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Analysis of Factor Affecting the Selection of Climate-friendly Building Materials in Housing Construction

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ABSTRACT

Drawing on the concept of Sustainability in Environmental Development (SED), building stock make significant contribution to CO_2 emissions. The feasibility of SED lies in the delivery of reliable elements for ongoing profound environmental analysis that lies outside the common question of academic and civil society stakeholders. The aim of this paper is to addresses two of the main objectives of this study: to indicate views and background information on themes related to economic, environmental, technical and sociocultural impacts of construction activities, with emphasis on the role of building material selection in housing construction; and to compare and contrast various technologies used in developed and developing economies for modeling decision in the selection of building material to highlight their strengths and weaknesses. The choice of the quantitative method helped to achieve the objectivity and logical reasoning required for the study. With results derived from questionnaire surveys with a cross-section of house building stakeholders, key sustainability principle indicators impacting the selection of building materials are identified, analyzed, grouped and ranked according to the relative importance that each decision factor holds, using IBM SPSS version 20 and Analytical Hierarchy Process (AHP) a concept of measurement through pairwise comparisons to drive priority scales. These scales measure intangibles in relative terms. This explained respondent's ranking technical highly among sustainability principal indicators and gave low weightage to technical criteria in the selection of building materials, the lack of informed knowledge in the awareness and implementation of sustainable construction practices, which has led to failure of realizing the benefits of sustainable approach to housing construction in the Ghanaian context and countries situated in the Volta Basin:

Keywords: Building materials; Decision factors; CO_2 emissions; Housing construction.

1.0 Purpose

The study developed an alternative approach to building materials selection for the housing industry of Ghana and useful to countries situated in the Volta basin using rapid population growth and corresponding housing deficit, increase carbon dioxide emissions/energetic expense as the basis

1.1 Background to the Research

Mahmoud et al. (1996) proposed a multi-criteria decision support system for quantitative cost analysis to provide information to aid Civil Engineers and Designers (CEDs) with material decision-making. Nevertheless, no specific information on the methodology for evaluating such materials is given. Rahman et al. (2009, 2008) described an integrated knowledge-based cost model for optimizing the selection of roofing materials and technology for residential housing designs. In the framework of their study they presented an evaluation tool to assess the cost sustainability of roofing materials with very little precise information about the technical, sociocultural and environmental issues. Ding et al. (2010) introduced a comprehensive assessment decision support system that measures the lifecycle environmental characteristics of a building product using a common and verifiable set of criteria and targets for building owners and designers, to achieve higher environmental standards. However, it appears to only direct sustainable material selection towards environmental issues.

Building Research Establishment's Environmental Assessment Method (BREEM) is an environmental building assessment method. BREEAM covers a range of building types including: offices, homes, industrial units, retail units, and schools. Material selection is based on awarding points for each criterion and the points are added for a total score calculated based on the credits available, number of credits achieved for each category and weighting factor. The energy performance assessment adopts the U.K building regulation as a benchmark to rate the level of performance improvement, which may not necessarily apply to other regions with an entirely different assessment structure. Australia's Green Star evaluates the environmental merits of building products using the credit rating system based on a number of points allocated to the credits in order to determine the total scoring and hence the level of certification. The disadvantage with this tool is that its use is limited to the evaluation of lettable areas within office buildings, hence excludes areas that are not offices or supporting the office. Moreover, the assessment structure is delineated in Australian standards and perhaps may not apply to other regions with different socio-technical background given the differing views on impact assessment. Sustainable Building Assessment Tool (SBAT), environmental building assessment method, considers building as a whole, the design of a building in terms of sustainability, and explicitly introduces performance criteria that acknowledge social and economic issues, mainly assesses building performance with little recourse to material indicators. Unable to differentiate between choices of materials except for indirect consequences.

