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A multi-criteria approach for energetic expense cut back through climate-friendly building material selection for the housing industry in Ghana: A conceptual framework

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Abstract

Drawing on the concept of sustainability in environmental development, this paper presents a conceptual framework for aiding a multi-criteria Material Selection Decision Process (MSDP) for the housing industry in Ghana. The framework explores and evaluates the significance of multi-criteria mode of assessment to assist Civil Engineers and Designers (CEDs) in the housing construction industry to make early-informed choices, when formulating decision-making to selecting building materials and component. With results derived from the relevant literature and 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 Analytical Hierarchy Process (AHP) methodology a concept of measurement through pairwise comparisons to drive priority scales. These scales measure intangibles in relative terms. This framework incorporates sociocultural as a major role in sustainability principles in MSDP that can be used in creating an understanding and explanation of decision making in the use of materials for housing construction especially in a developing country context. Expert surveys are currently being used to demonstrate the usefulness of the suggested MSDP. The applicability and validity of this model are further illustrated using an ongoing housing project in Ghana:

Keywords: Decision process; Materials and Components, Decision Factors/Variables/Criteria; Conceptual Framework

1.0 Purpose of the Study

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

- Building Assessment Methods

A multi-criteria decision support system for quantitative cost analysis proposed by Mahmoud et al. (1996) provides information to aid the designer with material decision-making. However, no specific information on the methodology for evaluating such materials is given. 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. 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.

- Review on Building Materials Selection Tools

Comprehensive Environmental Performance Assessment Scheme for Buildings (CEPAS) is a holistic assessment tool for various building types with clear demarcation of the entire building life cycle that covers the pre-design, design, construction, demolition and operation stages. It employs an additive/weighting approach, which introduces and organizes performance criteria make a clear distinction between "human" and "physical" performance issues as well as "building" and their "surroundings (Crawley and Aho 1999). However, for the CEPAS assessment model, only single-ownership buildings are eligible for assessment. *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.

- The Role Socio-cultural in Materials Selection Decision

The sociocultural perspective is a theory used to describe awareness of circumstances surrounding individuals and how their behaviors are affected specifically by their surrounding sociocultural factors (Jaramillo 1996). To this end social environment refers to the immediate physical and social setting in which people live or in which something happens or develops. It includes the culture that the individual was educated or lives in, and the people and institutions with whom they interact. San-Jose et al., (2007) argue that the sociocultural variable forms an implicit part of the design decision-making process, as it helps to define the architectural of the region, as well as promote the image of the community. Like-wise material choice also must be compatible with specific regional, local, cultural and aesthetic conditions. Hence, considerations must be given to socio-cultural variables during the early stages of the design to conserve the cultural asset. Variables within this group include: 1) material compatibility with traditions; 2) cultural restriction on usury; 3) local knowledge of the custom and lifestyle; 4) family structure; 5) material compatibility with client's preference; and 6) status in society. The socio-cultural values of mankind is known to vary from one society to another. The values of socio-cultural have direct and indirect influences on mankind's habitation. For instance, in Ghana the predominant traditional house form is the compound house form, which varies in pattern with the different ethnic settings that make up the country. The average size of a household in the country is five persons, about 60% of all urban households occupy single rooms (CHF International, 2004; UN-Habitat 2011). UN-Habitat report on Ghana, (2011) indicates that housing is built in horizontal stages, progressing vertically through the whole foundations, the walls and the roof, only being occupied by the homeowner when it is finished. In addition, much of the supply comes from adding a room or another building on the plot (UN-Habitat, 2012. p. 168).

The causality relationship between macro/micro-economic activities in the housing industry and their environmental issues/impact differ among countries due to the differences in their socio-culture. For example, thatched roofs, made from grass or palm leaves and clay roofs which have three layers; a surface of clay, which is laid on mats, which in turn are laid on beams of Borassus palm and wood, 4 which are horizontal in the northern areas of Ghana would not export well to the southern area of Ghana because, the northern area of Ghana is drier than southern area of Ghana, due to its proximity to the Sahel and the Sahara and the vegetation consists predominantly of grassland, especially savanna with clusters of drought-resistant trees such as baobabs.

- Carbon Dioxide Emissions

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:

- In the exploitation,
- In the production of materials and products,
- In the setting on site,
- In the construction of the building itself,
- The renovations,
- The later rehabilitations, and
- Up to the final demolition.

