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STRATEGIES FOR EFFECTIVE MATERIALS MANAGEMENT TOWARDS SUSTAINABLE CONSTRUCTION ENHANCEMENT

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Abstract
Despite the significance of the construction industry in developed and developing nations, construction activities tend to have adverse impacts on environmental and socio-economic aspects of society. This paper aims to evaluate the impact of construction materials management on materials usage efficiency towards the enhancement of sustainable building construction in the Western Cape Province of South Africa. The study adopts a quantitative research approach. Closed-ended questionnaires were administered to seventy (70) construction professionals in different construction companies in the Western Cape. The data obtained were analysed using the Statistical Package for Social Sciences (SPSS). Strategic planning before procurement at design stage, procurement strategy considered for materials purchase, enforcing the adoption of Green Building Councils of South Africa (GBCSA) policy in every construction projects in the country and evaluating the life-cycle analysis (LCA) of materials proposed for use were acknowledged as the predominant factors of materials management that enhance the construction of sustainable buildings. This study was delimited to construction professionals (project managers, procurement officers, engineers, and architects), contractors and company suppliers in the construction industry in the Western Cape Province of South Africa. The adoption of sustainable materials management principles during construction will have the following implications: increased competition amongst material manufacturers, leading to a reduction in material cost which will facilitate economic advancement; and a reduction of material wastage during construction by ensuring availability of material when required on site. Effective materials management during sustainable construction remains a significant attribute of a successful project which ensures waste reduction, cost profitability optimization and government participation in sustainable development through policy implementation related to construction.

Keywords: Construction materials management, Materials selection, Materials usage, Sustainable building construction, Sustainable development

1 Introduction

The construction industry is a significant contributor to the social, economic and environmental development of a country. Sustainability is *'the ability to meet the present needs of humans without compromising the ability of the future generations meeting their own needs*' (Du Plessis, 2007). Social, economic and environmental aspects of the human existence is also known as the 'Triple Bottom Line' (TBL). According to Asif, Brujin, Fissher and Steenhuis, (2008) TBL is a framework used in measuring the impact of human activities on the environment, the economic and social well-being of humans in a territory. Sustainable building

construction is a process aimed at restoring or maintaining a balance between built environment and the eco-system to create a settlement that promotes economic and social equity (Osec, 2010). Achieving sustainability in construction through the adoption of the principles of sustainability is therefore expedient towards human development and environmental protection.

Environmental issues in the last century have lightly been considered as a major problem in construction (Nagapan, Rahman, Asmi, Memon and Latif, 2012). However, recent studies have shown that these challenges are complex in nature as it affects the well-being of the society. The process of materials usage during the cycle of construction has imposed increasing damages to the environment over the years through illicit consumption of materials and illegal wastes disposal (Ljungberg, 2007). As a result of this increasing negative impacts of construction, mitigating measures such as legal frameworks, technical, strategic and managerial processes should be adopted at the pre and post phases of construction (Du Plessis, 2007). Gaustad, Olivetti and Kirchain (2011) added that the key strategy towards materials usage efficiency is the adoption of the four Rs of sustainability (Reduction, Reuse, Recycle and Renew).

This paper sets to evaluate the impact of construction materials management on materials usage efficiency towards the enhancement of sustainable building construction. Firstly, a literature review was conducted to establish a background for the study. Based on literature the factors that enhance efficient materials management were identified to form the basis for data collection and data analyses were carried out to determine and rank the factors considered during materials selection to facilitate optimum materials usage.

2 Construction Materials Management

Construction materials are a collection of materials utilized at any stage or phase of construction (Samarasinghe, Tookey, Rotimi and Thiruchelvam, 2012). Hillebrandt (1988) cited in (Samarasinghe *et al.,* 2012) noted the existence of a strong relationship between various construction projects and the materials used in the construction. Samarasinghe *et al.,* (2012) added that the success of a project towards stakeholders' satisfaction at minimum cost and time is dependent on the management process of materials used for construction. The value of construction materials used in a project has been confirmed to claim 40-70% of the total cost of construction which contributes to a significant measure of construction wastes (Kasim, 2011; Nagapan *et al.,* 2012). In affirmation, Donyavi and Flanagan (2011) highlighted that the total cost of construction is relatively high as a result of the material cost, procurement cost and the site-handling costs which includes the cost of transportation, cost of receiving, storage, issuing, and disposal. Thus, for reduced construction cost, increased productivity, quality and timely project delivery, effective materials management must be of top priority to the project manager (Donyavi and Flanagan, 2009).

