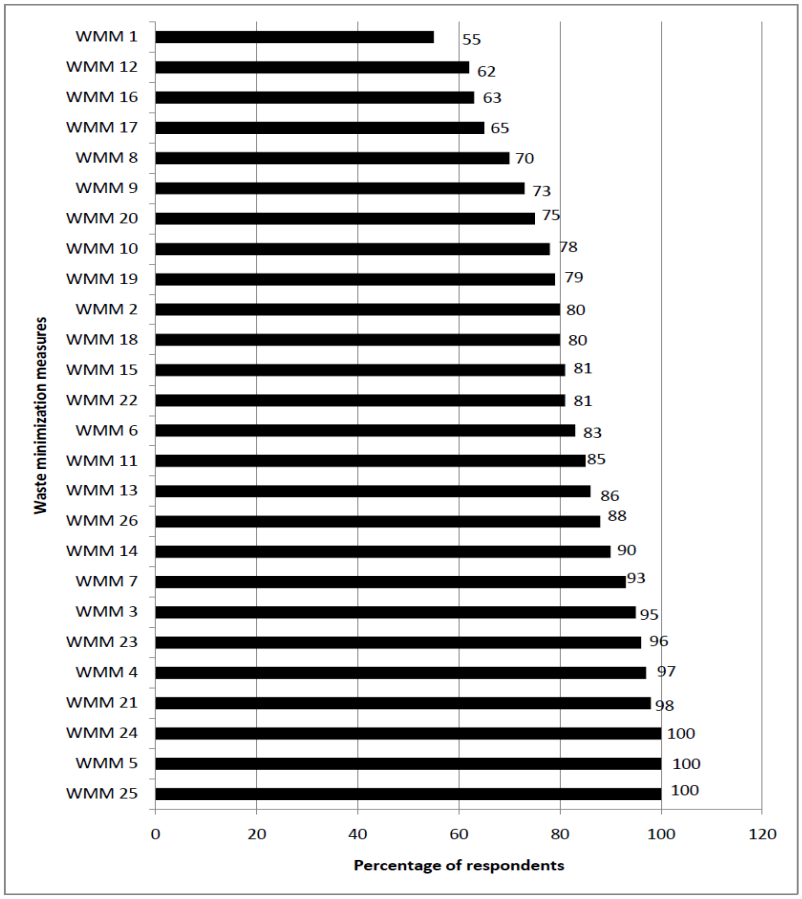

Figure 2. Level of practice of waste minimization measures

From the results, all the respondents (100%) considered "using materials before expiry dates", "using more efficient construction equipment" and "purchasing raw materials that are just sufficient" as measures practiced to minimize waste on construction sites in Ghana. Ninety-eight percent (98%), 97% and 96% of the respondents also considered "adoption of proper site management techniques", "good coordination between store and construction personnel to avoid over-ordering" and "minimizing design changes" to be practiced on sites to minimize waste respectively.

The 26 waste minimization measures were further categorized into three levels of practice: high, medium and low (Fig 6, 7 and 8 respectively). High level of practice comprised those measures rated by more than 90% of the respondents. Medium level of practice comprised measures rated by between 80% and 90% of the respondents and low level of practice comprised those rated below 80% of the respondents. "Using materials before expiry dates" (WMM 25), "use of more efficient construction equipment" (WMM 5) and "purchasing raw materials that are just sufficient" (WMM 24) are among the nine measures that are categorized as highly practiced on construction sites in Ghana, with ratings of more than 90% of respondents (Fig 6). Most of the measures in this category were also categorized as high contributors to waste minimization (Table 1 and Figure 3). The highly practiced measures are observed to be measures that can directly result in cost savings to construction organizations. Thus, in the opinion of the consultants, the highly practiced measures are those which contribute to waste minimization and those which result in cost saving to the organization. Since excess materials brought to the site can result in materials wastage, and such materials if not used on time may expire and result in wastage and financial loss to the organization, measures are usually adopted to prevent or reduce such situations. Consultants should reconsider the percentage waste allowance generally included in materials order to account for design and construction process waste, since it can lead to over-ordering of materials and consequently financial loss to the organization (Longdon, 2007). Construction organizations are also aware of the fact that use of more efficient construction equipment can save the organization frequent break down, repair costs and excessive use of fuel and lubricants, hence the high practice of this measure on construction sites.