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. Goldenberg (1998) defines carbon dioxide emissions as a third of the energetic expense that comes directly or indirectly from the construction activity. Furthermore, Edwards & Hyett (2001) states that a participation of close to 50% of the total energetic cost in developed countries is closely linked or is a consequence of the construction industry. The energy for maintenance has already received the positive attention of state institutions, which have emphasized the implementation of the use of alternative energies, as well as the intense use of thermal insulators and responsible consumption. These decisions can drastically reduce the energetic expense of the refrigeration of buildings. 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 & 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. Subsequently, drawing from the generic definition provided by Goldenberg (1998), it is contended that carbon dioxide emission measure should appropriately and explicitly be redefined as emissions from rethinking locally sourced and recycled building materials selection for mainstream housing developments. Furthermore, the emission should be linked to the conceptual phases of the project. Likewise, the deterioration of the physical environment due to housing construction activities is traceable to the choice of building products at the early design stages. For example, 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. Xing et al. (2008) in a comparing steel and aluminum with concrete, in residential buildings, in terms of embodied energy and carbon dioxide emissions, concluded that concrete exhibits lower energy consumption than steel or aluminum in the entire building life-cycle. The case studies revealed that concrete dominates in terms of mass, while steel and aluminum dominate in terms of carbon dioxide emissions due to the high values of carbon dioxide emissions per material mass.

Although the roles and benefits of technology transfer have been demonstrated in most literature (Ofori, 2006), such benefits remain relatively under-explored and are yet to be realized in less develop countries. Therefore, the technology to be adopted in this study must bring sociocultural factors to the attention of CEDs as the vital resources for strengthening the material selection decision-making process.

1.2 Statement of the Problem

Against the background information presented, the research problem was identified thus; rapid population growth and corresponding housing deficit, increase CO_2 emissions, especially so as building stocks have been identified to make significant contribution to CO_2 emissions that are considered to be responsible for the current global warming phenomenon, no rigorous attempt to examine the role of sociocultural as vital resources for strengthening the material selection decision-making process. As such, aspiring and experienced Civil Engineers and Designers (CEDs) are unaware of sociocultural criteria that can help engender best practices in materials selection process in the context of CO_2 reduction. Granted that the appropriate materials for sustainable design vary by impact priorities, regional issues, project budgets, and performance requirements (Florez et al., 2010) this lack of recognizing and embedding CO_2 reduction in building materials selection process has the potential of threatening the development and promotion of sustainable housing developments.

Many studies have acknowledged that the close relationship between the production of CO_2 and housing construction has the following aspects: estimation of CO_2 emission reduction by all industrial activities related to the building erection and estimation of energetic expense cut back, which can be reached by an adequate selection of materials (Xing et al., 2008; Monahan and Powell, 2011; Shams et al., 2011). Ljungberg et al., (2007) identified specific factors such as environmental impacts, economic impacts, customer requirements, highly satisfying to the user, safe to use, low reparable and highly prolonged, and market demand for assessing different sustainable construction products. Meanwhile, in the context of material selection no mention is made about the objective and subjective measures.

The Gaps are as follows: The lack of informed knowledge in the awareness and implementation of sustainable housing 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 locally source and recycle building materials 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:

- To identify an appropriate theoretical framework for developing a conceptual model suitable for achieving CO_2 emission reduction through climate-friendly materials selection in housing construction activities.
- To develop a conceptual model for measuring energetic expense cut back in office building development adopting the theoretical framework identified.

1.4 Research Methodology Employed

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.

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 climate-friendly building materials (locally sourced and recycled building materials) 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 AHP is designed to cope with the intuitive, the rational, and the irrational when making multi-criteria materials selection decision and handle the complexities of real-world problems. The top element of the hierarchy is the overall goal for the decision model. 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 (**Table 1**). Thus, although the hierarchical structure of the AHP method does facilitate analysis, it is the method's ability to measure and synthesize the multitude of factors within the developed hierarchy that truly sets the method apart (Singh et al. 2007).

In this paper, it is tested to derive weights of criteria by the prioritization of their impact to future reduction in CO_2 emissions and overall energy expense cut back in the selection of locally source building materials in construction activities. The AHP calculates the inconsistency index as a ratio of the decision maker's inconsistency and randomly generated index. Various methods have been devised to deal with inconsistency. Saaty (2007) suggests the following consistency index (CI):

$$\mathrm{CI} = \frac{\lambda_{max-1}}{\mathrm{n}^{-1}} \qquad 1$$

Table 1. Comparison scale adapted.