Materials management is thus defined as a plan or control adopted during construction to improve the flow of materials and to ensure that the appropriate quality and quantity of materials required for particular activities are acquired at a reasonable cost and when needed. To Patel and Vyas (2011), sustainable materials management is an integrated approach towards the reduction of materials wastages during construction in order to increase cost profitability, materials optimization and environmental protection. From the planning phase of the building to the selection of materials and disposal or recycling of materials waste during building production, the adoption of life-cycle analysis improves the chances of achieving the goals of sustainability. Thus, the aim of materials management is to reduce the adverse impact of materials usage during construction on the environmental and social well-being for a sustained economic prosperity.

With regards to achieving sustainability, it should be noted that materials used in construction determines the functionality, quality and other properties of the building regardless of the expertise involved during construction (Karana, Hekkert and Kandachar, 2010). However, it is vital for the project manager to understand the process of materials flow analysis (MFA) to determine the mass or quantity of materials used during production. The MFA is also known as Domestic Materials Consumption (DMC), used for the purpose of quality control and construction waste reduction (Fiksel, 2006). The process of materials flow analysis (MFA) involves several strategic methodologies, techniques and tools such as Life Cost Assessment, (LCA), Life Cycle Costing (LCC), Building for Environmental and economic sustainability (BEES), dematerialization, detoxification and other government established policies (Khalfan, Maqsood and Noor, 2011).

Materials selection in sustainable construction is being conducted in various ways which are guided by the same principles. These principles according to Ljungberg (2007) include the following:

- Function and structural demands of the building
- Environmental impacts
- Design
- Technological demands
- Cost of materials
- Construction method adopted

Remarkably to this effect, several sustainable materials management (SMM) policies have been launched by the South African government with regards to waste generation, quality control, environmental protection and sustainability realization. Policy bodies such as the Green Council of South Africa (GBCSA) and the South African Bureau of Standards (SABS) were established to raise awareness on the benefits of sustainable building and to facilitate and encourage the adoption of sustainable practices in the industry. The governments in some other developing countries such as Japan, China and Korea have adopted comprehensive policies and regulatory approaches relating to the reduction of material consumption, resource recycling, waste production and disposal, to ensure socio-economic equity and environmental justice during and after the building production process. Examples of these government policies as identified by Fiksel, (2006) include product life-cycle policies, waste management policies and natural resources policies. In addition, the integration of government policy should focus on the issues of materials management in an approach that transcends all boundaries of management (Fiksel, 2006).

Materials management towards sustainable construction simply poses an indispensable aspect of project management which aids in dissociating excessive material consumption from the increasing growth recorded in the construction industry. Hence, materials management during sustainable construction remains a significant attribute for successful project delivery.

3 Methodology and Methods

The study adopted a closed-ended questionnaire survey designed to examine the impact of construction materials management on materials usage efficiency towards the enhancement of sustainable building construction. This study identified fifteen materials management strategies considered during materials selection, thirteen factors that facilitate materials usage and eight approaches to materials usage towards enhancement of sustainable construction. Due to the vast size of the South African construction industry, the survey was delimited to the Western Cape Province. Data collection was conducted using the cluster sampling technique from construction industries situated in the Central Business District (CBD) of Cape Town. This

technique was adopted in order to obtain precise data with generalizable conclusions from companies in the district.