Eight measures including "accurate and good specifications of materials to avoid wrong ordering" (WMM 26), "checking materials supplied for right quantities and volumes" (WMM 13) and "change of attitudes of workers towards the handling of materials" (WMM 11) were categorized as having medium level of practice on construction sites in Ghana, with ratings between 80% and 90% of respondents (Fig 7). These measures, if not practiced, may result in financial loss to the organization. The results indicate that the respondents are aware of the implications of proper materials control and the adoption of good practices on site. Wrong ordering, over-ordering or shortage in materials supplied to the site, apart from resulting in delays, can cause material wastage on the construction site and financial loss to the organization. Better attention to materials control may also have significant influence on the pursuit of increased profit. The results agree with the literature which states that improper storage and handling of materials on building project sites could result in wastage (Johnston, 1981), and that losses due to materials are often higher than those due to other causes on the construction site (Harris & MacCaffer, 2001).

Nine measures including "encouraging re-use of waste materials in projects" (WMM 16), "use of low waste technology" (WMM 12) and "recycling of some waste materials on site" (WMM 1) were categorized as having low level of practice on construction sites, with ratings below 80% of respondents (Fig 8). These least practiced measures are also those categorized as low contributors to waste minimization (Table 1 and Figure 5). They require investment or further processing of materials to obtain value, especially re-use and recycling of waste materials. These measures are seen as adding to the organization's production cost instead of cost saving. Thus, in the opinion of the consultants, construction organizations do not practice what they perceive to require financial resources to achieve. According to Lennon (2005), there is hardly a single waste material from a job site that cannot be recycled. In almost all cases, the cost of recycling is lower than the cost of throwing materials away. However, applying environmentally friendly technology on site and using low waste technology are considered less attractive environmental management measures to construction organizations in Ghana. This result gives a different picture from the situation in Malaysia where "buying repairable, refillable and durable materials", "recycling of materials for resource recovery or as a by-product" and "re-using materials" are considered as the three highly practiced measures to reduce waste in Malaysia (Begum et al., 2006). The result, however, corroborates the findings of Begum et al. (2006), Shen and Tam (2002) and Horvath (1999) who noted that like other materials in the economy, re-use and recycling of construction materials are driven by economic benefits. An articulated obstacle to more recycling has been industry-wide reluctance to accept the uneven quality of recycled aggregates (US Geological Survey, 2000). According to Brooks et al. (1994) and Ayarkwa and Adinyira (n.d), construction waste is more difficult to recycle due to the levels of contamination and a large degree of heterogeneity. To a variety of construction organization, high cost of waste separation, insufficient areas for waste discharge and different waste production period in building sites make it difficult to recycle. For these reasons recycled aggregates mostly end up as road base material, replacing natural aggregates rather than in high-value products such as road wearing course and structural concrete. Teo and Loosemore (2001) and Lingard et al. (2000) asserted that waste management was initially considered a low project priority among construction workers in Australia. Waste sorting and recycling although widely publicized by government bodies in Australia, were not used on most sites at the time. Coffey (1999) suggested that considerable waste reduction can be achieved if waste management is implemented as part of project management functions. Ofori et al. (2000) encouraged the construction industry to re-use built assets, recycle materials and use environmental management systems to reduce waste.