Degree of importance	Definition
1	Equal Importance
3	Importance of one element over another
5	Strong importance of one element over another
7	Very strong importance of one element over another
9	Absolute importance of one element over another
2,4,6,8	Intermediate values between two adjacent degrees of importance

Where λ_{max} is the largest eigenvalue and n is the number of elements within a branch being compared. If a matrix is perfectly consistent (cardinally) then λ_{max} will be at a minimum and equal to n, producing a CI equal to zero. As inconsistency increases λ_{max} will become increasingly large, producing a larger value of CI. This consistency index can also be expressed as a consistency ratio:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \qquad 2$$

Where RI is a known random consistency index obtained from a large number of simulation runs and varies depending upon the order of matrix (**Table 2**). If the value of CR is less than 10%, it implies that the evaluation within the matrix is acceptable or indicates a good level of consistency in the comparative judgements represented in that matrix. In contrast, if CR is more than the acceptable value, inconsistency of judgements within that matrix has occurred and the evaluation process should therefore be reviewed, reconsidered and improved. An acceptable consistency property helps to ensure decision-maker reliability in determining the priorities of a set of criteria, table 2 (Saaty 2000).

Table 2. Average random index for corresponding matrix size.

Matrix size (n)	3	4	5	6
Random Index (RI)	0.58	0.9	1.12	1.24
Consistency Ratio (CR) less than or equal to	0.05	0.08	0.1	0.1

1.5 Towards a Conceptual Framework for Materials Selection Decision Process

The identification of the factors, strategies, drivers and barriers towards building material selection is a starting point to sketch out ideas and work out which factors are key for inclusion in the outline of a conceptual framework of multi-criteria decision-making for the housing construction in Ghana and suitable for countries situated in the Volta basin. The analysis of the surveyed questionnaires identified fifty-six (56) key influential factors as important components of the material selection process. The factors are compressed into six groupings: Environmental/Health; Economy/costs; Sensory; Socio-cultural; Technical; and Site conditions. For the purpose of clarity in the functions, similarities and differences in properties, the factors are compressed into four groupings namely: Performance capabilities, sociocultural benefits, Environmental Impact, and Economy efficiency. As it can be seen from **figure 1,** the visual tracking of the analyzed decision factors for measuring CO_2 reduction/Energy cut back for the construction industry in Ghana. The framework has been sub-divided into nine (9) areas. Each box represents a group of factors that the participants had identified as attributes that they consider when selecting building materials with sociocultural as key attribute. Building elements are: flooring, walling, doors/windows, ceiling and roofing. The sustainable principle indices are: technical factors, economy factors, and general site conditions, sociocultural, sensorial and environmental factors.

1.6 Discussion and Conclusions

Objective 1: *To identify an appropriate theoretical framework for developing a conceptual model suitable for achieving CO_2 emission reduction through climate-friendly materials selection in housing construction activities*

Table 3, shows the literature review revealed a reliance on psychology - based theory and model for establishing frameworks useful in CO_2 emissions reduction/Energetic expense cut back. This objective was therefore addressed by reviewing, in particular, the relevant literature on mainstream applied psychological literature. This led to the identification of sustainability principal indicators impacting materials selection as follows: Environmental/Health; Economy/costs; Sensory; Socio-cultural; Technical; and Site conditions. For the purpose of clarity in the functions, similarities and differences in properties, the factors are compressed into four groupings namely: Performance capabilities, sociocultural benefits, Environmental Impact, and Economy efficiency. Socio-cultural variables are intangible and have not received much attention in the architecture literature as other groups of factors (San-Jose et al., 2007).the sociocultural theory as an appropriate methodology for addressing this research agenda. The sociocultural theory posits that considerations must be given to sociocultural variables during the early stages of the design to conserve the cultural asset. Variables within this group include: 1) material compatibility with traditions; 2) cultural restriction on usury; 3) local knowledge of the custom and lifestyle; 4) family structure; 5) material compatibility with client's preference; and 6) status in society. In addition the argument by San-Jose et al., (2007) that the sociocultural variable forms an implicit part of the design decision-making process, as it helps to define the architectural of the region, as well as promote the image of the community and was incorporated into the theoretical framework. This framework was adopted here as it offered the opportunity for a potentially more detailed conceptualization of the CO_2 emission reduction/Energetic expense cut back. Granted that Analytical Hierarchy Process (AHP) is a pairwise comparison matrix of the main criteria with respect to the goal: Main criteria listed are one by one compared with each criteria listed on as to which one is more important with respect to the goal of selecting a material with the least Carbon emissions. All criteria are combined, an indexing algorithm termed the 'carbon dioxide utility index' is created to rank options of competing material choices on their contribution to future reduction in carbon dioxide emissions/Energetic expense cut back. These priorities may also be expressed in the ideal form by dividing each priority by the largest one. The effect is to make this alternative the ideal one with the others getting their proportionate value.

