International Research Initiatives Conference (IRIC) 2020
Accra Institute of Technology, Accra, Ghana

A multi-criteria approach for energetic expense cut back through climate-friendly materials selection

[1]G. Sarpong-Nsiah
Open University of Malaysia /Accra Institute of Technology, Accra, Ghana
ingnsiah@gmail.com

[2]Amevi Acappovi
Accra Technical University, Accra, Ghana
aacakpovi@gmail.com

[3] George Kwamina Aggrey
University of Cape-Cost, Cape Coast, Ghana
gaggrey@ucc.edu.gh

ABSTRACT

Drawing on the concept of sustainability in environmental development, a third of the energetic expense, and therefore of the production of CO_2, comes directly or indirectly from the construction activity. Energy consumption can be cut back through rethinking Locally Sourced Building Materials (LSBMs) selection decision making, in bringing cultural issues to the attention of civil engineers and designers in office building development, towards the wider use of concrete interlocking tile which is 91% as good as structurally insulated natural slates (reduction of 21.4% CO_2 emissions and cut back of 64.2% energetic expense). 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 LSBMs with the least CO_2 emissions. The analytical hierarchy process is a concept of measurement through pairwise comparisons to derive priority scales. These scales measure intangibles in relative terms. This explained reduction of 21.4% CO_2 emissions and cut back of 64.2% energetic expense for selecting concrete interlocking tile instead of structurally insulated natural slates and reduction of 9.6% CO_2 emissions and cut back of 28.8% energetic expense for selecting long-span corrugated aluminum roofing tile instead of structurally insulated natural slates, the lack of informed knowledge in the wider use of concrete interlocking tile and in the Ghanaian context towards climate change mitigation in the countries situated in the Volta Basin.

Keywords: Locally sourced building material; Decision factors; Energetic expense; Office building development.

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 owner 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) 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 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 of CO_2 and construction has been studied analysing the following aspects:

- To estimate CO_2 emission produced by all industrial activities related to the building erection—in this case the specific building type.
- To estimate CO_2 reduction, which can be reached by an adequate selection of materials.

1.4 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):

$$\mathrm{CI} = \frac{\lambda_{max-1}}{\mathrm{n}^{-1}} \quad (1)$$

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:

$$CR = \frac{CI}{RI} \quad (2)$$

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

- 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.

1.8 An Example of A Multi-Criteria Decision Process

The following is a multi-criteria decision process by a direct estimation which involves the expression of relative importance of the objectives or criteria in a direct way through questionnaire surveys to determine what kind of roofing material would be best for office building: structurally insulated natural slates, concrete interlocking tiles and long-span corrugated aluminum roofing tile. The goal is rethinking locally sourced building materials for future energetic expense cut back with a potential of climate change mitigation as spelled out by the criteria. Details for the three options of roofing materials for the proposed office building are illustrated in **table 3**. The description of the three options was based on the standard practices and construction details commonly used in the housing construction industry of Ghana. These three roofing materials were analyzed amongst a host of other material alternatives. This section will analyses the problem using the AHP mathematical multi-criteria decision-making technique, to identify and decide which material is the most suitable roofing material.

Table 3. Summary of the roofing option.

	A	B	C
Roofing Material	420mm x 330mm, Long-Span Corrugated Aluminum Roofing Tile	420mm x 330mm, Structurally insulated Natural Slates	420mm x 330mm, concrete interlocking tiles
Rate of carbon dioxide emissions $kgCO_2/m^2$	8.24 $kgCO_2/m^2$	0.235 $kgCO_2/m^2$	0.5 $kgCO_2/m^2$

1.8.1 Decomposition of the Decision Making Process

There are 14 pairwise comparison matrices in all. One for the criteria with respect to the goal, which is shown in **table 3**, shows 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 energetic expense. Similarly for the remaining 13 pairs are compared with the sub-criteria on top as to their importance with respect to the main criteria