The questionnaire design adopted the five point Likert scale and was administered by hand to two principle target groups. These groups are government establishments and private companies. These groups were selected because of their significant function in the construction supply chain and because their perceptions would be highly valuable to this research. In order to explicitly gain their perceptions, the target groups were sub-divided into site managers, project managers, architects, quantity surveyors, contractors, procurement officers and company suppliers. The Cronbach's alpha reliability test was conducted on the research questions to ensure the reliability of the questionnaire. A total of seventy (70) questionnaires were administered to aforementioned groups to ascertain the perspectives of the respondents on construction materials management and usage efficiency towards the enhancement of sustainable building construction. Forty-three copies (61%) of the questionnaires were retrieved after numerous phone calls, and visitation to the construction sites and consulting offices. This was observed to be as a result of the respondents' busy schedules on site, considering the positions they occupy in their organisations. Data analyses were conducted using the descriptive statically analysis in the Statistical Package for the Social Science (SPSS) version 23.

4 Data Analysis and Discussion of Findings

4.1 Data Analysis

Biographical information of respondents

Table 1 provides an overview of the respondents' background information in terms of profession and company information, working experience and highest qualification.

From the table, a high percentage of the survey respondents are working with contracting firms (30%), 33% work with government establishments, 14% work with quantity surveying companies and 21% work with engineering firms. The results reflect that 14% of the respondents have between 1-5 years' experience, 32.6% have between 6-10 years' experience, 27.9% of the respondents have between 11-15 years' experience, 18.6% of the respondents have between 16-20 years' experience and 6.9% of the respondents have had over 25 years' experience. Figure 4.1 illustrates the highest qualification obtained by the respondents, the result show that 29% of the respondents obtained National diplomas and 9% obtained Master's Degree while the majority obtained Bachelor's degrees (62%). The results of the analysis on respondents demographic and background information have shown that the respondents sampled were qualified and experienced practitioners in the construction industry whose judgments on issues of construction materials procurements can be reliable.

Table 1. Biographical information of respondents

QUESTIONS		VALID %	FREQUENCY
Participating company	Contractors	30.2	13.0
	Engineering	20.9	9.0
	Quantity Surveying	14..0	6.0
	Suppliers	2.3	1.0
	Government Establishment s	32.6	14.0
Company Specialization	Residential buildings	32.6	14.0
	Public buildings	16.3	7.0
	Both	51.1	22.0
Working experience	1-5years	14.0	6.0
	6-10years	32.6	14.0
	11-15years	27.9	12.0
	16-20years	18.6	8.0
	Above 20years	6.9	3.0
Profession	*Procurement officers*	32.6	14.0
	Quantity surveyors	18.6	8.0
	Site engineers	23.3	10.0
	Project managers	25.5	11.0

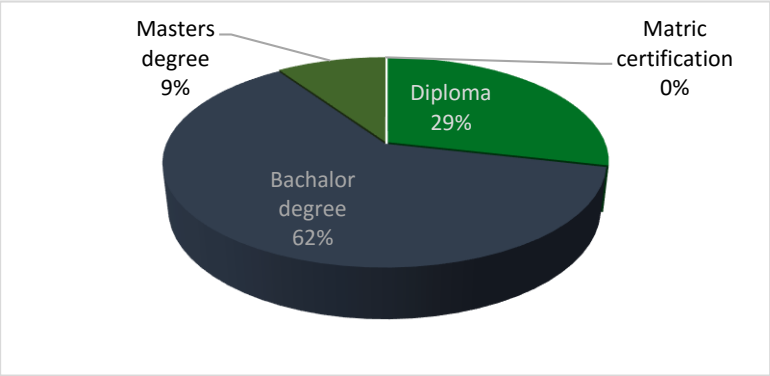

Figure 1. Highest educational qualification obtained

Table 2 shows the results obtained from the Cronbach's alpha test conducted on the questions to ensure the reliability of the research questions. Cronbach's alpha reliability test is an estimate of the internal consistency associated with the scores that can be derived from a scale or composite score (Allen, 2004). From the table, it is observed that the Cronbach's alpha coefficient values are greater than 0.70 (>0.70). To supports this, Tavakol and Dennick (2011) stated that the score values between 0.70- 0.90 are the standard acceptable values for the reliability of a test to be proven.