Carbon dioxide (CO_2) emission in the construction industry is very noticeable. This rate can be measured and quantified, both in energetic terms and in terms of carbon emissions. A great quantity of carbon dioxide is emitted into the atmosphere through the different phases of a building life cycle. The main sectors of energetic expense of a country are consumption for maintenance and air conditioning of buildings, transport and industry. Energy consumption for maintenance and air conditioning of buildings has a direct and immediate relation with construction. With reference to the other sectors of energy consumption, those of transport and industry, there is little information as far as building construction is concerned. However, many studies (Xing et al. 2008, Monahan and Powell 2011, Shams et al. 2011) have acknowledged that the close relationship between the production of carbon dioxide and construction has the following aspects: estimation of carbon dioxide produced by all industrial activities related to the building erection and estimation of carbon dioxide emission reduction, which can be reached by an adequate selection of materials. Shams et al. (2011), critically examined a five-floor residential building and the associated carbon dioxide emissions for different construction materials. The results of the analysis showed a 52% reduction in the total embodied energy and 45% reduction in the total carbon dioxide emissions. The achievement came from replacing cement concrete and mortar with fly-ash or blast furnace slag.

The sociocultural values of mankind is known to vary from one society to another. The values of sociocultural have direct and indirect influences on humans' habitation. "Self-build houses" involves the intermittent and piece-meal acquisition and utilization of housing inputs such as plots of land, sand, various building materials in the housing construction process in tandem with building owners resource flow. Indeed over 90% of housing stock in Ghana have been realized through this process which in effect can be simulated to gradual lock of housing capital during the housing delivery period ranging from 5 to 15 years. This is indeed the housing realization culture in Ghana (Ahadzie and Amoa-Mensah, 2010). However, Boamah (2010) argues that majority of houses in the country are provided by the private sector, mainly by individuals through personal savings and assistance from family members. This informal way of house financing constitutes about 90% of the houses delivered in the country and construction is done incrementally.

The Ghana building code approves the use of the following building materials: Mud or swish used in a plastic state to erect an earthen wall, wattle and daub, pisé or earth rammed between wooden or other form-works to make a wall in situ. Unburnt earth bricks or blocks, stabilized earth products, bricks, blocks, burnt clay products, concrete or reinforced concrete, thatch or leaves in roofing or otherwise, timber or bamboo products, asbestos-cement and metal products, glass and synthetic products. To this effect, the main type of material selected depends on the part of the building, sociocultural, availability and affordability of the material.

1.2 Statement of the Problem

Against the background information presented, the research problem was identified thus; decisions involve sociocultural factors can be traded of and measure alongside sustainability principle indicators impacting the selection of building materials whose measurements must also be evaluated as to, how well, they serve the selection of LSRBMs with the least carbon dioxide emissions in MHD assessment, no rigorous attempt has been made to deliver reliable elements for ongoing profound environmental analysis that lies outside the common question of academic and civil society stakeholders. As such CEDs who lack the relevant skills can acquire the relevant training as part of their professional development. CEDs who already possess the relevant skills may also appreciate the findings as it may provide a knowledge-based impetus for achieving best practices. Granted that the role of sociocultural as vital resources for strengthening the material selection decision-making process differ across geographical regions (San-Jose et. al., 2007; Sarpong-Nsiah and Ahadzie, 2018; Sarpong-Nsiah, 2020), this lack of bringing cultural issues to the attention of CEDs and encouraging LSRBMs selection in MHD assessment has the potential of threatening the development and promotion of effective building materials selection practices in MHD assessment.

Many studies (Xing et al., 2008; Monahan and Powell, 2011; Shams et al., 2011) have acknowledged that the close relationship between the production of CO_2 and construction has the following aspects: estimation of CO_2 produced by all industrial activities related to the building erection and estimation of CO_2 emission reduction, which can be reached by an adequate selection of building materials. Perera and Fernando (2002) acknowledged a computer-based cost modeling material management system for roofing material selection and did not encourage the integration of a broader range of factors into the material selection process.

The Gaps are as follows: The lack of informed knowledge in the awareness and implementation of sustainable construction practices, which has led to failure of realizing the benefits of sustainable approach to housing construction; and the lack of informed knowledge in the awareness and the application levels of sociocultural in LSRBM selection process and in the Ghanaian context towards revival of lost cultural traditions.

The rationale for solving the gaps: scientific research on climate and climate change has been intensified in West Africa (UNEP-GEF Volta Project, 2003 and GLOWA Impetus, 2011), consideration of local actors within the sub-region is still limited (Anoumou and Runge, 2016), Whilst there are related research in this area, limitations have been identified regarding the lack of input of sociocultural factors in the context of developing countries, as an Engineer with special interest in low impact building materials selection and having worked on numerous building projects, immediate action for climate-friendly building materials to address the housing backlogs was imperative.