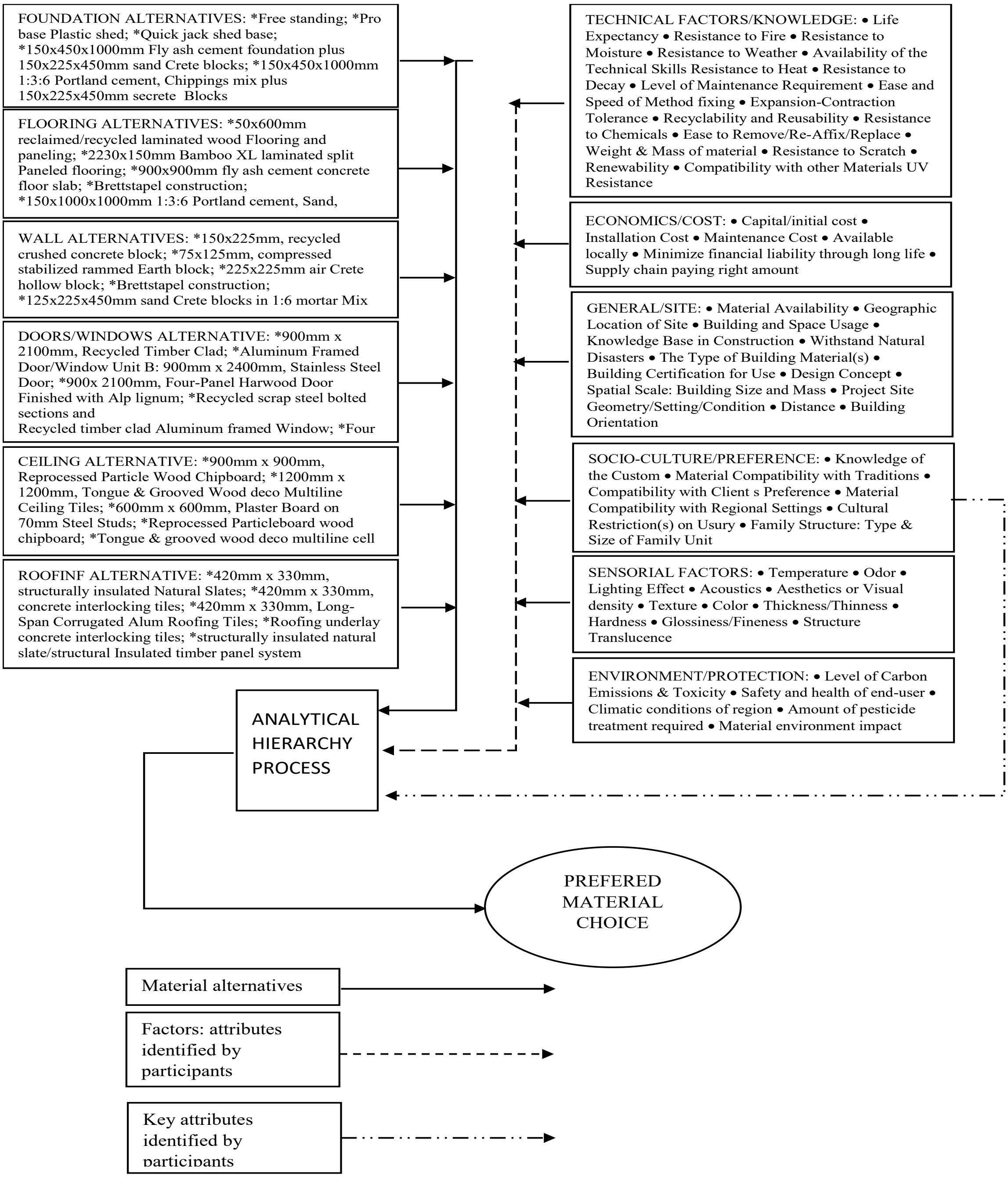

Figure 1. Conceptual framework of the analyzed decision factors for CO2 reduction/Energetic expense cut back for the housing construction industry in Ghana

Table 3. Pairwise comparison matrix of the main criteria

	Technical	Economics	Sociocultural	Technical	Priorities
Environmental	1	0.25	0.167	0.25	0.0563
Economics	4	1	0.333	3	0.2817
Sociocultural	6	3	1	4	0.4732
Technical	4	0.333	0.25	1	0.1887
		CI 0.0721	RI 0.9	CR 0.0721	CR < 0.08 OK

1.8.2 Final Weights of Each Criterion

To find the final global weight of each sub-criterion, the results of the weighting vector for standing CO2 emission weight criteria list were arranged (**Table 4**). The main criteria weighting vectors (1) are multiplied by the corresponding sub-criteria weighting vectors (2) to obtain the (global) criteria weight (3).

