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RESPONSIBLE MATERIAL SOURCING: AN ASSESSMENT OF FACTORS INFLUENCING CONSTRUCTION MATERIAL SUSTAINABILITY

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The term "responsible materials" refers to products that have been certified as meeting sustainability standards. Thus, the ethical management of sustainability challenges in the construction product supply chain is referred to as responsible sourcing. It encourages the appropriate availability of measurements that increase sustainability by assessing the environmental impact of materials in the construction supply chain. Due to its health implications, environmental pollution caused by material sourcing and usage has been a hot topic of investigation. Construction specialists responsible for selecting materials with low environmental footprints have a tough time doing so. In addition to the obstacles faced by essential specialists in material selection, numerous aspects must be considered in the sourcing and selection processes, such as comparing policies, to result in better material usage beginning with the design phase. This research is aimed at assessing the factors that influence material sourcing in the construction industry in which sustainability is promoted. A survey of Ghanaian construction professionals involved in the selection and procuring of construction materials was conducted. The variables were evaluated based on the mean of their ratings. All of the variables deemed to influence responsible sourcing of construction materials were subjected to a principal component analysis (PCA). PCA found four components with eigenvalues greater than one, accounting for 34.2 per cent of environmental criteria, 12.10 per cent of resource consumption criteria, 8.4% of technological criteria, and 6.9% of socio-economic criteria. As a result, all of the variables were significant, confirming the conclusions of the literature. Despite being considered an essential factor, eutrophication earned the lowest rating in the environmental factor category; this is a cause for concern in ecosystem management. The study contributes to the management of material sustainability in the Global South to promote the required material sourcing and selection response from decision-making professionals.

Keywords: global south, material sustainability, responsible material, responsible sourcing

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INTRODUCTION

The term "responsible materials" refers to products that have been certified as meeting sustainability standards. Thus, the ethical management of sustainability challenges in the construction product supply chain is referred to as responsible sourcing. It encourages the appropriate availability of measurements that increase sustainability by assessing the environmental impact of materials in the construction supply chain. Due to its health implications, environmental pollution caused by material sourcing and usage has been a hot topic of investigation. Van den Brink et al. (2019) emphasise that one of the most significant concerns linked with urbanisation has been environmental sustainability, mainly where raw materials or products are obtained from sources with regulatory limitations. Raw material resources are used to meet the rising demand for construction materials all around the world. However, construction specialists responsible for selecting materials with low environmental footprints have a tough time doing so (Mesa et al. 2020; Pacheco-Torgal and Jalali 2011). This has resulted in the adoption of several materials that have been certified but have a high environmental impact, necessitating more research. The general challenge is that poor material sourcing results in heavy environmental burdens.

Environmental implications are largely fixed once the materials for each component are established because material selection occurs during the product design phase. Since material selection impacts product performance, higher selection standards are required to maintain quality and value. There is little doubt that when materials are appropriately procured following established regulations and norms, environmental loads from construction materials will be decreased, making the environment safer and enhancing sustainability. In addition to the obstacles faced by essential specialists in material selection, numerous aspects must be considered in the sourcing and selection processes, such as comparing policies, to result in better material usage beginning with the design phase (Lee et al., 2020; Xu et al., 2020; Akadiri et al. 2013).

When exploring the relationship between material sourcing and sustainability, the modest positive influence will add to the total amount of sustainability gain necessary. According to (Lassio et al., 2016), the high demand for construction materials depends on raw materials. However, Pacheco-Torgal and Jalali (2011) explain that construction professionals have difficulty determining materials with environmental hot spots, which has led to the use of several materials with heavy environmental burdens worthy of attention. Therefore, this research aims to assess the factors that influence material sourcing in the construction industry in which sustainability is promoted.

According to Paquette (2006), the environmental impacts of specific materials, products and activities in the construction supply chain need to be closely monitored. Furthermore, their influence on the environment has to be proactively handled. The study of material sourcing based on provenance is a significant factor that gravitates the professional to using a particular material. According to Wilson (2007), the gravity model for selecting and procuring material based on provenance enables one to decide where to acquire their needs based on the likelihood of attraction to the source; this has been a significant economic module for material selection.

In his study on selecting sustainable materials for building projects, Akadiri (2011) argued that, historically, the object of evaluating the building construction material was to use the one with the least cost to the client. However, there were no consideration for origin, environmental protection and performance characteristics. When procuring materials and goods in most industrialised countries, the government needs contractors to think carefully about a range of environmental, economic, and social challenges. Again, the Global South's immature markets imply a lack of understanding of the industry's responsible sourcing (Glass, 2011). In the context of sustainability, Glass (2011) proposed that responsible sourcing (R.S.) provides the pathway to resolve the challenges associated with the supply chain of construction materials.

CONTEXT

Contextually, the study will help understand whether the factors on which decision-making construction professionals use in the Global South to procure materials are relevant to theory. Upstill-Goddard et al. (2015) report that the literature on responsible sourcing remains scarce. The traceability of material content and the ethical transparency needed for material sourcing have not been sufficiently evaluated. In order to direct the sustainability agenda on material origin, Glass et al. (2012) documented the lack of research awareness within industry and academia to promote the responsible sourcing drive to enhance material sustainability. "It is obvious that while qualification schemes abound, there is no indication of the current level of expertise and awareness", Glass et al. (2012) declared. The study, therefore, included information on factors and the criteria that enable the available materials to be responsibly sourced based on provenance.