1.3 Objectives of the Study

Basically, in the present research work the close relationship between the production and construction has been studied analyzing the following aspects:

- Indication views and background information on themes related to economic, environmental, technical and sociocultural impacts of construction activities, with emphasis on the role of building material selection in housing construction.
- Comparison of various technologies used in developed and developing economies for modeling decision in the selection of building material; to highlight their strengths and weaknesses.

1.4 Research Methodology

- Rationale and Approach to the Study Problem

The lack of an integrated theory of material selection and management is reflected in its multifaceted and multi-disciplinary nature, and for this reason, research in building material selection and practice often draws on a range of theoretical bases from the social and natural sciences (Soderland, 2004). According to Pollack (2007), the two main research paradigms are positivism which assumes that social phenomenon obeys natural laws and can be subjected to quantitative logic and interpretivist argues that social phenomenon does not obey natural laws but is interpreted based on peoples' conviction and/or understanding of the realism surrounding the phenomenon (Bailey, 1987). In positivism human interest is largely irrelevant because it is not the main subject under investigation and in interpretivist human interest is the main driver of the science. Furthermore with regard to positivism, the concepts need to be operationalized so that they can be measured, however with regard to interpretivist, the stakeholder interest has to be incorporated. Above all, while positivism may require relatively large sample size to draw statistical conclusions, with regard to interpretivist the concentration is normally on small sample size to help develop theoretical abstraction. In this research, time and financial constraints would not allow both paradigms to be explored and so the paradigm, which was considered most reasonable in satisfying the tenets of the research agenda was chosen. Adopting positivism the key sustainable principle indicators and variables have been operationalized to reflect repetitive construction intuition and from the constructs job dedication and the interpersonal facilitation. The conceptual model forces the researcher to be rational and systematic about the constructs and variables to be included in the research instrument. Thus, notwithstanding any potential limitations of quantitative logic in CO2 reduction/Energetic expense cut back, there is reasonable evidence to suggest that it has over the years stood the test of time and might therefore be appropriate for this research agenda as well (Sarpong-Nsiah and Ahadzie 2018; Sarpong-Nsiah, 2020). For the purposes of establishing methodological validity for this research, positivism was adopted. As a result it should reasonably be possible for the study to be replicated with relative ease if necessary.

- Methods

The material selection process for housing development is a complex undertaking and it depends on a number of factors as follows: geographical and geotechnical characteristics of the region, proximity to site and location, and cost of material and labor (Florez et al., 2010; Wastiels et al., 2007). The methodological background adopted to identify these factors or variables in this study was built on the quantitative research methods. Consequently, a quantitative questionnaire was developed as the result of the analysis of the results from the review. In Ghana, CEDs who are registered employees of Architectural and Engineering services Limited (AESL) are responsible for taking the corporate decisions affecting material selection in housing construction.

The first part of the survey instrument contained demographic information related to the classification of the participants; how long they have been in business; the type of housing construction they have implemented over the years; the overall value of housing construction executed in the last five years. This background information was needed in order to establish the potential credibility of the data. Given the descriptive nature of the data that was being sought in this section of the survey instrument, descriptive statistics, were to be used to make meaning out of the data. Apart from the demographic data, information was also gathered from CEDs on their perception of carbon dioxide decrease through LSRBMs selection process in housing construction. This exploratory information was required to help give some insight into how CEDs (constituting the sample) perceive decrease carbon dioxide emissions through locally sourced and recycled building materials selection and management issues in Ghana.

The second part of the survey instrument sought to gather information on the criteria (i.e. the dependent variables) the participants considered important for assessing decrease carbon dioxide emissions through locally sourced and recycled building material selection for housing construction development. The six (6) influential criteria identified were compressed into four (4) key sustainable principal criteria impacting building materials selection are namely: sociocultural, environmental, technical and economic factors. The dependent variables were to be ranked per their level of importance by the potential respondents on a five-point Likert rating scale of 1-5, where '1' not very important, '2' not important, '3' average, '4' important and '5' very important.