Table 4. Priority weights for energetic expense main and sub-criteria

Main criterion	Local weight $(1)^1$	CO_2 emissions sub-criterion	Local weight $(2)^2$	Global weight $(3)^{1x2}$
Environmental	0.0563	EN1: Amount pesticide treatment	0.0323	0.0018
		EN2: Amount pesticide treatment	0.1527	0.0086
		EN3: Level of carbon emissions	0.2613	0.0147
		EN4: Environmental statutory compliance	0.1032	0.0058
		EN5: Climatic condition of the region	0.4505	0.0254
Economics	0.2817	EC1: Life cycle	0.0286	0.0081
		EC2: Availability of material	0.2393	0.0674
		EC3: Clients financial budget	0.2930	0.0825
		EC4: Affordability of material	0.1017	0.0286
		EC5: cost Energy spent in manufacturing	0.3374	0.0950
Sociocultural	0.4732	SC1: Material compatibility with tradition	0.0259	0.0122
		SC2: Costume and life style	0.2067	0.1023
		SC3: Compatibility with clients preference	0.2569	0.1253
		SC4: Material compatibility with regional settings	0.0919	0.0435
		SC5: Cultural restrictions on usury.	0.4143	0.1899
Technical	0.1887	TN1: Weight and mas	0.0556	0.0105
		TN2: Resistance to chemicals	0.4497	0.0849
		TN3: : Resistance to heat	0.4947	0.0934

The final step in the pair-wise comparison involves comparing each pair of alternatives with respect to each sub-criterion. In comparing the three roofing materials, the decision-makers were asked which material is preferred with respect to each sub-criterion. As it can be seen from **table 5,** all criteria are combined, an indexing algorithm termed the ‘carbon dioxide emission utility index’ is created to rank options of competing material choices on their contribution to carbon dioxide emission reduction.

Table 5. Overall criteria rating.

Main Criteria	Local weight (1)	Sub-Criteria	Local weight (2)	Local weight (3)			Global weight (2)		
				A	B	C	A	B	C
EC	0.2817	EC5	0.3374	0.0590	0.5176	0.4235	0.0056	0.0492	0.0403
EC	0.2817	EC2	0.2393	0.0881	0.4088	0.5031	0.0059	0.0276	0.0339
EC	0.2817	EC3	0.2930	0.0909	0.4545	0.4545	0.0075	0.0375	0.0375
SC	0.4732	SC2	0.2067	0.0556	0.4497	0.4947	0.0054	0.0440	0.0484
SC	0.4732	SC3	0.2569	0.7999	0.0993	0.1008	0.0972	0.0121	0.0123
SC	0.4732	SC5	0.4143	0.0881	0.4088	0.5031	0.0173	0.0801	0.0986
TN	0.1887	TN2	0.4497	0.0544	0.4178	0.5278	0.0046	0.0355	0.0448
TN	0.1887	TN3	0.4947	0.0556	0.4497	0.4947	0.0052	0.0420	0.0462
Carbon dioxide utility index (Normalized priorities)							0.1488	0.3279	0.3619
Carbon dioxide utility index (Idealized priorities)							0.4112	0.9060	1

Table 6, shows that 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. Concrete interlocking tile is 91% as good as structurally insulated natural slates (reduction of 21.4% CO_2 emissions and cut back of 64.2% energetic expense), whiles long-span corrugated aluminum roofing tile is 41% as good as structurally insulated natural slates (reduction of 9.6% CO_2 emissions and cut back of 28.8% energetic expense).

Table 6. Comparing normalized and idealized priorities.

Roofing materials	Normalized Priorities	Idealized Priorities (%)	CO_2 emission Reduction (%)	Energetic Expense cut back (%)
420mm x 330mm, Long-Span Corrugated Aluminum Roofing Tile 8.24 kgCO_2/m^2	0.1488	41	9.6	28.8
420mm x 330mm, Concrete Interlocking Tiles 0.5 kgCO_2/m^2	0.3279	91	21.4	64.2
420mm x 330mm, Structurally Insulated Natural Slates 0.235 kgCO_2/m^2	0.3619	1	0	0

1.9 Discussion and Conclusions

- Objectives of the Study

- *To estimate CO_2 emission produced by all industrial activities related to the building erection—in this case the specific building type.*
- *To estimate of CO_2 reduction, which can be reached by an adequate selection of materials*

Table 7, shows that embodied energy of a building is the total energy required in the direct energy used in the construction and assembly process and the indirect energy is required to manufacture the materials and components of the building (Huberman and Pearlmutter, 2008). Goldenberg (1998) calculate that a third of the energetic expense, and therefore of the production of carbon dioxide, comes directly or indirectly from the construction activity. Energy consumption can be cut back through improving efficiency, which is an effective means to lessening carbon dioxide emission (Lee and Chen, 2008) and which can be reached by an adequate selection of building materials (Monahan and Powell, 2011; Shams et al., 2011).