Table 3. Sociocultural variables impacting material selection

Research Findings	Deduction from the Results	Relation to other Research
Sociocultural variables impacting building materials selection: material compatibility with traditions; cultural restriction on usury; local knowledge of the custom and lifestyle; family structure; material compatibility with client's preference; and status in society	This explains that material choice must be compatible with specific regional, local, cultural and aesthetic conditions	Ahadzie, D.K. & Amoa-Mensah, K. 2010. Management Practices in the Ghanaian House Building Industry. Journal Of Science and Technology 30(2): 62. Boamah, N.A. 2010. Housing Affordability in Ghana: A focus on Kumasi and Tamale. Ethiopian Journal of Environmental Studies and Management 3(3): 1-11

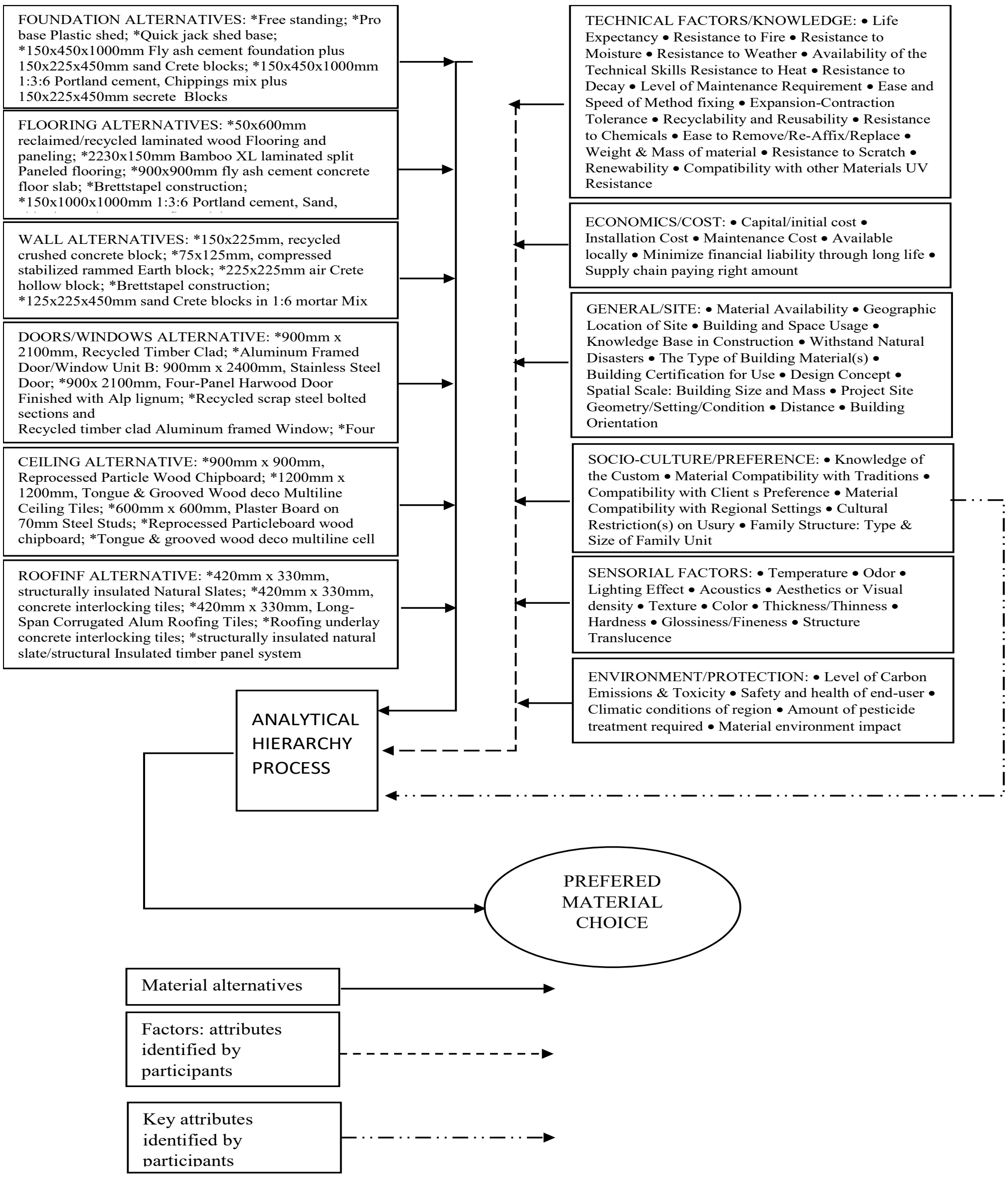

Figure 1. Conceptual framework of the analyzed decision factors for CO_2 reduction/Energetic expense cut back for the housing construction industry in Ghana

Objective 2: *To develop a conceptual model for measuring energetic expense cut back in office building development adopting the theoretical framework identified*

Table 4, shows that, drawing from the sociocultural theory of material selection decision process and AHP methodology; a robust conceptual model was developed reflecting the conceptual, design, construction and operational phases of housing construction based on the standard practices and construction details commonly used in the housing construction industry of Ghana. The constructs identified from the contextual-task framework, namely; Environmental/Health; Economy/costs; Sensory; Socio-cultural; Technical; and Site conditions in the conceptual model, and reflecting the context of housing construction

Table 4. Sustainability Indices

Research Findings	Deduction from the Results	Relation to other Research
Sustainability principal indices are: Environmental/Health; Economy/costs; Sensory; Socio-cultural; Technical; and Site conditions.	Decisions involve sociocultural factors need to be traded off. To do that, they have to be measured 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 LSRBM with the least CO_2 emissions.	Li, Y., Mathiyazhagan, K., (2018). Application of DEMATEL approach to identify the influential indicators towards Sustainable supply chain adoption in the auto components manufacturing sector. J. Clean. Prod. 2018, 172, 2931–2941 Feil, A. A., Schreiber, D., (2017). Sustentabilidade e desenvolvimento sustentável: Desvendando as sobreposições e Alcances de seus significados. Cad. EBAPE BR, 15, 667–681

- Policy/Practical/Theoretical Implications