RESPONSIBLE SOURCING DEFINED

According to Ramchandani et al. (2020), stakeholders have become more aware of the social and environmental consequences of a company's operations in recent years; even if a single product (material) is successfully certified, the certifying brand may benefit from favourable knowledge-based spillovers that encourage responsible sourcing across its entire product line. According to van den Brink et al. (2019), there are three definitions for responsible sourcing that have been used in recent years. The first from the British Standard Institute defines responsible sourcing as "the management of sustainable development in the provision or procurement of a product" (BRE Global, 2016). Second, Upstill-Goddard et al. (2015) define responsible sourcing as the "management of sustainability issues associated with materials in the construction supply-chain, often from an ethical perspective" Young and Osmani (2013) argue that the scope of responsible sourcing is within materials supply. The fourth definition van den Brink et al. (2019) failed to recognise is the argument made by Glass (2011), in which responsible sourcing was defined as the "procurement of products certified against sustainability criteria".

The practices of responsible sourcing and responsible procurement have a common ground. Van den Brink et al. (2019) argues that responsible procurement focuses more on monitoring relations with suppliers while responsible sourcing insists on production data. Table1 shows the basic delineations.

Table 1 "Responsible sourcing" versus "Responsible procurement"

Type	Objective	Approach
Responsible sourcing	Managing the sustainability (social, environmental and/or economic) of the supply chain	Via production
Responsible procurement	Managing the sustainability (social, environmental and/or economic) of suppliers	data

Source: (Van den Brink et al., 2019)

FACTORS THAT INFLUENCE MATERIAL SOURCING

According to the International Trade Organisation (2020), Ghana's construction industry was worth 18 billion dollars in 2018 and accounted for 18.8 per cent of the country's GDP in that year. This value implies that the construction sector's material economy cannot be underestimated since it plays a substantial role in constructing construction projects. Wilson (2007) categorised the factors for selecting material from the source as being geographic or geologic. However, in their consideration, the environmental sustainability of the source was not a significant criterion. Adjarko et al. (2015) carried out a study on incorporating environmental sustainability into construction procurement, in which several factors were suggested. The top four among these factors were leadership skills, environmental culture, public influence and personal skills. However, it is worth noting that the material source was not considered an environmental factor during the material procurement. Therefore, to achieve a holistic, sustainable material procurement, the source and the knowledge of those in a position to influence the choice of material selection need to be considered.

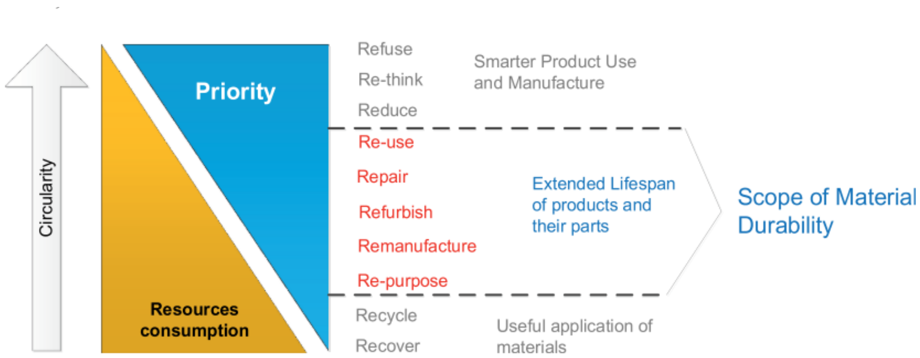
Environmental consideration

A study carried out by Pacheco-Torgal and Jalali (2011) and Levin (2016) indicated that the difficulty of determining the pattern of toxins emitted from building construction materials by the built environment professional has led to the use of several toxic materials which are worthy of attention. Some of these materials are legally accepted, yet they contain some form of toxicity. The material itself may not be toxic, but the processes of obtaining the materials may contain certain environmental negativities, and this may be attributed to the material in question. Thus, environmental assessment of building materials is needed to substitute those prone to sustainability ramifications with more environmentally friendly ones to deliver sustainable building construction projects (Farahzadi et al., 2016). Ruuska and Häkkinen (2014) suggest that since natural resources support the quality of life, there is the need to procure materials responsibly to create products and services with lesser resources and environmental impacts. In their study on the assessment of CO2 in selecting construction materials (using three live construction projects), González and Navarro (2006) found and concluded that the careful selection of building materials with environmental considerations reduces carbon emissions.

Technological consideration

Material selection and/or sourcing technology considerations include durability (design, production, and reprocessing). Lifset and Eckelman (2013) and Levin (2016) all supported the principle of material longevity. In his plenary Architecture lecture, Levin (2016, p.15) demonstrated that "selecting natural building materials that are robust has sufficient environmental benefits than the one that must be substituted more than once in the life of the building." For example, increasing the concrete cover from 10mm to 20mm doubles the service life of reinforcement (defined as the time it takes carbonation to enter the reinforcement, Levin (2016, p.63) by 400% but increases concrete consumption only 5-10%. Therefore, in responsible sourcing of construction materials, the source model that provides a better and more durable material should be considered since it will contribute to the material sustainability agenda.

The design for durability has been the strategy in the circular economy. In their study on developing an indicator for material selection Mesa, et al. (2020) posited, durability reduces the frequency of construction material maintainability.