- Relative index analysis

This technique was used to further analyze and aggregate the scores of the variables rated on an ordinal scale. The SPSS was first used to determine the valid frequencies (in percentage terms) of the variables rated, to calculate the variables' respective rank indices (RIs). Based on the ranking (R) of relative indices (RI), the weighted average for the six groups of factors were determined.

- Kendall coefficient of concordance and chi-square tests

Kendall's coefficient of concordance (W) was used to determine the degree of agreement among respondents in their rankings. This coefficient provides a measure of agreement between respondents within a survey on a scale of zero to one, with '0' indicating no agreement and '1' indicating perfect agreement or concordance. Using the rankings by each respondent, "W" was computed. To verify that the degree of agreement did not occur by chance, the significance of W was tested, the null hypothesis being perfect disagreement. The Chi-square (x^2) approximation of the sampling distribution. Calculated x^2 value greater than its counterpart table value implied that the (W) was significant at the given level of significance and as such the null hypothesis was not supported hence, rejected.

- Analytical hierarchy process

The Analytical Hierarchy Process (AHP) model offered a logical and representative way of structuring the decision problem and deriving priorities. The method is a theoretically sound and practicable approach for selecting, weighting, standardizing and aggregating individual criteria into a composite index. The technique allows both quantitative and qualitative criteria to be entered into the model and offers an overall solution for the model (Singh et al., 2007). AHP compares decision factors by pairs and assigns weights to reflect their relative importance (Saaty 1986). The hierarchy decomposes to a more specific attribute until a level of manageable decision criteria is met. The method's fundamental rationality is decomposing a dataset into smaller constituent elements and then eliciting pairwise comparisons by using a fundamental (1–9) scale developed by Saaty (1980) to determine their specific priorities.

1.5 Result and Findings of the Research

- Designation of respondents

How best a participant describe himself/herself, revealed the respective job affiliations. This allowed the respondents to choose from four (4) available categories including architects, surveyors, civil engineers and quantity surveyors. Hair et al. (1995), noted that unequal or uneven sample sizes amongst CEDs could influence the results. In order not to have bias results, the random sampling method was introduced to achieve sampling equivalence. To facilitate the response rate, snowball sampling was also adopted, where the approached respondents were asked to distribute the questionnaire to their colleagues and partners. **Table 1.1.1**, shows the description of the respondent; 22% Architects, 28.5% Civil Engineers, 19.9% Quantity Surveyors, and 29.6%

Surveyor. However, the encouraging finding here is that on the average, the size of each group was balanced. Therefore, views of CEDs can be reasonably compared and contrasted.

Table 1.1.1 Job Affiliation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Civil Engineers	53	28.5	28.5	28.5
	Quantity Surveyors	37	19.9	19.9	48.4
	Surveyors	55	29.6	29.6	78.0
	Architects	41	22.0	22.0	100.0
	Total	186	100.0	100.0	

- Experience of respondents

The second question revealed the participants' level of experience in the field of LSRBMs in MSHD assessment. To successfully implement carbon dioxide reduction in MSHD assessment, Zhou et al. (2009) note that the knowledge and experience of respondent is indispensable. **Table 1.1.2**, shows the participants' level of experience in the field of building materials selection; 88.7% had sufficient knowledge in the selection of locally sourced building materials, and 11.3% had less than 5-years working experience in locally sourced building materials selection. The encouraging finding showed that more than half of the respondents had reasonable experience in the selection of building materials. Therefore, the respondents were experienced to provide information that were reliable and credible in building material selection in office building development assessment.

Table 1.1.2. Experience of respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Below 1 year	21	11.3	11.3	11.3
	Less than 5 years	29	15.6	15.6	26.9
	6 to 10 years	34	18.3	18.3	45.2
	11 to 15 years	53	28.5	28.5	73.7
	Above 15 years	49	26.3	26.3	100.0
	Total	186	100.0	100.0	