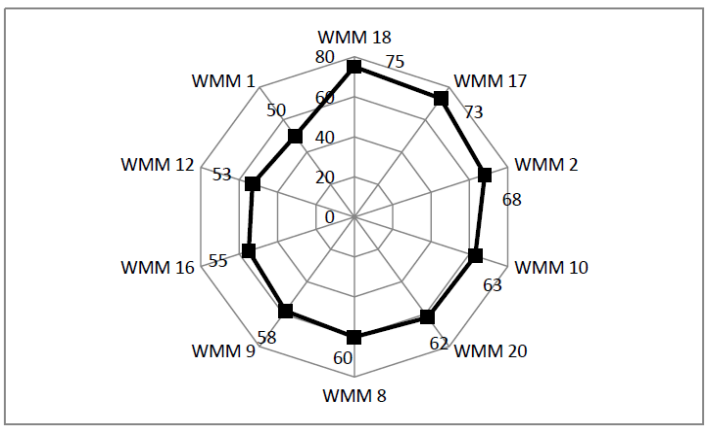

Figure 5. Measures contributing to low reduction of materials waste (Note 3)

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4. Conclusions and Recommendations

The results of the study provide evidence on the level of contribution and the level of practice of some waste minimization measures in the Ghanaian construction industry. Consultants perceive purchasing raw materials that are just sufficient, using materials before expiry dates, use of more efficient construction equipment and good coordination between store and construction personnel to avoid over-ordering as the measures that highly contribute to waste minimization and also those highly practiced. Encouraging re-use of waste materials in projects, using low waste technology and recycling of some waste materials on sites are perceived as measures with low contribution to waste reduction and the least practiced. This is because such measures are seen as adding to organizations' production cost instead of reducing cost or resulting in financial returns. The findings further revealed that measures such as checking materials supplied for right quantities and volumes, vigilance of supervisors, access to latest information about types of materials on the market and accurate measurement of materials during batching have medium level of contribution and medium level of practice among the professionals.

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

The results from the study will assist in the formulation of appropriate policy interventions to address construction waste management problems in the Ghanaian construction industry. It will also help firms to improve the quality of construction in Ghana.

5. Limitation of the Study

The study should have covered all consultancy firms in Ghana but due to lack of reliable information on firms in other parts of Ghana, only those in the Ashanti and Greater Accra Regions of Ghana were studied. The authors acknowledge the fact that measures which could not be studied as part of the 26 waste minimization measures obtained from the literature could have influenced the results somehow. The primary weakness of the descriptive approach used in the study is also acknowledged.

References

Al-Maghony, S. S. (2006). Managing and Minimizing Construction Waste in Gaza Strip. A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Construction Management, The Islamic University of Gaza – Palestine, February, 2006.

Architects Registration Council of Ghana. (2010). List of fully registered architectural firms in Ghana. Retrieved January 15, 2011, from: http://www.archghana.org

Ayarkwa, J., & Adinyira, E. (n.d.). Construction material waste in Ghana: Sources, causes and minimization. Submitted for publication in the Journal of Construction: South Africa ISSN 1994-7402.

Ball, J. (2002). Can ISO 14000 and eco-labeling turn the construction industry green? *Building and Environment, 4,* 421-428.

Begum, R. A., Siwar, C., Pereira, J. J., & Jaafar, A. H. (2006). Implementation of waste management and minimization in the Malaysian construction industry. *Conservation and Recycling, 51,* 190-202. http://dx.doi.org/10.1016/j.resconrec.2006.09.004

Bossink, B. A. G., & Brouwers, H. J. H. (1996). Construction waste: quantification and source evaluation. *Journal of Construction Engineering and Management, 122,* 55–60.

Brooks, K. A., Adams, C., & Demsetz, L. A. (1994). Germany's Construction and demolition debris recycling infrastructure: what lessons does it have for U.S.? Sustainable Construction. In: Proceedings of 1st Conference of CIB TG 16, C.J. Kibert ed., 647-656.

Chen, Z., Li, H., & Wong, T. C. (2002). An application of bar-code system for reducing construction wastes. *Automation in Construction, 11,* 521-533.

Coffey, M. (1999). Cost-effective systems for solid waste management. *Waterlines, 17,* 23-24.

Ekanayake, L. L., & Ofori, G. (2000). Construction material waste source evaluation. In: Proceedings of the Second Southern African Conference on Sustainable Development in the Built Environment, Pretoria, 35, 35–36.