Table 7. Sociocultural variables impacting material selection

Research Findings	Deduction from the Results	Relation to other Research
CEDs in the selection of roofing material for housing construction assigned low weight to environmental.	Clients and investors regularly have significant influence on material choices due to the terms they impose on a project through budget and brief.	The market for green building in developed Asian cities—the perspectives of building designers, Energy Policy, Volume 37, Issue 8, August 2009, Pages 3061-3070. (Chan et al., 2009) A needs based methodology for classifying construction clients and selecting contractors, Construction Management and Economics, 16(1), 91-98 (Chinyio et al., 1998)
Concrete interlocking tile is 91% as good as structurally insulated natural slates whiles long-span corrugated aluminum roofing tile is 41% as good as structurally insulated natural slates.	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.	A multi-criteria approach for CO_2 reduction through climate-friendly material Selection: Housing construction in the Volta Basin, Ghana. In J. Runge, A. Guézéré and L. Kankpénandja (1st Ed.), Natural Resources, Socio-Ecological Sensitivity and Climate Change in the Volta-Oti Basin, West Africa, E-Book ISBN: 978-1-003-10670-8, Hardbound ISBN: 978-0-367-61821-6. (Sarpong-Nsiah, 2020) Inventory analysis of LCA on steel and concrete construction office buildings. Energy and Buildings 2008, 40:1188- 1193. (Xing et al., 200**8**
Concrete interlocking tile (reduction of 21.4% CO_2 emissions and cut back of 64.2% energetic expense), whiles long-span corrugated aluminum roofing tile (reduction of 9.6% CO_2 emissions and cut back of 28.8% energetic expense).	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	A multi-criteria approach for CO2 reduction through climate-friendly material Selection: Housing construction in the Volta Basin, Ghana. In J. Runge, A. Guézéré and L. Kankpénandja (1st Ed.), Natural Resources, Socio-Ecological Sensitivity and Climate Change in the Volta-Oti Basin, West Africa, E-Book ISBN: 978-1-003-10670-8, Hardbound ISBN: 978-0-367-61821-6. (Sarpong-Nsiah, 2020)

- Policy/Practical/Theoretical Implications

Table 5 shows that, a significant endeavor in promoting best practice guide in LSRBMs 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 LSRBMs selection could help in combating climate change and in effect might be a declaration by government that alternative approaches to their selection process in MHD assessment may be actively explored or even encouraged.

- 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 implementation levels and the benefit of CO2 emissions reduction in building materials selection best practices in MHD assessment in Ghana and countries situated in the Volta basin

Table 5. Policy/Practical/Theoretical Implication

Research Objectives	Research Finding	Implication of Research Findings
To estimate CO_2 emission produced by all industrial activities related to the building erection—in this case the specific building type.	Concrete interlocking tile (reduction of 21.4% CO_2 emissions and cut back of 64.2% energetic expense), whiles long-span corrugated aluminum roofing tile (reduction of 9.6% CO_2 emissions and cut back of 28.8% energetic expense) housing construction	<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 estimate of CO_2 reduction, which can be reached by an adequate selection of materials	Concrete interlocking tile is 91% as good as structurally insulated natural slates whiles long-span corrugated aluminum roofing tile is 41% as good as structurally insulated natural slates	

References

Ahadzie, D.K. & Amoa-Mensah, K. 2010. Management Practices in the Ghanaian House Building Industry. Journal of Science and Technology 30(2): 62.

Ogunkah, I., C., Yang C., 2013.Analysis of factor affecting the selection of low-cost green building materials in Housing construction, International Journal of sciences Vol 2. (42-75) (Ogunkah and Yang, 2013)

Anoumou, A.C.N. and Runge, J. (2016): Von Menschen und Kakao: sozial-okologische Aspekte des Landnutzungswandels in Badou-Tomegbe, Togo (Westafrika). Zbl. Geol. Palaont, I, ½: 5-21.

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

Ding, L., Roberto, G.Q., Wei, L. and Ratcliffe, J. 2010. Risky Borrowers or Risky Mortgages Disaggregating Effects Using Propensity Score Models. Working Paper. Durham: Department of Urban Studies and Planning and the UNC Center for Community Capital.

Feil, A. A., Schreiber, D., (2017). Sustentabilidade e desenvolvimento sustentável: Desvendando as Sobreposições e Alcances de seus significados. Cad. EBAPE BR, 15, 667–681

Florez, L.D., Castro, D. & Irizarry, J. 2010. Impact of Sustainability Perceptions on Optimal Material Selection In Construction Projects. Proceedings of the Second International Conference on Sustainable Construction Materials and Technologies, University Politecnica delle Marche, Ancona, Italy, Coventry University and the University of Wisconsin Milwaukee Centre for By-Products Utilization, 28-30 June 2010: 719-727.