- Main criteria factors

Table 1.2.1, shows Kendall's coefficient of concordance (W) of 0.854 which was significant at 95% confidence level, suggesting that 85.4% of all survey respondents has assigned the same order to the list of concern; trend of agreement amongst the respondents. The implication here is that, the P value of 0.000 less than 0.05, the null hypothesis was not supported and thus rejected. The ranking results in order of relative importance are 1st Technical, 2nd Sociocultural, 3rd Environmental, and 4th Economics. These can be used as the basis to evaluate material option to know if moving towards or away from CO_2 reduction. According to Singh et al. (2007), bivariate analyses has been found to be inadequate. Consequently, the use of the multivariate analysis has become more acceptable in deciding the choice of materials due to its ability to address both tangible and intangible variables. As the name implies, multivariate analysis comprises a set of techniques dedicated to the assessment of relationships between more than two variables, which are random but interrelated so that their different effects are meaningfully and uniformly interpreted (Singh et al., 2007). The alpha reliability coefficient for the factors was 0.814, suggesting that 81.4% internal consistency of the criteria scale. Relative index analysis was used to rank the sub-criteria according to their relative importance. Here, five important levels are transformed from relative index values as follows: High (H) ($0.7 \leq RI \leq 1$); Medium (M) ($0.5 \leq RI < 0.7$); and Low (L) ($0 \leq RI < 0.5$).

Table 1.2.1. Main criteria importance rating

	Engineers and Designers	
	RI	Rank
Economics	0.640	4th
Environment	0.650	3rd
Technical	0.746	1st
Sociocultural	0.687	2nd
Test statistics	W=0.854, Chi-square=808.287, Sig=0.000	

- Technical factors

Table 1.2.2, shows the P value of 0.000 less than 0.05, the null hypothesis was not supported and thus rejected. The ranking results in order of relative importance are resistance to heat is high (H), resistance to chemicals is high (H), weight and mass of material is high (H), compressive strength is medium (M), and hygroscopic is medium (M). The alpha reliability coefficient for the factors was 0.806, suggesting that 80.6% internal consistency of the criteria scale. Mora (2007), maintained that undermining the issue of technical performance in housing construction has resulted in the colossal waste of material resources and under performance of housing.

- Sociocultural factors

Table 1.2.3, shows the P value of 0.000 less than 0.05, the null hypothesis was not supported and thus rejected. The ranking results in order of relative importance are as material compatibility with client's preference is high (H), material compatibility with regional settings high (H), material compatibility with tradition medium (M), local knowledge of custom and lifestyle medium (M); and cultural restrictions on usury medium (M). The alpha reliability coefficient for the factors was 0.893, suggesting that 89.3% internal consistency of the criteria scale. The sociocultural variable forms an implicit part of the design decision process, as it helps to define the architecture of the region, as well as promote the image of the community (San-Jose et al., 2007).

- Environmental factors

Table 1.2.4, shows the P value of 0.000 less than 0.05, the null hypothesis was not supported and thus rejected. The ranking results in order of relative importance are environmental statutory compliance is high (H), Material environmental impact is high (H), the climatic conditions of the region is high (H), Level of carbon emissions/Toxicity medium (M), and amount of pesticide treatment required low (L). The alpha reliability coefficient for the factors was 0.732, suggesting that 73.2% internal consistency of the criteria scale.

- Economic factors

Table 1.2.5, shows the P value of 0.000 less than 0.05, the null hypothesis was not supported and thus rejected. The ranking results in order of relative importance are affordability of material is high (H), client financial budget is high (H), life cycle cost is high (H), cost of energy spent in manufacturing and transporting materials to site is medium (M), and availability of materials is medium (M). The alpha reliability coefficient for the factors was 0.894, suggesting that 89.4% internal consistency of the criteria scale. The financial constraint is still one of the prime concerns to many building clients because of the huge capital requirement for housing construction (Goh and Yang, 2009).

Table 1.2.2. Technical factors

	Engineers and Designers		
	RI	Rank	Importance level
Resistance to chemicals	0.794	2nd	H
Resistance to heat	0.795	1st	H
Hygroscopic	0.662	5th	M
Weigh and mass of material	0.774	3rd	H
Compressive strength	0.677	4th	M
Kaiser-Meyer-Olkin Measure of Sampling adequacy.	0.762		
Bartlett's Test of Sphericity	Approx. Chi-Square 378.583, Sig 0.000		