Environmental Protection Agency of USA. (2000). Solid Waste and Emergency Response. EPA-530-F-00-001. United States.

Environmental Protection Department. (2002). Hong Kong Environment 2002, Hong Kong Government.

Faniran, O. O., & Caban, G. (1998). Minimizing waste on construction project sites. *Engineering. Construction and Architectural Management, 5*, 182–188.

Formoso, C. T., Isatto, E. L., & Hirota, E. H. (1999). Method for Waste Control in the Building Industry. Proceedings IGLC-7, University of California, Berkeley, CA, USA.

Garas, G. L., Anis, A. R., & El Gammal, A. (2001). Materials Waste in the Egyptian Construction Industry. Proceedings IGLC-9, Singapore.

Ghana Institution of Surveyors (GHIS). (2010). List of fully registered quantity surveyors in Ghana. Retrieved January 15, 2011, from http://www.ghisonline.org

Harris, F., & McCaffer, R. (2001). *Management of Construction Equipment* (2nd Edition). Hong Kong.

Horvath, A. (1999). Construction for sustainable development - A research educational agenda. Berkeley-Stanford Construction Engineering and Management Workshop: Defining a research agenda for AEC Process/ Product Development in 2000 and Beyond, August 26-28.

Johnston, J. E. (1981). *Site Control of Material Storage and Protection* (1st Edition). London:Butterworth.

Lennon, M. (2005). Recycling Construction and Demolition Waste: A Guide for Architects and Contractors (pp.1-38). Retrieved from: www.mass.gov/dep/recycle/reduce/cdrguide.

Lieu, Z., Osmani, M., Demain, P., & Baldwin, A. (2011). The Potential use of BIM to aid construction waste minimization. In proceedings of the CIB W78-W102 2011: INTERNATIONAL Conference (26-28 October, pp. 1-13), Sophia Antipolis, France.

Lingard, H., Graham, P., & Smithers, G. (2000). Employee perceptions of the solid waste management system operating in a large Australian contracting organisation: implications for company policy implementation. *Construction Management and Economics, 18* (4), 383–93.

Longdon, D. (2007). Reducing Materials Wastage in Construction. Waste and Resource Action Programme, UK. ISBN 1-84405-357-1. Retrieved from: www. Wrap.org.uk/construction.

Ministry of Water Resource, Works and Housing (MWRWH). (2011). List of registered building contractors in Ghana. Retrieved January 15, 2011, from: http://ghana-net.com/ Ministry of Water

Morledge, R., & Jackson, F. (2001). Reducing environmental pollution caused by construction plant. *Environmental Management and Health, 12,* 191-206.

Ofori, G., Briffet, C., Gang, G., & Ranasinghe, M. (2000). Impact of ISO 14000 on construction companies in Singapore. *Construction Management and Economics, 18,* 935-947.

Osmani, M., Glass, J., & Price, A. D. F. (2007). Architects' Perspectives on Construction Waste Reduction by Design. *Waste Management, 28,* 1147-1158. http://dx.doi.org/10.1016/j.wasman.2007.05.011.

Polat, G., & Ballard, G. (2004). Waste in Turkish Construction- Need for Lean Construction Techniques. Proceedings of the 12th Annual Conference of the International Group for Lean Construction IGLC-12, August, Denmark. 488-501.

Poon, C. S., Yu, A. T. W., & Jaillon, L. (2004). Reducing Building Waste at Construction Sites in Hong Kong. *Journal of Construction Management and Economics, 22,* 461– 470.

Poon, C. S., Yu, A. T. W., & Ng, L. H. (2001). On-site sorting of construction and demolition waste in Hong Kong. *Resources, Construction and Recycling, 32*(1), 157-172. http://dx.doi.org/ 10.1080/0144619042000213292

Shen, L. Y., & Tam, W. Y. V. (2002). Implementation of environmental management in the Hong Kong construction industry. *International Journal of Project Management, 20* (7), 535-543.