The Concept of Durability after Mesa et al. (2020)

Resource consumption

There is no doubt that the building construction industry requires much energy regularly. Liedtke et al. (2014) asserted that in the development and consumption of various systems, such as lifecycle stages, processes, production, transportation, and energy usage, these are all indicators that contribute to resource management through the economic management framework. Furthermore, according to Xu et al. (2020), natural resource extraction and processing are responsible for more than 90% of biodiversity loss and systemic ecosystem depletion. As a result, resource consumption is just as crucial as the contributing factors in the responsible sourcing of construction materials to promote material sustainability.

Social considerations

Social considerations in responsible material sourcing are understood as the impacts on human well-being, human capital, cultural heritage and social behaviour (Chhipi-Shrestha et al., 2015). Sourcing material responsibly relates to human well being as it relates to material consumption. A study conducted by Hosseinijou et al. (2014) found that it is essential for society to benefit from using construction materials. It is essential to improve the eco-efficiency of material production and develop mechanisms that would promote materials recovery with low environmental considerations during deconstruction. A study between steel and concrete concluded that steel has a better social impact than concrete. To support product and material policies, (JRC Technical Report by the European Commission, 2014) suggests a need to incorporate life cycle assessment to examine the environmental implications from raw material extraction to product end-of-life. The Life cycle assessment coupled with socio-economic analysis may support a more comprehensive study. Hence it is essential to integrate the social life cycle into the supply chain of construction materials.

RESEARCH METHODOLOGY

This research aimed at assessing the factors that influence material sourcing in the construction industry in which sustainability is promoted. For the aim to be achieved, the following objectives were set:

1. to estimate the perceived level of consideration of factors for material responsible sourcing;
2. to determine whether the factors considered in responsible sourcing of construction materials in Ghana fit standard factors provided in the literature.

A quantitative research approach was used. This approach is widely associated with the positivism research stance (Saunders et al., 2019). It also allows using a structured research questionnaire to enable the study to generalise the findings from the sampling methods applied.

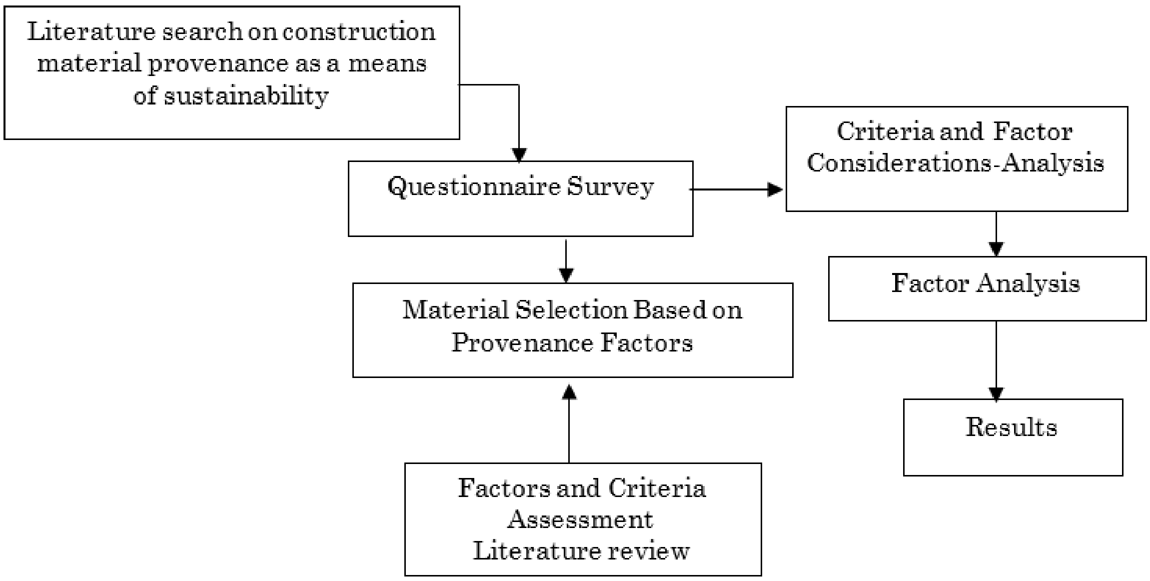


Figure 1: Research Framework and Methodology

Population and sample size

The unit of analysis (the focus of study) from which the data was collected was the construction industry. The unit of observation from which data was measured to understand the construction industry's material selection practices was the decision-making of construction professionals in selecting and procuring construction materials in Ghana. Accra, the capital and the construction hub of Ghana, was selected for the study since most of the identified decision-making professionals work in this city. The emphasis was that; these practitioners have a reasonably high degree of experience in construction material selection. Accordingly, this identification made the study homogenous (Saunders et al. 2019). A survey of Ghanaian Construction professionals in selecting building materials was conducted through the Google form platform to obtain the relevant factors required in the study.