Table 1.2.3. Sociocultural factors

	Engineers and Designers		
	RI	Rank	Importance level
Material compatibility with client's preference	0.779	1st	H
Local knowledge of the custom and lifestyle	0.646	4th	M
Material compatibility with tradition	0.653	3rd	M
Cultural restrictions on usury	0.463	5th	L
Material compatibility with regional settings	0.759	2nd	H
Kaiser-Meyer-Olkin Measure of Sampling adequacy	0.614		
Bartlett's Test of Sphericity	Approx. Chi-Square 415.516, Sig 0.000		

Table 1.2.4. Environmental factors

	Engineers and Designers		
	RI	Rank	Importance level
Level of carbon emissions/Toxicity	0.667	4th	M
Environmental statutory compliance	0.772	5st	H
Amount of pesticide treatment required	0.442	1th	L
Material environmental impact	0.764	2nd	H
The climatic condition of the region	0.705	3rd	H
Kaiser-Meyer-Olkin Measure of Sampling adequacy	0.777		
Bartlett's Test of Sphericity	Approx. Chi-Square 486.927, Sig 0.000		

Table 1.2.5. Economic factors

	Engineers and Designers		
	RI	Rank	Importance level
Cost of energy spent in manufacturing and transporting material to site	0.666	4th	M
Availability of material	0.649	5th	M
Clients financial budget	0.763	2nd	H
Affordability of materials	0.779	1st	H
Life cycle cost	0.760	3rd	H
Bartlett's Test of Sphericity	Approx. Chi-Square 614.877. Sig 0.000		

- Material assessment methods

Table 1.3, shows the Kendall's coefficient of concordance (W) 0.870 which was significant at 95% confidence level, suggesting that 87% of all survey respondents has assigned the same order to the list of concern; trend of agreement amongst the respondents. The alpha reliability coefficient for the factors was 0.714, suggesting that 71.4% internal consistency of the criteria scale. The implication here is that the P value 0.000 less than 0.05, the null hypothesis was not supported and thus rejected. The ranked perceived obstacles to the wider scale-use are 1st lack of clear and simple assessment method (Complexity), 2nd lack of adequate project information, 3rd high cost involved in its use, 4th high time consumption in its use, 5th lack of skill in using the tool. Giorgetti and Lovell (2010) for instance have reported the sub-optimal performance of existing tools. They argued that the subjective values and priorities of the authors of the assessment scheme largely dictate the technical characteristics of the systems, and currently represent the major focus of discussion. They suggest that it is necessary for potential users to analyses the local situation and identify the adaptability of using any tool before applying a universal green building assessment tool to a specific country and region.

Table 1.3. Material assessment methods

	Engineers and Designers	
	RI	Rank
Poorly updated program	0.547	7th
Lack of skill in using the tools	0.608	6th
Lack of clear and simple assessment method (Complexity)	0.811	1st
High time consumption in its use	0.734	4th
Lack of regional variation	0.746	3rd
Lack of skill in using the tools	0.732	5th
Lack of adequate project information	0.790	2nd
Test statistics: W=0.870, Chi-square=845.045, Sig=0.000		

1.6. Decomposition of the Decision Problem

The goal is rethinking LSRBMs for future reduction of carbon dioxide emissions with a potential of climate change mitigation. There are 5 pairwise comparison matrices in all: One for the criteria with respect to the goal and four for the sub-criteria. In (**Table 1.4.1**), the main criteria listed on the left are one by one compared with each criterion listed on top as to which one is more important with respect to the goal of selecting the material with the least carbon emissions.

Table 1.4.1. Pairwise comparison matrix of the main criteria

	Environmental	Economical	Sociocultural	Technical	Priorities

Environmental	1	3	5	7	0.5072
Economical	0.33	1	3	5	0.2959
Sociocultural	0.2	0.33	1	3	0.1437
Technical	0.14	0.20	0.33	1	0.0531
		CI 0.0395	RI 0.9	CR 0.0395	CR < 0.08 OK

- Final weights of each criterion

To find the final global weight of each sub-criterion, the results of the weighting vector for standing carbon dioxide emission criteria list were arranged (**Table 1.4.2**). The main criteria weighting vectors (1) are multiplied by the corresponding sub-criteria weighting vectors (2) to obtain the (global) criteria weight (3). Hence, the seven (7) highest weighted sub-criteria for standing list are shown in **(Table 1.4.3)**