Table 5 shows that, the usefulness of this framework emanates from its suitability as a checklist-type single evaluation method, to a multiple criteria framework that incorporates sociocultural factors as a major component that can be used in creating an understanding and explanation of decision making in the use of materials for housing construction especially in a developing country context. This discourse has laid down the theoretical and conceptual arguments for the development of the material selection decision model. The model once developed will aid CEDs adopting a systematic approach for selecting building materials with fewer CO_2 emissions which could help in combating climate change in Ghana and countries situated in the Volta Basin.

- Recommendations for further research

As indicated in previous sections, this research has investigated practices in housing construction. The investigation has also identified 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, 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. Furthermore, other multi-criteria techniques besides AHP may be used with the opportunity to draw some interesting connections.

- 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

Table 5. Policy/Practical/Theoretical Implication

Research Objectives	Research Finding	Implication of Research Findings
To identify an appropriate theoretical framework for developing a conceptual model suitable for achieving CO_2 emission reduction through climate-friendly materials selection in housing construction activities	Sociocultural variables impacting building materials selection: material compatibility with traditions; cultural restriction on usury; local knowledge of the custom and lifestyle; family structure; material compatibility with client's preference; and status in society	<u>Policy/Practical Implication</u> Promote best practice guide in climate-friendly building materials (LSBMs) selection, and attempt to stimulate motivation of its use in a wider industry context. The establishments of such precedents would spark and facilitate a considerable shift in awareness as to the potential role of LSRBM selection could help in combating climate change and in effect might be a declaration by government that alternative approaches to their selection process in OBD may be encouraged. <u>Theoretical Implication</u> Serve as a future reference for researchers on the subject of LSBM selection and managerial practices, and in turn act as a primary locus for further innovations and technological progress in building construction. The results of the study will also be beneficial in enriching knowledge on the energetic expense cut back of each material.
To develop a conceptual model for measuring energetic expense cut back in office building development adopting the theoretical framework identified	Sustainability principal indices are: Environmental/Health; Economy/costs; Sensory; Socio-cultural; Technical; and Site conditions.	

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