According to Rowley (2014, p. 319), purposive sampling should be used when some cases are identified and likely yield the most valuable results. The non-probability sampling used was purposive and snowball. Purposive because some of the decision-making professionals were known. Therefore, the questionnaire was circulated through the Google form platform (snowball) to their colleagues in the same category (homogeneity) who volunteered to participate in the research. However, there was no clear way of constructing a sampling frame from which a generalisation could be deduced. The rule for employing the non-probability sampling technique, according to Saunders et al. (2019 p.315), is unclear and hence becomes judgemental. It is thus dependent on what is required and the resources available. Using this premise from Saunders et al. (2019), 58 construction professionals were interviewed from 52 organisations using the non-probability sampling method. Pesämaa et al. (2021 p.219) argue that a study's realism is enhanced when the respondents are taken from knowledgeable informants and the sample size is representative and compatible with the study. This argument was consistent with the study.

Inclusion and Exclusion Criteria

Altogether 58 responses were received through the purposive and snowball sampling methods used. Six of the 58 respondents were discovered to work for the same organisation. In addition, those who work in the same organisation but provided the first responders were included using the dates (Timestamp) for the responses (and those who gave their responses later were excluded). This criterion ensured that a single expert delivered the required response from a single organisation.

Table 2: Exclusion and inclusion criteria

Questionnaire Distribution			
Population	Response Received	Response From same organisation	Valid Response
Undefined	58	6	52

Data collection

Data collection improves theoretical comprehension in a research sample. A questionnaire adapted from Akadiri's (2011) research was used to collect data. An ethical response form was provided to ask respondents to freely agree or disagree to participate in the study, allowing them to opt-out during the survey. The questionnaire was divided into two parts. Section A tried to learn about the respondents 'backgrounds. The bulk of the questions in section B were on a Likert-Scale scale of 1 to 5. Section B's questions focused on the factors perceived to influence responsible construction material sourcing based on provenance, obtained from literature thus; environmental criteria, technical criteria, resource use and socio-economic criteria, all concerning the provenance (source) of construction material procurement and use.

Summary

A longitudinal study might trigger an experimental design to obtain the underlying factors from primary analysis instead of literature. Thus, the longitudinal study would shed further light on the data. In addition, it would be fascinating to conduct a study that compared primary and secondary data analysis findings. Finally, even though the number of respondents is adequate, a larger sample size would allow better generalisation. From Table 2, The exclusion and the inclusion criteria were used to prevent repeated measurements from the same company to ensure the relevance of the results.

ANALYSIS AND RESULTS

In this section, the analysis and results are presented on the two specific objectives of the study, the first of which is to estimate the perceived level of consideration of factors for responsible material sourcing concerning provenance. The second objective is to determine whether factors considered in responsible sourcing of materials in Ghana are consistent with factors provided in the literature. Table 3 shows the descriptive statistics on the professional characteristics of respondents. The specific attributes considered are company age, position, and work experience.

Table 3: Participant characteristics

Variable	Group	Frequency/Mean	Per cent/SD
Company age	< 5 yrs	6	12%
	6-10 yrs	7	13%
	11-20 yrs	21	40%
	21-30 yrs	9	17%
	31-40 yrs	7	13%
	> 40 yrs	2	4%
	Total	52	100%
Position	Engineer	12	23%
	Project Manager	13	25%
	Quantity Surveyor	5	10%
	Contractor	6	12%
	Procurement Officer	3	6%
	Project Coordinator	4	8%
	Others	9	17%
	Total	52	100%
Work experience	---	12.17	6.59

Note: Mean and standard deviation apply to only work experience

It can be seen that 12% (n = 6) of participants 'organizations were less than 5 years, 13% (n = 7) had between 6- and 10-years 'experience as well as 31 to 40 years, 40% (n = 19) had between 11and 20 years, 17% (n = 9) had between 21 and 30 years, and 4% (n = 2) had more than 40 years 'work experience. About 23% (n = 12) of the participants were engineers, 25% (n = 13) were project managers, 10% (n = 5) were quantity surveyors, 12% (n = 12) were contractors, 6% (n = 3) were procurement offices, 8% (n = 4) were project coordinators, and 17% (n = 9) belonged to other categories. Finally, the average years of work experience of respondents was 12 years (Mean = 12.17; SD = 6.59). Thus, participants were adequately experienced in the subject matter concerned.

Table 4: Descriptive statistics showing the extent of consideration of criteria and factors

Criterion/factor	N	Min.	Max.	Mean	SD	% of mean
Material quality due to source	52	3	5	4.79	0.50	96%
Material harvest or extraction	52	2	5	3.88	1.00	78%
Zero or low toxicity	52	1	5	4.25	0.86	85%
Ozone Depletion Potential	52	1	5	3.77	1.10	75%
Impact of material on air quality	52	2	5	4.10	0.93	82%
Potential for recycling and re-use	52	1	5	4.04	1.10	81%
Global warming potential	52	2	5	3.90	1.07	78%
Acidification Potential	52	1	5	3.48	1.16	70%
Eutrophication Potential	52	1	5	3.46	1.07	69%
Environmental statutory compliance	52	2	5	4.33	0.81	87%
ENVIRONMENTAL	52	28	50	40.00	6.51	80%
Maintainability	52	3	5	4.46	0.75	89%
Sound insulation	52	1	5	3.94	1.04	79%
Resistance to decay	52	1	5	4.38	0.97	88%
Fire resistance	52	3	5	4.67	0.58	93%
Life expectancy of material (e.g. strength, durability	52	3	5	4.40	0.66	88%
TECHNOLOGICAL	52	15	25	21.87	2.87	87%
Embodied energy	52	2	5	4.12	0.81	82%
Availability	52	3	5	4.50	0.67	90%
Methods of extraction of raw material	52	1	5	3.90	1.11	78%
Likely waste in the use of material	52	1	5	3.92	1.17	78%
Transportation required	52	2	5	4.08	0.86	82%
RESOURCE CONSUMPTION	52	14	25	20.52	2.92	82%
Life cycle cost (initial, maintenance, and repair cost)	52	2	5	4.17	0.76	83%
Health and safety	52	3	5	4.63	0.53	93%
Ease of construction/ buildability	52	3	5	4.56	0.64	91%
Aesthetics	52	2	5	4.33	0.79	87%
SOCIO-ECONOMIC	52	13	20	17.69	1.85	88%