Table 1.4.2. Priority weights for carbon dioxide emission main criteria and sub-criteria

Main Criteria	Local weight $^{(1)}$	Sub-Criteria	Local weight $^{(2)}$	Global weight $^{(1x2)}$
Environmental	0.5072	Amount of pesticide treatment required	0.0544	0.0276
	0.5072	Material environmental impact	0.4178	0.2119
	0.5072	The climatic condition of the region	0.5278	0.2677
Economic	0.2959	Affordability of materials	0.0881	0.0261
	0.2959	Clients financial budget	0.4088	0.1210
	0.2959	Life cycle cost	0.5031	0.1489
Sociocultural	0.1437	Material compatibility with client's preference	0.0668	0.0096
	0.1437	Material compatibility with regional settings	0.1928	0.0277
	0.1437	Material compatibility with tradition	0.7404	0.1064
Technical	0.0531	Resistance to heat	0.0556	0.0030
	0.0531	Resistance to chemicals	0.4497	0.0239
	0.0531	Weight and mass of materials	0.4947	0.0263
				1

Table 1.4.3. Highest weighted sub-criteria for standing list

Main criteria	Sub-criteria	Global weight	Ranked
Environmental	The climatic condition of the region	0.2677	1st
Environmental	Material environmental impact	0.2119	2nd
Economic	Life cycle cost	0.1489	3rd
Economic	Clients financial budget	0.1210	4th
Sociocultural	Material compatibility with tradition	0.1064	5th
Sociocultural	Material compatibility with regional settings	0.0277	6th
Environmental	Amount of pesticide treatment required	0.0276	7th
Technical	Weight and mass of materials	0.0263	8th
Economic	Affordability of materials	0.0261	9th

1.7 Discussion and Conclusions

- Objectives of the Study

To indicate views and background information on themes related to economic, environmental, technical and sociocultural impacts of construction activities, with emphasis on the role of building material selection in housing construction.

Table 1.5.1 shows the aspect of the literature review that generated a number of important insights that explained the significance of the measure of CO_2 emission in the construction industry and its impact on the environment. There were clear indications that building stock makes a significant contribution to CO_2 emissions and measures are required to address housing situation with implications for energy consumption and potential climate change impact. A further study identified key sustainable principal indicator that impact the selection of building materials whose measurements must also be evaluated as to, how well, they serve the selection of Locally Sourced and Building Materials (LSRBMs) with the least CO_2 emissions. Decisions involve sociocultural factors need to be traded off. Hence, the need for a more appropriate resource.

Table 1.5.1. Sustainability principal indicators impacting material selection

Research Findings	Deduction from the Results	Relation to other Research
Respondents ranked technical highly among sustainability principal indicators. On the contrary, when selecting materials, they gave low weightage to technical criteria.	This explains the lack of adequate project information, hence the dire need of a simple and efficient building assessment method towards sustainable best practices.	Analysis of factor affecting the selection of low-cost green building materials in housing construction (Ogunkah and Yang, 2013) A multi-criteria approach for CO_2 reduction through climate-friendly material selection: Housing construction in the Volta basin, Ghana (Sarpong-Nsiah, 2020)
The key sustainability principal indicators impacting the selection of building materials with the least CO_2 emissions are technical, sociocultural, environmental and economics in the order of importance.	Possible explanation of the finding is that sustainable development can be operationalized through strategies that are elaborated based on the measurement of the sustainability level Sustainability, in turn, expresses concern about the quality of a system and evaluates its properties and characteristics; it covers environmental protection, ecosystem services, economic and financial issues, social issues, operating licenses, among others.	Approach to identify the influential indicators towards sustainable supply chain adoption in the auto components manufacturing sector (Li, 2018). Sustentabilidade e desenvolvimento sustentável (Feil, 2017).

To compare and contrast various technologies used in developed and developing economies for modeling decision in the selection of building material; to highlight their strengths and weaknesses.

Table 1.5.2 shows that, the literature review highlighted the viability of technology in fulfilling CO_2 reduction requirements in the material selection decision process. In this exercise, existing material assessment tools and methods used in both developed and developing countries were examined and found wanting. The findings were premised on the fact that most existing tools and methods are culturally implicit and complex.