Table 2. Reliability of the survey tool/instrument

Headings	No. of items	Cronbach's alpha values
Materials management strategies considered during materials selection	15	0.88
Materials usage facilitators	13	0.85
Approaches to materials usage backed by government policies	8	0.75

4.2 Data analysis and Discussion of findings

4.2.1 Strategies for Construction Materials Selections during sustainable construction

Table 3 presents the results of data analysed on management strategies considered during materials selection for optimum materials usage. The respondents were required to rank the importance of these strategies towards enhancing sustainable construction. Strategic planning before procurement at design stage (mv=3.84), procurement strategy considered for materials purchase (mv=3.79), competence Level of the workforce required for construction (mv=3.79) and the environmental impact of the materials emerged as the most important factors to consider during materials selection (mv=3.72). Isa *et al.* (2014) supported the adoption of the findings in their study, stating that the planning process at the early stage is the most important process conducted in managing the life-cycle of the building project. Isa *et al* (2014) argued that the planning phase of a building project is the most strategic phase to integrate the principles of sustainability, determine the procurement strategy to be implemented and evaluate the possible environmental impact of the materials proposed for construction.

Table 3. Construction materials strategies considered during materials selection

Strategies	Mean value (mv)	Rank
Strategic planning before procurement at design stage.	3.84	1
Procurement strategy considered for materials purchase.	3.79	2
Competence level of the workforce required for construction.	3.79	2
The environmental impact of the materials	3.74	3
Selection of SABS approved materials	3.72	4
Total involvement of clients at the design stage	3.72	4
Effects of materials cost fluctuations on cost of construction	3.72	4
General site organization which may affect the flow of materials on site	3.70	5
The level of communication between the workforce during construction	3.70	5
Availability of required materials in the market.	3.65	6
Availability of adequate materials storage facility	3.16	7
The sustainable nature of materials (recyclable or renewable materials)	3.12	8
Materials specifications take-off from building designs	3.07	9
Choice of building design by stakeholders	2.98	10
Properties of the materials required for construction	2.79	11

4.2.2 Materials usage facilitators

Table 4 presents factors considered in facilitating materials usage efficiency towards sustainable building construction. The respondents were required to rate the factors based on a five point agreement scale. 1= strongly disagree, 2= disagree, 3= neither agree nor disagree, 4=agree and 5=strongly agree. Proper project planning from the inception using sustainable building design was ranked as the top facilitator of effective materials usage by the respondents and 88.4% of the respondents agree that proper project planning from the inception using a sustainable building design (mv=4.21) improve the flow of construction resources on site and workforce productivity. Implementing government policies and laws regarding usage or disposal of materials (mv=4.16), environmental impact of the materials proposed for use (mv=4.09) and proper understanding of clients ideas at the conceptual phase of design (mv=4.07) were also identified to significantly facilitate the effective usage of materials to enhance the building sustainability.

Table 4. Facilitators of materials usage efficiency

Facilitators	Strongly disagree (%)	Disagree (%)	Neither agree nor Disagree (%)	Agree (%)	Strongly agree (%)	Mean	Rank
Proper project planning from the inception using sustainable building design	0.0	0.0	11.6	55.8	32.6	4.21	1
Government policies and laws regarding usage or disposal of materials	0.0	0.0	14.0	55.8	30.2	4.16	2
Environmental impact of the materials proposed for use	0.0	2.3	11.6	60.5	25.6	4.09	3
Proper understanding of clients ideas at the conceptual phase of design	0.0	7.0	9.3	53.5	30.2	4.07	4
Efficiency of the materials procurement strategy in place during construction	0.0	4.7	18.6	46.5	30.2	4.02	5
Timely delivery of construction materials to site	0.0	9.3	16.3	46.5	27.9	3.93	6
Implementing waste reduction techniques during construction	0.0	7.0	20.9	46.5	25.6	3.91	7
Effective communication amongst workers during construction	0.0	11.9	20.9	37.2	30.2	3.86	8
Early learning on sustainable building practices should be encouraged in institutes and universities	0.0	14.0	18.6	39.5	27.9	3.81	9
Staff innovations on materials usage for effective materials utilization	0.0	7.0	23.3	53.5	16.3	3.79	10
Using self-efficient material (durable, renewable and recyclable materials) to reduce construction waste	0.0	4.7	37.2	37.2	20.9	3.74	11