Note: factors are in block letters; S.D. – standard deviation; Min. – minimum; Max– maximum

Since the Likert scale used to measure the criteria and factors was associated with a five-point descriptive anchor representing a continuum (i.e. least crucial to extremely important), the mean scores in Table 4 represent the levels of consideration of the criteria and factors. In this regard, more significant mean scores indicate higher consideration of the criteria or factors and vice versa. In Table 4, the minimum and maximum scores of the criteria are 1 and 5, respectively. The four factors in the table (i.e. environmental, technological, resource use, and socio-economic) were developed by summing up the relevant items used to measure the factor. The resulting data is, thus, an index of the factors.

The minimum and maximum scores of the factors or indices are the sums of all minimum and maximum values of the relevant criteria. Thus, the higher the mean score of a criterion or factor, the higher the perceived level of consideration in responsible material sourcing. If so, it can be seen that all criteria in the table have a large mean score.

Among the environmental criteria, "Material quality due to source" has the largest mean score (Mean = 4.79; SD = 0.5), representing 96% of the maximum score of 5. That is, this criterion is the most important among the environmental criteria and other factors. In Table 3, the least important factor is "Eutrophication Potential" (Mean = 3.46; SD = 1.07), which is under the environmental factor. It accounts for 69% of the maximum score of 5, which means it is above average and can be considered a sufficiently important criterion. Environmental as a factor accounts for a mean score of about 40 (Mean = 40.00; SD = 6.51), representing about 80% of the maximum scale score of 50. Technological factors account for a mean score of about 22 (Mean = 21.87; SD = 2.87), representing about 87% of the maximum scale score. It can be seen those Technological accounts for the second-largest percentage among the factors, which means it is the second most important among the factors. The most important and applied factor is socio-economic, which accounts for a percentage score of 88%. It can be seen that the factor with the smallest percentage is environmental, which connotes that this factor is the least applied or considered, though one of its items is the most considered criterion.

With the above result, all criteria and factors were considered in Ghana in responsible sourcing of materials. Table 5 shows the results of a one-sample t-test, which assesses whether the mean scores of the factors are more significant than the median score of the factors. If the mean score is significantly greater than the median score, then it can be said that the extent of consideration of the factor is above average and appreciable.

Table 5: The one-sample t-test

Factor	Test value	t	df	p	Mean Difference	95% CI
Environmental	30	11.075	51	0.000	10.00	±3.63
Technological	15	17.25	51	0.000	6.87	±1.60
Resource Consumption	15	13.628	51	0.000	5.52	±1.63
Socio-economic	12	22.154	51	0.000	5.69	±1.03

Note: Test values are the median of the variable; CI – confidence interval

In Table 5, the test value is the median score corresponding to the factor. The test focuses on finding out if the mean scores of Table 5 are greater than these corresponding medians or test values. In Table 5, it can be seen that all the factors account for a positive mean difference, with environmental accounting for the largest mean difference of 10. This result indicates that deducting the test value from the mean gives a positive result, which connotes that the mean scores are greater than their corresponding medians. For each factor, the t-test is significant at $p < 0.001$. For example, the t-test of environmental is significant at $p < 0.001$ ($t = 11.08$; $p = .000$). Thus, the mean scores of the four factors are greater than their corresponding medians. Therefore, the level of consideration of the factors responsible for sourcing materials is above average — table 6 and 7 present findings on the second objective.

The Principal Component Analysis (PCA) was carried out on all the variables, as shown in Table 6. As a result, the total variance accounts for by the four-factor variables was 61.60% which meets the analysis requirements. Furthermore, the extraction values in table 5 show that the communality values were ≥ 0.5 (Kelava, 2016) and thus met the requirements in the literature.

Table 6: Extraction values from principal component analysis after Varimax

Criteria	Initial	Extraction
Material quality due to source	1	0.733
Material harvest or extraction	1	0.717
Zero or low toxicity	1	0.803
Ozone Depletion Potential	1	0.637
Impact of material on air quality	1	0.763
Potential for recycling and reuse	1	0.700
Global warming potential	1	0.872
Acidification Potential	1	0.758
Eutrophication Potential	1	0.793
Environmental statutory compliance	1	0.581
Maintainability	1	0.726
Sound insulation	1	0.517
Resistance to decay	1	0.871
Fire resistance	1	0.802
The life expectancy of material (e.g. strength, durability	1	0.695
Embodied energy	1	0.675
Availability	1	0.801
Methods of extraction of raw material	1	0.692
Likely waste in the use of material	1	0.735
Transportation required	1	0.624
Life cycle cost (initial, maintenance, and repair cost)	1	0.739
Health and safety	1	0.633
Ease of construction/ buildability	1	0.640
Aesthetics	1	0.675

Note: Kaiser-Meyer-Olkin (KMO) Measure = 0.658; df = 300; Ch-square; 936.24; p = 0.000

Extraction values in Table 6 are communality values that must each meet the condition: communality ≥ 0.5 (Kelava, 2016). Any criterion that meets this condition is considered part of the standard variables in responsible material sourcing from the literature. It can be seen that all the criteria met this condition. This means that all the standard criteria considered at the international level underpin the Ghanaian context. Beneath Table 6, the Kaiser-Meyer-Olkin (KMO) value of the factor analysis is about 0.658, whereas the Chi-square test is significant at $p < 0.001$. These results are satisfactory and suggest that the model is random (Kelava, 2016).