Shen, L. Y., Tam, W. Y. V., Chan, C. W. S., & Kong, S. Y. J. (2002). An examination on the waste management practice in the local construction site. *Hong Kong Surveyor, 13* (1), 39-48.

Teo, M. M. M., & Loosemore, M. (2001). A theory of waste behavior in the construction Industry. *Journal of Construction Management and Economics, 19* (7), 741–751. http://dx.doi.org/10.1080/01446190110067037

Tse, Y. C. R. (2001). The implementation of EMS in construction firms: case study in Hong Kong. *Journal of Environmental Assessment Policy and Management, 3* (2), 177-194.

United States Geological Survey (USGS). (2000). Recycled Aggregates- Profitable Resource Conservation. USGS Fact Sheet, FS- 189-199, Washington, DC: U.S. Geological Survey.

Womack, J. P., & Jones, D. T. (1996). Lean Thinking: Banish Waste and Create Wealth in Your Corporation. Simon and Schuster, New York, N.Y., USA.

Notes

Note 1. Where WMM 24 is 'Purchasing raw materials that are just sufficient', WMM 25 is 'Using materials before expiry dates', WMM 5 is 'Using more efficient construction equipment', WMM 4 is 'Good coordination between store and construction personnel to avoid over ordering', WMM 21 is 'Adoption of proper site management techniques', WMM 3 is 'Training of construction personnel' and WMM 26 is 'Accurate and good specifications of materials to avoid wrong ordering'

Note 2. Where WMM 7 is 'Proper storage of materials on site', WMM 13 is 'Checking materials supplied for right quantities and volumes', WMM 14 is 'Employment of skilled workmen', WMM 23 is 'Minimizing design changes', WMM 11 is 'Change of attitude of workers towards the handling of materials', WMM 15 is 'Accurate measurement of materials during batching', WMM 19 is 'Mixing, transporting and placing concrete at the appropriate time', WMM 22 is 'Access to latest information about types of materials on the market' and WMM 6 is 'Vigilance of supervisors'.

Note 3. Where WMM 18 is 'Weekly programming of works', WMM 17 is 'Careful handling of tools and equipment on site', WMM2 is 'Good construction management practices', WMM 10 is 'Adherence to standardized dimensions', WMM 20 is 'Waste management officer or personnel employed to handle waste issues', WMM 8 is 'Just in time operations', WMM9 is 'Early and prompt scheduling of deliveries', WMM 16 is 'Encourage re-use of waste materials in projects', WMM 12 is 'Use of low waste technology' and WMM1 is 'Recycling of some waste materials on site'.

Note 4. Where WMM 25 is 'Using materials before expiry dates', WMM 5 is 'Use of more efficient construction equipment', WMM 24 is 'Purchasing raw materials that are just sufficient', WMM 21 is 'Adoption of proper site management techniques', WMM 4 is 'Good coordination between store and construction personnel to avoid over ordering', WMM 23 is 'Minimizing design changes', WMM 3 is 'Training of construction personnel', WMM 7 is 'Proper storage of materials on site' and WMM 14 is 'employment of skilled workmen'

Note 5. Where WMM 26 is 'Accurate and good specifications of materials to avoid wrong ordering', WMM 13 is 'Checking materials supplied for right quantities and volumes', WMM 11 is 'Change of attitudes of workers towards the handling of materials', WMM 6 is 'Vigilance of supervisors', WMM 22 is 'Access to latest information about types of materials on the market', WMM 15 is 'Accurate measurement of materials during batching', WMM 18 is 'Weekly programming of works' and WMM 2 is 'Good construction management practices'.

Note 6. Where WMM 19 is 'Mixing, transporting and placing concrete at the appropriate time', WMM 10 is 'Adherence to standardized dimensions', WMM 20 is 'Waste management officer or personnel employed to handle waste issues', WMM 9 is 'Early and prompt scheduling of deliveries', WMM 8 is 'Just in time operations', WMM 17 is 'Careful handling of tools and equipment on site', WMM 16 is 'Encourage re-use of waste materials in projects', WMM 12 is 'Use of low waste technology' and WMM 1 is ' Recycling of some waste materials on site'.