4.2.3 Approaches to materials usage backed by government policies

Table 5 presents approaches to effective materials usage during construction aimed at enhancing the adoption of sustainability in the industry. The respondents were required to rate the agreement of the items using a five (5) point Likert scale: strongly disagree =1, disagree =2, neither agree nor disagree = 3, agree =4 strongly agree = 5. Majority of the respondents 86.1% agreed that the Green Building Council of South Africa (GBCSA) policy on selection and usage of building materials be enforced in every construction projects towards the enhancement of sustainable building production. Ninety-point-eight per cent (90.8 %) of the respondents indicated that evaluating the life-cycle analysis (LCA) of materials proposed for use as important and 86.1% agreed that adopting the principles of recycling material wastes to reduce environmental pollution are top policies that must be considered in enhancing sustainability during construction materials procurement.

Table 5. Approaches to materials usage backed by government policies

Strategies	Strongly disagree (%) (%)	Disagree (%)	Neither agree nor disagree (%)	Very effective (%)	Extremely effective (%)	Mean value
Enforcing the adoption of Green Building Councils of South Africa (GBCSA) policy in every construction projects in the country	0.0	14.0	25.6	37.2	23.3	3.70
Evaluating the life-cycle analysis (LCA) rating process of materials proposed for use	0.0	14.0	32.6	41.9	16.3	3.65
Adopting the principles of recycling materials wastes to reduce environmental pollution	0.0	14.0	25.6	41.9	18.6	3.65
Using renewable and reusable materials for construction	0.0	16.3	37.2	34.9	11.6	3.42
Adapting the principles of dematerialisation at every phase of construction	0.0	18.6	39.5	25.6	16.3	3.40
Adapting the use of alternative building materials(rammed earth, adobe etc) to reduce excessive consumption of manufactured materials	0.0	27.9	32.6	25.6	14.0	3.35
The use of Eco-friendly technologies during construction	4.7	20.9	32.6	27.9	14.0	3.26

5 Conclusions and Recommendations

Materials management "involves an integrated coordination of materials related functions such as taking-off, materials selection, vendor evaluation, purchasing, shipping, warehousing and distribution" (Linden and Josehson 2013). Effective selection and management of construction materials is identified as the easiest approach for project managers to incorporate sustainable principles in building construction project (Akadiri and Olomolaiye, 2012). This study evaluated the impact of construction materials management on materials usage efficiency and the identification of strategies for effective materials management towards the enhancement of sustainable building production in the Western Cape construction industry. The quantitative research approach was adopted in collecting empirical data. Data analysis indicated that strategic planning before procurement at the design stage is a significant approach to consider for effective materials management towards sustainable construction. Strategic planning before procurement at design stage gives engineers/contractors time to develop a feasible plan in meeting the building specifications with the available materials in the market. The building planning at the design phase involves the process of materials selection, ordering and scheduling. Based on the findings in this study, it can be concluded that a lapse in the planning process will negatively affect materials usage, workforce productivity, production cost (cost overrun) and construction resource wastages due to construction time delays. The findings suggested that to effectively manage construction materials' towards the enhancement of sustainable construction, the adoption of the Green Building Councils of South Africa (GBCSA) policy in every construction projects is a strategy that must be considered for implementation by the construction profession. The findings also indicated that in enhancing the sustainability of buildings during production, the LCA is one of the most effective tools available to the contractors to holistically evaluate the environmental and economic impacts of using certain materials in the construction phases. Based on the finding, it can be concluded that the evaluation of the life-cycle analysis (LCA) ratings of materials proposed for construction is an essential strategy in ensuring sustainability in a building. There,

considerations of these strategies in materials management for efficient materials usage will ensure and enhance sustainable development in building design and construction.