Table 7: Factor loadings, variance, and eigenvalues

Component	1	2	3	4
Variance (Total = 61.58%)	34.19	12.07	8.43	6.89
Eigenvalue	8.55	3.02	2.11	1.72
Material quality due to source	0.84			
Material harvest or extraction	0.65			
Zero or low toxicity	0.48			
Ozone Depletion Potential	0.70			
Impact of material on air quality	0.63			
Potential for recycling and reuse	0.47			
Global warming potential	0.77			
Acidification Potential	0.59			
Eutrophication Potential	0.83			
Environmental statutory compliance	0.60			
Concrete			0.91	
Maintainability			0.66	
Sound insulation			0.46	
Resistance to decay			0.89	
Fire resistance			0.64	
The life expectancy of material (e.g. strength, durability		0.61		
Embodied energy		0.58		
Availability		0.73		
Methods of extraction of raw material		0.43		
Likely waste in the use of material		0.41		
Transportation required				0.53
Life cycle cost (initial, maintenance, and repair cost)				0.57
Health and safety				0.62
Ease of construction/ buildability				0.76
Aesthetics				0.64

Note: factor 1 – Environmental; factor 2 = Resource Consumption; factor 3 – Technological; factor 4 – socioeconomic

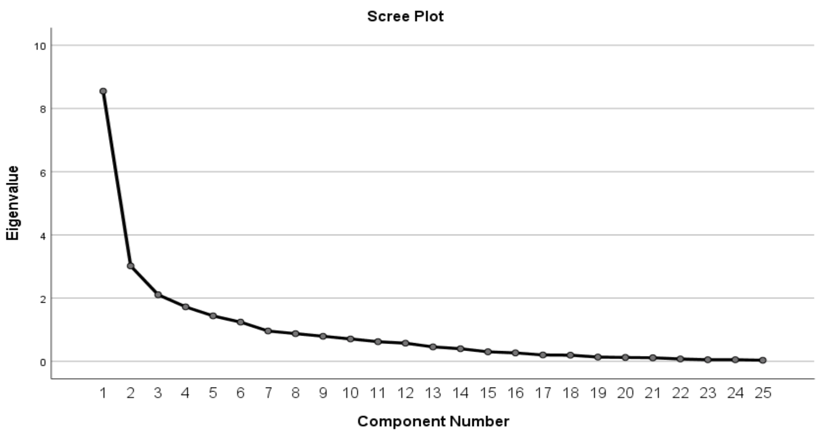


Figure 2: A scree plot (source: Field Survey 2021) showing factors extracted

Table 7 shows the factor loadings of four factors extracted. The total variance extracted and eigenvalues are also reported. The total variance accounted for by the four factors is 61.6%, which is satisfactory. The factor loadings of each factor meet the condition: factor loading ≥ 0.5, which affirms results on the communalities. Every criterion recognised by literature at the international level is considered as part of the factors analysed. The first factor is 'environmental', which accounts for a variance of about 34.2%. The second factor is 'resource consumption', which accounts for 12.1% of the total variance. The third and fourth factors are 'technological '(variance = 8.4%) and 'socio-economic '(variance = 6.9%) respectively. Figure 2 is a scree plot showing factors extracted from the factor analysis.

Twenty-four (24) factors were identified from the literature. After performing exploratory factor analysis (EFA) with varimax rotation and principal components extraction, eigenvalues ≥ 1 were retained; thus, 4 factors (i.e. Environmental, Technological, Resource Consumption and Socio-economic) were extracted. The scree plot confirms this. The four factors accounted for 61.60 per cent of the total variance, which met the analysis requirements. Table 6 shows that the communality values were less than 0.5, which matched the conditions in the literature. The varimax approach was used in the principal component extraction since it makes factor interpretation easier (Kelava 2016).

Tables 8–11 show a comparison of criteria derived from fieldwork and literature with the study's findings.