Table 1.5.2. Technology for modeling decision making

Research Findings	Deduction from the Results	Relation to other Research
Existing building assessment methods lack clear and simple assessment method (Complexity) and sociocultural implicit	Most experienced CEDs make decisions regarding the selection of materials on the basis of their past experience and the inexperienced engage the traditional mode of selection, by relying on subjective individual perceptions of values and priorities in the material selection process. Limiting creativity and resulting in considerable frustration.	Community Action for Sustainable Housing: Building a Low Carbon Future. (Seyfang, 2010) Green Building Rating Tools in Africa. (Malanca, 2010). Material Knowledge for Design: The Architect's Vocabulary, Emerging Trends in Design Research. (Wastiels et al., 2007) Decision Support System For Building Construction Product Selection Using Life-Cycle Management. (Quinones, 2011)

- Policy/Practical/Theoretical Implications

Table 1.5.3 shows a disparity between what CEDs profess to be convinced about and knowledgeable in and their commitment and practice. CEDs were unable to translate their technical awareness and knowledge into building materials selection decision. Hitherto sustainability concept are driven/led by reliable sustainability indicators for ongoing profound environmental analysis that lies outside the common questions of academic and civil society stakeholders.

- Recommendations for further research

As indicated in previous sections, this research has investigated practices in housing construction. The investigation has also identified four key sustainability principal indicators that can impact building materials selection. During the study, some observations indicated the need for further study outside the scope of this research. However, the scope of this research has meant that the in-depth investigation that many of the research issues warranted was not possible. Accordingly, it is recommended that further research is necessary to extend and to modify the findings in this research as follows: This area of research can, of course, be expanded to investigate other countries besides Ghana, with the opportunity to draw some interesting international comparisons; The opinions and rankings received from the survey may be confined to CEDs, thus, the opinion in ranking these criteria from other stakeholders deserve further investigation; and other survey methods such as interview and case study surveys may also be used to increase the coverage and to strengthen the survey results.

Table 1.5.3. Policy/Practical Implication

Research Objectives	Research Finding	Implication of Research Findings
To indicate views and background information on themes related to economic, environmental, technical and sociocultural impacts of construction activities, with emphasis on the role of building material selection in housing construction	Respondents ranked technical performance highly among sustainability principal indicators. On the contrary, when selecting materials, they gave low weightage to technical criteria	<u>Policy/Practical Implication</u> ECOWAS to advice countries in the Volta basin to implement policies to put the Volta basin into a path of CO_2 emission reduction. Civil engineers and Designers are in need of a building material selection tool that can aid the incorporation of sustainability principles into MHD.
	The key sustainability principal indicators impacting the selection of building materials with the least CO_2 emissions are technical, sociocultural, environmental and economics in the order of importance.	<u>Theoretical Implication</u> The prescription in the sustainability concept are driven/led by reliable sustainability indicators for ongoing profound environmental analysis that lies outside the common questions of academic and civil society stakeholders.
To compare and contrast various technologies used in developed and developing economies for modeling decision in the selection of building material; to highlight their strengths and weaknesses	Existing building assessment methods lack clear and simple assessment method (Complexity) and sociocultural implicit	<u>Theoretical Implementation</u> The prescription of Technology of materials is driven by the provision of information to aid designers with material decision-making. Hence, it is imperative to highlight on the strength and weakness to improve the generalizability of the proposed model as previous models have been developed on a high complex scale.
		<u>Policy/Practical Implication</u> ECOWAS to advice countries situated in the Volta basin to promulgate sociocultural issues as specification for building assessment methods and tool. Civil engineers and Designers can exploit such opportunity to preserve cultural heritage and housing compatible with lifestyle of the user

- Gaps filled by research

The following are the gaps filled by the study: The lack of informed knowledge in the awareness and implementation of sustainable construction practices, which has led to failure of realizing the benefits of sustainable approach to housing construction in Ghana and countries situated in the Volta basin; The lack of informed knowledge in the awareness and the application levels of sociocultural in LSRBMs selection process and in the Ghanaian context towards revival of lost cultural traditions; and The lack of informed knowledge in awareness and application of reliable elements for ongoing profound environmental analysis that lies outside the common questions of academic and civil society stakeholders.

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