Appendix

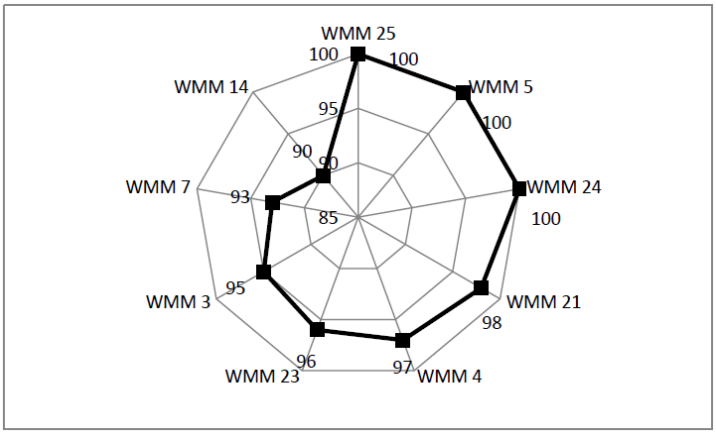

Figure 6. Measures that are highly practiced to reduce waste (Note 4)

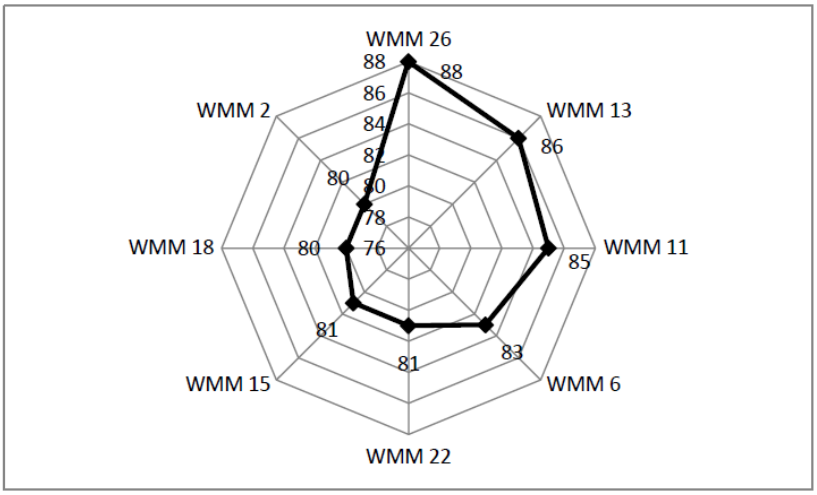

Figure 7. Measures with medium level of practice (Note 5)

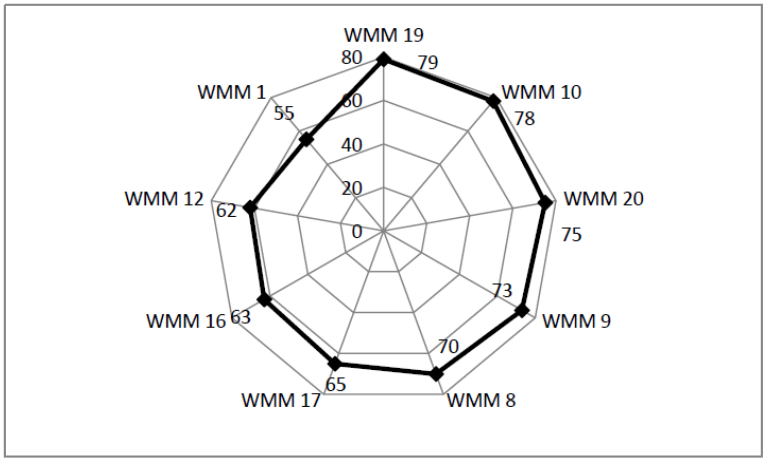

Figure 8. Measures with low level of practice (Note 6)