Table 8: Environmental criteria

Environmental	Mean	SD	Rank (Field Study)	Rank (Literature)	Level of Importance
Material quality due to source (Durability)	4.79	0.5	1	3	H
Environmental statutory compliance	4.33	0.81	2	1	M-H
Zero or low toxicity	4.25	0.86	3	3	M-H
Impact of material on air quality	4.10	0.93	4	9	M-H
Potential for recycling and re-use	4.04	1.1	5	5	M-H
Global warming potential	3.9	1.07	6	6	M-H
Material harvest or extraction	3.88	1	7	11	M-H
Ozone Depletion Potential	3.77	1.10	8	4	M-H
Acidification Potential	3.48	1.16	9	N/A	N/A
Eutrophication Potential	3.46	1.07	10	N/A	N/A

Table 9: Technological criteria

Technological	Mean	SD	Rank (Field Study)	Rank (Literature)	Level of Importance
Fire resistance	4.67	0.58	1	4	H
Maintainability	4.46	0.75	2	1	H
Life expectancy of material (e.g. strength)	4.4	0.66	3	2	H
Resistance to decay	4.38	0.97	4	6	M-H
Sound insulation	3.94	1.04	5	2	M

Table 10: Resource consumption criteria

Resource Consumption	Mean	SD	Rank (Field Study)	Rank (Literature)	Level of Importance
Availability	4.50	0.67	1	7	M-H
Embodied energy	4.12	0.81	2	7	M-H
Transportation required	4.08	0.86	3		
Likely waste in the use of material	3.92	1.11	4	6	M-H
Methods of extraction of raw material	3.90	1.17	5	11	M-H

Table 11: Socio-economic criteria

Socio-Economic	Mean	SD	Rank (Field Study)	Rank (Literature)	Level of Importance
Health and safety	4.63	0.53	1	3	H
Ease of construction/ buildability	4.56	0.64	2	5	H
Aesthetics	4.33	0.79	3	1	H
Life cycle cost (initial, maintenance, and repair cost)	4.17	0.76	4	2	H

H=high, M= medium, N/A = Not Applicable

Source: Field study (2021); Lee et al., (2020); Baglou et al. (2017) Akadiri et al. (2013); Akadiri and Olomolaiye (2012) Akadiri (2011)

Tables 8-11 confirm and validate the study's result with the factors obtained from the literature. Thus, even though the methodology used in the study was different from that found in literature, with the above result, all criteria and factors considered in Ghana in responsible sourcing of materials sourcing were relevant to literature.

DISCUSSION

No matter how small the benefits would be, responsible sourcing will add to the aggregation of the sustainability positives in the construction sector. It is thus one path of ensuring that the three fronts of sustainability are achieved in the construction industry. The subject of responsible sourcing is relatively new and lacks adequate literature resource. However, about a third of the available literature in the recent past years has come from the construction industry(Van den Brink et al., 2019). Though the focus has been on construction, there is a gradual development from other sectors as well. The emerging development of sustainability schemes and growing concern of responsible sourcing indicate it is gradually receiving the needed theoretical and practical attention.

However, a lack of transparency makes responsible sourcing challenging. It requires visibility, transparency and sound functioning legislation through the supply chain. In addition, firms need to develop high ethical standards from production through supply to realise the required material sourcing responsibility. A few research studies in the Global South (if any) have examined the subject of responsible sourcing. This study fills the gap by looking at the factors considered in responsible sourcing and the likely environmental impact at the material origin. It, therefore, provides a basis for future research, especially in the Global South.

CONCLUSION

This study has estimated the perceived level of consideration of standard factors for responsible material sourcing and procurement based on provenance and determined whether the perceived factors were consistent with factors found in the literature. A total of 4 group factors altogether having 24 criteria were identified from the literature. In addition, a questionnaire was sent to the relevant construction material selection professionals to obtain the criteria considered in responsible materials sourcing in the building construction industry in the Global South. The group factors considered for responsible material sourcing using provenance as a datum in the study were environmental, technological, resource use and socio-economic. All of the variables deemed to influence responsible sourcing of construction materials were subjected to a principal component analysis (PCA). PCA found four components with eigenvalues greater than one, accounting for 34.2 per cent of environmental criteria, 12.10 per cent of resource consumption criteria, 8.4% of technological criteria, and 6.9% of socio-economic criteria. As a result, all of the variables were significant, confirming the conclusions of the literature data were consistent with the responsible sourcing of construction materials in Ghana as a country in the Global South; this corroborates the research carried out by Lee et al. (2020); Baglou et al. (2017); Akadiri et al. (2013); Akadiri and Olomolaiye (2012); Akadiri (2011) and thus confirms and validates the findings from theory are relevant to the Global South context.

Material quality due to source obtained the highest mean of 4.79, supporting Wilson's (2007) study. The gravity model enables one to determine where to obtain their needs based on the probability of attraction to the source. However, eutrophication as a factor had the lowest environmental consideration, a mean of 3.46. It is a critical requirement that necessitates additional research because it contributes significantly to the general degradation of water quality, increases algae, and may cause morphological changes in the environment. This study provides an excellent start when looking at responsible material sourcing in the construction industry to promote materials sustainability.

REFERENCES

Akadiri, P. O., (2011). Development of a multi-criteria approach for the selection of sustainable materials for building projects. PhD Thesis - the University of Wolverhampton, [online] pp.1–437. Available at: <http://wlv.openrepository.com/wlv/bitstream/2436/129918/1/Akadiri_PhD thesis.pdf>.

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

Akadiri, P. O., Olomolaiye, P. O., & Chinyio, E. A. (2013). Multi-criteria evaluation model for the selection of sustainable materials for building projects. Automation in Construction, [online] 30, pp.113–125. Available at: <http://dx.doi.org/10.1016/j.autcon.2012.10.004>.

Baglou, M., Ghoddousi, P., & Saeedi, M., (2017). Evaluation of Building Materials Based on Sustainable Development Indicators. Journal of Sustainable Development, 10(4), p.143.