Giorgetti I. and Lovell A. 2010. Sustainable Building Practices for Low Cost Housing: Implications for Climate

Hair J., Anderson R. E., Tatham R. L. and Black W. C. 1995. Multivariate data analysis". 4th Ed. New Jersey: In Africa, Nairobi, 4-6 May 2010, pp. 16-25.

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

Mahmoud, M.A.A., Aref, M. & Al-Hammad, A. 1996. An expert system for evaluation and Selection of floor Finishing materials. Expert Systems with Applications 10(2): 281- 303.

Malanca M. 2010. Green Building Rating Tools in Africa. In: Conference on Promoting Green Building Rating

Monahan, J. and Powell, J.C. 2011. An embodied carbon and energy analysis of modern methods of Construction in Housing: A case study using a lifecycle assessment framework. Energy and Buildings 43(1): 179-188.

Mora, E. 2007. Life cycle, sustainability and the transcendent quality of building materials. Building and Environment 42(3): 1329-1334.

Perera, R.S. & Fernando, U. 2002. Cost Modelling for Roofing Material Selection. Built Environment: Sri Lanka 3(1): 11-24. Prentice-Hall Inc. 1995

Rahman, S., Perera, H. Odeyinka, H. & Bi, Y. 2009. A Knowledge-Based Decision Support System for Roofing Materials Selection and Cost Estimating: A Conceptual Framework for Cost Modelling. 25th Annual ARCOM Conference, (2009) September 7-9, Nottingham, England.

Rahman, S., Perera, H., Odeyinka, H. & Bi, Y. 2008. A Conceptual Knowledge-Based Cost Model for Optimizing the Selection of Material and Technology for Building Design," In A.R.J. Dainty (ed.), 24th Annual ARCOM Conference, Association of Researchers in Construction Management, University of Glamorgan, 1-3 September 2008: 217-22.

Saaty T.L. (1980): "The Analytic Hierarchy Process", McGraw-Hill, New York (1980).

Saaty, T.L. 1986. Axiomatic foundation of the analytic hierarchy process. Management Science 32(7)

San-Jose, J.T., Losada, R., Cuadrado, J. & Garrucho, I. 2007. Approach to the quantification of the Sustainable Value in industrial buildings. Building and Environment: 916–3923.

Sarpong-Nsiah, G. & Ahadzie, D.K. 2018. Multi-Criteria Material Selection Decision Support System for the Housing Construction Industry: A Conceptual Framework. ICCF-Psycon Conference, University of Woverhampton, United Kingdom

Sarpong-Nsiah, G. 2020. A multi-criteria approach for CO2 reduction through climate-friendly material Selection: Housing construction in the Volta Basin, Ghana. In J. Runge, A. Guézéré and L. Kankpénandja (1st Ed.), Natural Resources, Socio-Ecological Sensitivity and Climate Change in the Volta-Oti Basin, West Africa, E-Book ISBN: 978-1-003-10670-8, Hardbound ISBN: 978-0-367-61821-6.

Seyfang, G. (2009a) Community action for sustainable housing: building a low carbon future. Energy Policy doi:10.1016/j.enpol.2009.10.027

Shams, S., Mahmud, K. & Al-Amin, M. 2011. A comparative analysis of building materials for Sustainable Construction with emphasis on CO2 reduction. Int. J. Environment and Sustainable Development 10(4):

364 –374.
Singh, R.K., Murty, H.R., Gupta, S.K. & Dikshit, A.K. 2007. Development of composite Sustainability Performance Index for steel industry. Ecological Indicators 7(3): 565-588.
UNEP-GEF Volta Project 2003. Benin, Ghana, Togo and Burkina Faso Countries Report for the Intergrated Management of the Volta River Basin Project, Accra: UNEP.
Wastiels, L. Wouters I. and Lindekens J. 2007 Material Knowledge for Design: The Architect's Vocabulary, Emerging Trends in Design Research. International Association of Societies of Design Research (IASDR) Conference, Hong Kong, 16-19.
Wastiels, L., & Wouters, I., 2009. Material Considerations in Architectural Design: A Study of the Aspects Identified by Architects for Selecting Materials. In: Undisciplined! Design Research Society Conference 2008, Sheffield Hallam University, Sheffield, UK, 16-19 July 2008
Xing S, Xu, Z, & Jun, G. 2008. Inventory analysis of LCA on steel and concrete Construction Office buildings. Energy and Buildings 40: 1188-1193.