This paper recommends that the planning phase of any construction project should be given enough time for extensive planning as this is the best stage of construction to integrate sustainability into the processes of production. This paper also recommends that strict implementation of government legislation on sustainable building production should be enforced to ensure compliance by construction stakeholders'. It further recommended that the South African government enacts the GBCSA policies into law to ensure compliance in the industry towards the enhancement of sustainable buildings production in the country.

6 References

Akadiri, P. O., & Olomolaiye, P. O. (2012). Development of sustainable assessment criteria for building materials selection. *Engineering, Construction and Architectural Management*, *19*(6), 666-687.

Allen, K., "Explaining Cronbach's Alpha", available at http://coecs.ou.edu/sci under Publications. A paper is also being prepared with the findings

Arain, M., Campbell, M.J., Cooper, C.L., and Lancaster, G.A. 2010. What is a pilot or feasibility study? A review of current practice and editorial policy. BMC Medical Research Methodology. http://www.biomedcentral.com/content/pdf/1471-2288-10-67.pdf

Asif, M., Bruijn,E.J., Fisscher, O.A.M and Steenhuis, H.J. 2008. *Achieving Sustainability Three Dimensionally.* Proceedings of the 2008 IEEE, ICMT; pp. 423-28.

Babbie E. 2007. *The Practice of Social Research,* Eleventh Edition. USA: Thomson Wadsworth

Donyavi, S. and Flanagan, R. 2009. The impact of effective material management on construction site performance for small and medium sized construction enterprises. In: Dainty, A.R.J. (Ed) Proceedings 25th Annual ARCOM Conference, 7-9 September 2009, Nottingham, UK, Association of Researchers in Construction Management, 11-20

Du Plessis, C. 2007. *A Strategic Framework for Sustainable Construction in Developing Countries. Construction Management and Economics*. Vol. 25: pp.67-76.

Edwin, R. Teijlingen, V. and Hundley, V. 2001. Social research Update (ISSN: 1360-7898). Department of Sociology, University of Surrey, Guildford GU2 5XH, United Kingdom.

Fiksel, J. 2006. A framework for sustainable materials management. *JOM*,*58*(8), 15-22.

Gaustad, G., Olivetti, E., & Kirchain, R. 2011. Toward sustainable material usage: evaluating the importance of market motivated agency in modeling material flows. *Environmental science & technology*, *45*(9), 4110-4117.

Gillham, B. 2000. *Developing a Questionnaire*. London: Continuum.

Isa, N. K. M., Alias, A., & Abdul Samad, Z. 2014. Sustainability integration into building projects: Malaysian construction stakeholders' perspectives. *The Macrotheme Review*, *3*(3), 14-34.

Karana, E., Hekkert, P., & Kandachar, P. 2010. A tool for meaning driven materials selection. *Materials & Design*, *31*(6), 2932-2941.

Kasim, N. 2011. *ICT implementation for materials management in construction projects: Case Study.* KICEM Journal of Construction Engineering and Project Management.

Khalfan, M. A., Maqsood, T. and Noor, M.A. 2011**.** Attitudes towards sustainable construction amongst construction contractors. *Built Environmental Journal. Vol. 8, No. 2, 9-21*

Ljungberg, L. Y. (2007). Materials selection and design for development of sustainable products. *Materials & Design*, *28*(2), 466-479.

Nagapan, S., Rahman, I. A., Asmi, A., Memon, A. H., & Latif, I. 2012, December). Issues on construction waste: The need for sustainable waste management. In *Humanities, Science and Engineering (CHUSER), 2012 IEEE Colloquium on* (pp. 325-330). IEEE.

OSEC 2010 Sustainable Construction in Southern Africa. Available online: http://www.sge.com/en/filefieldprivate/files/6551/field_blog_public_files/796 [Assessed 9th June, 2014]

Tavakol, M and Dennick R. 2011. Making sense of Cronbach's alpha. *International Journal of Medical Education*. http://staff.neu.edu.tr/~cise.cavusoglu/Documents/ELT%20516/cronbachs-alpha2011.pdf