BRE Global, (2016). BES 6001. Framework Estandar for Responsible Sourcing. BRE Global, (2), p.368.

Van den Brink, S., Kleijn, R., Tukker, A., & Huisman, J., 2019. Approaches to responsible sourcing in mineral supply chains. Resources, Conservation and Recycling, [online] 145(November 2018), pp.389–398. Available at: <https://doi.org/10.1016/j.resconrec.2019.02.040>.

Chhipi-Shrestha, G. K., Hewage, K., & Sadiq, R., (2015). 'Socializing 'sustainability: a critical review of the current development status of the social life cycle impact assessment method. Clean Technologies and Environmental Policy, 17(3), pp.579–596.

Farahzadi, L., Urbano Gutierrez, R., Riyahi Bakhtiari, A., Azemati, H., & Hosseini, S. B., (2016). Assessment of Alternative Building Materials in the Exterior Walls for Reduction of Operational Energy and CO2 Emissions Assessment of Alternative Building Materials in the Exterior Walls for Reduction of Operational Energy and CO2 Emissions. International Journal of Engineering and Advanced Technology (IJEAT), (September), pp.0–7.

Glass, J., (2011). Briefing: Responsible sourcing of construction products. In: Proceedings of the Institution of Civil Engineers: Engineering Sustainability. pp.167–170.

Glass, J., Achour, N., Parry, T., & Nicholson, I., (2012). Engaging small firms in sustainable supply chains: Responsible sourcing practices in the U.K. construction industry. International Journal of Agile Systems and Management, 5(1), pp.29–58.

Gonçalves de Lassio, J. G., & Naked Haddad, A., (2016). Life cycle assessment of building construction materials: case study for a housing complex TT - Evaluación de ciclo de vida de materiales de edificaciones: estudio de caso en complejo de viviendas. Revista de la construcción, [online] 15(2), pp.69–77. Available at: <http://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-915X2016000200007&lang=pt>.

Hosseinijou, S. A., Mansour, S., & Shirazi, M. A., (2014). Social life cycle assessment for material selection: A case study of building materials. International Journal of Life Cycle Assessment, 19(3), pp.620–645.

International Trade Organisation, (2020). Ghana - Country Commercial Guide on Infrastructure. [online] International Trade Administration. Available at: <https://www.trade.gov/country-commercial-guides/ghana-construction-and-infrastructure> [Accessed 26 Feb. 2021].

JRC Technical Report by the European Commission, (2014). Social life cycle assessment revisited. Sustainability (Switzerland), Luxemburg.

Kelava. A, (2016). A Review of Confirmatory Factor Analysis for Applied Research. 20(June), p.2016.

Lee, D., Lee, D., Lee, M., Kim, M., & Kim, T., (2020). Analytic hierarchy process-based construction material selection for performance improvement of building construction: The case of a concrete system form. Materials, 13(7).

Levin, H., (2016). Building Ecology : An Architect's Perspective -- Plenary Lecture. (November 2014).

Mark N. K. Saunders, P. L., & A. T., (2019). Research methods for Business Students. Eighth Edn ed. [online] New York: Pearson Education Limited. Available at: <www.pearson.com/uk>.

Mesa, J., González-Quiroga, A., & Maury, H., (2020). Developing an indicator for material selection based on durability and environmental footprint: A Circular Economy perspective. Resources, Conservation and Recycling, [online] 160(January), p.104887. Available at: <https://doi.org/10.1016/j.resconrec.2020.104887> [Accessed 21 Mar. 2021].

Pacheco-Torgal, F., & Jalali, S., (2011). Toxicity of building materials: A key issue in sustainable construction. International Journal of Sustainable Engineering, 4(3), pp.281–287.

Paquette, J. R., (2006). The Supply Chain Response to Environmental Pressures. Massachusetts Institute of Technology.

Pesämaa, O., Zwikael, O., Hair, J. F., & Huemann, M., (2021). Publishing quantitative papers with rigour and transparency. International Journal of Project Management, 39(March), pp.217–222.

Ramchandani, P., Bastani, H., & Moon, K., (2020). Responsible Sourcing: The First Step Is the Hardest. SSRN Electronic Journal, (ILO), pp.1–37.

Ruuska, A., & Häkkinen, T., (2014). Material efficiency of building construction. Buildings, 4(3), pp.266–294.

Upstill-Goddard, J., Glass, J., Dainty, A. R. J., & Nicholson, I., (2015). Analysis of responsible sourcing performance in BES 6001 certificates. Proceedings of the Institution of Civil Engineers: Engineering Sustainability, 168(2), pp.71–81.

Wilson, L., (2007). Understanding Prehistoric Lithic Raw Material Selection : Application of a Gravity Model. Journal of Archaeological Method and Theory, [online] 14(4), pp.388–411. Available at: <https://www.jstor.org/stable/25702351 REFERENCES>.

Xu, M., Chen, D., Yu, Y., Chen, Z., Zhang, Y., Liu, B., Fu, Y., & Zhu, B., (2020). Assessing resource consumption at the subnational level: A novel accounting method based on provincial selected material consumption. Journal of Industrial Ecology, pp.1–13.

Young, J., & Osmani, M., (2013). Investigation into contractors 'responsible sourcing implementation practice. Proceedings of the Institution of Civil Engineers: Engineering Sustainability, 166(6), pp.320–329.